Matthias Kalkuhl · Joachim von Braun
Maximo Torero *Editors*

Food Price Volatility and Its Implications for Food Security and Policy

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Foreword

Eight years ago the global food crisis caught most governments and academic researchers unprepared. The crisis triggered not only extensive research on drivers of international food price shocks and volatility but also many policy interventions and tentative institutional reform at the global and national scale. Despite the efforts of national governments and international organizations in recent years to halve the number of hungry people by 2015, about 800 million people still suffer from undernutrition and many more from micronutrient deficiencies. This impedes health and contributes to conflicts and sluggish economic development. Ending hunger completely by 2030 as aimed for in the Sustainable Development Goals requires a much stronger political commitment. Moreover, it needs a solid scientific base for understanding the threats to food and nutrition security and their complex interactions with social, environmental, and political factors. Globalization has created a highly interconnected world where resources, information, and policies are not constrained by national borders. Economic shocks spread quickly over entire industries and sectors. At the same time, environmental risks triggered by climate change, biodiversity loss, land degradation, and water scarcity as well as political conflicts will increasingly become a force of disruption, threatening the reliability of our global agricultural and food production system. Drastic price changes are often the first signs indicating upcoming crises and recent calm agricultural markets can be deceptive and lead to unjustified complacency.

Analyzing Food Price Volatility and its Implications for Food Security and Policy, edited by Matthias Kalkuhl, Joachim von Braun, and Maximo Torero, is devoted to the stability dimension of food security and in particular the causes, consequences, and remedies related to extreme events in food markets. Volatility is a measure of risk and uncertainty which, in turn, is the antagonist of security. Price volatility is an intrinsically market-related economic concept. The economics of this book is, however, carefully embedded into the political, agricultural, climate, and nutritional domains. This makes the book an important contribution for the ongoing political agenda of the international community to reduce undernutrition and enhance food and nutrition security.

The first chapter, which is written by the editors, provides a comprehensive overview of the recent debates, concepts, and literature and serves as an overview of the subject of the book. Subsequent chapters emphasize the global and multi-market dimension of food markets and policymaking. Traditionally, harvests, stocks, and income were considered as the major determinants of food prices. Recently, new drivers emerged that are rooted in closer integration of food markets with energy and financial markets. Several chapters provide new evidence on these intensified linkages and explore the role of speculation. Another important topic of this excellent book is the role of policy as a tool to reduce volatility or to increase the capacity to cope with volatility and the potential or real consequences of poorly designed or implemented policies. The distortive trade restrictions in 2008 and 2010 provided a dramatic lesson. With unreliable international markets, some governments sought to become more self-sufficient—an often expensive way to reduce vulnerability to international market shocks. Chapter authors develop a promising third-way alternative between reliance on international market and autarky: regional trade and storage cooperation. While the economic gains of this alternative are high for Africa and Southeast Asia, political and institutional challenges prevail that need to be overcome. Trade integration and storage cooperation may be a catalyst for improved regional policy coordination and cooperation.

The concept of food security centers on the individual and its capability to satisfy basic nutrition and health needs. Consequently, the impact of market volatility on households is the subject of empirical analyses in several countries that were highly exposed to the international price shock in 2008. Besides household, farmers, traders, and communities deal with volatile prices at the local level and develop strategies to cope with volatility and reduce its negative impacts. By combining microeconomic and macroeconomic analyses, the book provides a comprehensive perspective on the manifold interactions of markets, people, and policymakers.

The book is outstanding in its methodological diversity and wide sectorial and geographical range. The contributions range from descriptive, empirical, and computational economic to simulation-based works. As such, it is a must-read book to guide researchers and research-oriented practitioners in governments, NGOs, and international organizations as well as students of agricultural, food, and nutrition policy.

Analyzing Food Price Volatility and its Implications for Food Security and Policy is one of the most comprehensive and interesting collections of applied state-of-the art research on food security, risk, and uncertainty, and it will influence the research and action agendas for many years to come.

Ithaca, New York Per Pinstrup-Andersen

Acknowledgments

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Joachim von Braun
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Part I

Introduction

1 Volatile and Extreme Food Prices, Food Security, and Policy: An Overview

Matthias Kalkuhl, Joachim von Braun, and Maximo Torero

1.1 The Relevance of Food Price Volatility

Price volatility describes the magnitude of price fluctuations or the risk of large, unexpected price changes. The risk of extreme price events can intensify and contribute to broader social risks in terms of food security, human development, and political stability. The aim of this book is to investigate the causal relationships between and the drivers of price volatility and extreme price events, in particular their implications on food and nutrition security. This book also aims to investigate the experiences with and implications of national and international policies aimed at preventing and mitigating volatility.

The economic history of food price crises has been studied in detail by Abel (1966). He found that the causes of food price crises had changed with changing political and economic contexts, such as the transmission of crises from agriculture to urban settings, and the prevalence of regional crises changed due more or less to the integration of markets. Analyses of the global food price crises of the 1970s focused on production and trade shocks (e.g., Valdes 1981), and the broader concept of food security evolved. Revisiting food price volatility in our age is necessary because of further contextual changes and advancements in methods of studying cause and effect.

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Concern about food price volatility is closely connected to the concept of food security, i.e., its four pillars of food availability, economic and physical access to food, food utilization, and stability (vulnerability and shocks) over time (FAO 1996, 2015). The slow progress in reducing hunger and malnutrition and the role of volatile agricultural markets in the food crises of 2007/2008 and 2010 fueled concerns about the stability and reliability of the global food system. This book, however, emphasizes that the abovementioned four dimensions of the food security concept should be viewed not only as four separate building blocks but also as a system of complex dynamic interactions. Price shock-related food and nutrition insecurity may undermine the resilience of poor people and low-income countries and thus exacerbate economic insecurity, often eroding societal cohesion.

Food policy is a sensitive political issue, and it is becoming increasingly so as the world becomes more urbanized with increased concentrations of political voice near power centers. Moreover, food policy is affected by strong normative beliefs not only about goals—like food security—but also about instruments to achieve these goals. Recommendations about how to deal with volatility need to consider the specific policy context (Pinstrup-Andersen 2015). When food prices rise, the power of political leaders may become contested. Rising onion prices changed election outcomes in India.[1] Increasing food prices caused thousands of protesters to take the streets of Port au Prince (in 2008) and Algiers (in 2011).[2] Rising food prices led the Haitian prime minister to resign from office in April 2008 and fueled the protests for a political change in several Arab countries. The 2007/2008 crisis also generated social and political turmoil in Bangladesh, Côte d'Ivoire, Egypt, Indonesia, Uzbekistan, and Yemen. Several other countries saw violent food riots, demonstrations, or social unrest as a result of rising food prices. Beyond the anecdotal evidence and the correlation between international prices, excessive price spikes, and food riots depicted in Fig. 1.1, recent empirical research suggests a causal relationship between food prices and social unrest (Bellemare 2015). Many governments of developing countries are held responsible for ensuring a certain degree of food security and decent living conditions. When these basic requirements are eroded, governments could quickly lose their legitimacy, and unrests and protests could arise especially in urban areas, where coordinating a collective protest action is easy. Thus, the scope of the protests could also broaden and trigger the demand for deeper institutional and political reforms (Costello et al. 2015).

As food prices are a sensitive political issue, it is not surprising that governments and the G20 aim to quickly respond to increasing prices. Much of this response has been only partly effective—or it even contributed to increasing volatility elsewhere [see Martin and Anderson (2012) for the case of trade policies]. This is partly based on a collective action failure to coordinate policies such that they re-enforce

[1] http://www.bloomberg.com/bw/articles/2013-07-25/for-indias-inflation-crisis-see-onion-prices

[2] http://www.bbc.com/news/world-africa-12134307 and http://www.theguardian.com/world/2008/apr/09/11

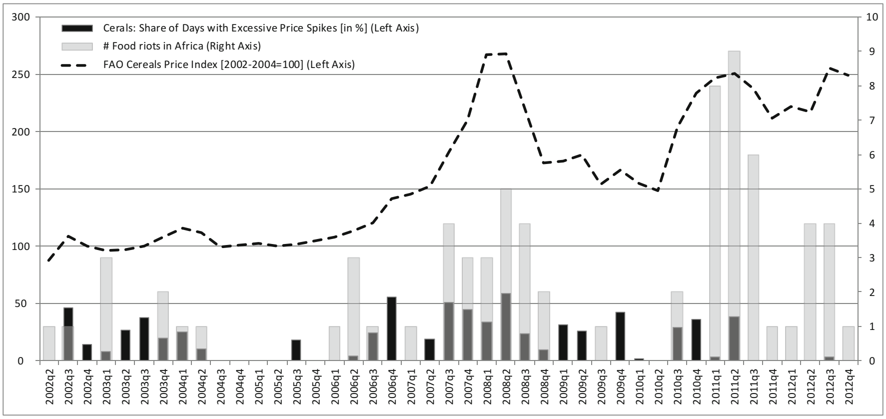

Fig. 1.1 Food prices, excessive volatility, and social unrests. *Note*: Average share of days with excessive price spikes for maize, wheat, and rice futures returns as reported by IFPRI's NEXQ model (see explanation below in the text). All values per quarter. *Source*: Own illustration based on data from foodsecurityportal.org (excessive volatility), Social Conflict in Africa Database (SCAD)[3], and FAO

rather than neutralize each other. On the other hand, increasing integration of local agricultural markets into global markets and of agricultural markets into broader financial asset markets makes it more difficult to identify the causes of extreme events. The traditional agricultural supply and demand fundamentals seem to have only little explanatory power for recent price movements. Energy prices and biofuel demand, interest rates and monetary policy, financial investments and speculation, sudden trade restriction, or lack of information are some of the factors which are considered to be important determinants of agricultural markets in recent times.

Without a proper understanding of the causal relations, excessive volatility cannot be reduced effectively. This book presents research on these causal relationships, their relevance, and policy implications to provide a better information base for political decision makers at the national and international level.

1.2 Understanding the Linkages Between Food Security, Price Volatility, and Extreme Events

1.2.1 The Concept of Food Security

Food security is commonly defined as a state whereby "[. . .] all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996, paragraph 1). The definition of nutrition security goes even beyond that of food

[3]We thank Regine Weber for preparing the SCAD data.

security by postulating that “[a] person is considered nutrition secure when she or he has a nutritionally adequate diet and the food consumed is biologically utilized such that adequate performance is maintained in growth, resisting or recovering from disease, pregnancy, lactation and physical work.” The Sustainable Development Goals (SDGs) of the post-2015 development agenda give food and nutrition security a high priority. Despite the efforts of governments and international organizations, the number of people affected by food and nutrition insecurity remains high, with 780 million people undernourished and about two billion malnourished (FAO 2015).

On an operational level, food security is conceptualized by the four dimensions: availability, accessibility, utilization, and stability [see also Upton et al. (2015) for new approaches to conceptualize food security measurements]. The availability of food, measured by the total food supply, and access to food, measured—for example—by real income of households (relative to food prices), are necessary but not sufficient conditions to ensure food security. Hence, they should not be considered as the only determinants of food security; they are only a subset of a much broader list of causal determinants of food security (von Braun 2014). What ultimately matters for the well-being and health of *individuals* is the extent to which each person is able to meet their dietary needs (including micro- and macronutrients) and qualitative or subjective food preferences. This ability—subsumed under the utilization dimension—is affected by intra-household allocation and distribution decisions, cultural or behavioral values, and complementary factors like diseases or other circumstances that require specific diets. While utilization is the decisive dimension for food security on the individual level, it is difficult and expensive to measure, which hinders the use of indicators focusing on food availability (e.g., per capita calorie supply) or accessibility (e.g., share of households with insufficient income to meet food and nutrition demands).

The first three dimensions of the standard food security framework focus on issues at different socioeconomic scales. The fourth pillar emphasizes the temporal dimension—the stability of the conditions that enable individuals to meet their food demand. The stability can be affected in various ways: harvest fluctuations (that are often moderated by trade and storage), fluctuations in real income affecting access to food and nutrients, and fluctuations in disease burdens (e.g., due to pandemics or floods). In any of these cases, changes in food prices are likely to signal changes in food security conditions. As prices are endogenous outcomes of underlying market forces, they cannot be a *fundamental* cause of changing food security conditions—a qualification that should be kept in mind and is highly important for policymaking. High prices could signal expectations of low food availability, which could severely threaten food security as policy intervention is limited in the short run (at least if the scarcity arises on a global scale). High prices could, however, also signal increasing demand for food, to which policymakers can better respond with a wide set of instruments ranging from trade policies, taxes targeted at wealthy consumers to transfers targeted at poor consumers. As poor people spend around two-third of their income on food, a change in food prices implies a change in real income; the direction of the change in real income depends on a household’s trade position:

Net sellers of food benefit from price increases, while net buyers would experience declining real wages in the short run.

Temporary deficiencies in food access can lead to long-term, irreversible nutritional damage, especially among children. For example, across several Latin American countries, simulations of the 2007/2008 price increases showed important reductions in calorie intake at both the national and the household levels, especially for children from poor households below the age of two, a critical period for a child's growth and development (Robles and Torero 2010). In all of the Latin American countries studied, poorer households with consumption levels that were already below the calorie adequacy threshold showed greater reductions in calorie intake. The long-term effects are especially detrimental to the already vulnerable populations. Other empirical work confirmed significant nutritional impacts of short-term disruptions in food security: Higher food prices increased the instances of underweight children in Mozambique (Arndt et al. 2012); the prevalence of childhood stunting increased in El Salvador after the 2008 food price increase (de Brauw 2011); harvest failures and adverse weather events have been associated with impeded child growth in Zimbabwe (Hoddinott and Kinsey 2001), reduced weight in children in Côte d'Ivoire (Jensen 2000), and decreased blood concentration of vitamin A and vitamin E in mothers in Zambia (Gitau et al. 2005). The deterioration of nutritional status has, in turn, long-term impacts on health, stature, and cognitive capabilities (Victora et al. 2008). Malnutrition in the form of insufficient micronutrient intake increases the probability of lifetime disabilities, such as blindness due to vitamin A deficiency (Black et al. 2008).

Despite the heterogeneity in linking *prices* to changes in underlying food security determinants, there are three reasons why prices are so important for understanding and assessing food security risks: First, they are closely linked to several causal factors of food security (supply, real income, cross-market linkages); second, they are observed more frequently and less costly to collect than most other food security indicators; and third, prices convey expectations about future changes and risks by a large set of market participants, which allows researchers to exploit the large information processing capacity of markets (Fama 1970). These three features make price dynamics a crucial element for understanding food security risks. It is therefore the main objective of this book to understand the stability dimension of food security from the lens of agricultural market linkages and food prices by studying their trends, changes, extreme spikes, and volatility. Chapter 2 provides a detailed overview of several techniques for decomposing price series and calculating volatility for empirical analysis. In the following section, we will briefly explain the different concepts of volatility used in this book.

1.2.2 Food Price Volatility

In a broad sense, volatility captures the idea that prices fluctuate around a rather stable long-term price or price trend (Hull 2012). These short-term fluctuations may refer to daily, weekly, or monthly prices. Periods of excessively high or low commodity prices are often associated with crises as they pose a challenge to producers, consumers, and policymakers. The concept of volatility captures the idea of price fluctuations in two different ways: in a historical (ex-post) perspective and in a forward-looking (ex-ante) perspective.

Ex-post volatility measures *realized* variability; it refers to unconditional volatility measures that do not control for lagged prices or lagged volatility. Ex-post volatility is also typically calculated over a longer time horizon consisting of several price observations. In contrast, dynamic models of conditional volatility use available information at time t to provide a *forecast* of price volatility at time $t + 1$. As conditional volatility measures change over time, they are dynamic and forward-looking and thus able to represent changing risk perceptions.

Table 1.1 lists several measures of volatility which are grouped into two basic approaches: (1) ex-post, or unconditional measures that assume a constant variance in the data generating process, and (2) forward-looking (conditional or dynamic) measures which use changes in past prices and variances to forecast future variances. Although there is some difference between unconditional volatility measures when considering inflation and trends, the two ex-post indicators are correlated and not fundamentally different (Huchet-Bourdon 2011). With respect to forward-looking volatility measures, Generalized Autoregressive Conditional Heteroskedastic (GARCH) methods are widely used (Hull 2012). They estimate volatility conditional on past shocks and volatility. Multivariate GARCH models also allow volatility (risk) spillovers from other markets or commodities to be considered (see, e.g., Rapsomanikis and Mugera 2011; Hernandez et al. 2014). The risk of price changes can also be derived implicitly from financial market data (Prakash 2011). Put and call options give holders the right to sell or buy a security (e.g., a commodity futures contract) at a specified price. The higher the expected volatility (risk of price changes), the more valuable an option becomes because it gives the right (but not the obligation) to sell or buy at a pre-defined price. Using the Black–Scholes option pricing formula and other observable data (the exercise price, current price, risk-free rate, and maturity of an option), it is possible to calculate the volatility which the market is expecting. As the Black–Scholes formula rests on the strong assumption of log-normally distributed returns with constant variance, it is questionable whether the formula is an accurate measure of the market expectations on volatility. Duan (1995), for example, reconstructed the original option pricing model to incorporate conditional volatilities. The last column in Table 1.1 lists nonparametric volatility models that do not assume a specific functional form for estimating volatility; these models are therefore even more flexible and precise in forecasting volatility than parametric GARCH models. An example of nonparametric models is the one developed by Martins-Filho et al. (2015).

The choice of the "right" volatility measure depends on the context, data availability, and research question. Ex-post volatility can easily be calculated for time series with a low number of observations and/or missing observations (both issues plague most price data from developing countries). Unconditional measures can provide an appropriate tool for studying the impact of *realized past shocks*.

Table 1.1 Different measures of volatility

Ex-post volatility measures (unconditional/realized variability)		Ex-ante/forward-looking volatility and risk measures (conditional/dynamic volatility)		
Standard deviation of log returns	Coefficient of variation from mean or trend $\overline{p}$	Conditional volatility (GARCH)	Implied volatility	Nonparametric volatility and extreme quantile models
$V = SD\left[r_t\right]$	$V = \frac{SD\left[p_t - \overline{p_t}\right]}{\overline{p_t}}$	$\sigma_n^2 = \gamma V_L + \sum_{i=1}^{q} \alpha_i\, \varepsilon_{n-i}^2 + \sum_{i=1}^{p} \beta_i\, \sigma_{n-i}^2$	$C = f\left(\sigma^2, \cdot\right)$	$r_t = m\left(X_t\right) + \sigma^2\left(X_t\right) \varepsilon_t$ $r > q\left(\alpha \vert X_t\right)$
Considers constant time trend of prices	Using CPI deflated prices or detrended prices $\overline{p_t}$ avoids bias due to inflation or long-term trends	Volatility σ_n^2 conditional on past volatilities and long-term volatility V_L	Perception of market about future volatility (price risk)	Nonparametric estimation of volatility $\sigma^2\left(X_t\right)$; extreme return if return higher than the α-quantile
Gilbert and Morgan (2010)	Bellemare (2015), Huchet-Bourdon (2011)	Rapsomanikis and Mugera (2011), Hernandez et al. (2014)	Prakash (2011)	Martins-Filho et al. (2015)

Note: $r_t = \log\left(\frac{p_t}{p_{t-1}}\right)$ (log returns)

As unconditional volatility measures assume a constant variance, they do not explicitly model how volatility evolves over time or how future price risks might be. Unconditional models are therefore of limited use when forecasting volatility or price risk or when modeling risk perceptions of forward-looking agents is required. In contrast to ex-post measures, they typically require more data and elaborate time series models, which may limit their applicability when data is sparse. However, the choice of the appropriate volatility measure also depends on how agents form their expectations about future price risk. While the rational expectation framework provides a useful benchmark, expectation formation in information-constrained environments, which is often the case in developing countries, might substantially deviate from this model.

1.2.3 Extreme Events

Extreme events refer to "unusual" events that are unlikely to occur frequently and whose occurrence can have major adverse impacts. The condition that extreme events are rare (or have been rare in the past) is important: Because their occurrence lies outside the sphere of normality, it is difficult (and expensive) to prepare for and cope with them (Sarris 2014). This difficulty does not only refer to individuals, firms, or public institutions (governments) but also to markets that are not always able to provide insurance against extreme events (e.g., Jaffee and Russell 1997).

A common way to conceptualize extreme events is to relate them to higher-order quantiles of a probability distribution, as illustrated in Fig. 1.2. Typically, events outside a certain quantile (gray-shaded area) are classified as extreme events. As they are so rare, even in countries with developed financial systems, insurances are not available. Whenever (private) insurances are not available, public insurance through government programs or policies might increase welfare. This includes also the case whereby a government alters the shape of the probability distribution, for example, due to public stockholding programs that prevent extreme price shocks. As insurance is costly and can be impaired by moral hazard and adverse selection problems, not all events should be covered by insurance (or not all volatility should be reduced through government intervention). This is indicated by the risk retention layer, in which households or societies can handle price changes. In practice, it is often challenging to determine the thresholds between the risk layers and optimal levels of interventions. They depend on risk preferences, development of insurance markets, self-insurance and coping possibilities, and the costs of insurance.

A common threshold used in statistical analysis is, for example, the 95 % quantile. This means, on average, only 5 % of the observed price changes will be above that threshold. Given the critical threshold, classifying an event as extreme requires knowing the variance of the probability distribution, i.e., the volatility. This is where the different concepts of volatility discussed above become relevant. Depending on the volatility measure used, a significant price increase, such as a 30 % increase within 1 month, may or may not be considered as excessive. With the aim of developing a statistically consistent measure of excessive volatility, Martins-

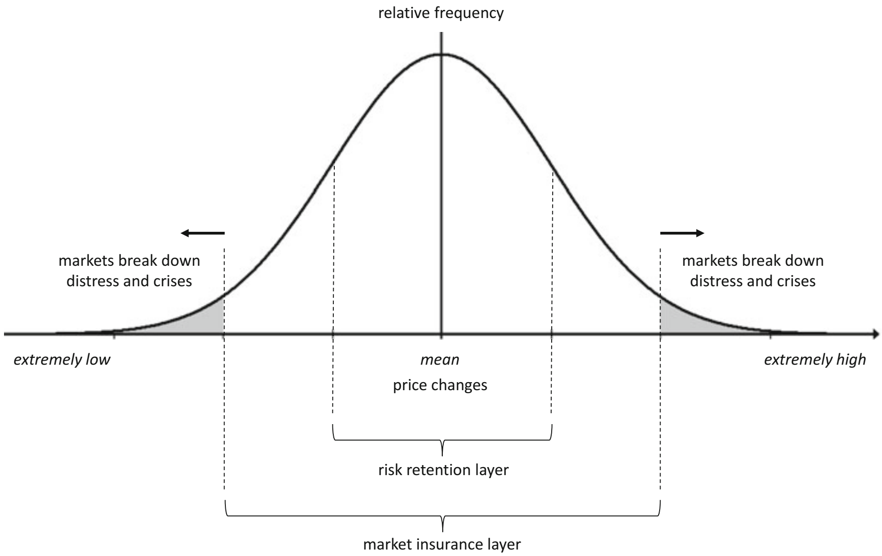

Fig. 1.2 Risk layers and extreme events. *Source*: Own illustration based on World Bank (2005) and Sarris (2014)

Filho et al. (2015) have developed the nonparametric extreme quantile (NEXQ) model that identifies extreme price variability based on a dynamic evolution of daily returns over time using historical data going back to 1954. The model is then combined with the extreme value theory to estimate higher-order quantiles of the return series, allowing any particular realized return (i.e., effective return in the futures market) to be classified either as extremely high or not.[4]

1.3 Conceptual Framework of Volatility, Food Security Impacts, and Policy Responses

Various chapters of this book deal with specific subsets of underlying causes of food price volatility and impacts on food security. Figure 1.3 depicts the broader conceptual framework embracing the subsequent analyses. As already mentioned, food price volatility is deeply related to markets where goods and services are exchanged and where prices are formed. Food markets cannot be considered in isolation: Spatially separated markets are linked through trade; food markets are influenced by commodity, asset, and financial markets; and these, in turn, influence

[4]The application of this volatility measure to most relevant agricultural futures contracts is publicly available under www.foodsecurityportal.org/policy-analysis-tools/excessive-food-price-variability-early-warning-system

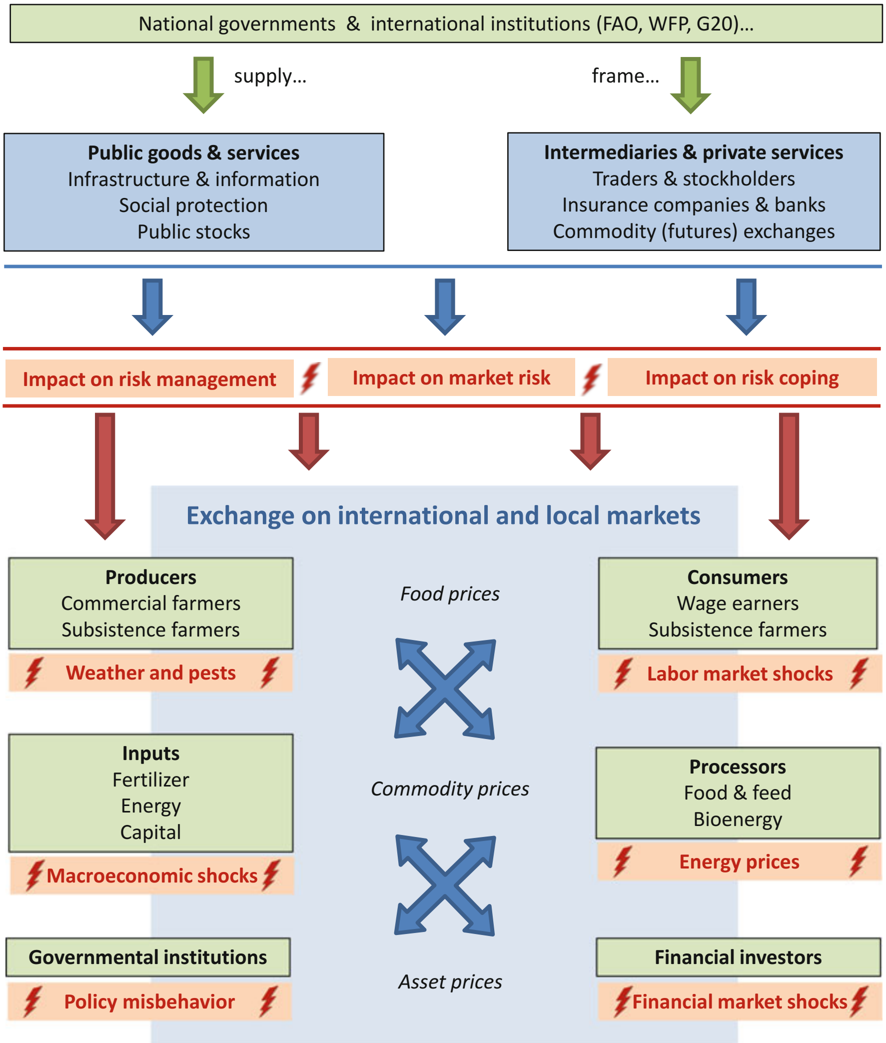

Fig. 1.3 Conceptual framework of the casual impacts of price volatility. *Source*: Own illustration

trading and allocation decisions of actors that also engage in food markets. Because of the complex interlinkages and interactions between several actors and economic sectors, food prices are not the mere result of farmers' supply and consumers' demand, and price volatility is not solely determined by harvest and income shocks. Food and feed processors form part of the agricultural value chain, as do biofuel refineries. Seeds, fertilizers, crop protection, and machinery are important inputs in the agricultural production process which increase productivity but may also increase financial risk because input investments have to be paid out of uncertain harvest revenues (Dercon and Christiaensen 2011). Governments and parastatal institutions intervene in markets by changing tariffs, imposing export restrictions or by holding stocks, and selling or buying grains (Demeke et al. 2009). Discretionary intervention can increase uncertainty and, thus, volatility.

The recent price booms led to a large debate on the role of speculation on commodity futures markets in contributing to price spikes. Speculation should not be mistaken for illegal market manipulation; it rather describes risky economic activities (buying, selling, or investing) which are associated with the *expectation* of future gains. Agricultural commodity prices are inherently volatile due to uncertain production and demand. Futures markets are a tool to hedge against this risk as it allows sellers as well as buyers to agree on a fixed price for a (physical) transaction that takes place in the future. Thus, farmers can already sell their harvest at planting time at the (then prevailing) price stipulated in a futures contract, which reaches maturity after the harvest. The futures contract therefore transfers the price risk from the farmer to the buyer of the contract. If the buyer is a commercial trader or physical hedger (who trades physical grains or processes them), they typically also want to reduce exposure to price risk by fixing the price in advance. The buyer (as well as the seller) can, however, also be a non-commercial trader who accepts the price risk because they are speculating that the price change would be favorable. It is often believed that such speculation reduces price volatility because rational profit-maximizing investors' buy contracts when prices are low and sell when prices are high. For example, this view was prominently adopted by Friedman (1953). However, economic theory is not unambiguous regarding this point, even under the assumption that speculators are rational and profit maximizing (see Hart and Kreps 1986). Other critics of speculation have referred to price developments that are beyond market fundamentals, so-called bubbles, that are caused by irrational or (trend-following) herd behavior or otherwise caused large inflows of speculative money (e.g., Masters 2008; UNCTAD 2011).

Agricultural commodities have become part of a diversified portfolio of financial investors. According to BarclayHedge, Commodity assets under management have increased from US$41.3 billion in 2001 to US$330 billion in 2012 and 2013 (World Bank 2015). The so-called "financialization" hypothesis claims that volatile liquidity flows and rebalancing of portfolios have caused commodity markets to be more exposed to shocks and price movements at other financial markets (Basak und Pavlova 2014). Holding grains for financial portfolio diversification may not necessarily increase grain price volatility (Vercammen and Doroudian 2014), and empirical studies have yet to reach a consensus about the impacts of speculation and financialization on volatility (Brunetti et al. 2011; Irwin and Sanders 2012; Tadesse et al. 2014); however, some studies have found indications of volatility transmission (Tang und Xiong 2012). While this debate continues, it is important to note that futures markets (that involve also the participation of risk-loving speculators as contracting party to risk-averse hedgers) are crucial to coordinate supply and demand over time. By doing so, they generally tend to reduce volatility (Jacks 2007), although they might also create the opportunity for exacerbating price spikes in extreme market conditions.

Because of the increasing market interlinkages across spatial and sectoral scales, understanding market risks and price volatility has become more complex. There is also the popular notion that market integration increases volatility, but there is little compelling evidence supporting the notion: Volatility of international commodity prices is not high compared to historical levels (see Chap. 2 by Díaz-Bonilla and Jacks et al. 2011). Also in African countries, volatility has not increased in the last decade (Minot 2014). Linking spatially separated markets, trade allows excess supply to be exported and grains to be imported in times of need. Diverting grains to biofuel production can reduce volatility and help stabilize food prices if conversion quantities are anticyclical to food prices.

However, export markets for all staple commodities—rice, maize, wheat, and soybeans—are highly concentrated in a few countries or very thin (i.e., only a small share of production is traded). In the case of both maize and rice, the top five producers account for more than 70 % of the global production, and the top five exporters account for about 80 % of total world exports. For wheat, the top five producers and exporters account for about 50 and 60 % of the global production and exports, respectively. These high levels of concentration imply that the world's capacity for coping with geographical risk is limited. Any weather shock or exogenous shock to production in these countries will immediately have an effect on global prices and price volatility.

Although market integration may reduce rather than increase volatility, it increases volatility spillovers. This makes it more difficult to respond to volatility and crises as causal effects become more complex and interlinked with the wider macroeconomic environment. Policy response cannot focus only on storing and releasing grains for balancing supply and demand, e.g., using public stocks. Governments affect the performance of markets through the infrastructure and information services they provide (Kornher and Kalkuhl 2013). By affecting inflation, interest rates, and exchange rates, monetary policy influences commodity storage, trade, and financial investments (Frankel 2006). Contract enforcement, rule of law, and effective government administration create the conditions for intermediaries to provide insurance and capital, thereby facilitating resource allocation and risk assessment (Levine et al. 2000; Conning and Udry 2007). Governments' commitment to predefined trade principles allows private traders and stockholders to operate and smooth prices by exploiting arbitrage possibilities.

Finally, social protection schemes could increase the resilience of households to cope with price and income shocks. Although social protection schemes and access to insurance markets have no direct impact on volatility, they reduce the negative welfare impacts of volatility and thus the need to reduce volatility by other measures.

Figure 1.3 focuses on the causal linkages between policies, markets, and agents. For greater clarity, the figure omits several feedback effects from volatility to the economy that are nevertheless relevant. Volatility itself influences the behavior of governments, producers, consumers, processors, and traders who might have difficulties in coping with excessive volatility. This can, in turn, lead to further policy misbehavior and misallocation of resources. Increased volatility may signal risks and thereby serve as a disincentive to investors, reducing the generally positive price response in production. The sensitivity of political systems and regime changes to food prices has been mentioned. An example of an empirical analysis of the sensitivity can be found in Bellemare (2015).

Commodity price volatility and macroeconomic market risk can have severe long-term impacts on economic growth and development (Ramey and Ramey 1995; van der Ploeg and Poelhekke 2009), in particular in countries with underdeveloped financial institutions (Aghion et al. 2009). Food insecurity and insufficient nutrition reduce health status and human capital, affecting labor productivity and economic output (Fogel 1994; Behrman and Rosenzweig 2004; Gyimah-Brempong and Wilson 2004; Weil 2007). Higher price volatility is also associated with greater potential losses for producers and poor subsistence farmers: Because high volatility implies large, rapid changes in prices, it becomes more difficult for producers to make optimal decisions on the allocation of inputs into the agricultural sector. Consequently, in a period of high price volatility, producers may use fewer inputs like fertilizer and high-quality seeds in their production, and they may dampen their investments in areas that improve productivity—which could adversely affect their income and the overall availability of food.

1.4 Contribution and Contents of the Book

In the subsequent chapters of this book, the problem of volatile food prices is approached from different perspectives to provide a comprehensive treatment of the subject at different geographical, political, and economic scales. This multilayer approach implies some overlap of specific topics: The role of policies, for example, is addressed in almost all chapters; likewise, the analysis of drivers and impacts of food price volatility cannot always be clearly separated due to various bidirectional linkages at different scales. Nevertheless, we choose to structure the book and the discussion of its content in five parts, starting with this introductory chapter as the first part. The second part focuses on the causes, drivers, and international policy responses that moderate or accelerate volatility. The third part provides in-depth analyses of specific market interlinkages between asset classes, commodities, and spatially separated markets. The fourth part of this book elaborates on several case studies analyzing the role of governments or supranational regional bodies to manage price volatility. The final part sheds light on how households, traders, and communities are affected by volatility and how they cope with price volatility and price shocks from a microeconomic perspective.

The book combines policy-relevant and applied research questions with advanced empirical and quantitative analysis methods. It differs from other relevant editions, which have focused mainly on international agricultural commodity markets (Piot-Lepetit and M'Barek 2011), or on theoretical and methodological works with little empirical analysis (Munier 2012). The scope of this book goes beyond a recent book by Chavas et al. (2014) by including microeconomic analysis, case studies, and explicit policy analysis. The book approaches the topic from a variety of ways, from on-the-ground field research to high-frequency time series analysis, and involves researchers who are close to political decision processes. Finally, it provides policymakers and applied researchers not only with answers to urgent questions related to food price volatility but also with tools and concepts to analyze and mitigate volatility in related contexts.

Part II: Food Price Volatility at International-Level Food Commodity Markets The second part of the book analyzes international agricultural markets, price volatility, and policy responses on an international level. It thus provides a broad overview of the major determinants and impacts. Chapter 2 by Eugenio Díaz-Bonilla examines different techniques to decompose price dynamics into long-term trends, medium-term cycles, spikes, and volatility for further analysis. It also describes ways to scale price developments by using appropriate deflators related to inflation, exchange rates, or national welfare impacts. Chapter 3 by Getaw Tadesse, Bernardina Algieri, Matthias Kalkuhl, and Joachim von Braun examines the drivers of prices of the three major food commodities—wheat, maize, and soybeans—using monthly data from 1986 to 2009. It combines agricultural fundamental variables typically used in empirical analyses (production, demand, stocks) with newly emerging determinants of commodity prices like energy prices, speculative activities, and financialization linkages. Unlike existing work that used only agricultural fundamentals (typically on an annual basis) or financial market and futures market data (on a weekly basis), the large set of variables allows the relative contribution of these two groups of drivers to international price spikes and price volatility to be explored.

In Chap. 4, Joe Glauber and Mario Miranda develop an intra-annual rational equilibrium trade and storage model for the global soybean market. The model considers the different seasonal production patterns in the Northern and Southern Hemispheres. Fitting their model to historic production and trade data and using USDA forecasts for future trends, they show how international trade exhibits increasing seasonal patterns. A more balanced production in the Northern and Southern Hemispheres further reduces volatility. Finally, the intra-annual modeling exercise cautions against the practice of summing up ending stocks from several countries with different seasonal production to obtain an aggregate indicator of global stocks. Chapter 5 by Will Martin and Maros Ivanic discusses the impact of food price spikes on poverty rates for different time scales. In the short run, price increases lead to increased poverty rates in most countries as many poor households are net buyers of food. In the medium to long run, higher commodity prices may also lead to higher wages due to agricultural–labor market linkages. This, in turn, would also reduce poverty for many net buyers of food who are wage receivers, leading to lower poverty rates in most countries and on the global scale. Anticyclical trade-related policies have been used by many countries to insulate their domestic markets from international shocks; these policies are collectively ineffective. Countries should instead establish or expand safety nets to provide assistance for adversely affected households.

Continuing with policy analysis, Maximo Torero discusses the role of the G20 in responding to the international food crisis in Chap. 6. He reviews the prevailing policy approaches to deal with volatile prices before the 2007/2008 crisis and the new proposals that emerged during and after the crisis. These measures focus on improving the information base by employing new instruments to make trade more reliable or market tools to hedge against international price shocks. Both physical and virtual emergency reserves are considered as potentially effective measures to prevent crises, but the technical and political aspects of implementing such reserves remain challenging. In Chap. 7, using national crop calendars from major global crop producers, Mekbib Haile, Matthias Kalkuhl, and Joachim von Braun construct a global panel data set on acreage, yield, and production response to international prices prevailing at the respective planting time. The empirical analysis confirmed that globally, producers respond positively to own crop prices and negatively to competing crop prices and price risk (volatility). Applying the empirical model to the recent price and volatility developments revealed that the global supply response to higher crop prices was substantially weakened by high fertilizer prices and price risk. Hence, excessive volatility also has negative long-run consequences for global production expansion, which in turn may contribute to high prices and high vulnerability of the global food system to harvest shocks.

Chapter 8 by Antoine Bouët and David Laborde focuses on trade policy and, more specific, export taxes in times of food crisis. Export restrictions are both a response of exporting countries to high international food prices and a driver of additional international price increases. The authors elaborate on the different motives behind applying export taxes and analyze and assess their quantitative role in the 2007/2008 food crisis. Although anticyclical trade policy is a rational individual choice to insulate domestic prices from international prices, collective action by different countries partly neutralizes this effect while leading to large market distortions. As existing WTO rules and legislation are not capable of solving this collective action failure, alternative mechanisms need to be implemented, e.g., on a plurilateral base or by introducing a Pigouvian tax that reflects the external social costs of anticyclical trade policy.

Part III: Commodity and Financial Market Linkages

The third part provides in-depth analyses of specific market interlinkages by analyzing volatility spillovers and transmission of price spikes between different asset classes (beyond commodities) or between countries (for specific commodities). Chapter 9 by Stephanie-Carolin Grosche and Thomas Heckelei calculates the directional spillovers of intraday volatility between agricultural, crude oil, real estate, bond, stock, and currency markets. The authors examined how market spillovers evolved since 1999; index-linked exchange-traded products have increasingly gained popularity since then. While overall cross-asset spillovers hardly changed during the period of the first financial crisis and during downturn in equity markets between March 2000 and December 2003, the market experienced a strong increase in volatility spillovers during the second crisis period between July 2007 and December 2012. The higher degree of market integration and interaction also affected agricultural commodities, in particular corn and wheat. Focusing on the wheat sector, Bernardina Algieri analyzes in Chap. 10 the role of weather events, grain stocks, monetary policy, speculation, and financial markets. A vector error correction analysis was used to confirm that a multitude of factors, including speculation (measured by Working's speculation index), monetary policy, oil prices, and global demand changes, are decisive for the wheat price formation. In Chap. 11, Carlos Martins-Filho and Maximo Torero develop a nonparametric model to analyze the impact of volatility on international markets on relative food prices in developing countries. They found that higher international wheat price volatility is often associated with higher relative domestic bread prices and cereal prices, while international maize price volatility affects relative meat prices in developing countries. As the direct welfare impacts of volatility are difficult to measure, their approach provides a useful alternative way to study the welfare impacts of excessive volatility.

In Chap. 12, Matthias Kalkuhl combines comprehensive price transmission analysis with data on poverty rates in countries to examine the exposure and vulnerability of the global poor to international price spikes. The analysis relies on an alternative grain prices index that consists of prices of the major domestic staples and is therefore a relevant proxy for food expenditures of the poor. The consideration of a large set of international reference prices, including prices of futures contracts at major exchanges, allowed for the identification of the markets that are relevant for price transmission in a specific country. Mapping transmission elasticities onto poverty rates showed that a large share of the global poor lives in countries where international market shocks have significant impacts on domestic food markets. Chapter 13 by Francisco Ceballos, Manuel A. Hernandez, Nicholas Minot, and Miguel Robles employed a multivariate GARCH to analyze the transmission of price volatility from major international commodity markets to domestic food products in 27 developing countries. The results indicate that African countries exhibit on average higher domestic price volatility. Volatility transmission from international to local markets is heterogeneous among commodities and countries. Maize prices showed the highest volatility transmission to Africa, rice prices to Asian country, and wheat prices to Latin America. The analysis suggest that not only do prices adjust through spatially separated agricultural markets but also *price risks*—i.e., the likelihood of experiencing strong future price changes—of local food markets are affected by international markets.

Part IV: National and Regional Policy Response to Volatility

The fourth part of this book contains studies analyzing the role of governments or supranational regional bodies in managing price volatility. In Chap. 14, Shweta Saini and Ashok Gulati describe the role of Indian agricultural policies in increasing domestic grain production and providing affordable food for poor people. These policies could temporarily isolate domestic prices from international price spikes in 2007/2008, but prices co-move over longer periods of time as India also frequently trades grains. The current policy reform agenda focuses on implementing the right to food, as formulated in the National Food Security Act, and on fostering further productivity increases. Both could contribute substantially to reducing hunger and malnutrition globally.

Based on the idea of risk pooling, Lukas Kornher and Matthias Kalkuhl examine how West African countries within the ECOWAS region can benefit from coordinated grain stocks in Chap. 15. Compared to the situation whereby each country establishes its own grain stock to balance against harvest shocks, a regionally coordinated or joint reserve could compensate equally for harvest failures with substantially lower stock-to-use ratios. This reduction in reserve size by more than one-third indicates the huge cost reduction potential of regional storage cooperation. However, agreeing on cost sharing and stock allocation rules may pose a political challenge in international negotiations. The chapter also emphasizes that the cost saving resulting from cooperation is large when emergency reserves are small (aimed at ensuring food supply for a targeted population of poor households), while the cost saving diminishes when buffer reserves are large (aimed at stabilizing prices in both directions). Chapter 16 by Ousmane Badiane and Sunday Odjo provides an in-depth trade analysis of three African Regional Economic Communities, including COMESA, ECOWAS, and SADC. Large benefits from diversification, a result of low correlation of yield shocks within regions, exist mainly for the COMESA and SADC region and to a smaller extent also for the ECOWAS region. High tariffs and high transportation costs due to poor infrastructure have impeded trade flows within Africa despite generally favorable conditions for specialization and product differentiation in agricultural production. Using a CGE model to simulate the impact of policies on reducing trade costs and increasing yields emphasizes the large potential to not only increase regional trade but also make trade more reliable.

Chapter 17 by Irfan Mujahid and Lukas Kornher presents a case study of the regional rice emergency reserve the member countries of the Association of Southeast Asian Nations (ASEAN). It first describes the historical and recent development of the joint emergency reserve, which culminated in the creation of the East Asia Emergency Rice Reserve (EAERR). To be able to maintain food security for at least 2 months after a supply short fall, the storage cooperation of ASEAS+3 countries reduces the required rice stocks by roughly 44 %. Due to the higher transportation costs arising from centralized storage, cost savings amount to around 40 % compared to individual emergency reserves. As shown by the authors, the relative benefit of cooperation decreases when more countries join the reserve due to decreasing marginal impacts of diversification. This may limit the inclusion of India into the regional reserve: The coordination and implementation costs may eventually exceed the benefits of cooperation.

In Chap. 18, Jan Brockhaus, Jikun Huang, Jiliang Hu, Matthias Kalkuhl, Joachim von Braun, and Guolei Yang analyze the impact of market price signals, weather shocks, and irrigation on grain production in China. Using province-level data, they found that Chinese farmers in general respond well to price signals. This implies that higher domestic demand for rice, wheat, and corn can, to a large extent, be met by increasing domestic supply. The authors also identified the months of a marketing year that are crucial to predict farmers' response to market prices, which is important for estimating grain supply in the short term. Furthermore, heat stress and droughts reduce production. This dependency on weather events despite the expansion of irrigation could become an important challenge against the background of climate change.

Maximo Torero provides a detailed assessment of the policy recommendations by international organizations in Chap. 19. He distinguished between the short-term and long-term policies that were postulated by key actors of the international community. Contrasting the policies with economic theory led to a refined conclusion regarding the role of trade policies implemented by small countries: These policies are effective and produce only small beggar-thy-neighbor effects which have been emphasized a lot in later policy debates. A comprehensive analysis of policies implemented by several developing countries shed light on the impact of international organizations on national policies and the importance of a solid scientific work to policy recommendations.

Part V: Impacts of Excessive Price Spikes and Volatility

The final part of the book examines how households, traders, and communities are affected by and how they cope with price volatility and price shocks from a microeconomics perspective. Chapter 20 by Mekbib Haile and Matthias Kalkuhl explains that farmers' price expectation formation is a result of a cost–benefit decision process on the (costly) acquisition of information. Using empirical data on expected and realized prices of Ethiopian smallholder farmers, they found that the use of information technologies, in particular mobile phones and radios, reduces price forecasting errors and thus improves the crop and input allocation process at planting. Likewise, infrastructure which reduces the effective distance between households and markets improves the price formation process. The chapter therefore provides alternative ways to reduce the negative impact of price volatility without the need to stabilize prices.

Anna d'Souza and Dean Jolliffe analyze the impacts of the 2007/2008 wheat price shock on Afghan households in Chap. 21. Using an unconditional quantile regression which accounts for heterogeneous impacts of wheat price increases, they found that extremely food-insecure households (the lowest decile) hardly reduce food consumption even when food prices increase, while households in the second to 10th decile reduce food expenditures and calorie intake at an increasing rate. Apart from calories, protein and micronutrient intakes are reduced as well. Households cut back on not only food expenditures but also non-food consumption, in particular health, grooming, and communication. They also increasingly purchase food on credit when prices of wheat flour increase.

In Chap. 22, Raymond Jatta explores the impact of community food reserves on local food security in the Gambia. Using a propensity score matching technique under a partly randomized development intervention program, he found that community reserves improve subjective indicators of food security. Furthermore, communal food reserves reduce seasonal price variability as part of the excess demand after harvest is stored for the lean season when prices are typically high. Chapter 23 by Lukas Kornher presents insights from a survey on grain traders in Ghana. Most traders store grains to exploit seasonal price fluctuations and, thus, aim to clear their stocks before the new harvest sets in. The trading and storing of grains are driven by different motives and strategies, but decision making seems to be influenced by risk aversion, policy uncertainty, and imperfect information on agricultural markets. The analysis emphasizes the need to further develop models of heterogeneous trader types in the context of information scarcity.

1.5 Implications for Policymaking

The main policy message of this book is volatility matters, and there is a lot which can be done about it. Volatility matters because volatile food prices are closely linked with the stability dimension of food and nutrition security. Extreme price shocks are associated with insufficient micro- and macronutrient intake, which negatively affects health and mortality and impedes the physiological and cognitive development of children (Black et al. 2013). Undernutrition, in turn, reduces labor productivity and economic growth.[5] The risk of future price shocks reduces investments in agricultural production, which has negative long-run impacts on food supply. Volatile food prices increase political risks which could induce governments to adopt ill-designed ad hoc market interventions.

Volatility did not only matter in 2007/2008 and 2010 at the global level, but it is also still a highly relevant issue today at regional and country level, despite declining global food prices. Many of the underlying structural problems leading to volatile agricultural markets since 2007 have not been properly addressed. Emerging risks from other domains—extreme weather events due to climate change, conflicts and political instabilities in the Middle East and Africa, and the ongoing use of expansive monetary policy leading to low interest rates—could lead to new sudden extreme events. The international community and many governments have yet to develop an effective risk management strategy to be well prepared for future crises.

Based on the analysis and evidence of this book, policymakers can address the problem of volatility with three major strategies:

1. Policies to reduce excessive volatility: embracing open trade, flexible bioenergy policies, grain reserves, and regulation of commodity markets
2. Social protection and nutrition policies to alleviate chronic and acute undernourishment; insurance markets
3. Redesigning international institutional arrangements and organizations for food security to address collective action failures

For policymaking, it is not about choosing one of the policy instruments proposed here, but rather a portfolio of policies that best addresses the relevant issues. The weights of such a portfolio will be context dependent: Countries with high

[5] Various studies investigate the link between nutrition, health, labor productivity, and growth, inter alia, Fogel (1994), Behrman and Rosenzweig (2004), Gyimah-Brempong and Wilson (2004), Weil (2007).

administrative capacity, for example, could rely more on social protection, while others may opt for rule-based storage policies. In any case, policies between countries and domains need to be coordinated to produce synergy and to avoid any possible offsetting effects.

1.5.1 Policies to Prevent and Reduce Excessive Price Volatility

Volatility is a natural phenomenon of the market economy, whereby prices respond to changes in demand and supply. Perfectly stable prices do not provide incentives for storage or supply adjustments due to prevailing situations of scarcity or abundance. Excessive volatility can, however, also be driven by exaggerated trading behavior, suboptimal grain storage, uncoordinated trade policies, excessive speculation, financial and energy market spillovers, and a lack of information. These issues provide areas for policy intervention to improve the functioning of agricultural markets and to avoid calamities during food crises.

1.5.1.1 Agricultural Markets: Information, Transparency, and Regulation

Improving the information base on global agricultural markets and increasing the transparency of commodity (futures) markets have been important goals of the international community, including the G20 and the UN (De Schutter 2010; UNCTAD 2012). The Agricultural Market Information System (AMIS), established in 2011 as a G20 initiative, still leaves a lot of room for uncertainty as there are major differences between the estimates from different sources, especially related to grain stock levels. Countries therefore need to increase their commitment to sharing high-quality information. Several price monitoring and early warning systems have been established by international organizations to detect any upcoming crises on food markets.[6] Nevertheless, high-frequency and high-quality price data is still not available for many developing countries, and a comprehensive information platform that harmonizes the different information and indicators and that also incorporate bottom-up information is still unavailable. Investment in additional price data collection could further improve these tools.

Possible ways to curb excessive speculation are (1) increasing the transparency of actors and transactions by introducing appropriate reporting obligations, (2) introducing position limits, (3) imposing transaction taxes, and (4) influencing prices and price expectations directly by intervening in commodity markets through physical and virtual reserves.[7] Agricultural commodity markets should not be exempted from the relevant regulation of banking and financial systems because grains and

[6]Important examples of such systems are FAO Global Information and Early Warning System and the WFP Price Monitor for domestic prices, IFPRI Excessive Food Price Variability Early Warning System for international prices, and FEWS NET for local harvest conditions.

[7]More in von Braun and Torero (2009)

oilseeds markets are closely connected to speculative activities in financial markets. As commodity exchanges are linked globally (Hernandez et al. 2014), much coordination is necessary to harmonize regulation. Excluding food commodities completely from speculative transactions, however, could be counterproductive as it impedes the price identification process and could even increase volatility (Santos 2002; Jacks 2007). An important alternative is therefore to strengthen responsible investment approaches of the financial sector, which include food security risk management strategies for imposing temporary restraints on commodity markets.

1.5.1.2 Stocks, Trade, and Regional Cooperation

In general, two modes of storage policy regimes could be considered: buffer stocks and strategic reserves. The former involves buying and selling at all times and attempting to stabilize farm gate and consumer prices. In doing so, additional supply is provided to the market when prices exceed a predetermined ceiling. On the other hand, whenever prices are low, governments act as a buyer of last resort. Buffer stocks aim at benefiting producers and consumers, by far the largest lobby group in developing countries, and buffer stocks are thus often backed by the population. Although large public buffer stocks can effectively stabilize prices,[8] they also have high fiscal costs, crowd out private storage, and are hardly compatible with free trade principles as subsidized grains would leak out.[9] In contrast, strategic reserves hold stocks for emergency situation only in order to supply the most vulnerable people with food during periods of food shortage or price hikes. In doing so, strategic reserves are very efficient in overcoming temporary supply shortages without distorting local markets substantially.

Facilitating trade has great potential to stabilize food supply, as indicated in Chaps. 4, 5, 8, 15 and 16. The larger the world market, the lower the price variations needed to balance demand and supply. A more open trade and stock release policy of India and China, two countries sitting on large grain stocks, could play a key role in improving global food security. More trade liberalization in general, and in particular by these two nations, could improve the global food security situation. Further cooperation can be achieved by building independent regional or international grain reserves (which include other nutritious foods) exclusively for emergency response and humanitarian assistance. Regional policy bodies, such as ASEAN, the South Asian Association for Regional Cooperation, and African regional and subregional bodies, have partly implemented joint reserve policies, which constitute a step in the proposed direction. As Chaps. 15, 16, and 17 will show, regional cooperation has a strong potential to reduce costs compared to national approaches. A regional set of arrangements, however, remains suboptimal as the full diversification potential could only be exploited under global cooperation;

[8] See, e.g., Kornher and Kalkuhl (2013), Serra and Gil (2013), Mason and Myers (2013), and Jayne et al. (2008).

[9] See Kozicka et al. (2015) for the case of India.

such arrangements may also run into problems of trust in regions with one or two dominating regional powers. Hence, regional cooperation should be seen as one promising step toward building a sustainable global architecture of trade and storage cooperation, including coordinated risk management.

1.5.1.3 Biofuel Policies, Energy Prices, Climate Change, and Technological Change

Climate change is strongly connected to food security and price volatility. Weather events affect agricultural commodity prices (Chap. 10), and extreme droughts and floods do not only affect food production but also the health conditions and disease environment that further interacts with the food system (Wheeler and von Braun 2013). Mitigating climate change, however, also affects food systems due to emission reduction in the agricultural sector, which is linked to changes in land use and cultivation systems. These trade-offs can best be addressed by policies that directly target GHG emissions and foster investments in adaptation, infrastructure, and technological advancement in seeds.

Energy prices have been shown to be an important determinant of food price spikes and volatility; they affect not only production and transportation costs but also demand for bioenergy, which is competing with food production for crops (Chaps. 3 and 10). Current biofuel policies are ill designed for two reasons: (1) Mandates or minimum quotas create an inelastic demand as they provide little flexibility in reducing biofuel production when food prices are high; this, in turn, can increase food price volatility due to supply variability (Beckman et al. 2012), and (2) biofuel subsidies tend to reduce energy prices and therefore increase energy demand, which leads to inefficient carbon emission reductions compared to a carbon tax or emissions trading scheme (Cui et al. 2011; Kalkuhl et al. 2013). Second-generation biofuel technologies may further increase the land efficiency of biofuel production and therefore lessen the trade-off between energy and food production (IPCC 2011).

1.5.2 Social Protection and Nutrition Policies

Actions related to agricultural production, trade, and reserves are necessary but not sufficient for overcoming the food and nutrition security crisis, which not only is an acute problem but also exacerbates a chronic global problem. As agricultural markets will always exhibit volatile prices due to random production shocks, health and nutrition risks have to be addressed through social protection and responsive health services. Most of these actions are carried out by national governments, but international support for these investments is also needed, especially in the least-developed countries (Morris et al. 2008). Setting priorities in this area requires a sound metric for targeting actions and measuring progress. Policy actions in three priority areas are called for: (1) Expand social protection and child nutrition action to protect the basic nutrition of the most vulnerable; (2) take protective actions to mitigate short-term risks (such actions would include cash transfers, pension systems, and employment programs); and (3) adopt preventive health and nutrition interventions to avoid long-term negative consequences.

Cash transfers are associated with lower cost of delivery than in-kind transfers, but the latter may have a lower inclusion targeting error, as the fact of being a beneficiary is more visible. The costs of a social transfer program depend on the scope of coverage and efficiency of the program. Social transfer programs rarely account for more than 1–2 % of a country's GDP, even in countries with generous social protection systems. Safety net programs in Mexico and Brazil cost around 0.5 % of their GDP (World Bank 2012). India is an example of a big scale food subsidy program associated with high fiscal cost (food subsidy amounts to close to 0.8 % of the GDP) and additional economic costs due to market distortions. A challenge in social transfer programs is their responsiveness to crises: Programs need to be upscaled as the size of vulnerable population and individual needs increase in times of crisis. This requires not only upfront investments in monitoring and targeting but also potential macro-insurances on the government level to secure public funding. Low-income countries typically lack the organizational and fiscal capacity of such macroeconomic responses and therefore need to resort to the second best option of addressing the social consequences of food price shocks. International finance organizations and development banks should play a more significant role in building preparedness and rendering assistance in creating economically efficient social protection for low-income countries' coping with extreme food price events.

In addition to nutrition-specific approaches, governments can improve the functioning of the financial sector with the focus on improving access of the poor to financial services. These measures are aimed at preventing income instability due to price volatility. Access to futures markets, credit, savings, and insurance could be an important buffer to protect the poor farmers and consumers from the effects of food price volatility. These tools are important for both food producers, in times of price drops, and food consumers, during price hikes. These instruments can support the poor in other critical situations not directly related to price volatility and thus have additional co-benefits. However, the poor often have problems accessing financial instruments as they do not have enough credibility, assets for collateral, or the means to pay for insurance. Thus, increasing access to financial services should become an important priority.

1.5.3 New International Institutional Arrangements

International extreme food price volatility calls for global governance action that requires institutional arrangements, which are currently lacking. Actions to shape a well-functioning global institutional architecture for food that is capable of delivering international public goods for food and nutrition security are overdue.

A legitimate, nimble, and innovative set of strategic bodies to help coordinate the actions of others (i.e., some of the existing international organizations) is needed: a *platform* that can facilitate global action as well as government-to-government networks while including private sector industry and civil society actors. Such a platform should have legalized political authority to watch over and broadly facilitate public goods delivery to support global agricultural development and food and nutrition security. A candidate could be a truly independently governed Committee on World Food Security (CFS). Global nutrition policy needs an organizational home and not split among currently five agencies. Additionally, to better mitigate and respond to emergency food crises, the World Food Programme (WFP) needs to be supported by getting a reliable global food store and funding that permits flexible response. Furthermore, the current and future challenges of food and nutrition security require a strong mechanism for implementing science- and research-based assessment as a permanent institutional arrangement. A global body tasked with this could be mapped along the lines of the Intergovernmental Panel on Climate Change (IPCC), but with less emphasis on achieving (political) consensus. The body needs to have a perspective on the coming two to three decades as the food situation is filled with both uncertainties and opportunities. The system should be redesigned step by step. The steps could be guided by cost-effectiveness assessments while adhering to the principles of legitimacy with accountability, effectiveness, and inventiveness. Leadership is required to meaningfully implement this redesign option. The leadership could come from developing countries via the UN and the G20, which could play a key role in initiating the change.

1.6 Implications for Future Research

This book provides insights into and some answers to volatility-related food security analysis. It also points to new research questions and directions for future research. Some of these are methodological and conceptual, while others refer to practical or political implementation issues. A challenge faced when researching into the drivers and impacts of volatility is to better establish causality and link empirical analysis to economic theory and structural (equilibrium) models. In the following section, we underline the main areas we have identified for future research.

Linking Extreme Events and Excessive Volatility to Social and Human Welfare The methodological discussion about the different ways to measure volatility and extreme events at the beginning of this chapter could not give a satisfactory answer as to which concept of volatility and which threshold for extreme events are the most suitable for welfare analysis. Future research should therefore concentrate on how households, firms, and governments anticipate volatility and form expectations about risk and on finding out the extent to which anticipated shocks differ from unexpected shocks in terms of social and human welfare.

Game Theoretic Modeling of Cooperation in Food Security Trade and storage cooperation have been identified as strategies to increase resilience in food systems. Cooperation is, however, not always in the interest of individual countries (Chap. 8). Additionally, a free rider problem can arise when emergency reserves are established by some countries or regions which also stabilize prices in other countries. The problem may be addressed within a game theoretic framework that explicitly models the objectives of individual countries, their interactions, and evolving strategies. There are a few important policy questions to answer: What institutional arrangements (e.g., sanctioning mechanisms) can facilitate cooperation and avoid collective action failure? Can a subset of countries (a coalition) also achieve large improvements or is full participation necessary? Which countries are necessary for such a coalition?

Analyzing Regulatory Policy Instruments in Agricultural Commodity Markets Speculation and financialization affect commodity prices (Chaps. 3, 9, and 10), yet it is unclear how permanent or temporary position limits and transaction taxes would influence price formation, volatility, and spillovers in agricultural commodity markets. Agent-based models can provide a framework for analyzing policy instruments in a setting whereby agents follow predefined behavioral rules (Grosche and Heckelei 2013). This, in turn, requires further research on the behavior of commodity traders and investors.

Understanding Expectations and the Value of Information Forming expectations about future prices and volatility is crucial for making production and storage decisions that involve large time lags. Apart from the classical approaches presented in economic theory (naïve, adaptive, and rational), how expectations are actually formed and how access to information can help to improve the expectation formation process are not well understood. Chapter 20 provides an initial attempt to understand these questions, but further analysis with broader data sets is needed to quantify the benefits of access to different types of information. A high degree of IT penetration in the developing world, which includes farmers in remote areas, may reduce market information constraints, even for the poor. This emerging change in information infrastructures needs to be factored in, and potential interventions in information services need to be further explored.

Integrating Risk and Volatility into Models with Longer Time Horizons Integrating a short-term concept like volatility into agricultural and economic equilibrium models with longer time horizons remains a challenge. Volatility is investigated using time series models (with high-frequency data) or rational expectation equilibrium models. Both classes of models can hardly represent global trade flows and trade policies, welfare changes, and (potentially endogenous) long-term trends in technological change. Advancing model integration in this direction is important not only for better understanding the impact of market risks on long-term developments but also for properly integrating climate change risks into agricultural economic models.

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Part II

Food Price Volatility at International Food Commodity Markets

Volatile Volatility: Conceptual and Measurement Issues Related to Price Trends and Volatility

2

Eugenio Díaz-Bonilla

2.1 Introduction

It is obvious that prices are crucial variables (although certainly not the only ones) in making decisions pertaining to production and consumption. Producers and consumers are affected by both price levels and changes in price levels (variability or volatility). In the case of agricultural and food policies, there have been several debates about adequate price levels of food products and ways of reducing price volatility to a degree that does not interfere with the signaling effects of prices for economic decisions. Those policy issues revolve around balancing the interests of producers and consumers in increasingly differentiated societies in both industrialized and developing countries.

In the 1990s, policy debates focused on global price levels and whether they were too low. The last two price spikes in 2008 and 2011 have led to renewed concerns about the impacts of high food prices and shifted the focus back on food price volatility. The effects of changes in price trends on food production and food consumption (a discussion about price levels) are different from the effects of changes in volatility around those trends (cycles and extreme events), but both aspects are related. Policy analyses about those developments require clarifying some existing questions about both price levels and their variability (Díaz-Bonilla and Ron 2010), such as what to measure (including the appropriate time frame and currency) and how to measure (for instance, how to characterize trends given the

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existence of different detrending methods; see, for instance, Canova 1998, 1999). The next section reviews in general several topics related to the impacts of price trends and variability. Then, the main section, divided into separate subsections, discusses different issues related to what to measure and how to do it. The final section concludes this chapter.

2.2 Price Levels and Price Variability

Price levels affect producers' profits (and therefore their incentives to produce) and food costs to consumers (and consequently their purchasing decisions and economic access to food). Therefore, much of the debate regarding different policy approaches to agricultural production and food security revolves around a traditional policy dilemma (Timmer et al. 1983): high prices to support production or low prices to help consumption. High agricultural prices and food prices should normally lead to more future production, improving future physical availability, while making consumption more costly and reducing economic access. The reverse is true for low agricultural prices and food prices, which would worsen availability but improve economic access.

Therefore, in the short run, high food prices benefit producers (all things else being equal), while low food prices help consumers. But in the medium to long term, high food prices may positively affect even net food buyers if higher food prices generate dynamic economic processes that raise employment rates and/or wages (in both rural and urban areas) by amounts that more than compensate for the greater cost of food. Ivanic and Martin (2014) and Headey (2014) have discussed the different short-, medium-, and long-term impact of price changes. For example, higher agricultural and food prices may lead to increased investments from the private and public sector in agricultural production and in rural areas; this positively affects employment and wages. If, as argued in different studies, growth in agricultural (and food) production has a large and positive multiplier effect on the rest of the economy (Haggblade and Hazell 2010; Haggblade et al. 2007), and appears to be more effective in reducing poverty than growth in other sectors (Christiaensen et al. 2010; Eastwood and Lipton 2000), then higher agricultural and food prices do not generally pose a dilemma in policymaking because they lead to more employment opportunities and higher wages, particularly for lower-income producers and workers. There may also be some positive dynamic effects if a policy leads to investments in productivity, thereby reducing production costs and prices in the medium term, even though it increases food prices in the short term.

The opposite may also happen: farmers shielded by highly protective policies and pampered by subsidies may not need to invest to attain their desired profit levels; therefore, protection and subsidization may lead to fewer investments and lower productivity (see, for instance, Fan 2008; Mogues et al. 2012; Allcott et al. 2006). Also, higher agricultural and food prices may increase wages and production costs in other productive activities. Consequently their external and internal competitiveness may be affected, leading to an overall reduction in domestic production and employment (see Díaz-Bonilla 2015).

Both high prices and low prices result in supply and demand adjustments if markets operate normally and if price signals are transmitted properly to producers and consumers. Higher prices should eventually lead to higher production and lower consumption; both effects would push prices lower (and vice versa in the case of lower prices).

Those who take the perspective of poor producers prefer high food and agricultural prices, arguing that the agricultural sector's multiplier effect has important benefits for employment and poverty alleviation; a small subset of those analysts gravitate toward protection and price support through government policies. Those who take the perspective of poor consumers emphasize the importance of low food prices because of their positive effect on urban and rural poverty and malnutrition. They usually suggest lower levels of protection and consider the use of some types of consumption subsidies. But governments need to take into account the welfare of both producers and consumers when considering the short-term impacts as well as the medium- to long-term dynamic effects.

This policy dilemma has led to a variety of policies in developing countries, with very mixed results. A government might try to keep producer prices high and consumer prices low through subsidies and market interventions, but the developing countries that have tried such an approach usually find the policies unsustainable. This is mostly caused by fiscal costs, the distortions generated in production and trade when not using market prices, and the usually inequitable distribution of costs and benefits.

The debate about *price volatility* differs from the previous discussion on price levels.

It has been argued that price instability generates uncertainties about the true price level for producers and consumers, and therefore, production and consumption decisions may lead to suboptimal outcomes compared with those attained under more stable price conditions. For producers, price volatility may reduce investments and cause production to shift toward lower-risk, but also less productive, technologies (although World Bank 2005 estimated that these effects may not be significant). High and variable food inflation and price spikes affect consumers negatively because of reduced or uncertain access to food. This is particularly true for poor and vulnerable households, whose incomes do not adjust with inflation and which do not have assets to stabilize their consumption patterns.

There may also be negative macroeconomic impacts, such as balance of payment, public deficits, and declining total investment because of uncertainty all of which may also have second-round effects on poverty and food security (Timmer 1989). It is also important to consider the political impacts—an increase in food prices could lead to social unrest and riots. However, some have noted that high price shocks (spikes), which are only one form of (asymmetric) volatility, rather than volatility in general, seems to motivate political riots and unrest (see Barrett and Bellemare 2011). Persistent food inflation also tends to generate political problems, but in many cases, sustained inflation (in contrast with price shocks) is the result of macroeconomic difficulties that may not be related to developments in food markets.[1]

It is therefore crucial to define "stability" and "volatility," polar opposites of each other. In the context of monetary policies, the idea of price stability has usually been interpreted as inflation in the range of 0–2 % per year. However, more recently, when evaluating policies to confront the effects of the 2007/2008 financial crisis, it has been suggested that price stability could be redefined as annual inflation that does not exceed 4 % (Blanchard et al. 2010). A "stable" annual inflation of 2 % means that the nominal price level is permanently increasing. For example, at 2 % annual inflation, the price level will increase almost 50 % in nominal terms in 20 years; at 4 %, the price level will more than double over the same period. In other words, stability in price levels and stability in the rate of change of those price levels (i.e., stability of inflation) are two different concepts.

In the case of food and agricultural prices, the notion of stability for producers refers mainly to price levels, while for consumers, the main problems are associated with high and persistent food inflation.

When considering stability of price levels, it is important to distinguish between the trend, potential changes in that trend because of the emergence of a new trend, and the variability or volatility around those trends. The last concept, in turn, may include both a reasonably smooth business cycle movement and shorter-term volatility surrounding the business cycle, which may or may not reach extreme values (such as in the case of price spikes or crashes). Smooth and predictable price movements that are part of the economic business cycle (as in the case of macroeconomic models of inflation that consider the gap between actual and potential GDP) may be more easily anticipated. Therefore, such variability may be incorporated ex ante into economic decisions. Further volatility, in excess of the trend and cyclical movements, tends to have shorter durations and may cause price shocks, leading to prices falling outside the range of trends or normal cycles, depending on the time horizon utilized. Those extreme price events may be defined by their frequency (e.g., those that only happen 10 % of the time historically) or by their magnitude (those that drastically deviate from the trend, such as by multiples of the standard deviation). These extreme price events are usually unanticipated, and they tend to cause economic and political disruptions.

In summary, not all types of what is commonly called "volatility" are the same, or have the same effects on production and consumption decisions; therefore, it is necessary to differentiate between price trends, their potential changes, business cycle variability around those stable or changing trends, and shorter-term variability, particularly in the event of extremely high (spikes) or low (crashes) prices.

[1] Hazell et al. (2005) argue that a nontrivial part of domestic price variability in agricultural and food products is related to macroeconomic factors (see also Dorosh et al. 2009; Rashid and Lemma 2011 in the case of Ethiopia).

2.3 Different Measures and Concepts

Before analyzing how to define trends and volatility, it is necessary to discuss several data and measurement issues related to the variables of interest (here, food prices), as discussed immediately.

2.3.1 Prices in Real or Nominal Terms

The first question is whether trends and volatility are analyzed in nominal prices or in real (also called constant or inflation-adjusted) prices. In the case of the latter, an appropriate deflator must be identified, such as the export unit value index (EUVI) for advanced economies, the US Consumer Price Index (CPI), or the US Producer Price Index (PPI).

Figure 2.1 shows the IMF index for food and beverages in nominal terms with two different deflators: the EUVI and the US CPI.

The behavior of the nominal food index is different from the two real food indices, while the last two indices also behaved differently.

The nominal variable shows a large increase in the early 1970s, reaching a plateau that lasted until the early 2000s. Then the index experienced another sharp hike, which is more drastic than the increase in the early 1970s, possibly arriving at a new plateau. In the plateau lasting from the mid-1970s to the late 1990s, the nominal

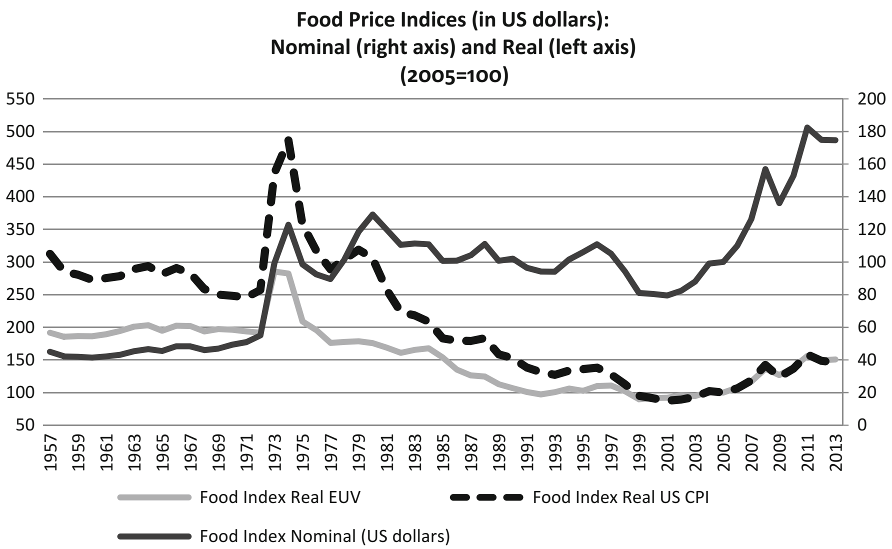

Fig. 2.1 Nominal and real food price indices. The IMF Food Price Index includes sub-categories for cereals, vegetable oils, meat, seafood, sugar, bananas and orange price indices *Source*: Author calculations based on data from the IMF

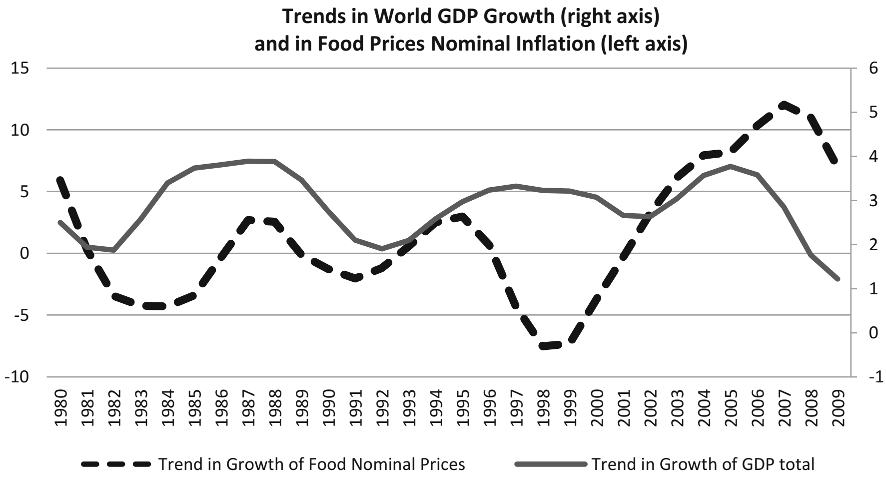

Fig. 2.2 Trends in world growth and inflation of nominal food prices. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

index showed a cyclical pattern and a relatively flat linear trend, with price peaks in 1974, 1980, and 1996. As the nominal index was climbing up to the second plateau, it peaked in 2008 and 2011.

The cyclical pattern during the plateau between 1980 and the mid-2000s appears to be influenced by, among other things, the global business cycle: When the world economy was growing faster, overall income and demand grew as well, and therefore, nominal prices went up. The opposite is true when there was slack in the global economy. This is a common pattern identified in the macroeconomic analysis of the business cycle and the behavior of variables such as wages and prices (see Rotemberg and Woodford 1999). Figure 2.2 shows the trends (using a Hodrick–Prescott filter) in world growth and food price increases.

The large increase in nominal prices in the first half of the 1970s was not exclusive to food products. Most commodities, including metals and energy, also experienced a nominal price upswing. This suggests that there was a common macroeconomic cause. In this case, the cause was related to the demise of the Bretton Woods monetary system of fixed exchange rates in the early 1970s, whereby the US dollar was strongly devalued against gold (see, for instance, Díaz-Bonilla 2010). In the 2000s, prices of metals and energy started rising in the earlier part of the decade, pushed by global growth and other macroeconomic factors; this was followed by the price increase of agricultural and food products, mostly happening in the second part of the decade (Díaz-Bonilla 2010).

The indices in constant 2005 prices, on the other hand, plateaued in the 1960s and 1970s, peaking once in 1973–1974 when deflated by the EUVI and twice when deflated by the US CPI (a larger peak in 1974 and a smaller one in 1979). Then both indices show a decline in real terms, but showing different patterns of decline. The

Table 2.1 Price volatility in nominal and real terms

Volatility	Nominal	Real EUVI	Real US CPI
1960s	3.4	2.8	3.9
1970s	21.3	17.1	21.4
1980s	6.7	5.0	7.0
1990s	7.2	6.4	6.9
2000s	9.9	6.4	9.1
2010s	10.2	7.4	9.8

Source: Author calculations based on data from the International Monetary Fund (IMF). The period of 2010s includes 2010–2014

index deflated by the US CPI shows an earlier and steeper decline compared with the index deflated by the EUVI. Both indices show a trough in the late 1990s and early 2000s, and they have recovered moderately since then. The recovery, however, is clearly of smaller magnitude than the steep increase of the nominal index, and the indices have yet to reach the levels in the 1970s. Even the large peaks of the nominal indices in 2008 and 2011 appear far smaller when expressed in real prices (a discussion of the causes of those patterns can be found in Díaz-Bonilla 2010, 2015). Since 2011, all indices, both in nominal and real terms, appear to have reached a new plateau. A key question is what the future trends in nominal and real prices would be from 2015 onward (more on this below).

Moving the discussion from trends to price volatility,[2] Table 2.1 shows a common measure of price volatility based on the standard deviation (SD) of a series constructed as $\ln p_t - \ln p_{t-1}$, where t represents the time period (which may be days, months, years, and so on), p_t refers to prices in levels, and ln is the natural logarithm (see, for instance, Gilbert and Morgan 2010; G20 2010). In this case, t is defined as one year, and the table presents the average of the annual SD for each decade. It should be noted that $\ln p_t - \ln p_{t-1}$ is an approximation of the growth or changes in prices (which may be also called price "inflation" and could be negative) between two consecutive periods. Therefore, the measure utilized here reflects the volatility of annual price inflation.

All three variables show that volatility was low in the 1960s when exchange rates were stable; volatility became higher during the multiple shocks in the 1970s, and then it declined in the 1980s and 1990s (but remained higher than the levels in the 1960s). The measured volatility increased somewhat in the 2000s and the first half of the 2010s in the cases of nominal prices in US dollars and real prices when deflated by the US CPI. The index deflated by the EUVI showed no changes in the 2000s and a small increase in the 2010s.

This section shows that it matters whether trends and volatility are expressed in nominal or real terms and which deflator is used.

[2]This measure can be applied to any variable and not only prices.

2.3.2 World Prices: In What Currency?

As noted before, developments in world macroeconomic conditions need to be considered when analyzing price movements (see, for instance, Díaz-Bonilla 2010, 2015). In particular, exchange rate movements strongly influence nominal world food prices (as in the case of the breakdown of the Bretton Woods monetary system).

Figure 2.3 shows the inverse relationship between the US dollar (measured as the effective nominal exchange rate against major currencies) and the IMF nominal index of food products. [3,4]

The figure shows that the relative value of the US dollar fluctuated significantly, with peaks in the mid-1980s and the early 2000s, while the nominal food index moved in the opposite fashion. This implies that the currency used must be considered when analyzing food prices.

Figure 2.4 compares the evolution of nominal food indices in US dollar terms and special drawing rights (SDRs), a quasi-currency issued by the IMF. Being a basket of four major currencies (the euro, Japanese yen, pound sterling, and US dollar), it represents a more stable measure of value than the US dollar alone.

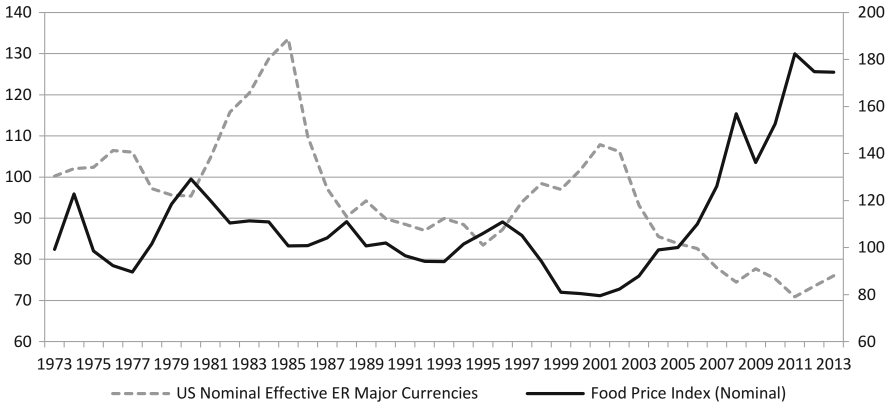

Fig. 2.3 Effective US exchange rate (nominal) (*left axis*) and nominal food price index (*right axis*). *Source*: Author calculations based on data from the International Monetary Fund (IMF) and the US Federal Reserve

[3]Mundell (2002), among others, pointed out the inverse relationship between the value of the US dollar and the price of commodities in that currency.

[4]The nominal food index is obtained from the IMF/IFS database. The US exchange rate is the index for major currencies in nominal terms calculated by the Federal Reserve. Major currencies include the euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. There is also a broader index that considers more than 20 currencies (including the major currencies already mentioned). The indices can be calculated in nominal or in price-adjusted terms. The chart shows the same pattern if presented using the price-adjusted index for the broader set of currencies.

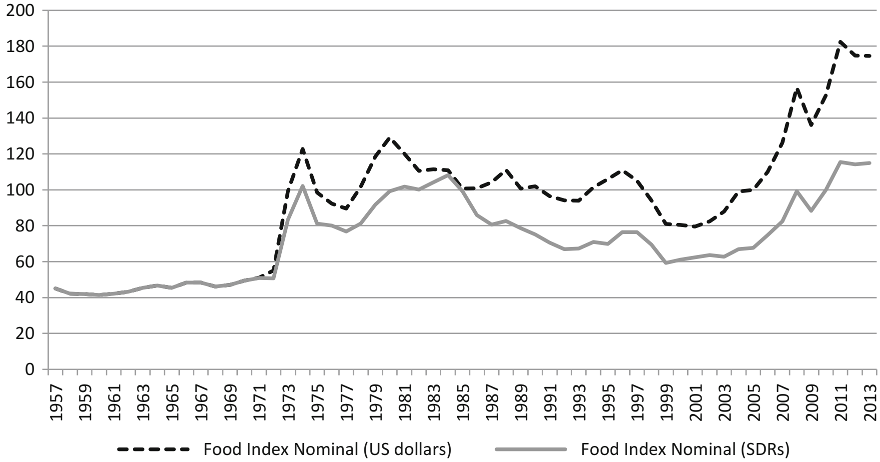

Fig. 2.4 Nominal food price indices in the US dollar and SDR (2005 = 100 for the US index). *Source*: Author calculations based on data from the International Monetary Fund (IMF)

Table 2.2 Price volatility in US dollars and SDRs

Volatility	SDRs	USD
1960s	3.4	3.4
1970s	18.8	21.3
1980s	6.9	6.7
1990s	7.1	7.2
2000s	8.0	9.9
2010s	8.0	10.2

Source: Author calculations based on data from the International Monetary Fund (IMF). The period 2010s goes from 2010 to 2014

It is clear that the latest price surge, even in nominal terms, is less pronounced when calculated in SDRs. The 2008 price spike in SDRs was at or below the levels observed in the 1970s and 1980s, while nominal prices in the US dollar have been above historical averages during the latest price shocks, influenced by the depreciation of the US dollar from its peak in the early 2000s. Only after the price increase in 2011, the SDR index moved slightly above the values in the early 1980s.

Moving to the discussion of volatility, Table 2.2 shows the same measure of volatility as Table 2.1, comparing the nominal price indices in the US dollar and SDRs. Price volatility seems to be much less pronounced when prices are measured in SDR terms than in US dollar terms, suggesting that at least some food price volatility observed was influenced by additional instability in exchange rates, which is affected by general macroeconomic factors.

The results above highlight the importance of taking into consideration the currency utilized in the pricing, which is affected by exchange rate fluctuations.

2.3.3 Domestic Prices and World Prices

In the earlier sections, the discussion focused on the different measures of world food prices. However, food security at national level is affected by domestic price volatility, which is correlated with world price volatility to different degrees in different countries. Price transmission from international to domestic prices can be limited because of several factors, such as domestic policies, high transportation costs, limited infrastructure, consumer preferences, and exchange rate variations.

Other sections of this book are devoted to the discussion of price transmission. It is important to note that as in the case of world prices, it is important to distinguish between nominal and real prices. The value chain level at which prices are measured also plays a role. Even if global food price changes are transmitted to the domestic economy (defined by some particular market level), their final effect on a consumer will be determined by the degree of integration between the local market in which the consumer participates and the national food market utilized as reference. In many developing countries in particular, there are clear distinctions between urban consumers, who may be more integrated with national markets, and rural consumers, who may have weaker links to national markets. Therefore, trends and volatility may differ when considering prices at the farm gate, wholesale, or consumer levels.

2.3.4 Time Horizons

The discussion of price volatility also requires the definition of a time horizon that is adequate for the purpose of the analysis. For instance, should data be analyzed daily, monthly, quarterly, annually, or at even longer intervals? Using annual values (as is the case so far) would obscure shorter term volatility: Daily, weekly, or monthly price movements may respond to several transitory causes that might cancel each other out during the course of the year. Still, these changes may be relevant for certain economic agents and their production and consumption decisions, therefore affecting their food security.

For instance, for consumers that are wage earners, the adequate interval may be a quarter or a month, in line with the timing of salary payments. For producers of annual crops, what matters may be the variability of the annual prices, while other producers, such as dairy farmers (who deliver daily), may be affected by shorter-term volatility. The level of development of futures markets and hedging instruments are also important when considering the appropriate frequency of analysis. In poor developing countries, daily and monthly price variability in futures markets does not drastically affect small-scale farmers' decision-making (with regard to crop production and marketing) because they do not have access to the futures markets.

On the other hand, farmers in more developed countries may use futures market information to enter into different contracts and therefore find volatility information at daily or monthly intervals relevant for their business.

2.3.5 The Selection of Food Indices and Food Prices

The choice of food indices or food items is another aspect that deserves attention when analyzing food price volatility. This is because the final effect of food price volatility on food security at the national level will depend on the dietary preference of individual countries.

According to the food balance sheets calculated by the FAO (FAOSTAT 2014), Indonesia is a clear example of the importance of considering country-specific dietary preferences. Rice, a storable produce, accounts for (using 2009 data) around 48 % of the calories and 40 % of the proteins consumed on average (these values were 56 % and 53 %, respectively, in 1980). The situation in India is somewhat more diversified than in Indonesia, with wheat and wheat products accounting for 21 %, and rice about 29 %, of the total calorie intake on average in 2009. On the other hand, many African countries show a consumption structure that shows a variety of products, including some (such as cassava and yams) that are difficult and costly to store. In 2009 in western Africa,[5] the average calorie consumption comprises the following: 5.4 % wheat and wheat products; 12.6 % rice, 9.1 % maize, and maize products; 10 % millet and millet products; 9.1 % sorghum and sorghum products; 8.7 % cassava and cassava products; and 7.9 % yams (see Díaz-Bonilla 2014).

The analysis of price movements may focus only on the most basic food staples (such as rice and wheat) as they represent an important portion of the dietary requirements in developing countries, and especially in the most vulnerable countries. However, as noted, some poor regions depend on several products for basic calories. Furthermore, access to a minimum level of food calories is insufficient to achieve food and nutrition security; dietary diversity also plays a role in nutrition security (Arimond and Ruel 2006). Therefore, to more comprehensively analyze the effects food price volatility, the price evolution of various food items should also be taken into consideration.

Also, if the analysis of price movements focuses on the impact of price volatility on general economic variables at the national level (in contrast to food security concerns), world food indices, such as those calculated by the IMF (used in this chapter), the World Bank, and the FAO, may not reflect the impact of price changes on a specific country because every individual index for those countries would

[5] Benin, Burkina Faso, Cabo Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Saint Helena, Ascension and Tristan da Cunha, Senegal, Sierra Leone, and Togo.

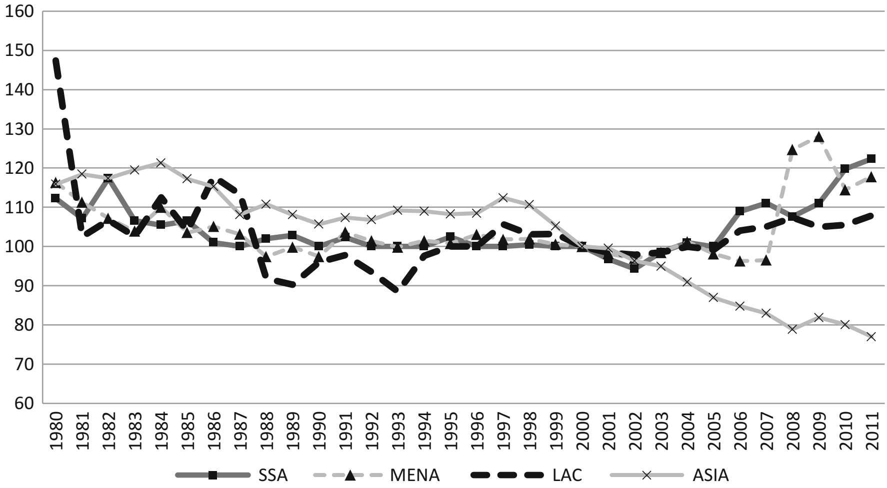

Fig. 2.5 Terms-of-trade index, median value (2000 = 100), 1980–2011. *Source*: Author's calculations based on World Bank (2014). *Note*: This corresponds to the median values for 36 countries for SSA, 17 for LAC, 6 for MENA, and 12 for Asia

have its specific basket of exports and imports.[6] Figure 2.5 shows an indicator that better reflects that composition: the terms of trade for different developing regions, corresponding to the median values for 36 countries in sub-Saharan Africa (SSA), 17 in Latin America and the Caribbean (LAC), 6 in Middle East and North Africa (MENA), and 12 in Asia.

The terms of trade differ across regions, showing different responses even during the price spikes in 2008 and 2011. This indicates that the composition of exports and imports is different for every region. For instance, oil constitutes a great portion of export in MENA, and metals and oils have a strong presence in SSA; therefore, MENA and SSA saw a larger improvement in their terms of trade than LAC, which has a more diverse export basket. In MENA and SSA, higher food prices were more than compensated for by the price increase of other commodities, highlighting the importance of analyzing developments in all commodities at the same time and not focusing only on some of them. On the other hand, the developing countries in Asia, whose import structure relies more heavily on commodities, showed a decline in the terms of trade because the price of all commodities and not only food increased.

[6]The food price indices calculated by the IMF, the World Bank, and the FAO, although sharing broadly similar trends, are somewhat different in their coverage, in the weights they use to aggregate the prices of individual commodities, and in the representative world prices selected for some of them. Therefore, while the IMF index shows an increase in nominal prices of about 107 % between 2003 and 2011, this figure is 121 % for the World Bank and 135 % in the case of the FAO. It would be useful if the international organizations could present a single index.

2.3.6 Trends and Volatility: Different Approaches

As already mentioned, a common measure of volatility is the standard deviation of price changes (or inflation) within a specific period, which may be defined in days, months, years, and so on.

It was also noted that $\ln p_t - \ln p_{t-1}$ is a proxy for nominal inflation for the period t, which is defined as one year in Tables 2.1 and 2.2 (annual inflation). However, monthly inflation is often used (see, for instance, Gilbert and Morgan 2010; G20 2010, which use monthly price changes). It has been argued that using standard deviations of log prices is a better measure than other potential metrics because it avoids the issue of defining trends (see Gilbert and Morgan 2010).

In some instances, it may be enough to evaluate this measure of volatility. However, by not considering trends and changes in trends, key elements may be missed when analyzing relevant policy responses. In macroeconomics, a few studies have already noted that many crucial variables, such as GDP, seem to exhibit variable trends (see, for instance, Stock and Watson 1988, focusing on the US economy; Aguiar and Gopinath 2004, analyzing emerging markets). Also, the factors and policies affecting trends and changes in trends are usually different from those affecting the variability around the trends (although there may be cross effects).

If we accept the argument that both the variability of a trend and the variability around the trend need to be considered, then it is crucial to identify methods of decomposing price movements into trend variability (explained by long-term factors), variability around the trend (partially related to the business cycle), and shorter-term variability that lies beyond both trends and cycles (which may include extreme events such as spikes or crashes) (see Díaz-Bonilla and Ron 2010; Tadesse et al. 2014). The best methods of separating trends and cycles have been long debated in applied macro-econometrics, with different approaches leading to different results about such decomposition (see, for instance, Canova 1998, 1999, 2007).

In the following section, trends and cycles will be discussed firstly; then the issue of extreme events will be examined in further detail.

2.3.7 Trends and cycles

In relation to trends and cycles, three different detrending methods are used to demonstrate the different results that can be obtained from the methods. The three methods are as follows: the lineal trend (LT) (Fig. 2.6), the Hodrick–Prescott (HP) filter (Fig. 2.7),[7] and the asymmetric Christiano–Fitzgerald (CF) filter (Fig. 2.8).[8]

[7]The HP filter is calculated with a lambda of 100. Compared to the CF, the HP does not capture the turn at the end toward a plateau.

[8]The CF filter is the full sample asymmetric specification with the underlying variable considered to be non-stationary (as indicated by the tests on the nominal food price index) and cycle periods

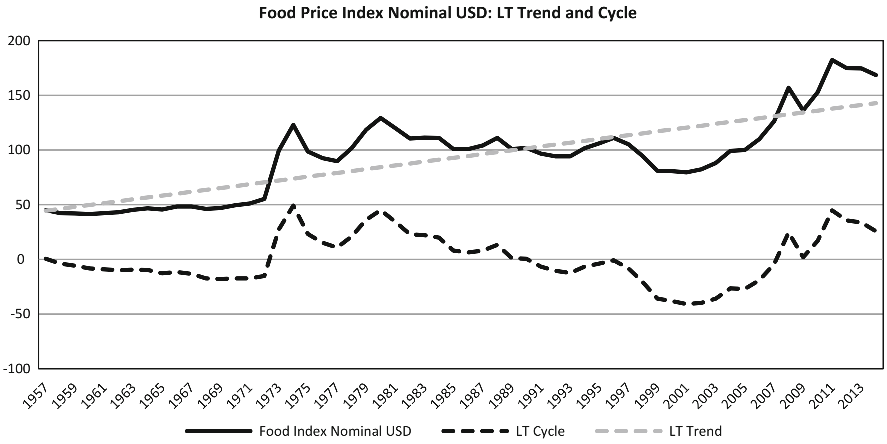

Fig. 2.6 Lineal trend

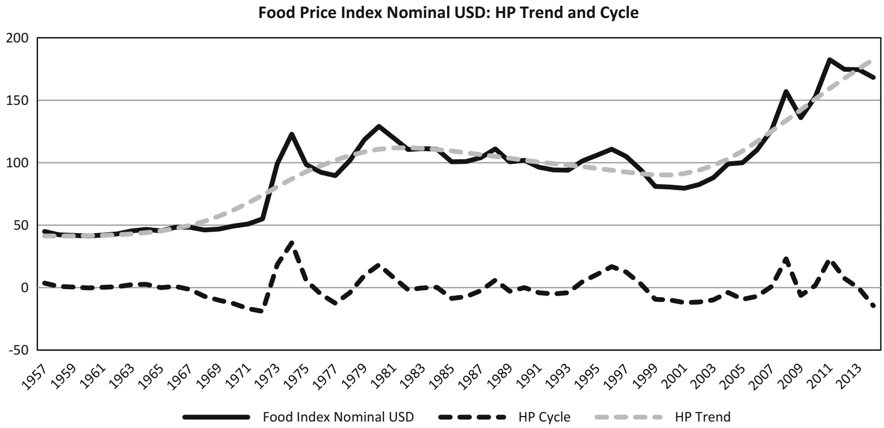

Fig. 2.7 Hodrick–Prescott filter. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

The cycle in the respective figures is obtained by subtracting the value of the trend from the nominal value of p_t at the same period t.

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between 2 and 8 years. This specification allows the values at the beginning and end of the time series to remain in the calculations. In contrast, other band pass filters with fixed lags lose the values at the extreme ends of a time series because of the lags. As noted, the Hodrick–Prescott filter also has problems capturing the trends at the beginning and the end of a series. The advantages and limitations of the different filters, neither of which are perfect, are discussed in detail in Canova (2007). Canova (1998) also gave a more detailed comparison of different detrending methods using macroeconomic series.

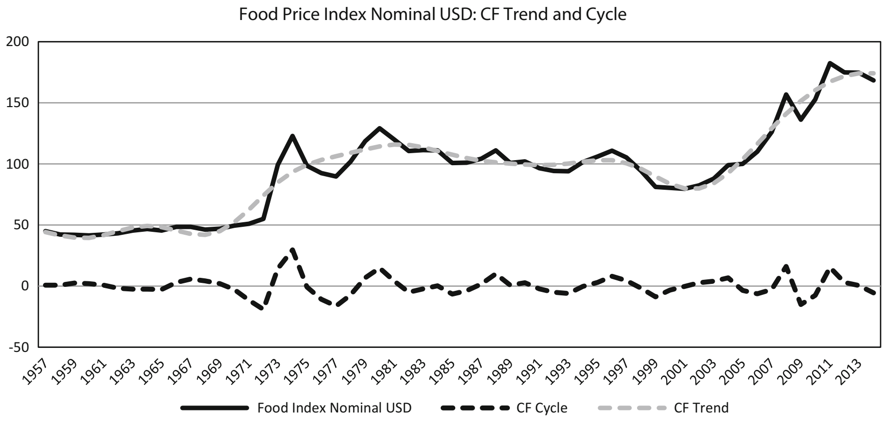

Fig. 2.8 Christiano–Fitzgerald filter. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

Several observations can be made about the figures above: First, regardless of the method applied, the price volatility between the late 1950s and the first half of the 1970s was lower compared to the rest of the series. Second, the LT has the problem of being constant during the period considered, even though tests have shown[9] that there were structural breaks in the trend. Both the HP and the CF were able to capture changes in trends, although they show slightly different results. There are no conclusive tests to determine which method captured the "correct" trend. Third, the HP, which usually has problems detecting changes at the end of a series, signals a continuation of the upward trend, while the CF is already pointing to an inflection point in the upward movement. Fourth, regardless of the method applied, the three detrending methods show larger increases in the mid-1970s than in the more recent price spikes. Finally, the CF filter considers the trough in the 1990s as a change in trend, while the LT and, to a lesser extent, the HP evaluated the period as a down cycle.

Table 2.3 presents a measure of volatility different from that shown in Tables 2.1 and 2.2. Here volatility is calculated as the decade average of the percentage deviation (in absolute values) of the food index from the trends calculated using LT, HP, and CF.[10] For comparison, the table also includes the measure of volatility

[9] A simple test, not shown here, was conducted on the stability of the coefficient of a trend variable with the following equation: $y(t) = a + b \times y\ (t-1) + c \times$ lineal trend. $Y(t)$ is the nominal index for food prices, in both original value and log form. Tests on the coefficient c of the lineal trend variable showed structural breaks in both cases of prices in normal values and in natural log.

[10] The calculation for Table 2.3 is as follows: First, calculate $[y(t) - \text{trend}(t)]/\text{trend}(t)$; t is defined as 1 year. This is the value of the deviation from trend, which is then expressed as percentage of the trend. Second, take the absolute value of that percentage for every year. Third, calculate the average for the decade. Conceptually, this is similar to the coefficient of variation calculated as the standard deviation of a variable divided by the average of that variable over a certain period.

Table 2.3 Different indicators of volatility

Volatility	HP	CF	LT	StDev of LN prices
1960s	5.1	6.1	20.6	3.4
1970s	17.2	13.8	31.1	21.3
1980s	5.1	4.5	20.4	6.7
1990s	7.4	4.3	9.6	7.2
2000s	8.7	5.2	20.8	9.9
2010s	5.6	3.8	22.4	10.2

Source: Author calculations based on data from the International Monetary Fund (IMF)

without the trend that is shown in Tables 2.1 and 2.2 (called "StDev of LN prices" here).

First, using a fixed trend for the whole period (LT) leads to higher estimates of volatility (a log-linear trend would produce qualitatively similar results). Second, all of the measures of volatility indicate higher volatility in the 1970s. However, to the extent that the HP and CF filters allow for the extraction of trends, the implied volatility around those trends is lower than those in the case of "StDev of LN prices." This last measure basically uses a different lineal trend for every decade (the average for the period), which although it avoids the problem of the LT of applying the same lineal trend for several decades, will still not capture changes in trends occurring within a decade. Third, as an extension to the previous point, because food prices increased at a slower rate in the 2000s than in the 1970s, the HP filter and particularly the CF filter regard part of the total volatility calculated using "StDev of LN prices" as changes in trend.

In summary, it is important to keep in mind that for any kind of analysis of price series, assumptions about trend behavior and the corresponding detrending method will affect the conclusion about price variability. When using measures that ignore trends, changes in underlying trends (which is usually related to more permanent factors) may be wrongly characterized as changes in volatility. Also, policies that address changes in underlying trends are different from those used to confront changes in volatility.

2.3.8 Shorter-term Variations

Until now, the discussion has focused on trends and cycles. However, as already noted, there are different forms of volatility that are conflated in the measure that uses the standard deviation of inflation, the latter measured as the difference of prices in logs (which corresponds to StdDEV of LN prices in Table 2.3) (i.e., the

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The main difference between the measure utilized in this chapter and the concept mentioned in the previous sentence is that in the latter, the trend is assumed to be a flat lineal value for the period, while in Table 2.3, the trend may be changing during that period.

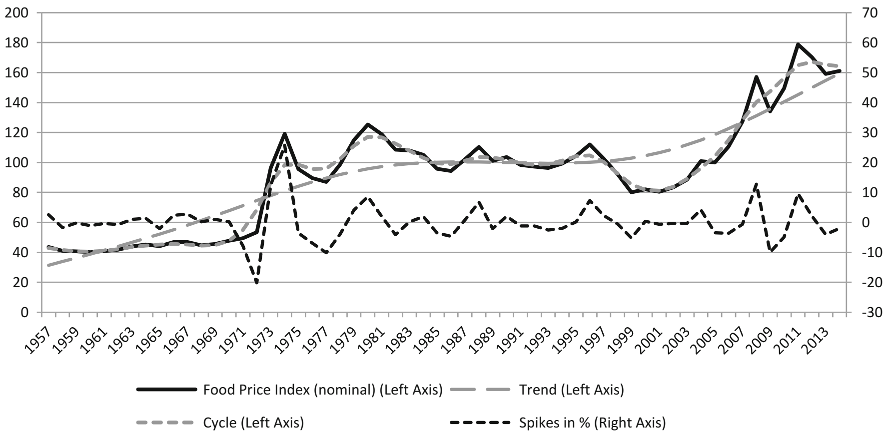

Fig. 2.9 Trends, cycles, and spikes. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

difference of prices in logs). An increase in volatility measured this way may be due to (a) changes in the longer-term trend, (b) a medium-term cycle, and (c) shorter-term volatility, which in some cases may reach the level of extreme events. Points (a) and (b) have already been discussed in the previous sections. Identifying short-term volatility is also a topic relevant to policymaking, particularly if volatility reaches the level of an extreme event.

Understanding the causes of an extreme price event is essential for designing an appropriate policy to react to the event. To do that requires differentiating between the three elements of volatility mentioned above. For instance, the policy approach to changes in price trends (point a), linked to significant long-term modifications of underlying income growth and demographic trends, may be different from the policy approach to demand-side macroeconomic forces driving the business cycle (point b). Weather problems, sudden changes in trade policies of systemically important countries, and abrupt shifts in financial conditions (all of which would affect short-term volatility in prices) may require yet other policy approaches. However, as before, such decomposition of the three aspects (trends, cycles and shorter-term variations) faces the problem of how to differentiate them.

Figure 2.9 presents a possible decomposition using the HP filter (for another approach to the decomposition, see Tadesse et al. 2014).

The smoothness of the variable resulting from the HP filter can be modified using different values of the penalty parameter (let us call it lambda) in the HP optimization algorithm. Applying the HP to a variable, the larger the lambda value, the smoother the series is; if lambda approaches infinity, the series is a lineal trend. Here, the lambda value of 100 is used for calculating the trend and 6.25 for the cycle (see Ravn and Uhlig 2002 for a discussion of how to adjust the HP filter). Then short-term volatility is the difference between the actual price p_t and the value of the HP filter at *t* representing the business cycle level expressed as a percentage of the value of the HP filter which, in turn, stands for the trend level.

In the 1970s, the breakdown of the Bretton Woods system of exchange rates and a series of supply and demand shocks led to a steep upward adjustment in nominal food prices and other commodities. From then until the mid-2000s, nominal food prices were oscillating around that new plateau, in part affected by the global business cycle (as already discussed). The nominal prices bottomed out between the late 1990s and early 2000s, a period in which price declines were deeper and more extended than the previous lows. This was the result of a series of financial crises–starting with the 1997 Asian financial crisis and ending with the 2002 Argentine crisis—which reduced demand and/or increased supply of food (and commodity) products. The early 2000s saw the decline in global growth and the last cycle of the US dollar peaking (see the discussion about the macro factors in the 1970s and the 2000s in Díaz-Bonilla 2008, 2015). However, until about 2005, the nominal increase was in line with previous nominal cycles.

In the second part of the 2000s, there are at least two events to consider: first, the trend was moving upward since hitting a nominal bottom in the late 1990s and early 2000s and second, the price spikes occurred in 2008 and 2011. As discussed in another study (see Díaz-Bonilla 2010), the peak of the 2008 spike was smaller, and reaching it took place over a longer period of time, when compared with the spike in the early 1970s. In the 1970s, there was an almost 200 % increase in the index of nominal food prices in about 5 years, while in the 2000s, the increase was less than 140 % over almost 9 years. If extreme high price events are defined as those being more than two standard deviations from the average, only the price spikes in 1974 and 2008 can be considered as an extreme price event (the 2011 shock was less than two SD from the average). Figure 2.9 also shows the smaller food price spikes in the late 1970s (related to the second oil shock) and in the second half of the 1980s and mid-1990s (more related to weather events) (see a discussion in Díaz-Bonilla 2010).

This book analyzes different reasons for the more recent price spikes in 2008 and 2011. The decomposition discussed in this chapter points to a component of that volatility: the potential change in the medium-term trends of nominal and real prices. Having reached another plateau in the 2010s, food prices in nominal terms may remain at that level (with likely fluctuations similar to those seen as prices reached the plateau in the 1970s). However, if nominal prices stay at the new plateau with oscillations, prices in real terms will decline. This would imply a reversion of the small upward trend shown in Fig. 2.1, probably returning to the long-term decline in real terms since the 1980s (a discussion of scenarios is in Díaz-Bonilla et al 2014; Díaz-Bonilla 2015). The analysis of changes in these medium- to longer-term events requires the variability of trends to be disentangled from the cyclical and temporary components of overall price volatility.

2.3.9 Expected and Historical Volatility

All the measures of volatility discussed so far have been based on historical data, which are the actual realization of the variables of interest. However, economic agents base their decisions on the expected value of the relevant variables, in this case food prices (Torero 2012). That expected values may follow some backward-looking and adaptive rules of thumb or be based on more sophisticated modeling of future scenarios. In the case of commodities with future markets, volatility can be calculated using future prices. However, only in the case of perfect foresight would ex post realized values of prices and their volatility coincide with ex ante expected values.

Furthermore, in this line of analysis, it can be argued that "true" volatility (the expected volatility) in the context of economic decisions is only the difference between the expected price at time $t+1$ that is forecasted at time t and the realized price at time t. On the other hand, the difference between the expected price at time $t+1$ that is forecasted at time t and the realized price at time $t+1$ is the unexpected volatility, which by definition is not included in a farmer's economic decision-making. In turn, these two measures are different from the calculations based on the realized price difference between t and $t+1$. Therefore, according to this view, the expected prices should be first estimated when calculating volatility. This opens the broader issue of how expectations are formed and modeled, which will not be discussed here (see, for instance, Triantafyllou et al. 2013).

2.3.10 Scaling the Shocks

The previous sections about trends and volatility have not yet discussed the impact of price changes on countries, producers, and consumers. Analyzing this impact requires not only trends and volatility to be properly characterized but also the relevant shocks to be properly scaled by macroeconomic variables, such as GDP, exports or fiscal accounts (at country level), and household income or consumption (at producer and consumer levels). An example of such scaling at country level is a series of studies conducted by Bela Balassa in the early 1980s to analyze different global economic shocks in the 1970s, including the price events during that period (see, for instance, Balassa 1984, 1986).

In the case of food prices, a possible indicator of the size of a price shock at country level may be obtained by dividing food imports by total exports (i.e., how much of the income from all exports a country needs to pay for the food import bill). This seems to be a better proxy for affordability and the potential burden on the balance of payment at national level than other indicators, such as the net food trade position (Díaz-Bonilla et al. 2000).[11] Figure 2.10 presents this indicator evaluated

[11]Like any other indicators, this indicator has its limitations. First, it reflects not only food prices but also other price and income effects on food imports and total exports. Also, in theory, if

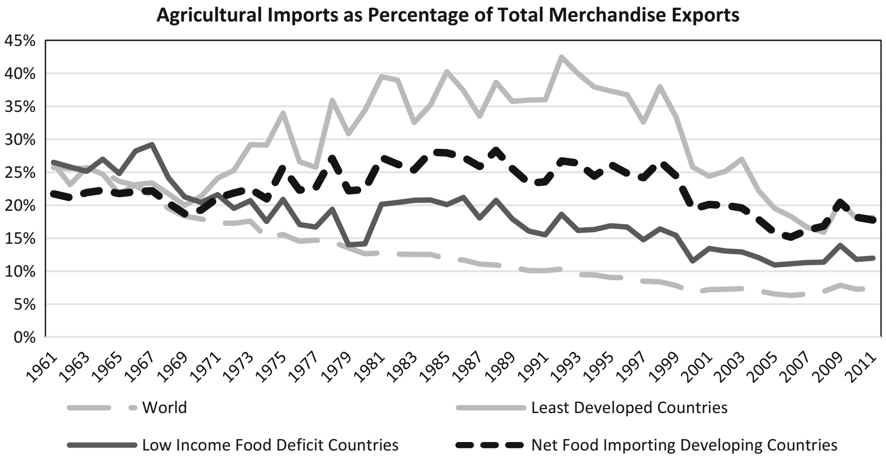

Fig. 2.10 Agricultural imports as percentage of total exports. *Source*: Author calculations based on data from FAOSTAT

with data on agricultural products (a broader category than food products alone) of several aggregates of countries: least developed countries (as defined by the UN), net food importing countries (as defined by the WTO, with some implications on trade negotiations), and low-income food-deficit countries (a category defined by the FAO).

The price shock in the 1970s clearly affected those groups of countries more than the 2008 price shock (at the time of this writing, data for 2012 was still unavailable; therefore, the effects of the 2011 shock cannot be evaluated). Of course, this indicator should also be calculated at country level and not only for the aggregates of countries.

2.4 Conclusions

This paper has argued that the analysis of volatility may benefit from differentiating between trends, cycles, and shorter-term events. And if so, it is important to clarify

quantities of food imports decline significantly because of high international prices, the indicator may not change at all, but domestic prices and welfare would still be affected. It should, however, be noted that food items are usually relatively price inelastic. Furthermore, at the level of aggregation of total food imports, results are even more muted because of substitution effects across different items. For instance, in the case of LDCs as a whole, quantities of food imports declined by 1.3 % in 2008 when compared with 2006, while world food prices increased by about 33 % during the same period, according to the IMF index. This translates into an uncompensated point elasticity of about −0.04 between those years. Finally, it should be noted that the ratio in Fig. 2.10 is not used as a welfare indicator, but it is a proxy for the economic burden of high food prices at the BOP level.

how trends are defined and measured and whether shocks can fall outside a "normal range" (which also requires "normal" to be defined). Different approaches to tackle those issues were discussed.

Regardless of whether price data are decomposed into trends, cycles, and shorter-term events, there are also various data issues to consider when analyzing volatility, for instance, (a) whether it corresponds to those of world markets or domestic markets; (b) if the focus is on world prices, it is necessary to define the currency of quoted prices (such as the US dollars, euros, SDRs, and so on); and (c) if a volatility analysis is centered on domestic prices, then the markets relevant to price formation and measurement must be identified along the value chain (production, processing, and distribution) that link primary producers to final consumers. It is also important to clarify whether volatility is analyzed using nominal prices or real prices; in the case of the latter, an appropriate deflator must be identified (such as the EUV index for advanced economies, the US CPI, or other nominal indices). In addition, it is crucial to identify whether the analysis focuses on specific commodities or broader aggregates of commodities. Finally, it is necessary to explicitly define the time period when determining volatility. Whether the time period is annual, seasonal, monthly, or even daily depends on the purpose of the analysis. For instance, if the analysis focuses on consumers, the time period (monthly) may be shorter than when the analysis focuses on producers. This is because producers make decisions based on longer time frames (at least yearly for planting decisions of many crops and even longer for investment decisions).

Irrespective of the way volatility is defined and measured, identifying its impact on nations, producers, and consumers requires (a) proper scaling of changes in prices; (b) taking a systemic view of trends, cycles, shocks, and crises; and (c) considering all macroeconomic cross effects (fiscal, monetary, inflation, exchange rates) of increases in all commodity prices (not only food) and other world variables (such as in Balassa 1984, 1986).

The price shocks in 2008 and 2011 focused the attention of the public and policymakers on price volatility. However, the results obtained from decomposing data into trends, cycles, and shorter-term volatility also suggest that there is a need to determine whether price variations respond to cyclical and shorter-term movements or whether they rather result from a changing trend reflecting adjustments in long-term fundamentals that need to be properly understood.

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3 Drivers and Triggers of International Food Price Spikes and Volatility

Getaw Tadasse, Bernadina Algieri, Matthias Kalkuhl, and Joachim von Braun

3.1 Introduction

The global food system recently showed exceptional developments in international commodity prices. In 2007–2008, the nominal prices of almost all food commodities increased by more than 50 %. Three years after the 2007–2008 global food price spikes, food prices surged again in 2010–2011 (Fig. 3.1). Though the two events were different in terms of the commodities affected,[1] a strong correlation was found among most food prices. More importantly, prices of all food commodities soared above the long-term average, with an adverse impact on poor people in developing countries (Conforti 2004; Dawe 2008; Dorosh et al. 2009; Hernandez et al. 2011). Indeed, the sudden increase in international food prices and its transmission to domestic prices led to rising inflation rates, which mainly affect the poor because they spend a large share of their income on staple foods. Volatility causes economic uncertainty and may result in lower investment, especially in small businesses which

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[1]The sugar price index was lower than its historical average during the first food price crisis (2007–2008) but reached a historic high in 2010–2011. Rice prices were the highest during the first high price episode but were lower than most other cereals during the second crisis.

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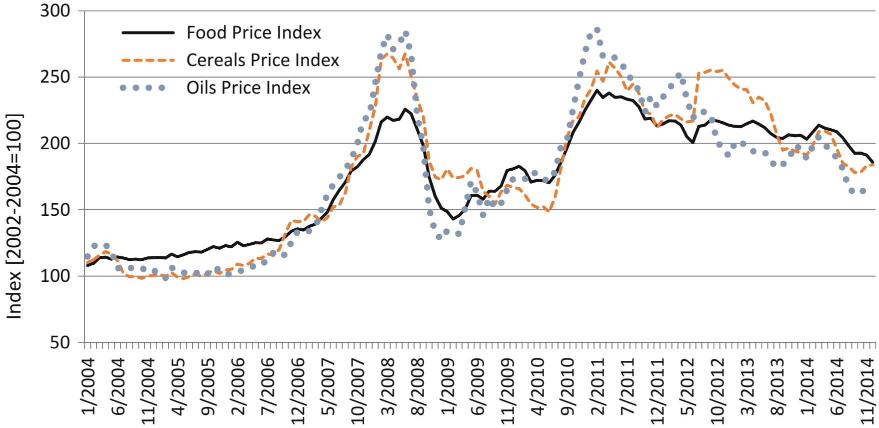

Fig. 3.1 FAO food price indices from January 2004 to November 2011. *Source*: FAO (2011)

lack access to credit. Although food grains are regarded mainly as commodities on the global market, they constitute the basic food of the poor and the "currency" of the poorest two billion people in the world.

Faced with rising food insecurity, social unrest, and accelerated inflation driven by food prices, developing and advanced countries as well as the international community began responding with a new sense of urgency. For instance, the G20 agenda of 2011 addressed food security. Nonetheless, although the price crises in 2007–2008 and 2010–2011 have led to some policy changes, the sense of urgency about preventing human suffering has not yet translated into comprehensive actions to stabilize world food supply and demand.

Unstable food prices at national and regional levels are not a new phenomenon. Some consider the 2007–2008 price spike part of normal price instability caused by temporary shocks (Díaz-Bonilla and Ron 2010). In fact, average price volatility did not differ significantly between the 1970s and the late 2000s, but the nature of the volatility and its causes may be different. Traditional market fundamentals—that is, supply and demand factors—were found to be inadequate to explain the extreme price spikes in 2007–2008 and 2010–2011.

In the past few years, many studies have investigated the causes of and solutions to soaring food prices (Abbott et al. 2009, 2011; Gilbert 2010; Roache 2010). They have identified a set of drivers of food price upsurges, including biofuel demand, speculation in commodity futures markets, countries' aggressive stockpiling policies, trade restrictions, macroeconomic shocks to money supply, exchange rates, and economic growth. The relative importance and actual impact of these causes have been widely discussed. While there is a certain consensus regarding how weather, biofuel production, and export restrictions affect food commodity markets, the dispute surrounding speculation on the commodity food markets is far from settled. Most of the empirical studies focus primarily on using the Granger-causality test to explain the role of speculation in price returns or volatility (Irwin et al. 2009;

Robles et al. 2009; Gilbert 2010). Another strand of research seeks to identify bubble behavior—that is, explosive increases in prices—in commodity markets during the period 2007–2008 (Gilbert 2009; Phillips and Yu 2011; Shi and Arora 2012). The Granger-causality test, however, has been criticized for presuming a time-lag structure that might be too long to allow any reaction on the liquid financial market to be observed (Gilbert and Pfuderer 2012; Grosche 2012). Analyzing bubbles may be useful for identifying abnormal price behavior, but it does not explain the causes of the observed price increase.

This study goes a step further by examining the impact of speculation and agricultural fundamentals on price spikes and volatility. Price spikes are the short-term ups and downs of prices following short-term shocks, and volatility is the variability of price around its trend. From a welfare perspective, the distinction between price spikes and volatility is more important than trends in overall price levels. This is because price spikes and volatility are the primary indicators of food crises.[2] Furthermore, this distinction is also essential for differentiating between factors that cause risks to poor consumers and those that cause uncertainties to agricultural investors. We argue that a food crisis is more closely related to extreme price spikes, while long-term volatility is more strongly connected to general price risks.

In particular, this study provides empirical evidence about the quantitative importance of widely discussed determinants of commodity prices. In our empirical analysis, we consider agricultural supply shocks, stock-to-use ratios, demand shocks [energy prices and gross domestic product (GDP)], and futures market shocks (speculative activity in commodity futures trading and financial crises). The empirical analysis is carried out using three models: (1) a price spike model in which monthly food price returns (spikes) are estimated against oil prices, supply shocks, stock-to-use ratios, demand shocks, and the volume of speculative futures trading; (2) a volatility model in which annualized monthly variability of food prices is estimated against yearly observable variables, such as supply shocks, stock-to-use ratios, economic growth, the volume of speculative futures trading, oil price volatility, and a financial crisis index; and (3) a trigger model that estimates the extreme values of price spikes and volatility using quantile regression. The methodology will allow us to shed light on the formation of price spikes and price risks, rather than simply considering the so-called high food prices. The food commodities whose prices are investigated are wheat, maize, and soybeans.[3] The rest of the paper is organized as follows: Sect. 3.2 presents the conceptual framework of the approach. Sections 3.3 and 3.4 describe the setup of the adopted models and the variables included in the empirical analysis. Section 3.5 discusses the econometric results. Section 3.6 presents the conclusion of this study.

[2]Although there is no universal definition of "food crisis," here it is understood as an abrupt and unanticipated change that affects people severely and negatively.

[3]We do not include rice because of its different international market patterns.

3.2 Conceptual Framework

Recent literature has identified the determinants of food price hikes as biofuel demand, speculation in commodity futures markets, and macroeconomic shocks. These determinants represent both the demand and the supply side of the world food equation. In an attempt to distinguish how different factors affect price changes, three groups of potential causes have been singled out: exogenous shocks, also called “root” causes; “conditional” causes; and “internal” drivers (Fig. 3.2). Root causes, such as extreme weather events, oil price shocks, production shocks, and demand shocks, are independent core factors affecting food price fluctuations. They are exogenous because the possibility of a causal relationship between the agricultural sector and root causes is minimal. Exogenous shocks are expected to generate food price spikes and volatility, and the magnitude of their impacts depends partly on the political and economic environment of a given country. In other words, a second group of factors related to specific political and economic conditions—labeled here as conditional drivers—can dampen or exacerbate exogenous shocks. Some of these factors (such as a high concentration of production or low transparency in commodity markets) are time invariant and rather difficult to measure; they are

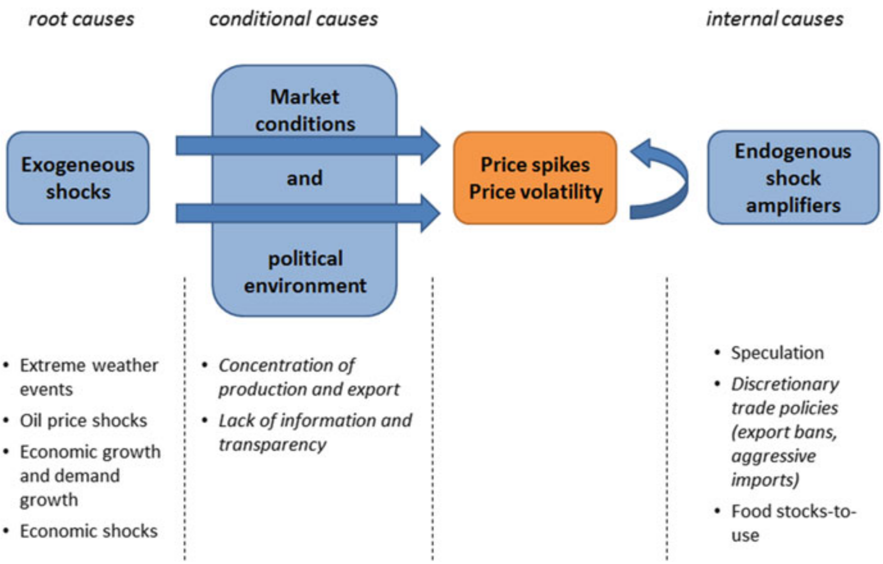

Fig. 3.2 Stylized framework of the causes of global food price volatility and spikes. *Source*: authors’ elaboration. *Note*: Exogenous shocks are the “root” causes of price volatility and price spikes. The extent to which exogenous shocks translate to food price changes depends on the market conditions and political environment of a given country (“conditional” causes). Food price shocks can further be amplified by nonlinear endogenous responses (“internal” causes) to food price shocks. The factors in *italics* are not considered in our econometric analysis as they are time invariant or as there is no appropriate quantitative indicator available

therefore not considered in the empirical analysis in this chapter. The third group of causes consists of factors that are triggered by the same price dynamics, and these internal causes are endogenous shock amplifiers and include discretionary trade policies, speculative activities (driven by price expectations), and declines in world food stocks. The present study focuses primarily on exogenous shocks because they may be the major root cause that stimulates the emergence of the other factors. At the same time, special attention is given to speculation and food stocks, which are (partly) endogenous factors.

This categorization of drivers comes with a caveat: the line between endogenous and exogenous causes is very subtle. There are multiple and complex interactions between the factors, and the drivers influence each other through various linkages and feedback loops. For example, restrictive trade policies induced by price increases have further contributed to price surges. Likewise, low US stock-to-use ratios have been considered an important factor in increasing price volatility. Low stock levels are, however, caused by reduced government activities in public storage (exogenous) as well as current supply and price expectations (endogenous), as highlighted by Piesse and Thirtle (2009). Furthermore, the UNCTAD 2011 *Report on Trade and Development* (UNCTAD 2011) indicated that there could be some correlations among different factors. For example, extreme weather may render financial investment in commodity futures more attractive. However, empirical evidence suggests that the correlation among these variables is not strong.

Figure 3.2 shows that extreme weather events such as droughts and floods—exacerbated by global warming—are considered a root cause of global food price fluctuations because they cause crop failure and reduce global food supply, which consequently causes food prices to increase. In this analysis, we used short-term global food supply fluctuation and its projection as an indicator of extreme weather changes.

Another root cause consists of oil price shocks, which affect grain commodity prices in a number of ways. On the supply side, a rise in oil prices exerts upward pressure on input costs such as fertilizer, irrigation, and transportation costs. The rise in costs in turn leads to a decline in profitability and production, with a consequent rise in commodity prices. On the demand side, higher crude oil prices induce a higher derived demand for grains destined for biofuel production—maize, soybeans, and other grains such as wheat—thus resulting in higher prices of these grains. The demand for biofuels has been further facilitated by indirect and direct subsidies and biofuel mandates.

Both the United States and the European Union, for instance, have adopted mandatory blending policies that require a sharp increase in biofuel usage. Studies have shown that higher biofuel demand and energy mandates have a large impact on food prices (Mitchel 2008; Chen et al. 2010; Chakravorty et al. 2011). A further linkage between oil and agricultural prices operates through index investments. Tang and Xiong (2012) found an increasing correlation between futures prices of agricultural commodities and oil after 2004, when significant index investments started to flow into commodity markets. The two authors highlighted that the correlation with oil prices was significantly stronger for indexed commodities than off-index commodities because oil is an important index constituent (Basak and Pavlova 2013).

The third root cause is the high demand for food crops coming mainly from emerging markets, primarily China and India. Krugman (2010) noted that rising commodity prices are a sign that "we are living in a finite world, in which the rapid growth of emerging economies is placing pressure on limited supplies of raw materials, pushing up their prices." In addition, economic development and income growth are changing not only the quantity of food demanded but also the structure of demand for food commodities. As dietary patterns move away from starchy foods toward meat and dairy products, there is an intensifying demand for feed grains that drives their prices up (von Braun 2011).

One of the other root causes of price increases is economic shocks, such as the depreciation of the US dollar, the currency of choice for most international commodity transactions. These shocks put upward pressure on demand from commodity consumers and producers not trading in US dollars.

While there is a certain consensus on the impact of some root causes (such as oil prices and extreme weather conditions) on food prices, the debate about some internal causes is still open. In particular, it is highly debatable whether speculation has exacerbated food price volatility. Two conflicting hypotheses prevail: the perfect market hypothesis and the speculative bubble hypothesis. The first, sometimes referred to as the "traditional speculation" hypothesis, argues that speculation helps to stabilize prices by facilitating increased liquidity and improving price discovery in the market. The second hypothesis claims that speculation tends to generate spikes and instabilities because of a herd mentality in commodity exchanges. The UNCTAD (2011) report elaborated the different types of herd behavior in detail and explained how they can drive prices far away from their fundamentals. The basic mechanism is that traders base their decisions on past price trends rather than new information on market fundamentals. This situation makes it difficult for other market participants to distinguish between fundamental causes of price increases and the causes driven by herd behavior, thereby impeding the role of speculation in price formation. Even informed traders may not be willing or able to intervene to correct prices if they can benefit from a potential bubble or if their arbitrage possibilities are limited. Herd behavior can therefore reinforce price increases, which may also lead to excess correlation if bubbles spill over to related markets.

Despite some arguments against the importance of speculation in causing the 2007–2008 food price hikes (Irwin et al. 2009; Wright 2011), empirical evidence shows the possibility of the speculative bubble hypothesis (Robles et al. 2009). An increase in speculative activities raises the volume of futures trading, with a consequent increase in futures prices and inventory accumulation. This will then translate into an increase in spot prices. However, skepticism remains about the link between volume of futures trading and futures prices. According to some economists (such as Krugman 2008), speculation is a random bet, whereby traders' buying and selling futures cancel each other out and hence do not have a significant impact on futures prices. This theoretical skepticism is supported by a lack of empirical evidence on the accumulation of inventory, especially in 2007–2008, when prices increased steeply. If speculative actions were responsible for the rise in food prices, private inventories should have accumulated. On the contrary, a substantial decline in global food stocks was registered. This fact has been used to justify the assumption that speculation plays an insignificant role in causing food price spikes (Krugman 2008). However, wheat and maize reserves in the United States did not decline substantially during the 2007–2008 crisis (they declined substantially after the crisis). And even when stocks decline because of supply shortages and high prices, grain releases could have been higher without speculation. This can be answered only by conducting an econometric analysis and not simply by comparing stocks over time.

Another aspect of financialization refers to investors' increasing use of commodity futures contracts as part of their portfolio diversification strategy, particularly when other asset classes become less attractive. This has produced rapid growth in commodity index investments in recent years. According to the capital asset pricing model, an optimal portfolio should include assets with low or negative correlation with riskier high-return assets (such as equity). This strategy reduces the overall portfolio risk. Hence, investors may choose commodity futures not because they expect increasing commodity prices, but because commodity futures have the potential to reduce their overall portfolio risk. In this view, commodities become attractive if alternative assets (such as real estate, bonds, metals, and gold) become too risky or expensive. This process can have significant economic consequences for food commodity markets. On the one hand, the presence of commodity index investors can facilitate the sharing of commodity price risk; on the other hand, their portfolio rebalancing can spill price volatility across commodity markets (Tang and Xiong 2012).

Both the theoretical and empirical skepticism require further explanations and empirical analysis. The existing literature uses different approaches for identifying empirical evidence. For instance, storage modeling and price threshold analyses have been used to evaluate accumulation of stocks motivated by speculation (Tadesse and Guttormsen 2011); Granger-causality analyses have been adopted to investigate the relations between futures prices and spot prices (Robles et al. 2009). In this study, we explore the price effects of (1) an "excessive" volume of futures contracts based on the disaggregated position of futures traders and (2) a financial crisis index developed by Reinhart and Rogoff (2009). The two financial variables, together with a set of other fundamental drivers, may shed light on how different sets of exogenous and endogenous variables affect price spikes and volatility. Our study differs from other existing studies because it considers fundamental-based drivers *and* financial market-based factors of price changes.

Other internal factors are (1) restrictive trade policies and (2) declining world food stocks. A host of authors (Yang et al. 2008; Headey 2011; Martin and Anderson 2012) have shown that a sequence of export restrictions and bans implemented by countries such as India, Thailand, China, and Russia caused panics in international markets and exacerbated price increases. Trade restrictions are designed to curtail the effects of higher global prices on domestic prices and to protect consumers. From a country's perspective, restrictive policies seem to have the desired effect:

Domestic prices are shielded from the full impact of a steep price increase. However, restrictive policies affect the world market negatively. When many countries restrict exports, so much food disappears from the global market that prices rocket higher than without government intervention. Inventory stock levels have a crucial role in commodity pricing and at the same time are affected by commodity prices. When prices are low, rational firms tend to store some units of the commodity, and total demand equals demand for current consumption plus demand from inventory holders. Thus positive inventory implies that total demand is more elastic than demand for current use. When prices are high, storage is unprofitable, inventory goes to zero, and total demand equals current-use demand.

3.3 Estimation Methods

We differentiate between price spikes, volatility, and trends. Since trends are somewhat anticipated long-term price changes that have little relevance to food crises, this study focuses only on price spikes and volatility.

A price spike is a large, quick, and temporary rise or fall in price following a short-term shock. Price spikes can cause crises for consumers, investors, and farmers. Food price spikes are usually measured using the logarithm of period-over-period prices. Expressed as a formula:

$$d \ln P_t = \ln\left(\frac{P_t}{P_{t-1}}\right), \tag{3.1}$$

where $t = m \times y$, m denotes the month, and y denotes the year. To capture the contemporaneous correlation of shocks across commodities, a seemingly unrelated regression has been used to estimate spikes of maize, wheat, and soybean prices.[4] The model is specified as:

$$d \ln P_t = \beta R_t + \varepsilon_t, \tag{3.2}$$

where $d \ln P_t$ is a $I \times 1$ vector of price spikes (returns) with I number of commodities identified as $i = 1, 2, 3, \ldots I$; R_t is a vector of explanatory variables that include monthly supply shocks, oil price spikes, economic shocks, beginning stock-to-use ratios, and excessive volume of speculative futures; and $\varepsilon_t = I \times 1$ is the error term where $\operatorname{cov}\left(\varepsilon_{it}, \varepsilon_{jt}\right) \neq 0$ for $i \neq j$. Some of the R_t are commodity specific, such as supply shocks and excessive volumes of speculative futures, whereas others are commodity nonspecific.

[4]Using a standard ordinary least squares model, however, gives similar results: signs and significances, as well as the order of magnitude of the coefficients, remain the same.

Monthly supply shocks are measured as log ratios of the US Department of Agriculture forecasts on global production $d\ln X_t = \ln\left(\frac{X_t}{X_{t-1}}\right)$, as the USDA forecasts are widely recognized and play an important role in the price formation process, which is influenced by monthly information on the available grain supply in the current agricultural year. Economic shocks are calculated using the same equation with monthly interpolated global GDP per capita (nominal). The stocks-to-use ratio is the relationship between the beginning stocks (of the current agricultural year) and consumption as forecasted by the USDA. Oil price spikes are estimated using the same procedure as in the case of food commodity spikes (Eq. 3.1).

We have hypothesized that the effect of speculative activities on commodity price dynamics depends on the extent of deviation between noncommercial and commercial trading activities. However, many observers, including the US Commodity Futures Trading Commission (CFTC), have recognized that the distinction between commercial and noncommercial is elusive, and hence it can be misleading to measure speculation relative to hedging. One problem is that small speculators, who may be influential as a whole, are exempted from certain reporting obligations. Another shortcoming is that categorizing traders as noncommercial does not allow for differentiating traders who speculate based on fundamentals from those who engage in "irrational herding" (UNCTAD 2011). Both issues can lead to an underestimation of the impact of speculation due to irrational herding. Nevertheless, the data on this broad classification of traders constitute the only publicly available source and therefore provide the only possibility for approximating excessive speculation.

Previous studies (Irwin et al. 2009) have used the Working index to measure the impact of speculation on food prices. The Working index tries to measure speculation intensity relative to hedging activity. It is, however, insensitive to the net positions of speculators—that is, whether they are net long or net short. Because, as mentioned above, excessive net long speculation leads to price increases (and excessive net short speculation leads to price decreases), we prefer to give equal weight to commercial and noncommercial trading activities and to measure speculation based on the deviation between the two types of trading activities. In a perfectly competitive commodity market, there should be no deviation between commercial and noncommercial trading activities. To meet commercial traders' demand for hedging, an equal number of noncommercial traders' contracts is necessary at most.[5] However, we have observed a significant difference between commercial and noncommercial positions. This could be associated with the existence of a significant number of unsettled noncommercial positions for an extended period of time, motivated by speculation and the increasing use of food commodities as an asset class. Thus, using the excessive open interest of speculative futures seems to be a more appropriate way of capturing the speculative effect than using the

[5]Fewer noncommercial traders are necessary if commercial traders can already match their different short and long hedges, i.e., when a producer makes a contract with a processor.

Working ratio. Technically, the extent of excessive speculative activities in month t is expressed as:

$$\mathrm{ESV}_t = \frac{\sum_{d=1}^{N_t} \left[(\mathrm{NCL}_d - \mathrm{NCS}_d) - (\mathrm{CL}_d - \mathrm{CS}_d) \right]}{N_t}, \tag{3.3}$$

with N_t denoting the number of days d in month t in which CFTC position data are available. As the trading position data are published every Friday for the preceding Tuesday, only four to five observations are available per month. NCL is the open interest of noncommercial long positions in a trading day, NCS is the open interest of noncommercial short positions in a trading day, CL is the open interest of commercial long positions in a day, and CS is the open interest of commercial short positions in a day.

Price volatility is a long-term price movement indicating the risk associated with price changes. It is usually measured in terms of price dispersion from the mean. Realized total volatility is measured in terms of the coefficient of price variations (CV), which captures both monthly and yearly variability. The normal coefficient of variation captures only the monthly price variability in a year. However, the mean price changes from year to year, and thus inter-year price variability cannot be captured. To capture both changes, we divided each year's standard deviation by the mean price of the entire sample. This allows us to measure variability relative to a common price level.

$$\mathrm{CV}_y = \frac{\sum_{m=1}^{12} \left(P_m - \overline{P_y} \right)^2}{\sum_{t=0}^{T} P_t} \frac{T}{12}, \tag{3.4}$$

where y indicates year, m month, and t month by year.

This metric does not measure the direction of price changes but rather evaluates price risks. This means that high variability does not necessarily reflect high prices. Realized total volatility is the sum of high- and low-frequency volatility (Peterson and Tombek 2005; Karali and Power 2009; Roache 2010). While high-frequency volatility is related to price spikes, low-frequency volatility is related to the cyclical movement of agricultural prices. Since high-frequency volatility is already modeled in the price spikes equation, we do not disaggregate volatility into its high- and low-frequency components. Instead we attempt to explain the realized total volatility using the percentage of annual standard deviation from the long-term average price.

Volatility is estimated using a panel regression in which commodities are represented as panels and years as time variable. Two alternative specifications have been adopted: ordinary least squares (OLS) and feasible generalized least squares (FGLS). The first, which assumes no heterogeneity across commodities, is expressed as:

$$V_{iy} = \alpha + \beta' X_{iy} + \varepsilon_{iy}, \tag{3.5}$$

where i and y denote commodities and years, respectively, and X consists of the aforementioned explanatory variables—that is, supply shocks, volatility of oil price, global nominal economic growth rates, beginning stock-to-use ratios, excessive speculative futures volume, and an annual financial crisis indicator (an alternative to speculation). The supply shock variable is defined as the normalized deviation of total annual production from its long-term trend; this is to account for the market size of each commodity. Normalized supply shocks are given by $\mathrm{SS} = \frac{|Q_t - \mathrm{HQ}_t|}{\mathrm{HQ}_t}$, where Q_t is the world production for each specific commodity and HQ_t is the Hodrick–Prescott smoothed production time series. The results derived from the production series using the Hodrick–Prescott filter have a similar distribution to those obtained using other time-series filters, such as Baxter-King, Butterworth, and Christiane-Fitzgerald. However, the Hodrick–Prescott filter is preferred to the others because it considers extreme values (Baum 2006). All the variables in this equation are measured annually.

The FGLS specification with fixed effects controls for heterogeneity among commodities and is expressed as

$$V_{iy} = \alpha + \beta' X_{iy} + \gamma_i + \varepsilon_{iy}, \tag{3.6}$$

where γ_i denotes the fixed effect.

A price trigger model has been designed to complete the empirical assessment and to account for endogenous shock amplifiers. The impact of a price trigger at high prices might be different from that at low prices. When prices are getting high, markets are expected be more sensitive to a shock than when prices are low. This effect is sometimes referred to as the tipping effect. The tipping effect is estimated using a quantile regression in order to capture the effect of explanatory variables at lower and upper tips of the response variable (Koenker and Hallock 2001). Put differently, it measures how an explanatory variable affects the τth quantile of the response variable as opposed to the mean value of the response variable in OLS. It gives a comparison of the effect at the upper and lower tail of the price distribution. Equations (3.2) and (3.4) are estimated at the τth quantile, where $\tau \in \{0.05,\ 0.15,\ 0.25, \ldots, 0.95\}$. If a variable is significant and has a higher effect at the upper tail, the variable indeed triggers price changes. In the price spike equation, the lower quantiles represent negative values, and the upper quantiles positive values. In the volatility equation, both the lower and upper quantile are positive values, with the upper quantiles denoting higher values.

3.4 Data

The nominal prices of maize, wheat, soybeans, and crude oil were obtained from the World Bank database (World Bank 2011). We used current prices quoted as "US No. 2 yellow f.o.b." for maize; "US HRW" for wheat, "c.i.f. Rotterdam" for soybeans, and "average spot prices of Brent, Dubai, and West Texas" for crude oil.

Nominal prices were chosen because of the lack of an accurate consumer price index for deflating world prices. Although different sample periods are used for different analyses, most of the datasets are based on data from 1986 to 2009. Position data before 1986 are unavailable.

Data for annual supply shock estimation were collected from the FAO (2011)—specifically, annual production data of the major producing countries. Data for monthly supply shocks were obtained from the world agricultural supply and demand estimates published monthly by the USDA.[6] Open interest of futures trading of the Chicago Board of Trade (CBOT) was obtained from the CFTC for maize, wheat, and soybeans.[7] The CFTC reports disaggregated open interest of futures trading positions into long and short and spread by commercial and noncommercial participants. Since a spread represents the equal value of long and short positions, it is not included in our calculation of excessive speculative activities.

3.5 Results and Discussion

3.5.1 Determinants of Food Price Spikes

Table 3.1 presents the results of the seemingly unrelated regression estimates for different time periods. Production is led by 1 month as markets are assumed to anticipate supply shocks shortly before the USDA publishes its estimates; this is a result of private market research and information acquisition.[8] As expected, price spikes are negatively correlated with (anticipated) supply shocks and positively correlated with economic growth (demand) shocks. The results show the positive and significant effect of excessive speculative activities on food price spikes, although the anticipation of supply and demand shocks is already controlled for. The extent of excessive speculation is significant both before and after 2000; however, the effect is stronger after 2000. A strong belief exists among financial practitioners that speculative activity became detrimental only after 2000, when commodity markets were deregulated and financialization intensified (UNCTAD 2011). For example, Gheit (2008), Masters (2008), and Frenk (2010) among others, argued that since the introduction of the 2000 Commodity Futures Modernization Act, "speculative money" has been flowing into commodity derivatives, which in turn drives commodity spot prices up and down far beyond their fundamental values. Our results, together with the research of Gilbert (2010) and Henderson et al. (2012), provide further evidence of this claim.

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[6]Data are available at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194 (accessed February 18, 2013).

[7]Data are available at http://www.cftc.gov/MarketReports/CommitmentsofTraders/HistoricalCompressed/index.htm (accessed February 18, 2013).

[8]The anticipation effect vanishes, however, for a lead of 2 or more months.

Table 3.1 Seemingly unrelated regression results on food price spikes (coefficients and *z*-values)

	1986–2009	1986–1999	2000–2009
Maize price spike			
Production shock (%), led	−0.8607***	−0.8124***	−1.1293**
	(−3.84)	(−3.46)	(−2.23)
Speculation (1000 contracts)	0.000070***	0.000072***	0.000086***
	(8.00)	(7.34)	(4.73)
Beginning stock-to-use ratio	0.0004	0.0005	0.0016
	(0.84)	(0.96)	(1.11)
Oil price spike (%)	0.0146	−0.0623	0.0958*
	(0.44)	(−1.59)	(1.69)
GDP shocks (%)	1.2333*	−0.2324	1.8303*
	(1.73)	(−0.23)	(1.67)
Constant	−0.0204**	−0.0208**	−0.0439
	(−2.12)	(−2.04)	(−1.54)
Wheat price spike			
Production shock (%), led	−1.4537***	−0.2039	−2.7769***
	(−2.93)	(−0.39)	(−3.21)
Speculation (1000 contracts)	0.000206***	0.000295***	0.000387***
	(5.37)	(7.40)	(3.44)
Beginning stock-to-use ratio	−0.0006	0.0020	−0.0032**
	(−0.64)	(1.60)	(−2.17)
Oil price spike (%)	0.0375	−0.0631*	0.1277**
	(1.05)	(−1.70)	(2.13)
GDP shocks (%)	2.0971**	0.1329	2.5479**
	(2.42)	(0.12)	(2.02)
Constant	0.0034	−0.0674**	0.0799**
	(0.15)	(−2.48)	(2.27)
Soybean price spike			
Production shock (%), led	−0.3413**	−0.3218	−0.4052**
	(−2.45)	(−1.08)	(−2.45)
Speculation (1000 contracts)	0.000083***	0.000080***	0.000136***
	(5.98)	(4.99)	(3.66)
Beginning stock-to-use ratio	0.0003	−0.0002	0.0001
	(0.47)	(−0.16)	(0.13)
Oil price spike (%)	0.0614**	−0.0155	0.1514***
	(2.07)	(−0.44)	(2.98)
GDP shocks (%)	1.9804***	1.5647	1.6171*
	(2.92)	(1.45)	(1.68)

(continued)

Table 3.1 (continued)

	1986–2009	1986–1999	2000–2009
Constant	−0.0204*	−0.0157	−0.0145
	(−1.87)	(−0.98)	(−0.71)
R^2	0.24	0.32	0.21
N	304	167	137

Note: Dependent variable: maize, wheat, and soybean price spike. ***, **, * denote that the level of significance is at 1, 5, and 10 %, respectively. Values in parentheses are *t*-values. All variables refer to monthly data; spikes and shocks (in %) denote therefore the deviation of that variable from the level in the previous month. Production shocks are led by 1 month as significance and explanatory power increases. The coefficients for production shock, oil price shock, and GDP shocks can be interpreted as elasticities (percentage change of commodity price due to a percentage change of the respective explanatory variable). Speculation refers to the excessive speculation index given in Eq. (3.3)

Table 3.2 Historic quantitative impact of speculation on price spikes

	Maize (%)	Wheat (%)	Soybean (%)
Price spike due to one standard deviation increase in speculation	2.2	1.6	1.4
Average monthly price spike due to speculation during July 2007 and June 2008	3.2	0.2	1.8
Compound (12-month) price spike due to speculation during July 2007 and June 2008	37.9	2.5	22.1

Note: The first row was calculated by multiplying the standard deviation of speculation by the respective speculation coefficient in Table 3.1 for the full sample. The second row was calculated by multiplying the average monthly speculation volume between July 2007 and June 2008 with the respective speculation coefficient in Table 3.1; for the third row, the value of the second row was multiplied by the number of months (12)

Although the coefficient of speculation variable is smallest for maize and largest for wheat, the variation of speculation is much larger for maize than for wheat. Table 3.2 shows the impact that one standard deviation change in speculation has on spikes, showing that maize price spikes are more affected by speculation than wheat price spikes. Regarding the role of speculation in the 2007–2008 crisis, excessive speculation predicts that, all other things being equal, maize price increased by approximately 38 % within the 12 months following July 2007, but wheat price increased by only less than 3 %. These numbers must, however, be treated with caution because not only is speculation caused by exogenous (financial market) events, but it is also endogenous to price expectations. By considering anticipated information on market fundamentals, speculation could be endogenous to other factors that influence price expectations, such as export bans. These factors are difficult to control for. Financial market shocks, however, clearly constitute a part of the exogenous elements in the speculation variable.[9]

The results further suggest that anticipated production fluctuations play an important role in causing short-term food price spikes. Supply shocks measured using USDA monthly forecasts were found to be statistically significant in most of the estimations. Production shocks were included to represent extreme weather conditions or flood outbreaks, which could lead to supply shortfalls in one part of the world and higher price expectations in other parts of the world. For example, a flood in Australia may affect the amount of food supply from Australia as well as farmers' and traders' price expectations in Europe or the United States. These effects were expected to cause temporary price spikes. The results confirm that expectations on production influence prices. Thus, short-term price spikes are partly created by information about supply relating to weather events.

Oil price spikes have increasing effects on food price spikes over time (Table 3.1). Before 2000, the effect was insignificant or negative (in the case of wheat). After 2000, however, it became positive and statistically significant for maize, wheat, and soybean prices. As mentioned above, oil prices are linked to food prices through demand (biofuels), supply channels (cost of production), and increased index fund activities. The significant impact of oil prices on food prices in recent years suggests that demand factors and financialization dynamics are more relevant in explaining price increases than supply factors. The United States accounts for about 40 % of the world's maize production. In 2010, about 40 % of the total US maize harvest was consumed by ethanol producers (USDA 2013). Increasing demand for biofuel affects prices through not only a direct conversion of food crops to feedstock, but also the reallocation of production resources (such as land and water) to the production of biofuel commodities. Reallocation of production resources affects non-biofuel food commodities as well. The link between oil and food prices is a more important factor in causing short-term food price spikes than the actual scarcity caused by biofuel demand. When energy prices are linked to food prices, political, environmental, and commercial shocks can easily translate to food crises. Stock-to-use ratios are insignificant, except for wheat since 2000; low wheat stocks increased the magnitude of price spikes.

[9]There are two standard approaches to dealing with endogeneity: lagging variables and instrument variables. In our case, both are problematic. A 1-month lag is already too long for data on speculation; financial markets operate on a daily basis, and speculative activities in the preceding month should not have any impacts on price spikes. Selection of appropriate instrument variables that explain speculation volume due to financial market shocks should be guided by a portfolio model, such as the Capital Asset Pricing Model (CAPM). This model, however, considers complex relationships between expected returns, variances, and covariances among many different assets, which cannot be subsumed under a linear combination of a few financial market variables.

3.5.2 Food Price Volatility

A panel analysis is used to quantify the relative importance of supply, demand, and financial shocks in affecting food price volatility. The explanatory variables included in this volatility equation are the same as for food price spikes, except for two differences. First, the variables are measured on an annual basis. For example, the normalized supply shock, the GDP growth, and the beginning stock-to-use ratios are calculated using annual data; excessive speculation is calculated based on the number of marketing days in a year; and oil price volatility is measured based on annual coefficients of variation. Second, the financial crisis index developed by Reinhart and Rogoff (2009) is also included in the equation. This index combines measures of banking crises, foreign debt defaults, domestic debt defaults, inflation crises, and exchange rate crises. The index serves as a proxy for financialization and speculation in the commodity futures market, and hence speculation and the financial crisis index are used as alternatives.

The different estimates of the models are presented in Table 3.3. A comparison of the effect of an excessive volume of futures trading and the financial crisis index on volatility indicates the importance of commodity-specific and common economic factors in affecting food prices. The result clearly shows the insignificance of futures trading on volatility, which is in contrast with the results of the price spikes estimation. This underlines the importance of distinguishing between volatility and spikes in this type of analysis. Conversely, the effect of the financial crisis index is significant and robust across all specifications, implying that the financial crisis is more relevant in explaining food price volatility than excessive futures trading.[10] It is worth noting that in terms of elasticity, a 1 % increase in the financial crisis index caused price volatility to rise by about 0.40 % in the OLS estimation and 0.35 % in the FGLS estimation. The positive relationship between the financial crisis index and food price volatility implies the significance of food commodities as financial instruments. When banks, sovereign debt, and exchange rates experience a crisis, the food market will enter a crisis too.

The normalized supply shock variable has a statistically significant effect on food price volatility when the restriction of homogeneity is imposed. The variable was determined not to be significant when the restriction is relaxed. This could be because heterogeneous production shocks can offset each other (because of geographical variation) without affecting price volatility. In the presence of homogeneity, extreme weather events exert an effect on food crises and agricultural risks.

The results show that when significant, oil prices and GDP—which can be regarded mainly as demand-side shocks—are more meaningful in explaining food

[10]We also estimated the models using the lagged values of the speculation and financial crisis variables. Although this is a convenient way to technically correct for endogeneity, the economic sense behind this choice is questionable because it implies that 1-year lagged financial variables can influence current price volatility. For this reason, we prefer to consider only the current values of all the variables.

Table 3.3 OLS and FGLS regression results for food price volatility

Explanatory variables	With speculation				With financial crisis index			
	OLS	OLS elasticities	FGLS	FGLS elasticities	OLS	OLS elasticities	FGLS	FGLS elasticities
Normalized production shock in millions of tons	0.3773** (2.31)	0.2138*** (2.35)	0.3395 (1.10)	0.1608 (1.10)	0.3690*** (2.40)	0.1865*** (2.47)	0.3340 (1.56)	0.1438 (1.56)
Oil price coefficient of variation	0.3595*** (7.29)	0.4202*** (6.76)	0.3506*** (5.20)	0.4939*** (5.20)	0.3801*** (6.63)	0.4306*** (5.87)	0.3771*** (6.84)	0.5031*** (6.84)
Beginning stock-to-use	0.1020 (1.35)	0.3405 (1.35)	0.0385 (0.41)	0.1002 (0.41)	0.1067 (1.50)	0.3862 (1.47)	0.0894 (0.94)	0.2526 (0.94)
GDP growth rate	0.0132** (2.24)	0.5629*** (2.34)	0.0130*** (7.14)	0.4552*** (7.14)	0.0038 (0.48)	0.1793 (0.48)	0.0035 (0.44)	0.1322 (0.44)
Speculation (1000 contracts)	0.00001 (1.39)	0.0714 (1.64)	0.0001 (1.66)	0.0839 (1.66)				
Financial crisis index					0.0007** (1.96)	0.3915** (2.05)	0.0007** (2.30)	0.3417** (2.30)
R^2	0.57		0.59		0.58		0.58	
Breusch–Pagan LM test			Prob = 0.823				Prob = 0.936	
Modified Wald test			Prob = 0.274				Prob = 0.939	
Wooldridge test			Prob = 0.549				Prob = 0.601	
Number of obs.	69	69	69	69	88	88	88	88

Note: Dependent variable: food price volatility. *t*-values are in brackets. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$. The models control for heteroskedasticity using the VCE robust estimator. Elasticities are calculated as marginal effects at mean values. Diagnostic checking rejects the presence of cross-sectional dependence, heteroskedasticity, and serial correlation. The Breusch–Pagan LM test (H_o: no cross-sectional dependence) reveals that there is independence, thus residuals are not contemporaneously correlated. The modified Wald test for groupwise heteroskedasticity (H_o: homoskedasticity) does not reject the null and concludes for homoskedasticity. The Wooldridge test for autocorrelation in panel data (H_o: no serial correlation) fails to reject the null and concludes that data do not have first-order autocorrelation price volatility than market shocks (speculative volumes and financial crisis) and supply-side shocks (Table 3.3). This is because the marginal effect of oil price and GDP growth on food price volatility is higher than that of speculation and supply shocks. Specifically, a 1 % increase in oil price volatility caused food price volatility to rise by 0.42–0.45 % when the model controls for speculation. When the financial index is included, volatility rose by 0.43–0.50 %. A 1 % upsurge in global growth rates generated an increase in food price volatility of 0.56 and 0.45 % when the model controls for speculation. The variable becomes insignificant when considering the financial crisis. The importance of oil prices in explaining food price spikes and volatility suggests that food and energy markets have become more interwoven.

The variable stock-to-use ratio turns out to be insignificant in explaining food price volatility. As described in the theoretical section, the effect of exogenous shocks depends on the economic and political environment. If the stock-to-use ratio is low in times of financial and environmental shocks, exogenous shocks may well have a greater impact than when stocks are high. As we control for exogenous shocks in the models, the direct impact of stocks on volatility might vanish. This may suggest that the stock-to-use ratio is an amplifier or intermediate variable that reflects the effect of supply and demand shocks on food price volatility.

In sum, the determinants of price spikes and price volatility are somehow different, at least in terms of the degree of significance and the magnitude of marginal effects. Market-related shocks (speculation) affect price spikes much more than demand- and supply-side shocks. In contrast, demand-side shocks (oil prices and GDP) lead to higher price volatility than market- and supply-side shocks.

3.5.3 Food Price Trigger

Recent discussions about food prices noted the possibility of a tipping point where the market may stop responding “normally” to market changes, opting instead to exaggerate and overreact. In order to identify triggers and test the tipping-point hypothesis, we estimated a series of quantile regressions for both the price spike and the volatility equations. The quantile regressions indicate the price or volatility levels at which the dynamics of price spikes and price volatility change (or whether the dynamics estimated in Tables 3.1 and 3.3 are robust for all price and volatility levels). In the price spike equation, the effects of oil prices, speculative futures trading, and supply shocks are compared at both higher and lower prices. In the volatility equation, the effects of supply shocks, oil price volatility, and the financial crisis index are compared at both lower and higher volatility. The tips in the price spike and price volatility equation are therefore different. In the price spike equation, the upper tip denotes the highest price, but in the price volatility equation, a high quantile signifies high volatility.

The results are presented in Figs. 3.3 and 3.4. The figures show the marginal effects of the explanatory variables on the response variables at different level of quantiles. The line graphs indicate point estimates, and the shaded regions

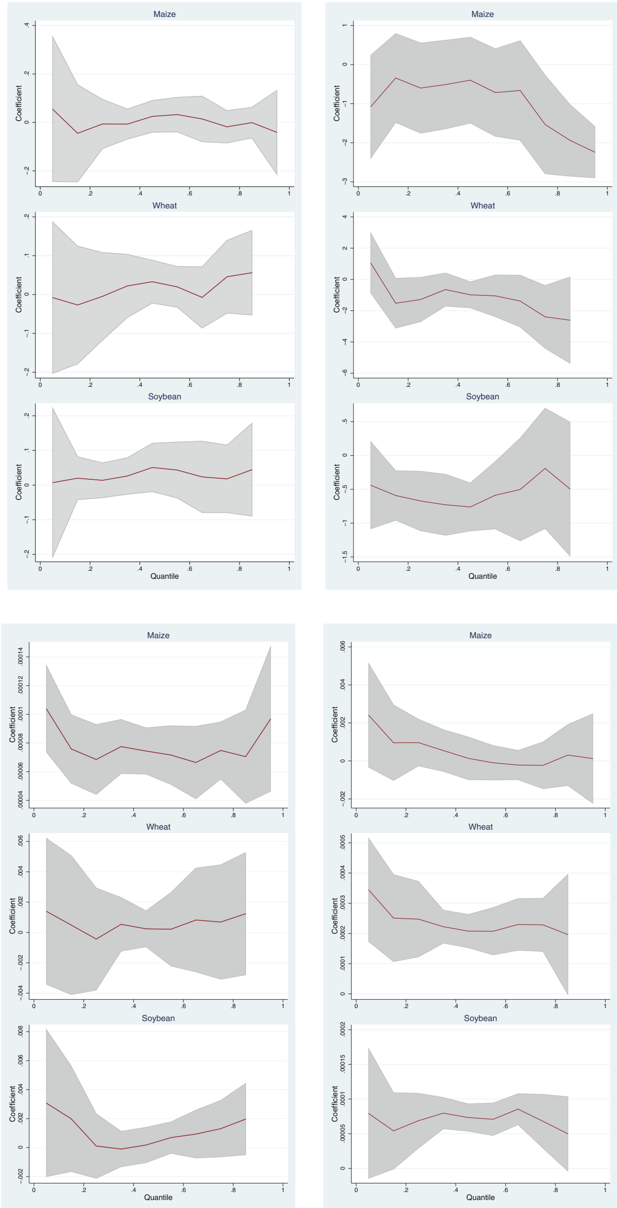

Fig. 3.3 Triggers of food price spikes. *Source*: Authors' estimation based on data explained in Sects. 3.3 and 3.4. *Note*: The *middle line* shows the coefficient which explains price spikes using (**a**) oil price shocks, (**b**) production shocks, (**c**) excessive speculation, and (**d**) stock-to-use ratios. The quantile regression shows the coefficients for different quantiles of commodity price spikes. At low quantiles, the corresponding coefficient shows the impact on price spikes when price spikes are low; at high quantiles, the corresponding coefficient shows the impact on price spikes when price spikes are already high. Shaded regions are the 95 % confidence intervals, and the *line* in the *middle* is the coefficient

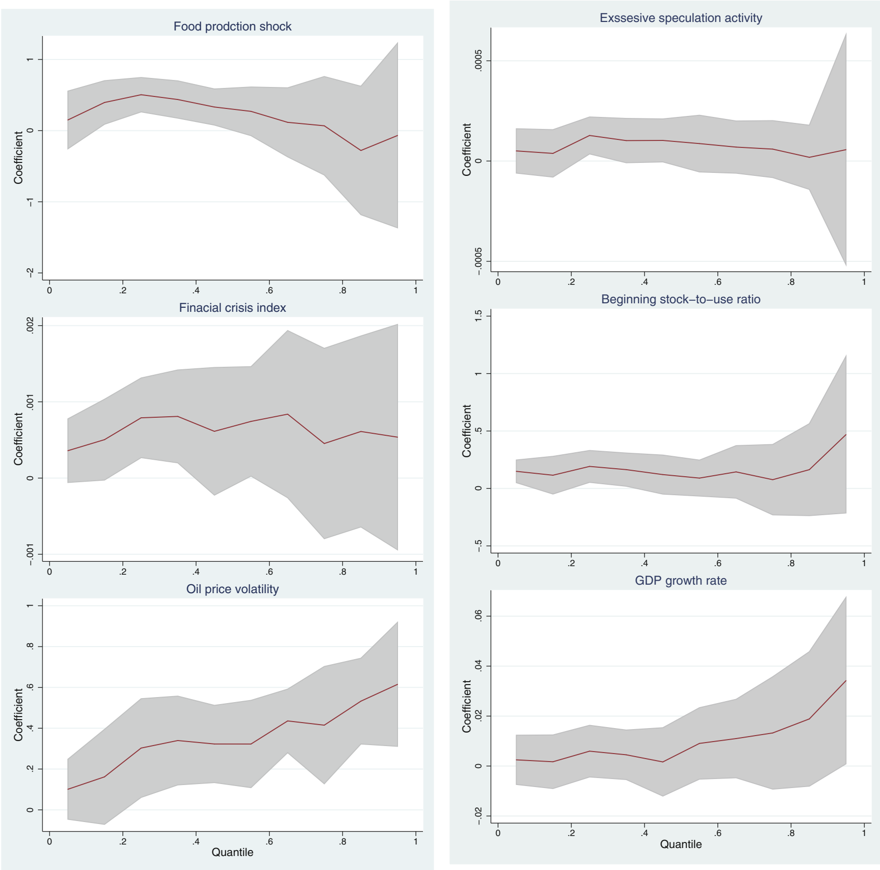

Fig. 3.4 Triggers of global food price volatility. *Source*: Authors' estimation based on data explained in Sects. 3.3 and 3.4. *Note*: The *middle line* shows the coefficient which explains food price volatility using different explanatory variables. The quantile regression shows the coefficients for different quantiles of food price volatility. At low quantiles, the corresponding coefficient shows the impact on price volatility when volatility is low; at high quantiles, the corresponding coefficient shows the impact on price volatility when volatility is high. *Shaded regions* are the 95 % confidence intervals, and the *line* in the *middle* is the coefficient

show the 95 % confidence intervals. A variable is defined as a trigger if the confidence intervals do not include zero values in the shaded region and if the line graph is visibly increasing (a positive relationship between food price and variable) or decreasing (a negative relationship between food price and the variable) as the quantile increases. The results of triggering price spikes are mixed. Of all the variables included in the price spike equation (Fig. 3.3), the trigger effect is evident only when maize or wheat production experiences a shock, or when there is speculation on maize. Other variables such as oil prices and stock-to-use ratio have no trigger effects, as depicted by flat and insignificant marginal values over quantiles.

The effect of production shocks on price spikes generally becomes stronger as the quantile increases, except in the case of soybeans. This result could imply that the USDA production forecasts have a larger impact on price movements when prices are high rather than low. Thus, production shocks are a significant contributor to food price spikes.

The u-shaped curve visible in the quantile regressions for speculation suggests that speculation is more important in times of extreme price dynamics. An increasing price trend, driven by changes in fundamentals (commodity demand and supply), gives rise to market nervousness, causing speculators to overheat the market. Speculation is also observed to have a strong impact on price spikes at lower quantiles of price spikes. This is an indication of the stabilizing effect of speculation when markets are calm. When markets are flooded, since the lower spike quantiles are negative values, an increase in speculative activities restores market prices. In sum, speculation has the capacity to create price hikes and reduce price slumps.

The results from the volatility quantile regression suggest the importance of oil prices in triggering food price volatility (Fig. 3.4). The effects of supply shocks, stock-to-use ratio, and global GDP growth also increase over quantiles, but they are all statistically insignificant. The evidence also shows that financial crises and speculation do not necessarily trigger volatility, in contrast to price spikes as shown in the quantile analysis above.

Oil prices have remained a primary factor in causing extreme volatility in food prices. Apart from being affected by production costs and biofuel-related demand, food price volatility is also affected by oil prices through a real income effect. This is because of oil prices' dominant impact on the overall economy. The trigger effect may be associated with the interaction between these effects. All the effects are evident at the higher level of food prices.

3.6 Conclusion

This study has investigated the main drivers of food price spikes and volatility for wheat, maize, and soybeans. It has also shown how these factors trigger a crisis when there are extreme price changes. The analysis has indicated that exogenous shocks as well as the linkages between food, energy, and financial markets play a significant role in explaining food price volatility and price spikes.

In addition to demand and supply shocks, speculation is an important factor in explaining and triggering extreme price spikes. Excessive speculation is more strongly associated with price spikes at extreme positive price changes rather than negative price changes. This implies that the stabilizing effect of speculation (generated through price discovery) is smaller than its destabilizing effect (generated through creating market bubbles).

The results also confirm that supply shocks are reflected in price spikes and that oil price shocks affect price risk more than they affect food crises. The effect of oil prices on food price spikes has become significant only in recent years. Financial crisis exerts a strong impact on food price volatility, which confirms that the link between financial and commodity markets is becoming stronger.

On the basis of the empirical results, it seems opportune for policymakers to prevent excessive speculative behaviors in the commodity market in order to reduce price spikes and prevent short-term food crises. In this context, policymakers could put caps on trading in extreme market situations or impose a tax on food commodity futures trading, along the lines of the Tobin tax. Designing flexible biofuel policies that are responsive to the food supply situation can also help stabilize prices and reduce volatility spillovers from oil markets in times of a food crisis. Recent changes in the US biofuel mandate, for example, include flexibility mechanisms that allow for relaxing the blending requirement in a certain year if compensated for in another year.

Improving the market information base would further help all market actors to form their expectations based on fundamentals and to detect shortages early. While the Agricultural Market Information System (AMIS), an initiative of the G20, strives for higher transparency, contributions from some of the member states are still insufficient.

Recently, many countries are increasing their national grain stocks to reduce domestic volatility and import dependency, leading to an increased grain scarcity and in turn higher grain prices in the short term. International levels of storage, however, are only one of the options to reduce volatility, and they turned out to be mostly insignificant in our analyses. One reason might be the lack of cooperation between countries: The governments which build stocks only for their citizens tend to complement storage policies with trade restrictions, effectively withdrawing their stocks from the global grain market. Such failure to act collectively needs to be addressed in regional and global trade talks. The international consequences of national stock-holding policies should also be discussed during these talks.

Besides policies to reduce volatility and prevent extreme price spikes, governments can improve the resilience of producers and consumers to price changes. This can be achieved by supporting contract farming and price insurance mechanisms on the production side and by enhancing safety nets and access to financial services on the consumer side.

Governments and their international associations such as the G20 should therefore carefully analyze all available options for preventing food price spikes and volatility—from interventions in financial markets to biofuel policies—and they should also facilitate market information.

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The Effects of Southern Hemisphere Crop Production on Trade, Stocks, and Price Integration

4

Joseph W. Glauber and Mario J. Miranda

4.1 Introduction

The past 35 years have witnessed a rapid expansion of grain and oilseed production in the southern hemisphere, particularly in South America. Expanded land use and increased productivity have propelled southern hemisphere exports from accounting for about 20 % of world soybean exports in 1980 to over 50 % in 2010 (Fig. 4.1). Over the same period, southern hemisphere maize exports grew from 18 to 33 % and wheat exports from 15 to 25 %. Over this period, Brazil has become the world's largest soybean exporter and the second-largest maize exporter.

Projected grain and oilseed trends by various forecasters (USDA 2015; FAPRI 2014; FAO-OECD 2014) point to expected continued growth by southern hemisphere producers over the next 10 years. Moreover, to meet world food needs by 2050, FAO concludes that much of the needed production gains will have to come from South America and sub-Saharan Africa where there remain potential supplies of arable land and where yields lag potential (Bruinsma 2011; Alexandratos and Bruinsma 2012).

The growth of southern hemisphere production is significant, not only for the increased supplies to meet world food needs but also because it effectively shortens the crop growing cycle by 6 months. Since production seasons for most grains

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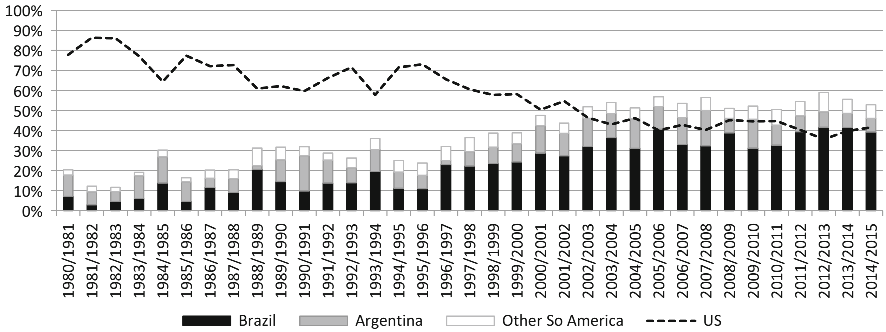

Fig. 4.1 Share of global soybean exports. *Source*: US Department of Agriculture *Production, Supply, and Distribution Database*

and oilseeds are largely counter-seasonal to the northern hemisphere, southern hemisphere producers can react rapidly to production shortfalls in the northern hemisphere. For example, in response to the widespread North American drought in the summer of 2012, Brazilian producers planted a record of 15.8 million hectares of maize, which provided needed supplies to a tight world market and helped to reduce price volatility.

What is less well understood, however, is the effect of the growth of southern hemisphere production on trade, inventories, and pricing. For example, how do shifts in production and consumption affect intraseasonal patterns of trade between the northern and southern hemispheres? Are there stronger incentives to hold stocks in one hemisphere and does this vary seasonally? How are seasonal price patterns affected in importing and exporting countries when the share of production and consumption shifts between hemispheres? Lastly, how closely are prices integrated between exporting and importing markets when new supplies are available to the market every 6 months?

Our objective is to gain a clearer understanding of how cross-hemispheric shifts in agricultural production over the past two decades have affected trade patterns, global price relationships, and stockholding. In our running example, the commodity is soybean, and the major producer-exporters are the USA and South America (Brazil and Argentina).

4.2 The Model

Consider a storable agricultural commodity called "beans." The global bean market consists of two major exporting countries ($i = 1, 2$) and the rest of the world or, more simply, the "world market" ($i = 0$). Beans are produced, consumed, and stored in the two exporting countries. Although production and stockholding may occur in the rest of the world, the rest of the world is treated as a net consumer of the exports generated by the exporters.

Time t is measured not in years but in semiannual periods. Harvesting occurs in the period after planting. Exporter $i = 1$ plants in odd periods and harvests in the subsequent even period; exporter $i = 2$ plants in even periods and harvests in the subsequent odd period. The model is driven by a single exogenous random variable $\widetilde{y}_{ti}$ and random new production in period t in exporting country i. Since planting periods alternate between the two exporting countries, $\widetilde{y}_{it}$ is zero if $i = 1$ and t is odd or if $i = 2$ and t is even.

The model features the following endogenous variables: p_{ti}, market price, year t, region $i = 0,\ 1,\ 2$; c_{ti}, consumption, year t, country $i = 1,\ 2$; q_{ti}, availability at beginning of year t, country $i = 1,\ 2$; x_{ti}, exports to the world market, year t, country $i = 1,\ 2$; and z_{ti}, ending stocks, year t, country $i = 1,\ 2$. Market equilibrium is governed by the following six sets of relations:

Material Balance. Each period t begins with predetermined quantities of beans available in each of the two exporting countries; these quantities must either be consumed, exported, or stored:

$$q_{ti} = c_{ti} + x_{ti} + z_{ti},\ \ i = 1,\ 2. \tag{4.1}$$

Trade Balance. Total exports to the world market must meet the demand for imports in the rest of the world at the equilibrium world price:

$$x_{t1} + x_{t2} = \alpha_0 - \beta_0 p_{t0}. \tag{4.2}$$

Here, $\alpha_0 > 0$ and $\beta_0 > 0$.

Regional Demand. The quantities consumed in each of the exporting countries must meet the demand for consumption in those countries at the local equilibrium prices:

$$c_{ti} = \alpha_i - \beta_i p_{ti},\ \ i = 1,\ 2,. \tag{4.3}$$

Here, $\alpha_i > 0$ and $\beta_i > 0$.

Spatial price equilibrium. Competition among profit-maximizing exporters guarantees that arbitrage profit opportunities from exporting are eliminated in each of the exporting countries:

$$x_{t0} \geq 0 \perp p_{t0} \leq p_{ti} + \tau_i,\ \ i = 1,\ 2. \tag{4.4}$$

Here, τ_i indicates the unit cost of exporting to the rest of the world from country $i = 1,\ 2$. Also, the symbol $\perp$ indicates that both inequalities must hold and at least one must hold with equality.

Intertemporal Price Equilibrium. Competition among expected profit-maximizing storers guarantees that expected arbitrage profit opportunities from storing are eliminated in the exporting countries:

$$z_{ti} \geq 0 \perp \delta E_t p_{t+1,i} \leq p_{ti} + \kappa_i, \; i = 1, \; 2. \tag{4.5}$$

Here, κ_i indicates the unit cost of storing between periods in country $i = 1, \; 2$ and δ is the biannual discount factor.

Availability. The quantities available at the beginning of next period in each of the exporting countries equal the sum of the quantities stored in the current period and new production:

$$q_{t+1,1} = \begin{cases} z_{t1} + \widetilde{y}_{t+1,1} & t \text{ odd} \\ z_{t1} & t \text{ even} \end{cases} \tag{4.6}$$

and

$$q_{t+1,2} = \begin{cases} z_{t2} & t \text{ odd} \\ z_{t2} + \widetilde{y}_{t+1,2} & t \text{ even.} \end{cases} \tag{4.7}$$

We assume that the model is annually stationary. That is, although model parameters may vary across semiannual periods within years, they do not vary from year to year. We also assume that new productions are serially and spatially uncorrelated, stationary, and lognormal distributed with means $\overline{y}_i > 0$ and standard deviations $\sigma_i > 0$ in the country $i = 1, \; 2$.

4.3 Numerical Solution Strategy

Under the specified assumptions, equilibrium market prices are functions of the availabilities in the two exporting countries:

$$p_{ti} = \begin{cases} f_{1i}\left(q_{t1}, q_{t2}\right), & t \text{ odd} \\ f_{2i}\left(q_{t1}, q_{t2}\right), & t \text{ even} \end{cases}, \; i = 0, \; 1, \; 2 \tag{4.8}$$

so that under rational expectations,

$$E_t p_{t+1,i} = \begin{cases} E_{\widetilde{y}_1} f_{2i}\left(z_{t1} + \widetilde{y}_1, z_{t2}\right), & t \text{ odd} \\ E_{\widetilde{y}_2} f_{1i}\left(z_{t1}, z_{t2} + \widetilde{y}_2\right), & t \text{ even.} \end{cases}, \; i = 1, \; 2. \tag{4.9}$$

The equilibrium price functions f are characterized by a system of functional equations that do not possess a known closed-form solution. However, the price functions may be computed to any desired degree of accuracy using collocation methods for standard functional equations. In particular, we construct finite-dimensional approximations of the form

$$f_i(q_1, q_2) \approx \sum_{j=1,2,\ldots,n} c_{ij}\phi_j(q_1, q_2) \tag{4.10}$$

for $i = 0, 1, 2$, where the c_{ij} are a set of $3n$ coefficients to be determined and the ϕ_j are cubic spline basis functions. The coefficients are fixed by requiring the price function approximants to satisfy the equilibrium conditions, not at all possible points in their domain, but rather at n prescribed collocation nodes. This poses a finite-dimensional root-finding problem that may be solved using standard nonlinear equation methods, such as the Newton's method or function iteration (see Miranda and Fackler 2002).

4.4 Model Simulations

The global market is simulated using Monte Carlo methods to assess the impact of key model parameters on the performance of key model variables. Generally speaking, we are interested in the effects of (a) shifts in global production, (b) changes in market integration, and (c) synchronicity of production on intra- and interannual price variability and stockholding.

Our simulations are designed to address two major questions. First, how does producing half of the world's yearly bean output in period 1 and half in period 2 affect carryout compared to a world where most of the bean production takes place in one period or the other? Presumably, if production is split equally between periods (and thus equally between exporting countries), carryout in the exporting country would be lower during the harvest period than if the country were the dominant producer. Second, how does this scenario affect inter-seasonal price differences? With one dominant producer, inter-seasonal price differences show full carrying charges. Does this hold when both countries are of the same size or will bean prices in one country rise only to fall when the harvest from the other country enters the market?

Base case model parameters are initially calibrated to reflect the global soybean market conditions in 2014 with quantities and prices normalized to 1 (see Table 4.1). More specifically, in the model, expected annual world production equals 1, and total annual world demand at a price of 1 equals 1. The semiannual discount factor δ is assumed to equal 0.975.

Table 4.2 shows the average soybean production, consumption, and exports during the periods 1990–1994, 2000–2004, and 2010–2014. In addition, it shows the average production, consumption, and exports in the period 2020–2024; these figures are obtained through simulation under expected prevailing conditions

Table 4.1 Base case parameters

Parameter	USA	South America	Rest of the world (ROW)
$A_{1990–2004}$	0.163	0.117	0.220
$A_{2000–2004}$	0.130	0.144	0.260
$A_{2010–2014}$	0.093	0.152	0.255
$A_{2020–2024}$	0.079	0.159	0.263
β	−0.20	−0.20	−0.25
σ_d	0.10	0.10	0.10
K	0.01	0.01	–
τ	0.15	0.15	–
$y_{1990–1994}$	0.489	0.301	0.210
$y_{2000–2004}$	0.396	0.441	0.163
$y_{2010–2014}$	0.333	0.507	0.160
$y_{2020–2024}$	0.295	0.575	0.130
σ_y	0.18	0.18	–

Table 4.2 Production and consumption shares in the four scenarios

	1990–1994	2000–2004	2010–2014	2020–2024
Global production (mil tonnes)	116.8	192.1	274.3	344.2
Global consumption (mil tonnes)	116.6	188.1	265.8	342.6
Share of global production				
USA (%)	48.9	39.6	33.3	29.5
South America (%)	30.8	45.2	52.3	57.5
ROW (%)	20.3	15.2	14.3	13.0
Share of global consumption				
USA (%)	32.5	25.9	18.6	15.7
South America (%)	24.2	30.1	31.7	31.8
ROW (%)	43.2	44.0	49.7	52.5
Production as a percent of consumption				
USA (%)	150.4	156.2	184.8	188.9
South America (%)	127.2	153.1	170.4	181.6
ROW (%)	47.2	35.3	29.7	24.8

Source: USDA, PSD Database, and ERS. 2015 International Long-Term Projection to 2024

according to the US Department of Agriculture's International Baseline Projections (2015).

Three major trends have characterized the soybean market over the past 20 years. First, production and consumption have expanded rapidly. Over the period 1990–1994 to 2010–2014, global soybean production and consumption increased by over 4 % per year. Over the next 10 years, soybean production and consumption growth is expected to decline to about 2.5 % annually, even though the figure is still strong compared to growth rates of other grains.

Second, the growth in soybean production has occurred largely in South America. While the USA accounted for almost half of the world's soybean production during the period 1990–1994, by 2010–2014, it accounted for only about one-third of the global production. Over the same period, South American production rose from 30.8 % of the global production in 1990–1994 to over 52 % in 2010–2014. Production in the rest of the world (ROW) fell from about 20 % of global production in 1990–1994 to about 14 % in 2010–2014.

Lastly, growth in soybean consumption has occurred largely in South America and ROW. The US share of global soybean consumption fell from 32.5 % in 1990–1994 to less than 19 % in 2010–2014. During the same period, the ROW's share of the global consumption grew, and its share of global production declined, causing the self-sufficiency rate (production divided by consumption) of the ROW to fall from 47 % in to under 30 %.

In the simulations that follow, we consider four stylized scenarios corresponding to historical production and consumption shares for the three regions. In the first scenario ("1990–1994"), global production shares were calibrated to reflect 1990–1994 historical levels where roughly 49 % of the world's soybeans were produced in the USA and 31 % in South America. In the "2000–2004" scenario, the global share of the US production declined to 40 %, while South America accounted for 45 % of the world's production. In the "2010–2014" scenario, soybean production in the USA accounted for about 33 % of global production, while soybean production in South America rose to 52 %. Lastly, we consider a scenario taken from the US Department of Agriculture's 10-year agricultural baseline projections ("2020–2024"), in which the US share of global production is projected to be 30 %, while the South American share is projected at 58 % (USDA 2015). While simulations under these stylized scenarios should not be interpreted as historical, they are structured to reflect the growth of South American soybean production so as to simulate the impact of that growth on global trade flows, inventory, and pricing relationships.

4.5 Impact of Shifting Production on Trade

Table 4.3 shows the simulated effects of shifts in regional production and consumption on seasonal trade flows between the USA and South America and the ROW. As production shifts to South America, trade shifts as well. In the 1990–1994 scenario, in which US soybean production accounted for about 49 % of the global production, the global share of US exports amounted to almost 71 %. As production shifts to South America, the US production share falls to about 30 % by 2020–2024 and the export share falls to about 35 %.

Over the same period, as soybean consumption grew faster than production in the ROW, imports from the two major production regions to the ROW grew as well, and the imports are higher in fall. Our highly stylized model assumed that the ROW consumes its domestic production prior to importing.[1] As self-sufficiency rates fall

[1] In reality, many importing countries import year round due to insufficient domestic production, high transportation costs, or other factors.

Table 4.3 Effects of shifts in production on trade patterns

	1990–1994 (%)	2000–2004 (%)	2010–2014 (%)	2020–2024 (%)
Share of total exports				
USA	70.7	47.0	42.0	35.1
South America	29.3	53.0	58.0	64.9
Share of ROW imports				
Fall	19.5	30.2	34.2	35.1
Spring	80.5	69.8	65.8	64.9
Share of spring exports				
USA	66.4	39.5	31.3	17.2
South America	33.6	60.5	68.7	82.8
Share of fall exports				
USA	88.6	64.4	62.5	63.4
South America	11.4	35.6	37.5	36.6
Share of US exports				
Fall	24.4	41.4	50.9	69.9
Spring	75.6	58.6	49.1	30.1
Share of South American exports				
Fall	7.6	17.2	22.1	21.8
Spring	92.4	82.8	77.9	78.2

to less than 25 % in the 2020–2024 period, 35 % of ROW total imports are estimated to occur in the fall compared to just 20 % in the 1990–1994 period.

In the 1990–1994 period, the USA dominated the soybean trade, accounting for two-thirds of spring exports and almost 89 % of fall exports. Over three-quarters of US exports occurred in spring. By contrast, South American exports occur largely following their harvest in the spring with less than 8 % of total exports occurring in the fall.

Increased ROW imports in the fall and increased South American production in the spring led to a pronounced shift in the pattern of exports from the United States and South America. In the 2020–2024 period, South America dominates the soybean export market in spring, accounting for almost 83 % of global exports. US exports continue to dominate the fall; however, South American exports account for almost 37 % of total trade in the fall compared with only 11 % during the 1990–1994 period.

How do the simulated results compare to empirical data? Figure 4.2 shows the seasonal pattern of actual soybean imports to China from the 2009/2010 to 2013/2014 marketing years. The data mirror the simulated results. While the seasonal import pattern is less pronounced in the empirical data, China, on average, tended to import more soybeans in the second half (55 %) than in the first half of a year, when domestic crops in China are harvested. Chinese imports from the USA mostly occur following crop harvest in the USA in late fall and continue through to early spring. As the South American crop begins to be harvested in late winter

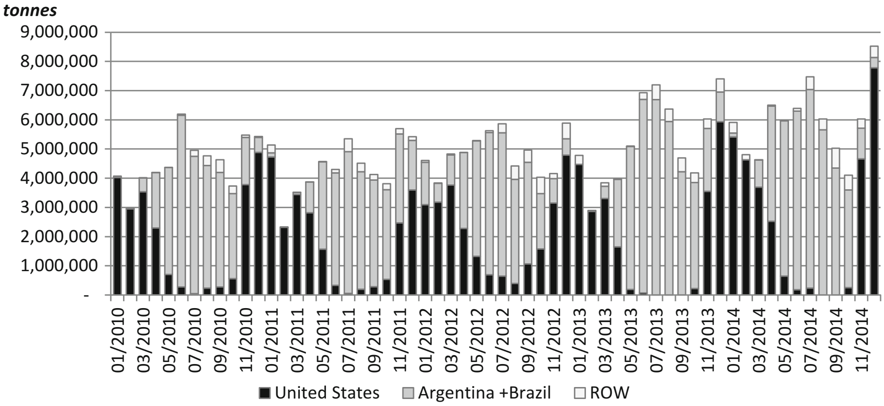

Fig. 4.2 Monthly China soybean imports by origin. *Source*: Global Trade Information System

and early spring, importers shift their attention to that region as their source of soybeans.

4.6 Effects of Shifts in Production on Regional Stocks

As South American soybean production takes up a larger share of global production, a larger share of global stocks are held in that region (Table 4.4). In the 1990–1994 period, US carryout stocks accounted for almost 93 % of global fall carryout stocks. This reflects the fact that production occurs during the fall in the USA, and carryout of old crop soybeans in South America is low.[2] While South America accounts for the majority of soybean carryout in spring (following harvest), US old crop carryout still accounts for almost 32 % of the total stocks. During the 2020–2024 period, however, South America accounts for over 92 % of the global carryout in spring and 25 % in fall.

With the shift in production from the USA to South America, the time at which global supplies are tightest (measured by the stocks-to-use ratio) shifts as well. In 1990–1994, when US production accounted for the majority of global soybean production, global supplies in late summer (i.e., before harvest of the new US crop) marked the seasonal low point of available soybean supplies in the world. In the simulations, carryout in spring accounted for an average of 48.5 % of the total spring use, while the stocks-to-use ratio in fall averaged 84 %.[3]

[2]Here we are talking about speculative stocks, that is, stocks held because the expected return from storing the crop equals or exceeds the costs of storage.

[3]Stocks-to-use ratios are typically calculated as ending stocks as a percent of total annual use. Here, we separate use by period (fall vs. spring) to more accurately reflect available intraseasonal supplies.

Table 4.4 Effects of shifts in production on stocks

	1990–1994 (%)	2000–2004 (%)	2010–2014 (%)	2020–2024 (%)
Share of spring stocks held by				
USA	31.9	16.4	6.9	7.8
South America	68.1	83.6	93.1	92.2
Share of fall stocks held by				
USA	92.7	85.3	77.7	74.9
South America	7.3	14.7	22.3	25.1
Global stocks to use				
Spring	48.5	58.1	60.7	63.8
Fall	84.1	65.6	53.7	42.8

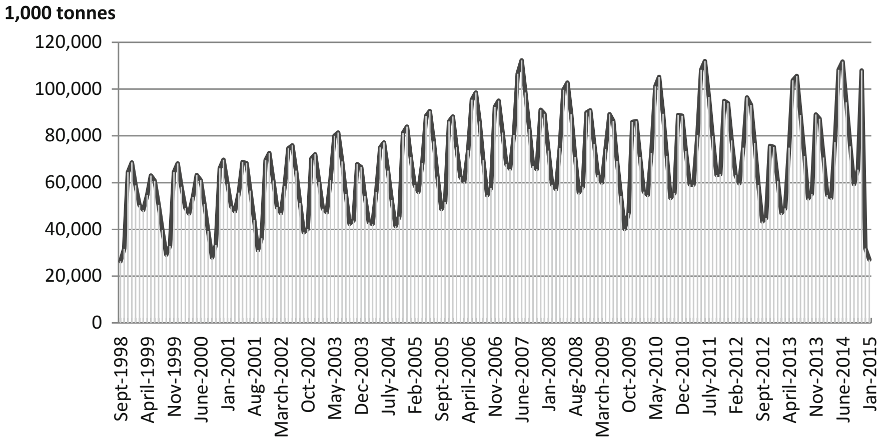

Fig. 4.3 Monthly ending stocks of the major exporters (the USA, Brazil, and Argentina). *Source*: USDA, *based on monthly crush and export numbers from Oil World and Global Trade Information System*

As supplies in South America grow, the low point in the year for available supplies is when South American supplies are at their lowest levels, that is to say, at the end of the fall quarter before new crops are harvested. In the simulated results for the period 2020–2024, for example, global fall carryout stocks account for 43 % of total use, while global spring carryout stocks (i.e., just prior to harvest of the US crop) account for 64 % of total use.

Empirical data again support the simulated findings. Figure 4.3 shows soybean stocks in the USA, Brazil, and Argentina from September 1998 to September 2014.[4] Initially, soybean stocks tended to be lowest in September just prior to the US harvest. Stocks fell throughout winter until the South American crops became available.

[4]Monthly soybean stocks were calculated using monthly crush and export numbers. Production was allocated across months based on harvest progress reports from exporting countries.

With the South American harvest, available soybean supplies increased in spring but then fell again to a low point in September. As ROW imports increase in fall, and South American production increases, the pattern becomes more pronounced, with stock levels in March falling to similar (or lower) levels than in September.

The ratio of stock level to consumption is often used as an advanced indicator of abnormal market conditions (see, e.g., Bobenrieth et al. 2013). Typically these metrics are constructed based on northern hemisphere production cycles with carryout stocks measured when northern hemisphere stocks are lowest. Our analysis suggests that, at the very least, such metrics tell only a partial story for crops with significant southern hemisphere production.

4.7 Effects of Shifts in Production on Soybean Price Integration

Spatial arbitrage ensures that prices in the exporting countries differ from the world price by the cost of storage (Enke 1951; Samuelson 1952; Takayama and Judge 1971; Fackler and Goodwin 2001). Thus, if transportation costs to the world market are the same in both exporting countries, prices must be the same in both exporting countries, even though they do not trade with each other. This is true, however, only if both exporting countries are guaranteed to export in both periods. If in any period, one country exports, but the other does not, then the link is broken and prices could diverge. The question is whether this is possible or likely.

In the stylized model presented here, we measure the degree to which the prices in one region are linked with prices in the other region with a simple correlation statistic. Table 4.5 shows the correlation between prices in the USA, South America, and the ROW in the fall and spring periods. Note that in the 1990–1994 period, when US exports accounted for 70 % of total global exports, the correlation coefficient for US prices and ROW prices is close to 1 in both the fall and spring periods. South American prices were more closely correlated with the prices in the ROW during the spring period, when the exportable supplies were at their highest level (and they account for about one-third of total world exports). By contrast, South America accounted for just 11 % of the total exports in fall, and the correlation coefficient with the prices in the ROW fell to 0.708.

Table 4.5 Effects of shifts in production on regional price correlations

Region/time period	1990–1994	2000–2004	2010–2014	2020–2024
USA–ROW/fall	0.999	0.996	0.999	1.000
USA–ROW/spring	1.000	0.967	0.952	0.856
South America–ROW/fall	0.708	0.735	0.737	0.863
South America–ROW/spring	0.946	1.000	1.000	1.000
USA–South America/fall	0.707	0.733	0.737	0.862
USA–South America/spring	0.946	0.967	0.952	0.856

As South American soybean production increases relative to the USA, US prices remain closely correlated during the fall period. This reflects the fact that US prices remain linked with ROW prices through trade. Recall that by 2020–2024, the US exports almost 70 % of its goods in fall as compared to the 1990–1994 period when over three-quarters of the exports from the USA occurred in spring. The correlation between US and ROW prices falls to 0.856 in the spring reflecting the fact that the USA is uncompetitive in ROW markets. With South America emerging as the dominant supplier to the ROW in the spring period (accounting for 83 % of total exports), the correlation between prices in South America and the ROW is 1.0.

Figure 4.4a shows that monthly export prices of soybeans from the USA, Brazil, and Argentina were closely correlated between 1990 and 2014. The simple correlation matrix suggests correlation coefficients of 0.99 or higher for the three time periods. Expressing the US Gulf price as a percentage of the prices in Brazil or Argentina, however, reveals a more seasonal pattern: US prices tend to fall relative

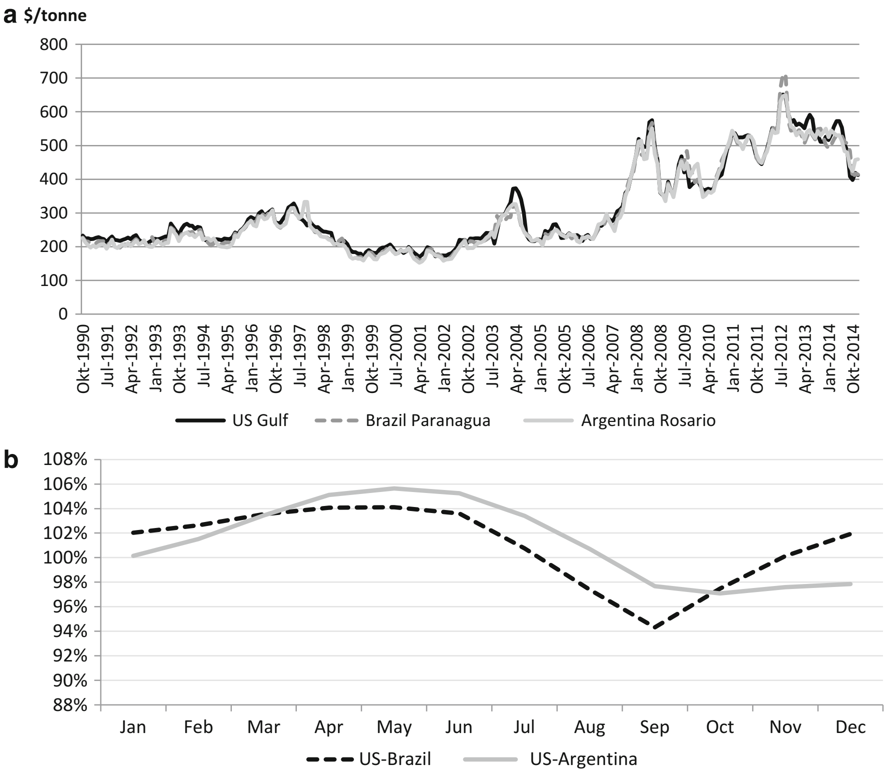

Fig. 4.4 (**a**) Soybean export prices. *Source*: USDA, Foreign Agricultural Service, *Oilseeds: World Markets and Trade*. (**b**) US price as a percentage of prices in Brazil and Argentina, average 2005–2014. *Source:* USDA, Foreign Agricultural Service, *Oilseeds: World Markets and Trade*

to southern hemisphere prices in fall, during harvest time in the USA, and rise in spring, during harvest time in the southern hemisphere (Fig. 4.4b).

A large body of literature has emerged that has examined price movements to test market efficiency and the degree to which markets are integrated (see Ravallion 1986; Mundlak and Larson 1992; Fackler and Goodwin 2001; Fackler and Tastan 2008). These studies have used time series and other empirical methods to examine how tariffs, transportation costs, exchange rates, and other transaction costs affect market integration. Our analysis suggests that intraseasonal timing of production is also an important factor. Previous studies about the soybean market noted how the seasonal aspect of soybean production affects price transmission between southern and northern hemispheres' producers and import markets, such as the EU (Margarido et al. 2007; Machado and Margarido 2004).

4.8 Carrying Costs Among Northern and Southern Exporters

In a market determined by one supplier, prices tend to rise throughout the marketing year, reflecting the costs of holding the crop over a period of time (Lowry et al. 1987; Miranda and Glauber 1993; Williams and Wright 1991). Those carrying costs can be indirectly measured by examining the spread between futures contracts (Williams 1986). In this paper, futures spreads are constructed using closing futures prices from the Chicago Mercantile Exchange (CME), the Bolsa de Comercio in Rosario, Argentina (Bolsa), and the Dalian Commodity Exchange in China (DCE). To compare the array of futures prices at a given point in time, we averaged the daily closing futures prices in October of each year sampled for the November through September futures contracts. To compare the contracts across time and exchanges, we normalized the spreads by expressing all of the contracts in terms of the November contract.

Figure 4.5a shows the spreads for CME soybean futures. For the most part, the spreads exhibit the expected pattern: future contracts show positive carrying charges through the marketing year, reflecting carrying costs. As the arrival of new crops on the market approaches, prices weaken and can show negative carrying costs (often referred to as backwardation). The exceptions to this pattern are the 2012/2013 and 2013/2014 marketing years, which were characterized by tight US supplies following the drought in 2012 and large expected harvests in South America. As a result, futures contracts exhibit backwardation throughout the marketing year. That pattern reverted to the more typical pattern in 2014/2015 following the large soybean harvest in the USA and the rebuilding of US soybean stocks.

Consistent with results from the storage model, closing prices in Argentina for the same period reflect the fact that southern hemisphere harvest starts 6 months after the northern hemisphere harvest (Fig. 4.5b). Bolsa futures show backwardation from November through May and subsequently positive carry in the months following harvest. The pattern resembles that of the CME, except out of phase by 6 months.

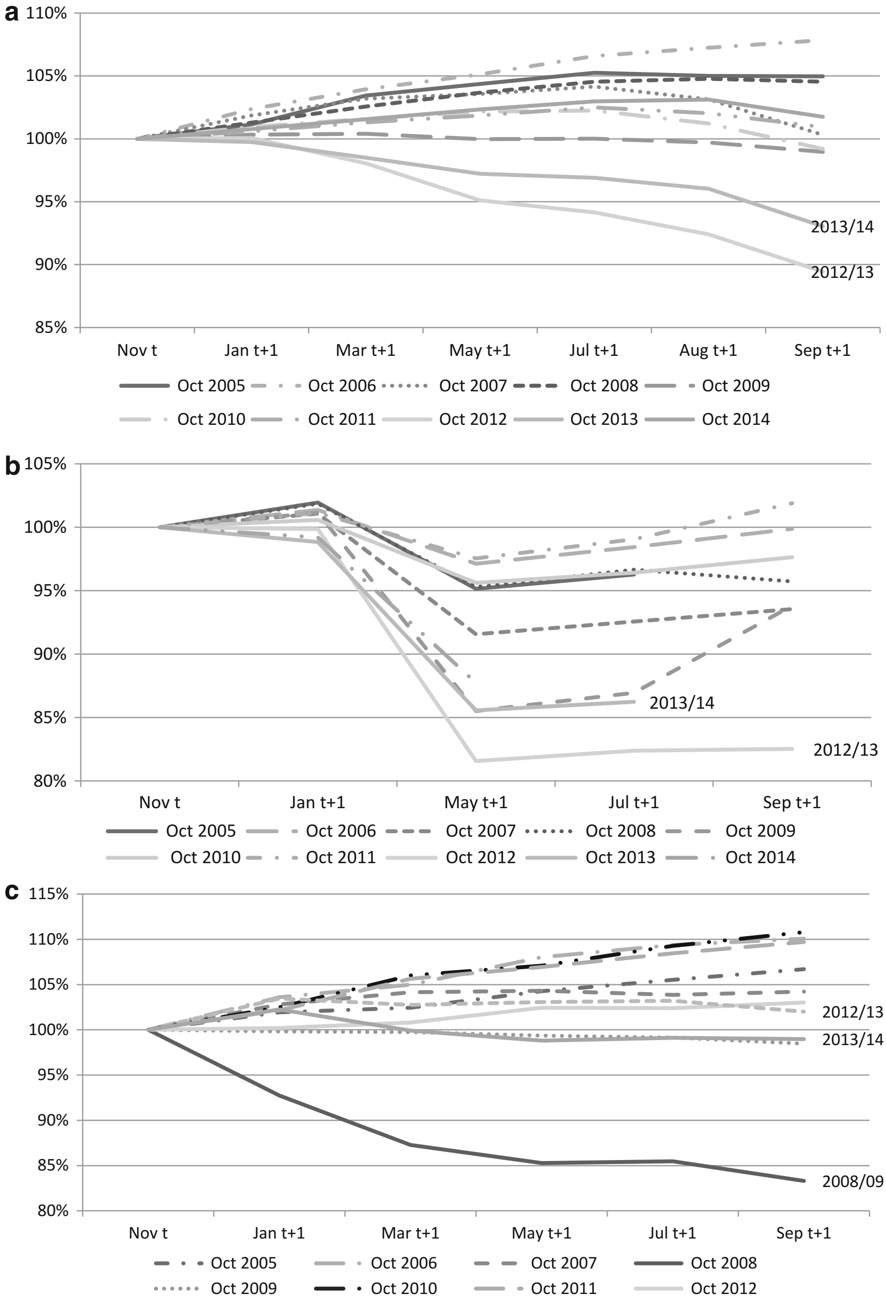

Fig. 4.5 (**a**) Soybean futures—Chicago Mercantile Exchange. *Source*: Chicago Mercantile Exchange. (**b**) Soybean futures—Bolsa de Comercio de Rosario. *Source*: Bolsa de Comercio de Rosario (Argentina). (**c**) Soybean futures—Dalian Commodity Exchange. *Source*: Dalian Commodity Exchange (China)

Figure 4.5c shows the same array for DCE futures taken from the same period. As discussed earlier (Fig. 4.2), China largely imports soybeans from the USA in the first part of their marketing year and then switches to importing from the southern hemisphere after crops are harvested there. All else equal, one would expect that there would not be large incentives to store since one could purchase lower cost soybeans when new supplies become available in the other hemisphere. Many of the years in the limited data sample exhibited this pattern (e.g., 2007, 2009, 2012, 2013, and 2014). In some of the years considered here (2005, 2006, 2010, and 2011), the pattern of DCE futures exhibited a similar pattern to that of CME, with futures showing positive carry throughout the marketing year. Lastly, backwardation was present throughout the 2008/2009 market year.

Two factors may help explain the anomalies. First, China's domestic soybean consumption grew by over 8 % annually over 2005–2014; imports grew annually by 11 % over the same period. Strong carrying charges may reflect, in part, the demand for current supplies to meet future consumption. Second, China introduced a price support for soybeans beginning 2008 to keep market prices high throughout the marketing year (Gale 2013). From 2009 to 2012, soybean support prices were raised steadily. While the Chinese authorities have signaled their intent to experiment with more direct (income) support measures that allow prices to be determined by market forces, price supports continue to have the potential of distorting intraseasonal price relationships.

4.9 Effects of Production Shifts on Price Variability

How has the production growth in the southern hemisphere affected price variability? Assuming yields are uncorrelated between northern and southern hemispheres, global exporter yield variability could be expected to decline when production in the southern hemisphere approaches levels similar to those in the USA. Lower production variability would mean more stable prices. However, in the scenarios considered here, those effects are likely to be small. Figure 4.6 shows how global exporter yield variability is affected by the share of production from southern hemisphere exporters. From 1990 to 1994, South America accounted for about 38 % of total production among global exporters. By around 2020–2024, South America is projected to account for almost two-thirds of production among global exporters. Within this range, global yield variability in exporting regions does not vary much (Fig. 4.6).

Nonetheless, shifts in production are estimated to have profound effects on intraseasonal price variability in importing and exporting regions. Table 4.6 shows the simulated standard deviation of prices in the fall and spring periods in the three regions. For the exporting countries, prices are more volatile in the second half of their crop year, when supplies are tighter; this result is consistent with the findings of Lowry et al. (1987).

Price variability in the ROW is largely tied to price variability in exporting regions. During the 1990–1994 period, in which the USA accounted for over 70 %

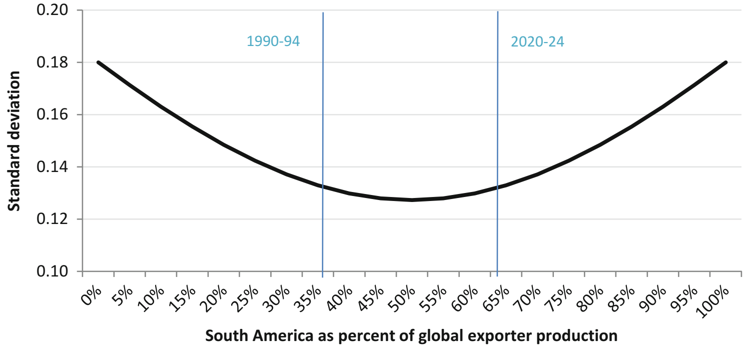

Fig. 4.6 Annual yield variability of major exporting countries. *Note*. The standard deviation of normalized yields in South America and the USA are assumed equal to 0.18 (Table 4.1)

Table 4.6 Effects of shifts in production on price variability

	1990–1994	2000–2004	2010–2014	2020–2024
	Standard deviation			
USA				
Spring	0.332	0.342	0.363	0.406
Fall	0.254	0.230	0.244	0.318
South America				
Spring	0.341	0.321	0.342	0.348
Fall	0.400	0.419	0.439	0.411
ROW				
Spring	0.332	0.321	0.342	0.348
Fall	0.254	0.233	0.245	0.320

of global exports and was the dominant exporter in both spring and fall, ROW price variability is roughly equal to US price variability (as measured by the standard deviation). Because of this, price variability in the ROW tends to be higher in spring than fall. As the ROW becomes more reliant on imports from South America in the spring period (almost 83 % by 2020–2024 compared with 34 % in 1990–1994), ROW spring price variability is tied to its counterpart in South America. ROW price variability continues to be tied to its counterpart in the USA in fall, during which the USA supplies the majority of exports to the ROW. The simulation results suggest a small increase in price variability over the 30-year period which may reflect, in part, the increasing reliance on imports to meet the consumption in the ROW.

Lastly, as mentioned earlier, production is assumed to be exogenous with respect to price in our stylized model. In models with price-responsive supply, a supply shock in one region would affect plantings in the other region, allowing for more rapid adjustment (see, e.g., Haile et al. 2014; Lybbert et al. 2014). When such models are applied to the sample, the growth of South American production would likely show a more significant role in reducing price volatility.

4.10 Conclusions

The growth of southern hemisphere production has increased global supplies of grains and oilseeds, helping to meet the large growth in global demand witnessed in the past 30 years. The structural model presented in this paper gives important insights into intraseasonal patterns of storage, trade, and market prices that have accompanied the growth in southern hemisphere production, patterns that are generally not captured in annual models. Applying the model to the global soybean market, we show how increased production share in the southern hemisphere has resulted in more pronounced seasonality in exports between exporters in the northern and southern hemispheres. The analysis also suggests that the shift in production means that from a global perspective, the crop "season" has shortened from 12 to 6 months. With a new crop available every 6 months, stock levels in March are as relevant as those in September in indicating supply availability. While trade and storage link market prices across time and space, the analysis suggests that seasonal trade patterns can also disrupt price integration or, more accurately, result in a more seasonal pattern of integration. Failure to recognize those patterns can obscure and bias analyses of global food security, potentially exaggerating the impact of shortages or surpluses when they occur in one hemisphere but not in the other.

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5 Food Price Changes, Price Insulation, and Their Impacts on Global and Domestic Poverty

Will Martin and Maros Ivanic

5.1 Introduction

Changes in food prices have extremely important impacts on poor and vulnerable households. Although some households benefit from higher food prices, others are adversely affected, depending whether they are net buyers or sellers of food and the extent to which their incomes adjust to food price changes. Low-income households tend to spend a large share of their incomes on staple foods, making them potentially vulnerable to food price increases. Policymakers in many countries respond to food price changes—and particularly food price increases—by insulating their countries from these developments. Exporters often achieved this insulation by restricting export, whereas importers most commonly respond by reducing import barriers. While individually rational, these responses create a collective action problem—each country's actions contribute to a further rise in world prices—exactly the problem that they are individually trying to avoid.

Our concern in this chapter is with the impact of food prices and policies on the poorest in the society. We focus on the impacts of food price changes on individual households, particularly on those living near the poverty line. One very simple indicator of the effect at the household level is the change in the number of people living below the poverty line. We focus primarily on the World Bank's standard measure of poverty, which is defined as US$1.25 per day in international purchasing power. An economic shock that increases the number of people below the poverty line is clearly an adverse development. We then consider governments' policy responses to economic shocks and their effects on the welfare of individual

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households, and hence on the number of households below the poverty line. Finally, we discuss the implications of countries' trade policy choices—initially from the viewpoint of an individual country and then from the viewpoint of all countries.

5.2 Effects of Food Price Changes on Poverty

One widely accepted measure of the short-run effect of a small change in a commodity price on household welfare is given by the household's net trade share for that good, as defined by Deaton (1989). A household that is a net seller of a good benefits when the price of that good rises. By contrast, a household that is a net buyer is put at a disadvantage when the price rises. This is only an approximation as demand can respond very quickly, but given the magnitude of the relevant demand elasticities, the associated second-order impact is quite small. Therefore, the first-order measure is a good approximation. Essentially, this is the same measure that is used here for determining the effect of a change in prices on national income (see Martin 1997 for a fuller discussion). The concept of short run used in this analysis is the length of time in which other effects, such as output adjustment or effects on wages, do not arise. Some analyses, such as that by Ravallion (1990), suggest that much of the longer-run impact is felt after 3 years.

At the household level, there are some important stylized facts that influence the likely effect of this measure. Perhaps the oldest of such stylized facts is that poor households spend a large share of their incomes on food. This might suggest that the poor are always put at a disadvantage when food prices rise. However, this need not be the case because most of the world's poor population live in rural areas, and the majority of them earn their living from agriculture. Nevertheless, many farmers in developing countries are also net buyers of food. Thus, the short-run effect of food prices on poverty becomes an empirical question that can be resolved only by using detailed data on the income sources and expenditure patterns of households.

A great deal of evidence shows that short-run increases in most food prices, other things equal, raise the poverty level in most developing countries (see, for example, de Hoyos and Medvedev 2011; Ivanic and Martin 2008; Ivanic et al. 2012; Jacoby 2013; Wodon and Zaman 2010). This is often the case even in countries that are net food exporters and therefore benefit from the terms-of-trade effect of the shock (see Ferreira et al. 2013, for Brazil). In some countries, such as Vietnam, where agricultural resources are relatively evenly distributed, higher prices of key products such as rice may lower the poverty level (Ivanic and Martin 2008). Similarly, higher milk prices appear to lower poverty in Peru. This is because the milk producers are much poorer than their customers. The net increase in poverty associated with a food price rise does not mean that all people are adversely affected. For example, Ivanic et al. (2012) found that although higher prices resulted in a net increase in the number of people living in extreme poverty by 44 million in 2010, 68 million people fell below the poverty line, and 24 million rose above it.

Once markets are given more time to adjust to changes, two additional factors need to be considered. First, changes in food prices may result in changes in factor returns. Second, changes in the output patterns of poor households may occur. The factor return which is most likely to affect poor households is the wage rate paid for unskilled labor sold by the households outside their farm (Lasco et al. 2008; Ravallion 1990). The effect on wage rates is likely to be much more important when the product is (a) very labor intensive; (b) has a large share of output, as with rice in Bangladesh; and (c) involves intensive use of intermediate inputs.

5.2.1 Short-Run Effects

The available evidence suggests that the full effect of food price changes on wage rates and output volumes takes time to materialize. A useful measure of the short-run effects of higher food prices on poverty considers only the direct impact on incomes due to the initial net trade position of households. The sign of this measure is an important building block of longer-term measures that also consider wage rates and output change effects. These measures are, of course, potentially vulnerable to mismeasurement of the initial production or consumption levels of the households—an issue which requires further research (Headey and Fan 2010, p. 72; Carletto 2012). The measures should also take into account a small second-order impact—the ability of consumers to adjust their consumption in response to price changes. Given the low value of compensated demand elasticities in small countries, this refinement makes very little difference to the estimated impacts. Table 5.1 presents the results of a simulation analysis of these short-run effects based on survey data from 31 countries (Ivanic and Martin 2014a). Two key features of this analysis need to be taken into account. First, these results are based on a broad food price index, rather than price changes for any particular food. Second, they are based on a specific type of price change—one that results from shocks outside the developing countries studied. This is a realistic approach for analyzing an event such as the food price shock in 2006–2008, which was primarily caused by external factors, such as the sharp increase in demand for foodstuffs from the biofuel sector in industrial countries (Wright 2014).

Table 5.1 shows that increases in food prices adversely affect the poor in most countries except Albania, Cambodia, China, and Vietnam; in these countries, a 10 % increase in food prices reduces the poverty level. Strikingly, the relationship between poverty effects and food price changes is frequently highly nonlinear. In Albania and Vietnam, food price changes have favorable impacts on near-poor net sellers of food; some of them rise above the poverty line when faced with a small food price increase. In contrast, net buyers of food are negatively affected by larger price increases, resulting in them falling below the poverty line. For most countries, the effects are monotonic, but the relationship between price change and poverty is frequently nonlinear. The poor population in countries, such as India, Indonesia, and Pakistan are severely affected by price changes.

Table 5.1 Short-run poverty effects of food price increases, changes in percante points of people with income below US$1.25 per day

Country	Survey year	10 %	50 %	100 %
Albania	2005	−0.1	0.7	4.8
Armenia	2004	0	1.3	4.9
Bangladesh	2005	1.4	9.7	18.1
Belize	2009	0.5	3.2	8.6
Cambodia	2003	−3.0	−10.1	−14.9
China	2002	−1.3	−4.0	−3.2
Côte d'Ivoire	2002	1.1	7.2	17.6
Ecuador	2006	0.3	2.3	7.2
Guatemala	2006	1.4	9.7	27.2
India	2005	2.6	14.2	25.8
Indonesia	2007	1.7	10.2	25.2
Malawi	2004	0.7	3.1	5.7
Moldova	2009	0	1.1	7.9
Mongolia	2002	1.4	8.7	21.6
Nepal	2002	0.5	3.2	6.8
Nicaragua	2005	1.1	5.8	17.4
Niger	2007	0.6	6.9	17.1
Nigeria	2003	1.0	5.6	9.8
Pakistan	2005	2.7	14.0	27.5
Panama	2003	0.3	2.5	8.0
Peru	2007	0.2	1.5	6.9
Rwanda	2005	1.1	4.4	8.5
Sierra Leone	2011	2.4	12.5	22.1
Sri Lanka	2007	1.8	11.6	29.1
Tajikistan	2007	0.8	8.7	28.1
Tanzania	2008	1.9	8.2	14.5
Timor-Leste	2007	1.9	10.0	20.1
Uganda	2005	0.7	3.8	8.7
Vietnam	2010	−0.4	2.1	12.8
Yemen, Rep.	2006	2.0	13.4	33.2
Zambia	2010	1.1	6.0	12.5
World		0.8	5.8	13.0

Source: Based on survey data collected by the authors

The results presented in Table 5.1 were used to represent the global effects of price changes on poverty. The study followed the sampling methodology outlined in Ivanic et al. (2012). The global impacts are presented in the final row of the table. They provide a useful summary of the effects of price changes: global poverty rises despite a decline in poverty in important countries such as China and Vietnam.

5.2.2 Longer-Run Effects

As noted above, the longer-run effects of food price change differ from the short-run effects for two main reasons: (a) the effects of food price changes on wages and (b) the change in output volume resulting from the food price increase (i.e., the supply response). In our earlier work about the effects of food prices on poverty, we focused on the short-run effects, taking into account potential short-run wage changes (Ivanic and Martin 2008).

In our more recent work, we have also examined the longer-run effects, considering both changes in wage rates and changes in the quantities of output supplied (Ivanic and Martin 2014a). In this chapter, we wanted to assess the implications of food price changes on the wage rates of unskilled labor. The goal is to capture the impacts of price changes for a range of commodities; therefore, we could not rely on the type of econometric models used in Ravallion (1990). Instead, we developed a model, which is similar to the production module of the Global Trade Analysis Project (GTAP) model, for each country. These models are very similar in structure to the workhorse Heckscher–Ohlin model used in international trade theory (Caves and Jones 1973, pp. 182–185): The output in each sector is determined by the level of a composite factor input, and the substitution between factors that constitute the composite factor input follows a constant-elasticity-of-substitution technology. The version we used also considers the real-world phenomenon of intermediate inputs, which magnify the impacts of output-price changes on factor returns.

In medium-run analyses, all factors except labor are fixed in each sector, and changes in output come about through intersectoral movements of labor. In the longer run, we took into account movements of labor and capital in a manner consistent with the Heckscher–Ohlin model of trade, modified to make allowance for the real-world imperfect mobility of land between sectors. The resulting elasticities of wage rates with respect to the prices of agricultural goods vary by country, but they are typically around unity for increases in all agricultural prices. To remain consistent with the economy-wide analysis which is used to estimate the wage effects of food price changes, we used the structure of the GTAP general equilibrium model to represent the response of households, which allocate their available resources between the commodities that they produce.

The impacts of commodity prices on wages (Stolper–Samuelson effects) used in this analysis were derived from simulation models for individual economies rather than the direct estimation of statistical relationships. This is the only feasible approach given our need to assess the impacts of price changes by a specific commodity and at the global level. In an important study, Jacoby (2013) developed similar simple simulation models of the production side of the economy (in his case, for regions in India). He showed from first principles that the impacts of food price changes on wages depend upon key parameters, such as the importance of a commodity in labor demand, and the share of intermediate inputs in production. He also tested whether the impacts of food prices on wages were consistent in scale with econometrically based estimates. The study concluded that the impacts were consistent with the estimates and that the test used in the study has considerable significance.

The price elasticities of wages used in our study average slightly above one for a broadly defined food group, which includes not just basic staples but also processed foods (Ivanic and Martin 2014a, p. 36). As expected, the price elasticities of unskilled wages tend to be relatively large with respect to food prices for the most important commodities. In many cases, the commodities with the greatest impact are dominant staples like rice in Bangladesh and cassava in Nigeria. The group “Other Processed Foods” is more important in many cases because this is a large commodity group and the models take into account the labor used in food processing.

When considering a much wider coverage of foods, the results from our study are consistent with those from Jacoby (2013) for India using cross-sectional data and the global results in Headey (2014). Ravallion (1990), and Boyce and Ravallion (1991) estimated that the elasticity of the agricultural wage rate in Bangladesh to the price of rice was 0.22 in the short run and 0.47 in the long run. The long-run elasticity is quite similar to the estimate of 0.4 used in Ivanic and Martin (2014a) for rice in Bangladesh. Lasco et al. (2008) found a largely similar long-run estimate of 0.57 for rice in the Philippines.

Headey’s (2015) analysis found that food prices had a considerably smaller impact on urban wages in Ethiopia, with preferred elasticities of around 0.3. This result may suggest the presence of barriers between urban and rural markets for unskilled workers. Assessing the implications of higher food prices on wages, Ivanic and Martin (2008) suggested that the overall poverty impact of higher food prices would likely only be slightly affected by such barriers. The barriers are significant in rural areas, where the population tends to be poorer; the benefits of higher wages for net-labor-selling households are concentrated mostly in these areas. When the barriers are not significant, the benefits of higher wages for unskilled workers are spread across more of the low-income population.

In a study about barriers to agricultural exports, higher agricultural prices (including processed agricultural products such as wine) were found to have a very large impact on wages in Moldova (Porto 2005), with an elasticity of 2.9. Using a symmetry relationship to estimate the parameters, another econometric study found that the food prices had a lower impact on wages in six African countries than the estimates used in this study (Nicita et al. 2014). This resulted in the long-run relationship between food prices and poverty being essentially the same as the short-run relationship for these countries.

Considering the global estimates shown in the first column in Table 5.2, global poverty rises in the short run with increasing food prices. When prices increase by 10 %, global poverty is estimated to rise by 0.8 % points. The rate of increase grows faster as the food price rise increases because so many households near the poverty line spend extremely large shares of their incomes on food. When the food price shock increases fivefold from 10 to 50 %, poverty is predicted to rise by 5.8 % points, and doubling the price shock from 50 to 100 % more than doubles the estimated global poverty estimate to 13 % points.

Table 5.2 Global poverty effects of general food price increases, changes in percante points of people with income below US$1.25 per day

Scenario (%)	Household group	Short run	Short run + wages	Medium run	Long run
10	All	0.8	−1.1	−1.2	−1.4
50	All	5.8	−3.9	−4.8	−5.8
100	All	13	−5.7	−7.6	−8.7

Source: Ivanic and Martin (2014a)

It is important to understand what causes the simulation results for the short run and the long run to be different, as shown in Table 5.2. The second column shows the results obtained after adding the impact of wage changes to the direct impact of higher food prices. Since selling unskilled labor is a very important source of income for many poor households, and the impacts of higher food prices on wages are found to be substantial for unskilled workers in many countries, it is not surprising that higher wages have important, favorable impacts on poverty. The results obtained for the medium run, in which farmers are able to change their outputs of food commodities, is quite similar to the results in the second column. This implies that the ability to adjust output and transfer labor between agriculture and other sectors has a much smaller impact than the impact of wage changes emphasized by Jacoby (2013). In the longer-run scenario, in which all factors are mobile, the importance of adjustment responses increases, but they remain quite small relative to the impacts of higher wages resulting from food price changes.

5.3 Policy Responses

A widely observed policy response from developing countries, and historically from today's industrial countries, to fluctuations in world food prices is to insulate their domestic markets from these changes. When prices surged in 2007–2008, many developing country exporters used export restrictions to lower their domestic prices relative to world prices. Even more countries lowered either their import or their consumption taxes on food (Wodon and Zaman 2010, p. 167). But this response is not confined to instances of sharp price increases. For staple food commodities, such as rice, domestic markets are more or less constantly insulated. Figure 5.1 shows the strong inverse relationship between the world average rate of protection for rice and the world price—a relationship that is consistent with the consistent stabilization of domestic prices relative to world prices.

However, the dynamic response pattern for key agricultural commodities appears more complex and interesting. Developing countries tend to adopt an extremely high degree of insulation against rapid changes in food prices but, if these changes are sustained for a period of time, to pass them through domestic markets. This pattern is clearly shown in Fig. 5.2 for the average food price, which takes into account the prices of rice, wheat, maize, edible oils, and sugar. In the case of price increases, this policy seems to be particularly suitable for managing the adverse impacts of higher

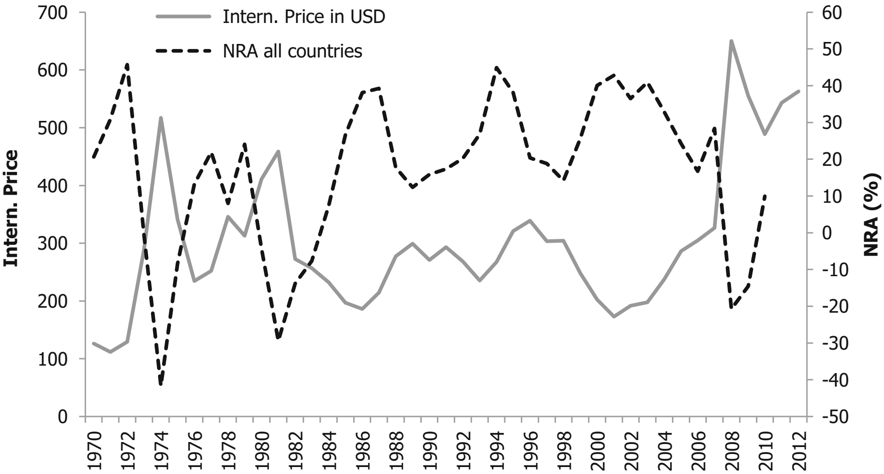

Fig. 5.1 World prices and the average protection rate for rice. *Source*: Calculations based on data from http://www.worldbank.org/agdistortions. *Note*: NRA = nominal rate of assistance. See Anderson (2009)

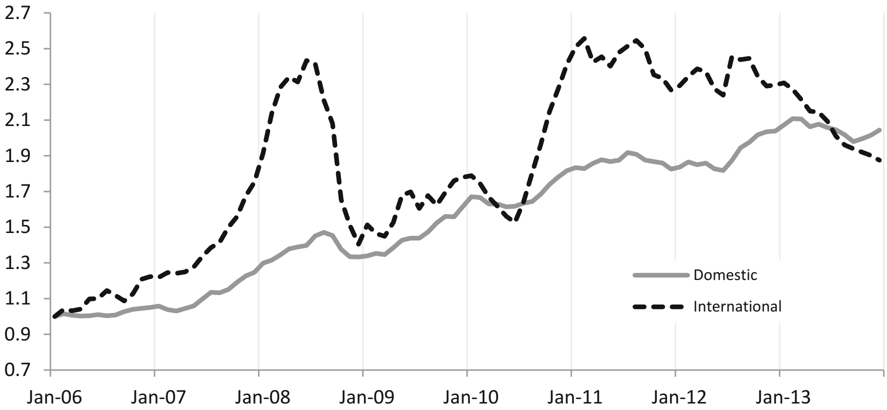

Fig. 5.2 Domestic and world price index of rice, wheat, maize, oil, and sugar, developing countries. *Source*: Ivanic and Martin (2014b)

food prices on the poor in individual countries. But after a while, food prices can feed through into wages, and producers are able to respond by increasing supply, therefore allowing the beneficial impacts of higher food prices on the poor to be noticeable.

This policy approach is, for individual countries, an effective way to stabilize their domestic prices. Using trade measures to stabilize domestic prices is very likely to be less costly than using storage policies alone. However, the widespread usage of the approach creates a serious collective action problem. If every country seeks to reduce its price by the same amount, the domestic price is unaffected (Martin and Anderson 2012). The mechanism is simple—export restrictions in exporting countries push up world prices, as do import duty reductions in importing countries. Martin and Anderson (2012) pointed out that the problem is akin to everyone in a stadium standing up to get a better view of a game. Their analysis suggests that almost half of the increase in world rice prices between 2006 and 2008 was the result of countries' attempting to insulate their markets against the increases in world prices, thus creating a serious collective action problem. Countries that prefer not to use export controls or import barrier reductions in response to a rise in prices may feel compelled to do so because of the actions of other countries, thereby further amplifying the increase in world prices.

In reality, different countries insulate to different extents, and insulation might reduce poverty if the countries which are the most vulnerable to a surge in food prices insulate their domestic markets to a greater degree than the others. For instance, if developing countries insulated their domestic markets and therefore forced the adjustment onto developed countries (which are much more capable of managing this problem), the global poverty effects of a food price surge might be reduced. There are, however, no guarantees that all interventions follow this pattern. Historically, some of the most enthusiastic users of price insulation have been relatively wealthy countries, such as members of the European Community with its pre-Uruguay Round system of variable import levies. To learn whether the pattern of interventions during the 2006–2008 price surge actually reduced poverty, Anderson et al. (2014) examined the actual interventions used and assessed their effects on global poverty, taking into account the effects of the interventions on the world price. They concluded that the interventions appeared to reduce the poverty level by around 80 million people, as long as the effects of the trade interventions on world prices were not taken into account. Once the effects were considered, the intervention generated a small and statistically insignificant increase in world prices.

Many countries try to use a combination of trade and storage measures to reduce the volatility of their domestic prices. In principle, the combination of trade and storage measures is potentially more effective than trade or storage measures alone (Gouel and Jean 2014). Gautam et al. (2014) found that the combination of trade measures, which are beggar-thy-neighbor approaches, and storage measures, which might be beneficial to the neighbors, reduces—but does not eliminate—the adverse effects of one country's policies on food price volatility in the rest of the world. Implementing these policies tends to be extremely expensive; the policies are also likely to include rigidities that frequently cause them to collapse (Knudsen and Nash 1990).

The central role of the WTO is to deal with collective action problems that affect the level of world prices and/or their volatility. The use of bindings on import tariffs reduces the extent to which importing countries can depress world prices by discouraging imports. The Uruguay Round introduced important measures to discourage the insulation of domestic markets against world price changes, a practice that exacerbates price volatility. The reforms include banning variable import levies and subjecting administered prices to discipline both the market access and domestic support pillars.

Because of its mercantilist focus, the WTO has done very little to discourage the use of export restrictions—from the point of view of an exporter, any export restriction imposed by another exporter represents an export opportunity. While quantitative export restrictions are subjected to a general proscription under Article XI of GATT, export taxes are not constrained except in limited instances, such as restrictions negotiated under WTO accession agreements. But unless all export restrictions are disciplined, they are likely to contribute to upward pressure on food prices in times of crisis, making it difficult for other exporters not to follow suit and for importers to refrain from lowering domestic prices through duty and tax reductions—all of which put further upward pressure on world prices while being collectively ineffective in dealing with the problem. Importantly, constructive suggestions for binding and progressive reduction of export taxes have been put forward (see the discussion in Anderson et al. 2014), but there has not been enough attention on dealing with this collective action problem. Instead, the focus lies on maintaining countries' rights to contribute to the problem.

5.4 Recent Developments in Poverty Reduction

A question about the impact of food price increases on poverty, highlighted by Headey and Fan (2010) and Headey (2011), is that poverty appears to have declined sharply between 2006 and 2012 despite food prices rising substantially during that period. If the short-run impacts of higher food prices were as adverse as suggested by short-run simulation studies, then how could poverty have continued to decline between 2006 and 2012? Recent studies about the difference between the short- and long-run impacts of food price changes, and the pattern of transmission of food price increases may offer an explanation for this question.

A recent study by the authors (Ivanic and Martin 2014b) found that price transmission was very low in the initial phase of a food price increase. This reduced the adverse impacts of higher domestic food prices on poverty while exacerbating the increase in world food prices. With a sustained increase in world prices, domestic prices begin to rise over a time frame in which wage responses are able to take effect. When the results on world food price changes, food price transmission and food price impacts on poverty are brought together, as in Table 5.2, we found that the food price increases between 2006 and 2012 were likely to have contributed substantially to the large reduction in poverty observed over this period. According to projections, poverty will have declined by 8 % between 2006 and 2015; to which food price increases may have contributed 5 % points. Clearly, these numbers should be interpreted with caution, particularly because the figure for 2015 is only a projection (Fig. 5.3).

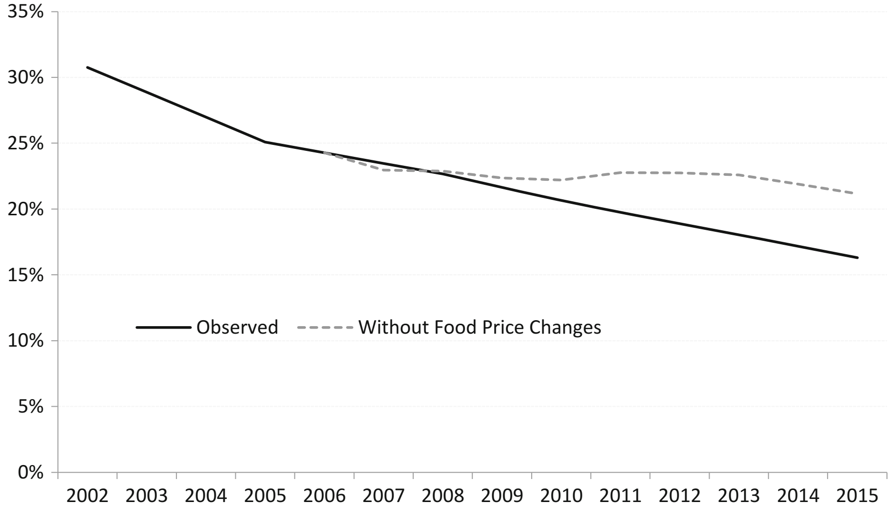

Fig. 5.3 Global poverty headcount: estimated versus without food price changes

5.5 Conclusions

This chapter has examined the critical issue of the short- and long-term welfare effects of food price changes, and the associated policy responses. It has focused on the effect of food price changes on individuals and households. As shown by Ferreira et al. (2013) for Brazil, many people may be adversely affected by food price changes even when their country as a whole benefits from the change. The evidence surveyed here strongly suggests that a rise in food prices will result in a net increase in poverty in the short run. Inevitably, some net sellers of food are able to rise out of poverty, while some net buyers of food fall into poverty. But, in most countries, the number of people falling into poverty is greater than the number of people rising out of poverty.

The chapter has also examined the emerging evidence about the longer-run effects of food price changes on poverty. There are two important differences between the shorter- and longer-run effects. In the case of longer-run, wages have time to fully adjust to the change in prices, and producers have the opportunity to adjust their output levels and output mix to the change in prices. Here, the evidence suggests that higher food prices tend to lower poverty in most countries—frequently by substantial margins. It is important to note that the results considered here for both the short- and the long run are related to changes in food prices that are purely exogenous to developing countries. In developing countries, if a price increase is due, in whole or in part, to a decline in productivity, estimates of the effect on incomes will need to consider the direct adverse effect on incomes of the decline in productivity.

The concluding section of this chapter has reviewed the policy options for developing countries when dealing with the problem of food price volatility. As noted, the most commonly adopted response—insulating domestic markets against changes in world market prices—introduces a collective action problem. This problem renders domestic market insulation ineffective in stabilizing most prices and in mitigating the adverse poverty effects of price surges. Complementing trade policy measures with storage measures alleviates, but does not solve, this collective action problem. It also poses a serious challenge in terms of management, cost, and sustainability. There is a strong case for first-best policies based on creating social safety nets at national level and also for efforts to diminish the collective action problem through agreements that restrain the extent of beggar-thy-neighbor policy responses.

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6 Alternative Mechanisms to Reduce Food Price Volatility and Price Spikes: Policy Responses at the Global Level

Maximo Torero

6.1 Background

The food price crisis of 2007–2008 saw a steep rise in food prices, which brought food security to the forefront of global attention. In June 2010, food prices started rising again; between June 2010 and May 2011, the international prices of maize and wheat roughly doubled. Food prices peaked in February 2011. According to the Food and Agriculture Organization of the United Nations (FAO), the spike in 2011 was even more pronounced than in 2008 (see, for example, the evolution of maize prices in Fig. 6.1, which exceeded the levels of prices in 2008 even when adjusted for inflation). Moreover, recent increases in price volatility are not in line with historical data (dating back to the late 1950s) and have particularly affected wheat and maize in recent years. For soft wheat (used for cakes and pastries), for example, there were 207 days of excessive price volatility between December 2001 and December 2006 (an average of 41 days a year), whereas there were 395 days of excessive price volatility between January 2007 and June 2011 (an average of 88 days a year), as shown in Fig. 6.2.

The 2007–2008 food price crisis led to economic difficulties, particularly for the already poor population. Despite the varying level of price transmission from international to local markets among regions, it generated social and political

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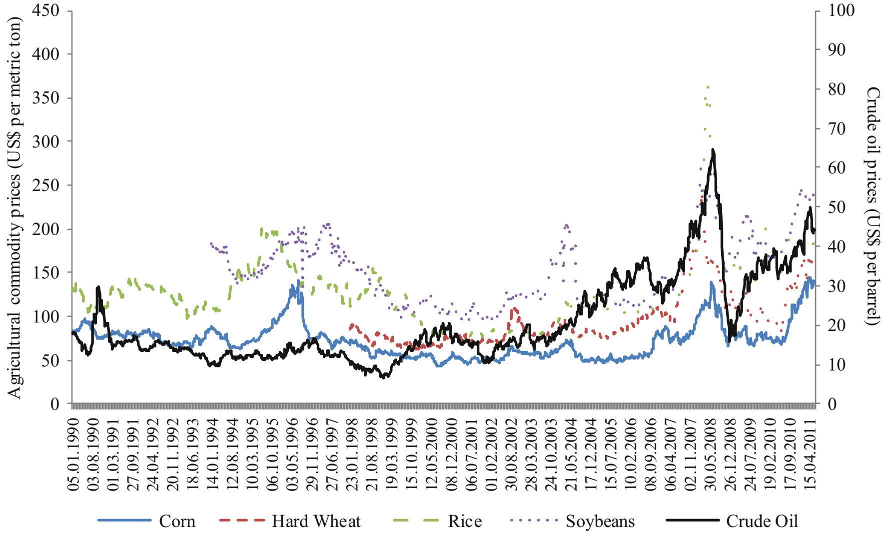

Fig. 6.1 Inflation-adjusted prices of agricultural commodities and oil, 1990–2011 (weekly data). Note: corn is U.S. no. 2 yellow, wheat is U.S. no. 2 hard red winter, rice is white Thai A1 super, soybeans is U.S. no. 1 yellow, and crude oil is spot price from Cushing, Oklahoma WTI. *Source*: FAOSTAT Online, Grain Council, and U.S. Energy Information Administration

turmoil in many countries. In addition, food price spikes and excessive volatility worsened the problem of hunger by increasing poverty (see Chap. 1 of this book for a detailed review of the nutritional impacts). The effects of high and volatile food prices are also particularly harmful for countries with high net food imports, and high food inflation affects countries with large numbers of poor people, such as China, India, and Indonesia.

As long-term solutions to the food price crisis are sought, it is important to understand the root causes of the problem. The crisis was triggered by a complex set of long- and short-term factors, including policy failures and market overreactions. In this respect, Table 6.1 shows a more complete discussion of the different demand- and supply-side factors that contributed to the 2007–2008 food price crisis.

As shown in Table 6.1, outside of traditional fundamentals, an important factor contributing to the crisis may have been the entry of significant financial resources into futures markets, including food commodity markets. This large financial inflow of resources may have contributed to a price spike during the first 6 months of 2008 and also later in 2010. It is important to note that there is no consensus among experts on this; there is, however, significant discussion surrounding the possibility that channeling financial resources through commodity futures markets, by speculators in particular, may have triggered the food crisis. Establishing theoretical and empirical linkages between future prices and spot prices is not easy, and testing causality is even more complex (for the theory on the topic, see Sanders and Irwin 2010 and see Chap. 1 for a detailed discussion).

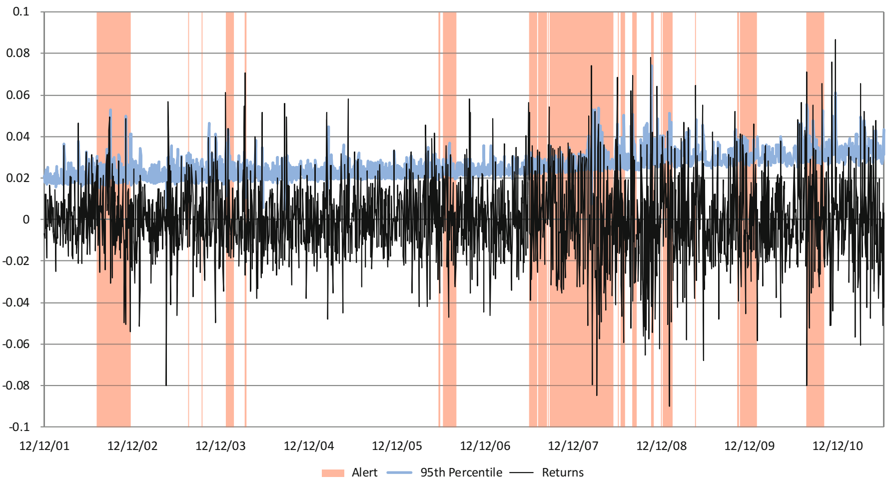

Fig. 6.2 Excessive food price volatility for hard wheat. *Note*: This figure shows the results of a model of the dynamic evolution of daily returns based on historical data going back to 1954 (known as the Nonparametric Extreme Quantile (NEXQ) Model). This model is then combined with extreme value theory to estimate higher-order quantiles of the return series, allowing for classification of any particular realized return (that is, effective return in the futures market) as extremely high or not. The *blue line* is a logarithm of the observed daily return (rate of increase of prices from 1 day to the other) on investment. The *red line* represents a level below which returns have a 95 % probability of occurring (i.e., the higher-order return estimated by the NEXQ model). When the *blue line* (return) exceeds the red line (95th percentile), it is characterized as an excessively large return. One or two such returns do not necessarily indicate a period of excessive volatility. Periods of excessive volatility are identified based on a statistical test applied to the number of times the extreme value occurs in a window of consecutive 60 days. *Source*: Martins-Filho et al. (2010). See details at http://www.foodsecurityportal.org/soft-wheat-price-volatility-alert-mechanism

Today's agricultural markets have three key characteristics that increase price responses to any of the drivers behind the causes of rising prices and volatility. First, export markets for all staple commodities—rice, maize, wheat, and soybeans—are highly concentrated in a few countries or very thin (that is, only a small share of production is traded). In the case of both maize and rice, the top five producers account for more than 70 % of global production, and the top five exporters account for about 80 % of world exports. For wheat, the top five producers and exporters account for about 50 and 60 % of global production and exports, respectively. These high levels of concentration imply that the world's capacity in coping with geographical risk is limited. Any weather shocks or exogenous shocks to production in these countries will immediately have an effect on global prices and price volatility. Second, the world's maize reserves and restricted wheat reserves are now at historically low levels. To function effectively, the market requires a minimum level of grain reserves to serve as a buffer against sudden changes in supply or demand. These reserves are needed because the supply of and demand for grain

Table 6.1 Explanations for rise in agricultural commodity prices

Factors	Mechanism	Effects
Demand-side factors		
Income growth, population growth, and urbanization	Cereal demand has been growing at 2–3 % per year, attributed to rising incomes in China, India, and, more recently, sub-Saharan Africa. Meanwhile, yield growth in these cereals has declined from 3 % in the 1970s to 1–2 % in the 1990s	This resulted in a significant reduction of cereal reserves from 700 million tons in 2000 to less than 400 million tons in 2007
Ethanol/biofuels	With oil prices at an all-time high of more than US$120 a barrel in May 2008 and with the US and the EU subsidizing agriculture-based energy, farmers have shifted their cultivation towards crops for biofuels	The reported impacts vary. Lipsky (2008) estimated that the increased demand for biofuels accounted for 70 % of the increase in maize prices and 40 % of the increase in soybean prices. Rosegrant et al. (2008) estimated the long-term impact of the acceleration in biofuel production from 2000 to 2007 on weighted cereal prices to be 30 % in real terms
Supply-side factors		
Increased oil/fertilizer prices	Oil prices increased significantly	Affected directly transportation costs and indirectly price of fertilizers (see IMF Fiscal Affairs 2008)
Low R&D investments in agriculture	The neglect of agriculture in public investment, research, and service policies during the past decade has undermined its key role in economic growth	As a result, agriculture productivity growth has declined and is too low
Droughts/climate change	Occurring in large grain-producing nations, droughts and climate change have lowered worldwide production	More volatile weather patterns related to climate change increased
Other fundamental factors		
Dollar devaluation	The indicator prices of most commodities are quoted in US dollars, and the dollar went through a substantial depreciation	Even though when adjusted for inflation and the dollar's decline (by reporting in euros, for example), food price increases were smaller but still dramatic

Large excess of liquidity in G7 countries	Large excess liquidity in several non-G7 countries, nourished by the low interest rates set by the G7 central banks	Commodity prices are the result of portfolio shifts against liquid assets by sovereign investors, sovereign wealth funds, partly triggered by lax monetary policy, especially in the USA (for details, see Calvo 2008 and Rojas-Suarez 2008)
Second-round effects		
Protectionist measures	Ad hoc trade policy interventions, such as export bans, high export tariffs, or high import subsidies, were partly triggered by the price crisis and exacerbated the crisis symptoms. As of April 2008, 15 countries including major producers imposed export restrictions on agricultural commodities, thereby narrowing the global market	Policy responses, such as export bans or high export tariffs, may reduce risks of food shortages in the short term for the respective country, but they are likely to backfire by making the international market smaller and more volatile. IFPRI simulations with the MIRAGE global trade model had shown that these trade restrictions can explain as much as 30 % of the increase in prices in the first 6 months of 2008
Speculation	The flow of speculative capital from financial investors into agricultural commodity markets was significant. From May 2007 to May 2008, the volume of globally traded grain futures and options increased substantially	There is still no agreement on this, and there are basically two schools of thought: (1) Robles et al. (2009) and Robles and Cooke (2009) used Granger causal test to identify to what extent indicators of speculative activity can help forecast spot price movements using CBOT monthly and weekly data. They showed some evidence that speculative activity partly explains the price spike since January 2008. Similarly, Gilbert (2010) showed some evidence of speculation; (2) Wright (2009) and Irwin et al. (2009a–c) opposed this argument

are not very responsive to price changes in the short term. When prices go up, for example, it is difficult for farmers to immediately produce more or for consumers to immediately consume less. As a result, any supply shocks, caused by events such as a drought or flood, can lead to price spikes and hoarding by farmers seeking to take advantage of higher prices in the future. In both 1973 and 2007, global grain stocks hit record lows, prompting the global food crises. Insufficient stocks can lead to large price increases and a breakdown of functioning markets. In 2007–2008, grain stocks were only about 60 million tons (2.7 % of global production) lower than in 2004–2005. But as evident in prices rising sharply in 2007–2008, this difference in grain stocks was enough to cause serious problems in the market, especially for commodities whose production is concentrated in just a few countries, such as rice (Timmer 2010). Third, appropriate, timely information on food production, stock levels, and price forecasting is sorely lacking. When this information gap leads to overreactions by policymakers and traders, it could result in soaring prices.

In summary, despite the recent literature regarding the potential causes of the 2007–2008 and 2010 crises, we do not yet have a definitive causal diagnosis that analyzes all the potential causes on a quantitative basis. As a result, it is even more difficult to analyze the potential policies that are necessary to avoid such a crisis in the near and long-term future. However, the general consensus is that this episode and what has been happening since October 2010 highlight the need for more research into the architecture of international financial and agricultural markets so that we can identify proper mechanisms for reducing price spikes and extreme price volatility, especially given the extreme impacts they have on the livelihoods of the poor (Sommer and Gilbert 2006; Bakary 2008; Brahmbhatt and Christiaensen 2008; OECD 2008; UNCTAD 2009; von Braun 2008a–c; von Braun et al. 2008; World Agricultural Outlook Board 2008; Headey and Fan 2010; HM Government 2010).

The new global reality involves both higher and more volatile prices—two different conditions with distinct implications for consumers and producers. For several decades, the dominant approach to managing food price volatility has been to stabilize income without affecting prices. The idea behind this approach is that prices guide behavior, so any attempt to change prices damages this mechanism of resource allocation. At the same time, the "natural" insurance that comes from the negative correlation between harvest size and price level stabilizes producers' incomes—in particular in closed economies. Thus, any effort to stabilize food prices reduces the correlation between prices and harvests and disrupts the existing natural equilibrium. Under this strategy, private insurance and hedging instruments, along with public instruments targeting vulnerable households, are used to manage risk and stabilize prices. However, in the changing global economy, local prices are becoming less correlated to local harvests, and prices do not always convey the appropriate information to economic agents. Mechanisms to reduce excessive price volatility then become essential in eliminating the endogenous component of price instability without affecting the natural price instability component.[1]

[1]For more information, see Galtier (2009).

In the short term, both the supply of and demand for grain are very inelastic. Droughts, floods, or any other severe weather shocks can have significant impact on country-level supply because grain production is so sensitive to weather events. Combined with demand inelasticity, any supply shocks can lead to price spikes and hoarding behavior by farmers trying to take advantage of higher prices in the future. At a regional level, on the other hand, grain production is less affected by weather, and shortages in production in certain areas can be compensated for by higher production in other areas. As a result, international trade can reduce the need for large national-level grain reserves. However, because so many countries had reduced their public grain reserves by 2007, when prices began to rise, many governments had no mechanism for stabilizing their grain markets. A few countries did have sufficient reserves but did not want to sacrifice those reserves to stabilize the global market. Governments in a few exporting countries further worsened the situation by temporarily establishing export barriers and reducing import barriers; thus, by adding upward pressure on commodity markets, global market stability was sacrificed in order to stabilize domestic prices.

Variable temperatures, changes in precipitation patterns, and increased occurrence of extreme weather events brought about by climate change, such as droughts and floods, will increasingly affect the global food supply. As a result, the global community will have to increasingly deal with the issues prompted by the food price and financial crises of recent years as prices are increasingly affected by both supply and demand issues around the world. From these crises, it is evident that governments will find it difficult to deal with these issues at a national level.

A careful analysis of the different policies that could be implemented to reduce or diminish the effects of increasing price volatility, and especially to reduce the probability of significant price spikes, is therefore necessary. The price spike episode of early 2008 clearly highlighted the need to modify the institutional architecture of international financial and agricultural markets to address their effects on the livelihoods of the poor. This chapter reviews the most prominent policy proposals aimed at reforming international agricultural markets and addressing price volatility at the international scale.

6.2 Review of Policies Proposed/Implemented to Reduce Price Volatility Before 2007

Physical reserves have been used at national, regional, and international level at different times throughout history to control price spikes and reduce price variability. For decades, large countries, such as China and India have kept a significant level of physical reserves because of their size and the effects that their entry into world markets would have on prices during harvest shortfalls. The US operated a farmer-owned reserve for several decades. The farmers received loans and money as reimbursement for their storage costs; in exchange, they were required to follow stipulations concerning when the stored grain could be sold. The farm bill passed in 1996; however, it virtually eliminated physical grain reserves.

Many African countries, including Burkina Faso, Mali, Mozambique, Niger, Ethiopia, and Tanzania, established national-based food security reserve stocks between 1975 and 1980. During the time, agriculture was heavily managed, and because global grain prices were extremely high, many of these governments did not trust world markets to be secure sources of grain during an emergency. However, it proved to be quite difficult to accurately estimate how much grain was actually needed in these reserves. There was a tendency to overestimate the amount of grain needed in an emergency (Rashid and Lemma 2010). Quantities were based on estimates of normal consumption; in reality, however, people facing hunger eat less and often switch to cheaper foods, which then make up some of the shortfall. There were a number of other difficulties which eventually led to the disappearance of these food security reserve stocks in most countries, including the use of the reserves in normal market operations by the parastatals, insufficient resources to replenish reserves, and the unwillingness of donors to support these activities. Interest in the establishment of strategic grain reserves was revived following the liberalization of the cereal markets during the structural adjustment of the 1990s. Governments attempted to insure against the failure of the private sector during this period, but many of the experiences in managing these reserves were similar to previous attempts at operating grain reserves. Mismanagement, corruption, damaged donor relations, and erroneous estimates of consumption and production plagued governments as they tried to manage these reserves.

Interest in regional reserves also increased after the last food price spike in 1973–1974. The FAO (1980) noted the establishment of the Association of Southeast Asian Nations (ASEAN)'s Food Security Reserve (which was never operational) and also a proposal by CILSS (Inter-State Committee on Drought in the Sahel) to establish a regional reserve in the Sahel. The FAO provided technical assistance to support these initiatives. The idea of creating a regional food reserve for Mediterranean countries was also put forward, but it was not until the recent food crises that the ASEAN initiative was reactivated. To ensure food security in the region, ASEAN has established various cooperation programs, one of which is the East Asia Emergency Rice Reserve (EAERR). The EAERR is a regional cooperation program between the ten ASEAN member states, China, Japan, and the Republic of Korea. Specifically, it is an initiative of the ASEAN Ministers on Agriculture and Forestry and the Ministers of Agriculture of the People's Republic of China, Japan, and the Republic of Korea (AMAF Plus Three) to provide food assistance, strengthen food security in emergencies caused by disasters, and alleviate poverty. The EAERR is therefore a mutual assistance system through which rice stocks are shared between the 13 countries. It also aims to contribute to price stability of rice in the region (Chap. 17 by Irfan Mujahid and Lukas Kornher estimate the benefits of the EAERR through risk pooling). The EAERR plans to develop a proposal to upgrade the pilot project to a full-fledged scheme among the ASEAN Plus Three countries. The ASEAN Plus Three Agreement on Emergency Rice Reserve is currently being drafted for this purpose. However, the realization of a permanent scheme is subject to internal consultation, further assessment, and the evaluation of the outcomes of the pilot project. For a mechanism like the EAERR to work, political support from the ASEAN Plus Three countries is necessary. The EAERR pilot project is closely related to the ASEAN Food Security Information System (AFSIS) project and the work of the ASEAN Food Security Reserve Board (AFSRB)[2] in establishing food security in the region.

International commodity agreements (ICAs) (see Gilbert 1987, 1996) were established to stabilize individual commodity prices at the global level after the Second World War. However, most of these agreements collapsed, and by the early 1960s, only the agreements for wheat, sugar, coffee, tin, and olive oil remained. Although opinions differ as to why these agreements were not successful, the ICAs mostly played a peripheral role in stabilizing prices. The ICA on rubber actually had procedures to deal with increases and decreases in its price bands, but because it followed market prices for the most part, it was only able to smooth, not stabilize, prices. The cocoa and sugar agreements were simply too weak to accomplish their objectives, while the tin agreement was trying to hold prices at levels which were too high without the necessary financial backing. The agreement on coffee was arguably the most successful in raising and stabilizing prices before it lost consumer support and collapsed. Although some of the governing bodies of the ICAs still exist,[3] these days they mostly assist the respective industries by publishing relevant statistics and studies rather than stabilizing prices.

Price stability and a stable supply of wheat were maintained during the early years of the International Grains Council (previously the International Wheat Council). However, this is most likely due to the relative stability of the supply and demand during this time; the agreements broke down during the 1973–1974 food crisis. Prompted by the price shock, international interest in grain reserves was reignited, and the United Nations Conference on Trade and Development (UNCTAD) organized discussions on the possibility of establishing international grain reserves (Wright and Bobenrieth 2009). The idea was to hold stocks nationally while managing them internationally, but issues of trigger price levels, stock levels and contributions, and special provisions for developing countries caused the discussions to fail, and the proposed international grain reserve was not established.

6.3 Review of Policies Proposed as a Result of the 2007–2008 and 2010 Food Price Crises

Following the food price crisis of 2007–2008 and the events since October 2010, there have been numerous proposals aimed at preventing such events from occurring again. The proposed plans address a range of ideas for improvement, including

[2]The AFSRB is an ASEAN mechanism for sharing of rice stocks in times of shortage, particularly through the trigger of a collective operation of the committed ASEAN Emergency Rice Reserve (AERR). Currently, the total quantity of the AERR is 87,000 metric tonnes for emergency purposes.

[3]Coffee (ICO); cocoa (ICCO); cereals, oilseeds (IGC); sugar (ISO); jute (IJSG); rubber (IRSG); bamboo, rattan (INBAR); tropical timber (ITTO); cotton (ICAC); olives, olive oil (IOOC).

physical reserves at different levels, virtual reserves, improvements in information and coordination, and trade facilitation. Several proposals have been made for storage: emergency reserves for food aid, internationally coordinated public grain reserves, and national and regional stocks. More than ten proposals have been put forward with the aim of preventing price spikes and price volatility in the future. These proposals can be grouped as follows: (a) information and research, (b) trade facilitation, (c) reserves and stocks, (d) financial instruments, and (e) regulatory proposals.

6.3.1 Information

There are two key proposals for improving information and coordination in order to increase market confidence and relieve temporary disruptions in supply. First, Wright (2008, 2009) and Evans (2009) proposed an international food agency (IFA); second, Martins-Filho et al. (2010) proposed an early warning mechanism (EWM) to identify price abnormalities.

Wright (2009) argued that confidence in markets could be increased if there were more and better information regarding stocks. Similarly, Evans (2009) and Wright (2008) proposed the creation of an IFA, modeled after the International Energy Agency (IEA),[4] which would report on stock levels and develop protocols for international collaboration to improve the global response to shortages and help prevent the onset of market panic. Two potential criticisms are central to this proposal. First, many international agencies are not optimistic that better information regarding existing stocks and their evolution can be generated without considerable effort, international coordination, and costs. This is even more relevant given the current lack of appropriate information regarding public holding of stocks by key producer countries such as China and India; there are also much stocks held by private enterprises which consider their stock levels as commercial secrets. The lack of appropriate information on and knowledge of the holders and the type of stocks at a given time calls into question the development of the IFA as proposed by Evans (2009). Second, it is unclear how emergency response protocols could be agreed upon at such levels of asymmetry of information or which mechanisms would be used to identify critical levels of stocks which would necessitate the IFA to call for a collaborative international response. Resolving both of these problems could be extremely costly, although the availability of information on physical stocks at the global level could by itself help to reduce price volatility.

[4]The IEA was established in 1974 in the wake of that commodities spike. It reports on public and private petroleum stocks in OECD member states and has developed protocols for international collaboration in assuring supplies reach a member country should there be a disruption to their import market (Wiggins and Keats 2009a, b).

Martins-Filho et al. (2010)[5] proposed a model for estimating conditional quantiles for log returns of future prices (contracts expiring between 1 and 3 months) of hard wheat, soft wheat, corn, and soybeans. This fully nonparametric model identifies the cases in which the values of the realized returns (log returns of future prices contracts expiring between 1 and 3 months) are higher than the forecast 95 % conditional quantile for the log return on the following day based on a model that includes daily returns since 2001. When this event happens, it means that the realized return is an abnormality, and we expect it to fall under the 95th percentile return on the following day. This additional market information could in itself help to reduce potential asymmetry of information among buyers and sellers and therefore helping to reduce extreme price volatility. One main caveat of the model is that it is currently operating only for commodities traded in the futures market, but the framework can also be extended to spot markets if better price information existed.

The G20 has clearly understood the need for better information and has agreed to launch the Agricultural Market Information System (AMIS) to encourage major players in the global agrifood market to share data, enhance existing information systems, promote greater understanding of food price developments, and advance policy dialogue and cooperation. AMIS, in a way, captures both of the proposals explained before. If properly linked to existing global, regional, or national early warning systems for food security and vulnerability, AMIS could substantially improve countries' capacity to make appropriate decisions regarding food security matters and help reduce price volatility. However, as the UN Special Rapporteur on the Right to Food, Olivier De Schutter (2010), has already pointed out, without the full participation of the private sector, the information will be incomplete. So far, private companies are merely urged to participate in AMIS. Support should be provided to build national and regional capacity to develop and implement transparent and publicly accessible food security monitoring and information systems.

6.3.2 Trade Facilitation

Other proposals aim to facilitate trade in order to reduce risks in grain trading when supplies are low and to avoid disruptions in grain market. Sarris (2009) proposed a type of food import financing facility (FIFF) that would alleviate financing constraints as well as an International Grain Clearinghouse Arrangement (IGCA) to ensure the availability of staple food imports. This international clearing house would reduce the risk of exporters reneging on contracts when supplies are tight by guaranteeing contracts for grain deliveries. Finally, Wright (2009) and Lin (2008)

[5]For further details see http://www.foodsecurityportal.org/sites/default/files/Martins-FilhoToreroYao2010.pdf

took a different approach to trade facilitation (TF) with plans to prevent export bans in order to avoid any disruption of supplies.

The FIFF was initially proposed to the IMF in the early 1980s by the World Food Council and the FAO, and it was implemented in May 1981, although as mentioned it raised several questions about its possible effect on world grain prices. The facility could create a significant increase in demand for grains in developing countries in years of tight supply and thus could put strong upward pressure on prices. Moreover, despite its existence, the facility has not been used in the last 10 years, not even during the 2007–2008 crisis. According to Shaw (2007), "terms for accessing the facility were set too high to make it attractive or acceptable." When countries have existing balance of payment weaknesses, they cannot access the FIFF without a parallel fund-supported adjustment program. If this facility is to be used more as a humanitarian instrument as a result of the price crises, it clearly seems to be targeting more on emergency situations rather than directly on reducing price volatility. In addition, the facility is susceptible to significant governance problems and costs, and it would be necessary to develop an independent FIFF without IMF-attached conditionalities (for further details, see Huddleston et al. 1984; Valdés 1981; Adams 1983).

On the other hand, the IGCA proposal, as mentioned by Wiggins and Keats (2009a, b), looks somewhat similar to the International Commodity Clearing House (ICCH) proposed in 1949. Wiggins and Keats pointed out that at that time, the world food situation was characterized by commodity surpluses in areas with strong currencies (particularly the US dollar), while countries with weaker currencies and insufficient supplies could not afford imports. This led to the ICCH proposal: a public corporation to be housed in the FAO with a budget of US$5 billion. The initial proposal covered half a dozen main functions, which included the coordination and negotiation of bilateral and multilateral trade agreements, but given its complexity and the requirement need to transfer power to multilateral organizations, it was rejected by FAO member nations.

In the current revision of the IGCA proposal, as explained by Wiggins and Keats (2009a, b), grain trade contracts (between countries or private entities) in the medium- and long-term would be guaranteed. It would be housed in an existing institution, such as an international bank or multilateral financial institution, and would function as a holding body for a "good faith margin" contributed by the buyer and the seller in any particular contract. These amounts, posted as margins, could be borrowed from international banks or other multilateral financial institutions. To guarantee availability of physical supplies, the IGCA would invest its financial reserves in physical stocks of grain in locations of excess supply or in the form of futures contracts in organized commodity exchanges. Any commitments in futures taken out as insurance on a particular contract could be liquidated upon execution (physical delivery between buyers and sellers) of said contract.

As in the initial proposal, and in addition to the governance issues, the key questions are: how large would these margins have to be, and who would invest in them? Will it require international support? If so, how will this be coordinated, especially during times of tight global supply? In addition, it poses two more key problems: first, the need to have a global storage mechanism in place and its necessary international governance; second, the need to specify any triggering mechanism that will make it effective, i.e., when the grain guarantee would be executed.

Finally, in the case of Wright (2009) and Lin's (2008) proposal, the most difficult part would clearly be persuading countries to commit to the IGCA and then adhere to it during a food crisis. When facing the choice between breaking international agreements and protecting their citizens by ensuring national food security, some countries are likely to impose export bans, regardless of any punitive actions against protective trade policies. Moreover, as shown by Martin and Anderson (2010), and Bouet and Laborde (2009), if export taxes are raised in a large agricultural-based economy, world food prices will rise (through a reduction in world supply), which will hurt small net food-importing countries. The reduction of import duties has exactly the same effect: an increase in world prices through an expansion of demand in world markets. Furthermore, when export taxes are augmented in large food-exporting countries and import duties are reduced in large food-importing countries, small food-importing countries would be affected economically; thus, the solution is not only a facilitation of trade but also the understanding of the effects of different trade policies could have and to understand the importance of the required governance to prevent large countries from implementing policies aimed at maintaining constant domestic food prices. The costs of insufficient cooperation in and regulation of (binding process) such policies in a time of crisis is an extremely complex issue, and it is unclear whether the WTO dispute resolution mechanisms could be used effectively (see also Chap. 8 of this book by Bouët and Laborde).

6.3.3 Reserves and Stocks

There have been several proposals regarding physical reserves: (1) emergency reserves (ERs) (von Braun and Torero 2008); (2) international coordinated grain reserves (ICGRs) (Lin 2008; von Braun et al. 2009) and rice reserves (Timmer 2010); (3) regional reserves (RRs) by regional associations of governments; and (4) country-level reserves (CRs) by multilateral institutions, such as the World Bank.

The ERs is a modest emergency reserve of around 300,000–500,000 metric tons of basic grains—about 5 % of the current food aid flows of 6.7 million wheat-equivalent metric tons—which would be supplied by the main grain-producing countries and funded by a group of countries participating in the scheme. These countries would include the Group of Eight Plus Five (G8+5) countries (Canada, France, Germany, Italy, Japan, Russia, the UK, the US, Brazil, China, India, Mexico, and South Africa) and perhaps other countries. This decentralized reserve would be located at strategic points near or in major developing country regions and make use of existing national storage facilities. The reserve, which would be used exclusively for emergency response and humanitarian assistance, would be managed by the World Food Programme (WFP). The WFP would have access to the grains at precrisis market prices to reduce the need for short-term ad hoc fundraising. To cover the cost of restoring the reserve to its initial level (i.e., the difference between the post and precrisis price multiplied by the quantity of reserves used by WFP), an emergency fund should be created, and its level maintained by the participating countries. The fund should be accompanied by a financing facility that the WFP could draw from as needed to cope with any potential increase in transport costs, as experienced in the 2008 crisis. This arrangement could also be defined under a newly designed Food Aid Convention. It should be solely for humanitarian purposes rather than the reduction of excessive price volatility. Following this initiative, the G20 has proposed studying the feasibility of a global humanitarian emergency reserve through a pilot implementation in West Africa under the leadership of ECOWAS and the support of the WFP.

The other three mechanisms had been proposed as ways to mitigate excessive price volatility. A combination of the proposed reserve systems would likely be necessary, but country-level reserves should be thought of as a strategic reserve rather than food stock held by marketing board/parastatals. Enforcing floor and ceiling prices by marketing boards or parastatals has always involved holding physical stocks of grains; there is significant evidence that these measures would distort markets (Rashid and Lemma 2010). Strategic grain reserves are different from such stocks. Strategic reserves were introduced in many countries because marketing boards failed to address shocks, such as the prolonged droughts in the countries of the Sahel region; however, they cannot be thought of as mechanisms to reduce international price volatility. Moreover, three key challenges arise when maintaining these types of strategic reserves: the determination of optimum stock levels, the level of costs and losses associated with these reserves, and the uncertainties that strategic reserves could cause in the market place. Not only is the process of determining optimum stock levels politically challenging, but reserves are also highly dependent on transparent and accountable governance. In addition, predicting supply, demand, and potential market shortfalls can be extremely difficult. Physical reserves also require financial resources and must be rotated regularly; in African countries, the costs of holding a metric ton of food ranged from US$20 to US$46 (Rashid and Lemma 2010). The countries that need reserves most are generally those which are least able to afford the costs and oversight necessary for maintaining them. The private sector is better financed and better informed and has more political power, which puts it in a much better position to compete than most of the governments that would be managing these reserves. Finally, the uncertainties that strategic reserves can introduce into the marketplace can be problematic.

With respect to the coordination of global reserves and regional reserves, in addition to high storage costs (both opportunity and effective costs when creating a new physical reserve) and the fact that the creation of reserves will put more upward pressure on prices during times of tight supply, there are several other concerns that need to be taken into account. First, similar to the security provisions of the IEA, the key challenge would be to develop a governance structure such that member countries would honor their commitments to the reserves even when markets are under stress. Second, the global or regional reserves would clearly require trigger mechanisms to determine when to release stocks to calm markets in times of stress.

Such mechanisms are a necessary condition for a reserve to operate as a tool to reduce extreme price volatility. In addition, it is imperative to keep the trigger mechanisms highly transparent. The model proposed by Martins-Filho et al. (2010) could be a solution to address the need for transparency. Finally, a physical reserve, whether regional or global, would not resolve the problem of interlinkages within the financial, energy, and food commodity markets; the problem could be extremely relevant if excessive speculation is indeed a cause of extreme price spikes.

6.3.4 Financial Instruments

There are two major proposals linked to the use of financial instruments: (1) the virtual reserves proposed by von Braun and Torero (2008, 2009a, b) and (2) a toolbox of market-based risk management tools, such as physical or financial commodity price hedges, insurance and guarantee instruments, and counter-cyclical lending, which can play an important role in helping vulnerable countries mitigate and manage the risks associated with excessive food price volatility. The toolbox was proposed in the Paris G-20 meeting and is still in its planning stage.

The proposal of virtual reserves is a safeguard mechanism to manage risk through the implementation of a virtual reserve which is backed by a financial fund and is aimed at calming markets during extreme price volatility. The concept has been widely used by central banks for inflation targeting and dirty flotation of the exchange rates.

The virtual reserve concept incorporates a global market analysis unit (GMAU), which has two functions. First, and perhaps most importantly, the GMAU is an early warning mechanism based on a model [see Martins-Filho et al. (2010) for details about the model] that forecasts changes in returns for key staple commodities in the futures market and identifies when a price abnormality occurs or when a price spike appears imminent. When this price abnormality happens, it means that the realized return is an extreme value and there is a high probability that it will fall under the 95th percentile return on the following day or days; on the other hand, if the realized return remains over the 95th percentile, it could imply the formation of a price spike. The announcement of a potential price spike alerts the market to a higher likelihood of an intervention in the futures market, which will immediately increase the discount rate of potential short-term investors. If there is evidence of an emerging price spike despite this alert, the GMAU will indicate that returns are significantly above their normal. Finally, an autonomous technical committee would then decide whether to enter the futures market. This intervention would consist of executing a number of progressive short sales (that is, selling a firm promise—a futures contract—to deliver the commodity at a later date at a specified price) over a specific time period in futures markets at a variety of market prices in different futures months until futures prices and spot prices decline to levels within the estimated price bands. The GMAU would recommend the price or series of prices to be offered in the short sales.

This increase in the supply of short sales will reduce spot prices and should help to significantly reduce extreme price volatility by reducing the probability of abnormal returns. In other words, the intervention will create a backwardation in the market (the situation in which, and the amount by which, the price of a commodity for future delivery is *lower* than the spot price or a far-month future delivery price is *lower* than a nearby month future delivery price). Reducing these abnormal returns would minimize potential second-round effects (such as export bans, export restrictions, or reduction of import tariffs), given that spot prices would again become consistent with market fundamentals; therefore, lower spot prices would not result in the accelerated use of available supplies. All futures contracts will ultimately be settled either through liquidation by offsetting purchases or sales (the vast majority of agricultural futures contracts are settled this way) or through delivery of the actual physical commodity. In this respect, the virtual fund will only stand for delivery if there is a need to realize the futures sales, in which case the fund will be used to obtain the necessary grain supply to comply with futures contract delivery requirements and calm the markets. Usually, this action would not be necessary and the whole operation would remain virtual because the signal will deter speculators from entering. Questions would remain about the price, the amount of short sales, and the duration of the intervention in the futures markets; answering these questions would require political consultation and continuous market monitoring and research.

The innovative concept behind the virtual reserve is the early warning alert system provided to markets and regulators. The presence of the system alone is likely to deter short-term financial investors from entering this market; the probability of a real intervention is minimal. Nonetheless, the committee must be ready to trade grain when necessary and to assume the potential costs of buying back contracts at a higher price than they were sold for. In that sense, a clear financial commitment is needed to give the correct signal to the market. The size of the initial commitment is still being studied. A comprehensive cost–benefit assessment of the system must look beyond agricultural markets and also include food security and poverty considerations.

The key advantages of the virtual reserve compared to a physical reserve are that (1) it involves a signaling mechanism, (2) it does not put more stress on commodity markets, (3) it does not incur the significant storage and opportunity costs of a physical reserve, (4) it resolves the problem of the interlinkages between the financial and the commodity markets, and (5) its effect on markets would be minimal because it is only a signal.

There are some critics of the virtual reserve concept. First, some have questioned whether rising futures prices actually lead to increased spot market prices; however, several studies suggested that changes in the futures prices of certain commodities generally lead to changes in spot prices.[6] In addition, the recent analysis by Hernandez and Torero (2010) complements these earlier studies by examining causal

[6]See Garbade and Silber (1983); Brorsen et al. (1984); Crain and Lee (1996).

relations in the current decade with a much more developed futures commodity market. Their analysis used both linear and nonparametric Granger causality tests and identified a causal link in all cases. The results indicated that spot prices are generally discovered in futures markets. In particular, they found that changes in futures prices in the markets analyzed led to changes in spot prices more often than the reverse case. Thus, from a policy perspective, these findings support the viability of implementing a global virtual reserve to address grain price abnormalities through signals in the futures market and, if necessary, market assessment in the exchange of futures.

Wright (2009) also argued that it would be difficult for the responsible parties to be certain that markets are out of equilibrium and that the proposed interventions would not do more harm than good under any given circumstances. In this sense, the model developed by Martins-Filho et al. (2010) has made significant progress toward the capacity to predict price abnormalities, as previously explained. There has also been significant concern regarding the size of the financial funds necessary to ensure the success of the signal given by the virtual reserve. In that respect, the virtual reserve requires a coordinated commitment from the group of participating countries. Each country needs to commit to supplying funds, if needed, for intervention in grain markets; this does not imply effective expenditure. Therefore, the resources needed are promissory rather than actual budget expenditures. Further analyses are required to determine the size of this fund because commodity futures markets allow for high levels of leverage. This commitment cannot be compared with budgets allocated for R&D. First, it is a commitment rather than an expenditure; second, the size of this commitment should be significant enough to provide a strong signal to the market. It is noteworthy that similar activities have been implemented by central banks, such as the dirty flotation of the US dollar, a practice whereby the US central bank uses reserves to maintain the target limits of appreciation or depreciation of the currency within a certain range. Finally, there is also a question of the governance behind the virtual reserve mechanism. Clearly, reaching an agreement on the arrangements of the virtual reserve would not be easy and may require a high-level United Nations task force to analyze the way forward. Yet similar institutional arrangements have been made in the past; examples include the International Fund for Agricultural Development (IFAD), the Food Aid Convention (FAC), the IMF Cereal Import Facility, and the IEA. The IFAD was established as an international financial institution in 1977 and was a major outcome of the 1974 World Food Conference in response to the food crisis of the early 1970s. The FAC, which was first signed in 1967 and have since been renewed five times, is the only treaty under which the signatories have a legal obligation to provide international development assistance.

With respect to the toolbox of risk-coping mechanisms, there are basically two initiatives being implemented. First, the International Finance Corporation (IFC)'s new Agriculture Price Risk Management (APRM) product will allow producers and consumers to hedge against downside or upside price risk on a pilot basis by using a financial intermediary with both global reach and expertise in Latin America. Efforts to introduce the APRM product will be supported by two other financial intermediaries focusing on lower income countries in sub-Saharan Africa, North Africa, and the Middle East. In addition, other multilateral and regional development banks are exploring their interest in risk-sharing by using APRM facilities in order to take advantage of APRM's operational infrastructure. Nevertheless, as the literature has pointed out, the pickup rate of these insurance tools and their cost effectiveness still needs to be assessed. Second, the World Bank has developed a proposal to facilitate governments' access to risk management markets by providing assistance in structuring and executing financial and physical commodity risk hedging, and in building the legal/regulatory/technical capacity required for using these tools. The impact and process of this mechanism need to be evaluated to ensure its effectiveness, viability, and sustainability.

6.3.5 Regulatory Proposals

Since late 2005, a number of serious problems have plagued the futures and cash markets for grains (corn, soybeans, and wheat). The most dominant problem is lack of price convergence between cash and futures prices (see, for example, Garcia et al. 2014 and Adjemian et al. 2013). There seem to be several factors related to the uncoupling of cash and futures prices. The first concerns delivery certificates, which are issued by warehouses to those holding a long position in the futures market until the contract expires. The problem in this case is that the parties holding long positions are not using these certificates to take delivery but are holding them, in part because of the value the certificates retain. The second problem is that actual delivery is not occurring. Many market participants believe that the lack of load-out is contributing to the lack of convergence in futures and cash prices. Because the demand for delivery is diminished, storage facilities have less space available. This raises a concern about storage rates, which should be reviewed to ensure that they are kept at the right levels. An incorrect storage rate could contribute to the uncoupling of cash and futures prices. Proposed solutions for the lack of price convergence include changing the storage facility fees, changing the futures contract to a cash-settled contract, changing the design of the delivery instrument, compelling load-out (i.e., compelling entities with long positions to stand for delivery), and reviewing trading patterns of fund traders to ascertain their effect on the market.

The Commodity Futures Trading Commission (CFTC) and other agencies of the US government and the European Commission, along with the futures industry, have reviewed proposals and implemented seasonal storage rates, limits on the number of delivery certificates an entity can hold for noncommercial purposes, and an additional issue of the Commitment of Traders report to increase transparency. If these structural changes do not significantly improve the price convergence between futures and cash prices, then a cash-settled contract must be seriously considered. In any regard, exchanges and regulators cannot afford to continue pursuing solutions at a slow pace. These problems began in late 2005, and so far very few structural changes have occurred.

Despite these regulatory measures being seemingly complementary to many of the proposals described above, a major problem hindering any regulatory mechanism in futures exchanges is the level of linkages between the main futures commodity markets. If activities in different future exchanges mutually influence each other, then regulations implemented in an exchange would merely transfer the problem to another exchange; this again requires managing the complexity of multicountry coordination, as in the case of the virtual reserve or any global or regional reserves.

Possible solutions to address potential excessive speculation include imposing stricter speculative limits and larger margins, phasing out existing position limit waivers for index traders, imposing additional restrictions on index traders, investigating index trading in other agricultural markets, and strengthening data collection on index trading in nonagricultural markets.

To summarize the analysis of all proposed alternatives, Fig. 6.3 classifies the major proposed initiatives based on their cost (horizontal axis) and their effectiveness in reducing price volatility (vertical axis). It is important to mention that only these two dimensions are used because the major objective of this chapter is to identify the existing mechanisms proposed and their effectiveness in reducing price volatility. In that respect, some of these initiatives, such as the emergency food reserves (von Braun and Torero 2009a, b) and the food import facility (Sarris 2009), have objectives other than reducing price volatility; therefore they were ranked low in that dimension. This does not mean that they are ineffective in meeting their core objective. On the other hand, policies such as the virtual reserves (von Braun and Torero 2009a, b), the internationally coordinated grain reserves (Lin 2008), the regional reserves (such as the ASAEN), and the International Grain Clearance Agreement (Sarris 2009) were ranked higher in terms of effectiveness in reducing price volatility, although they vary significantly in the amount of resources needed for their implementation and in the amount of additional research required to implement them properly.

6.4 Conclusion

The international food price crises of 2007–2008 and 2010 led to economic difficulties for the poor, generated political turmoil in many countries, and could have severely affected confidence in global grain markets, thereby hampering the market's performance in responding to fundamental changes in supply, demand, and the costs of production. More importantly, food crises could result in unreasonable or unwanted price fluctuations, which could harm the poor and cause long-term, irreversible damage to the body because of malnutrition, especially among children. The food crises highlighted the need to modify the architecture of international financial and agricultural markets in order to address the problem of price spikes.

Appropriate global institutional arrangements for preventing such market failures are missing. A global solution to prevent excessive price volatility in food markets may be costly, but given the losses caused by food price crises like those in

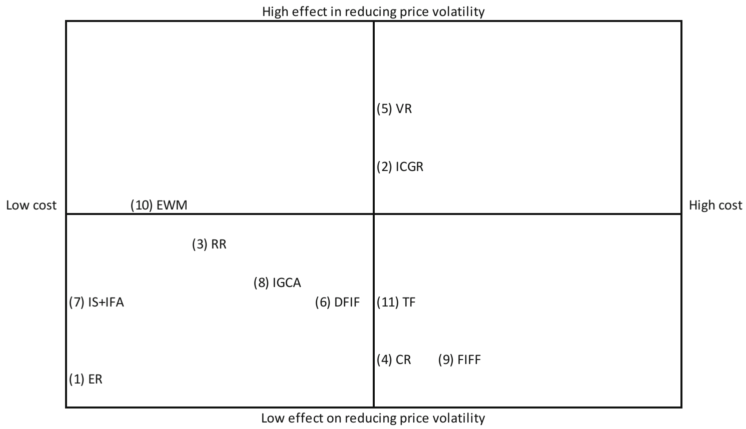

Fig. 6.3 Proposals for reducing price volatility. *Note*: The vertical axis refers to the potential effect in reducing price volatility and the horizontal axis to the costs required for its implementation. (1) ER = emergency reserve, von Braun and Torero (2009a, b), it requires US$7.5 Mpa but is to alleviate requirements of WFP during food scarcity and not to reduce price volatility. (2) ICGR = internationally coordinated grain reserves, Lin (2008), it implies opportunity costs and coordination costs (approx. US$1.05 Bpa) and it could have an impact in reducing volatility but high risks of coordination failure, requires capacity to predict price spikes, and not necessarily effective to tackle speculation in futures market. Timmer (2010) proposes a similar idea only for rice given how concentrated this market is we expect it to have a higher effect in reducing volatility in this specific commodity. (3) RR = regional reserves as the one of ASEAN, it implies opportunity costs and coordination costs; depending on the market share on the commodities of the countries involved, it could have an impact in reducing volatility, but very high risks of coordination failure, and could distort market prices, patronage problems, and other principal agent problems. (4) CR = country level reserves, this could imply significant relative costs at the country level, significant distortions, and little effect on volatility given low effect over international markets. (5) VR = virtual reserves, von Braun and Torero (2009a, b), it requires US$12–20 B, risk of coordination failure, requires capacity to predict price spikes, could be effective in tackling speculation in futures market, requires certainty that markets are out of equilibrium to avoid distortion of interventions. (6) DFIF = diversion from industrial and animal feed uses, Wright (2009), it implies opportunity costs, could distort market efficiency, and necessarily effective to tackle speculation in futures markets. (7) IS + IFA = better Information on Storage and International Food Agency (Wright 2009), very low cost not clear effectiveness in reducing price volatility (8) IGCA = International Grain Clearance Arrangement, Sarris (2009). Not too costly, not clear how it will operate, not clear size of margins, not clear if it will work when stocks are tight, and not necessarily effective to tackle speculation in futures markets. (9) FIFF = food import financing facility, Sarris (2009). Similar to IMF's food import facility, could be costly, possible moral hazard problems, and not effective to tackle speculation in futures markets. (10) EWM = early warning mechanism. (11) TF = trade facilitation—Wright (2009) and Lin (2008)

2007–2008 and 2010, such solution would still have large positive net returns. Clearly, some of the key drivers behind the excessive price volatility can be directly addressed by, for example, revising biofuel policies through curtailing biofuel subsidies, making mandates flexible and liberalizing biofuel and feedstock trade. Another way to address the problem is by increasing and diversify global productivity and production in order to raise the number of countries that export staple foods and, at the same time, increase aggregate global reserves to the minimum critical level needed.

On the other hand, the incentives for excessive financial activity in the food commodity futures markets, which is one of the causes of price volatility, could be reduced by (1) changing regulatory frameworks to limit the volume of speculation versus hedging, (2) making delivery on contracts or portions of contracts compulsory, and (3) imposing capital deposit requirements on every futures transaction. These regulatory measures could be implemented on a case-by-case basis or as a platform through an international "alliance of commodity exchanges." Therefore, there is a need to discuss exchange regulation and the role of speculative traders, and this discussion must include the issue of international harmonization of any regulatory policy to increase the probability of successful policy implementation. There is also a clear need to improve the quality of information on and forecasting of price spikes for any of these potential policies to work properly. AMIS could be an important option for addressing this issue.

Several of the proposals that are specifically for reducing price volatility or the effects of the price crises require significant and quick investment in further research into their implementation and potential risks and benefits. In addition, many of them have different objectives and therefore could substantially complement each other. For example, the following three proposals complement each other: (1) von Braun and Torero's (2009a) proposal of emergency humanitarian reserves and a financial instrument to reduce the incentives for excessive speculation, (2) Lin's (2008) proposal of an international coordinated regional reserve,[7] and (3) Wright's (2009) proposal of providing better information regarding storage and the development of an international food agency. Moreover, the institutional design of the virtual reserve concept included a specialized research unit that would not only improve information regarding storage but also enhance the capacity of monitoring the probability distribution of price spikes and the periods of excessive volatility (similarly to what is being implemented through AMIS). While the proposed actions will entail costs, the modest costs of the required organizational elements must be balanced against the benefits of more effective international financial architecture. The benefits include the prevention of economic hardship and political instability, improved market efficiency, and stronger incentives for long-term investment in agriculture.

All other proposals focused on different objectives and do not seem to have the potential to significantly reduce price volatility; nevertheless, they may have positive effects on other issues, such as trade financing (Sarris 2009) and the long-term effects of some of the variables behind the changes in supply and demand fundamentals (Wright 2009).

In the meantime, we observed a diverse set of policy actions being taken: many countries try to build up costly national reserves, others focus on increasing self-

[7] See von Braun et al. (2009) for a joint proposal.

sufficiency, and still others engage in FDI to secure national food security through transnational land acquisition rather than trade because of lost confidence in trade owing to uncertainty surrounding volatility. In addition, some countries are pressing for more regulation of exchanges, which would not prevent extreme price spikes and could even further distort markets. All of these policy actions threaten to move food agriculture further away from efficient market designs. A more promising step may be regional coordinated reserves, as recently planned by ASEAN. Nevertheless, a global problem needs global institutional responses.

A clear message from all these proposals is that comprehensive research is needed to provide the decision-making body with independent and trustworthy information on possible alternatives for coping with the new global scenario of price spikes and excessive price volatility. All of these alternatives would clearly benefit from improved information availability. At the same time, improving information availability would allow for better evaluation of the costs and benefits of each proposal.

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7 Worldwide Acreage and Yield Response to International Price Change and Volatility: A Dynamic Panel Data Analysis for Wheat, Rice, Corn, and Soybeans

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7.1 Introduction

After about three decades of low and relatively stable prices of staple food commodities, the world has experienced a surge in the prices of many of these commodities since 2005. Such high prices are typically expected to bring about a supply response by which producers allocate more land to the agricultural sector and increase investment to improve yield growth (OECD 2008). The higher prices were, however, accompanied by higher volatility (Gilbert and Morgan 2010). Price volatility introduces output price risk, which has detrimental implications for producers' resource allocation and investment decisions (Sandmo 1971; Moschini and Hennessy 2001). Because agricultural producers in many developing countries are often unable to deal with (Binswanger and Rosenzweig 1986) and are unprotected from (Miranda and Helmberger 1988) the consequences of price volatility, they are exposed to the effects of international agricultural market price instability to the extent that the instability is transmitted to local markets. Yet Bellemare et al. (2013) pointed out that reducing commodity price volatility could benefit wealthier rural households more than poorer ones.

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This study analyzes the supply responsiveness of the key world staple food commodities—namely, wheat, corn, soybeans, and rice—to changes in output prices and volatility. It assesses how global food commodity producers allocate cropland and how their production decisions are affected by changes in price levels and volatility. These are fundamental questions for designing policies related to agricultural growth and food supply. Additionally, the study provides relevant information on how quickly current scarcities in global food supply, which are indicated by high prices, can be overcome by increasing production in the short term.

The literature about estimating supply response to prices has a long history in agricultural economics (Houck and Ryan 1972; Lee and Helmberger 1985; Nerlove 1956). Nevertheless, there are various reasons for the renewed interest in the research about supply response. The majority of the previous empirical literature concentrated only on a few countries, without having to estimate the worldwide supply response to international prices. Furthermore, the impact of price volatility and price risk is rarely considered because the small number of observations limits the use of additional explanatory variables or because price risk has not been considered as an important factor at the global level. The prices of many agricultural commodities have become more volatile after 2005, resulting in new interest in the impacts of price risk and volatility on (global) food security. The current study addresses this debate from the supply-side perspective, that is, it attempts to assess the extent to which price risks reduce production and supply response to increasing price levels.

Many existing econometric analyses focused on national supply responses to domestic prices. In contrast, this paper investigates the worldwide aggregate supply response to international market prices for the key world staples. In doing so, this article makes the following major contributions: First, it provides updated short- and long-term supply elasticities, which indicate how major agricultural commodity producers have responded to the recent increase in global food prices and volatility. This reveals to what extent the global agricultural system is responding to emerging global food scarcities. Second, some empirical evidence suggests that acreage adjustments constitute the largest share of the supply response to output price in the short run (e.g., Roberts and Schlenker 2009), and therefore, both acreage and yield responses are estimated to examine this finding. And third, this study evaluates whether the recent increase in prices and price volatility poses an opportunity or a challenge to the aggregate agriculture sector in general and, in particular, agricultural producers. To this end, we use simulation analyses to assess the overall impacts of the agricultural commodity price dynamics on the worldwide supply of the aforementioned key staple crops during the 2006–2010 period.

This study differs from a related work by Haile et al. (2014) in terms of methodology and research question. They employed several time series models to investigate annual and intra-annual global acreage response, whereas the current study uses a panel econometric modeling approach that makes use of data in which international prices are assigned to the corresponding planting season of the respective country and crop. Thus, this paper estimates global supply response of the aforementioned agricultural commodities by employing a newly developed multi-country, crop- and calendar-specific, seasonally disaggregated panel data with price changes and price volatility applied accordingly. This is an alternative approach to modeling heterogeneous seasonal planting patterns on the global scale, which has the advantage of using a larger number of observations without sacrificing the underlying nature of the monthly time resolution of production decisions. In addition, this study investigates not only acreage but also yield supply response to prices and price risk. The joint consideration allows us to make inferences about the global production response (as the product of acreage and yield response), which is relevant for policymakers. Finally, and importantly, this article assesses the net impacts of the recent agricultural commodity price dynamics on acreage, yield, and production of the key interest crops.

7.2 Related Literature

This study builds on the extensive agricultural economics literature about the estimation of agricultural supply response. Elasticities in a supply response model refer to the speed and size of adjustments in desired output relative to expected output prices. Neither the desired output nor the expected price is observable, however. The empirical literature employed different types of proxies for these variables, which could affect the results obtained. We provide a brief review of the literature with respect to the alternative proxies for these two variables.

In terms of the proxy for expected output prices, the literature did not provide unambiguous evidence regarding which expectation model should be used for empirical agricultural supply response estimation (Nerlove and Bessler 2001; Shideed and White 1989). Expectation formation hypotheses, widely applied in the supply response literature, include naive expectation (Ezekiel 1938), whereby expected prices are assumed to be equal to the latest observed prices; adaptive expectation (Nerlove 1958), whereby farmers are assumed to revise their expectations depending on past errors; and rational expectation (Muth 1961), which assumes that expectations are consistent with the underlying market structure and that economic agents make efficient use of all available information. Other research has focused on modeling supply response by using quasi-rational price expectations (Holt and McKenzie 2003), which is consistent with price prediction from a reduced-form dynamic regression equation. Futures prices are also used as a proxy for price expectations (Gardner 1976).

The naive and adaptive expectation hypotheses have been criticized because they are backward-looking (Nickell 1985); in other words, they ignore that the dynamics of price expectations of decision-makers can influence futures prices. Although the rational expectation hypothesis can be forward-looking, it implies that economic agents make efficient use of all available information, which may not be the case when some information is costly or difficult to process (Chavas 2000). Additionally, the rational expectation hypothesis is not supported by some experimental and survey datasets (Nelson and Bessler 1992). It is also doubtful whether futures prices are applicable as a proxy in supply analyses for countries where farmers are unable to make any futures transactions and have no access to information from exchange markets. Moreover, some empirical evidence showed that heterogeneous expectations coexist among agricultural producers (Chavas 2000).

Following Nerlove (1958), several empirical supply response models employ the adaptive expectation hypothesis and its variants. Askari and Cummings (1977), and later Nerlove and Bessler (2001), provided a thorough review of such literature. Some recent examples are Yu et al. (2012), Vitale et al. (2009), and de Menezes and Piketty (2012). Aradhyula and Holt (1989) employed the rational expectation hypothesis to investigate broiler supply in the USA; Eckstein (1984) and Lansink (1999) applied it to estimate crop acreage elasticities using aggregate agricultural data and farm-level data, respectively. Moreover, other empirical applications showed the relevance of the quasi-rational expectation approach in their supply models (Holt and McKenzie 2003; Nerlove and Fornari 1998). Lastly, Gardner (1976), Lin and Dismukes (2007), Liang et al. (2011), and Hausman (2012) are a few examples of studies that used harvest-time futures prices as a proxy for farmers' price expectations during planting season.

The empirical agricultural supply response literature has often used acreage, yield, or production as a proxy for desired output supply. Several studies preferred to use acreage when modeling output supply response (Coyle 1993; Haile et al. 2014) because acreage, unlike observed output, is not influenced by external shocks that occur after planting. However, acreage elasticities may only serve as a lower bound for the total supply elasticity (Rao 1989) because the latter depends also on how yield responds to prices. Several studies estimated both acreage and yield responses to prices (Weersink et al. 2010; Yu et al. 2012). When how supply responds to output prices is trivial (via acreage or yield), total observed production is another proxy used in the literature to estimate output supply response (Coyle 1999). Because "external" factors such as weather and pest shocks—which usually happen after farmers make their production decisions and are hardly predictable, such that farmers are unable to consider them when making production decisions—influence total observed production, the estimated supply response may not reflect how farmers actually respond to prices.

There is, however, another proxy used in recent studies—total caloric production, which is the sum of the caloric value of specific crops (Roberts and Schlenker 2009, 2013). This proxy implicitly assumes that the crops in the caloric aggregate are perfectly substitutable, which is less plausible as it assumes identical land and other input requirements for each crop. This ignores the possibility that producers might switch crops as a result of changes in relative prices by shifting out land from "low-demand" crops. This is supported by literature that showed acreage expansion of "high-demand" crops such as corn (Abbott et al. 2011; Goodwin et al. 2012). Such aggregation excludes intercrop acreage and other input shifts, which, by definition, implies that aggregate output elasticities are likely to be smaller than crop-specific elasticities. This is consistent with several empirical studies that found statistically significant cross-price elasticities of crop acreages. Hendricks et al. (2014), for instance, concluded that most of the acreage response to prices of corn and soybeans in the USA occurs through substitution rather than area expansion. Moreover, aggregation of crops conceals any implications for and effects of crop-specific policies with respect to changing intra-commodity price relationships.

On the other hand, output supply can be estimated at the plot or farm level, whereby farm size, soil quality, and other farm characteristics can be controlled for; at the household level, which enables better understanding of farmers' supply behaviors; or at larger aggregation scopes (such as at national, regional, or global levels), which have methodological limitations to capture the effects of contextual factors but still enable sufficient measurement of supply responsiveness. Yet, the estimation of aggregate agricultural supply response to changing price incentives has crucial implications for economic growth and poverty alleviation in economies in which the agricultural sector constitutes a sizable share of the national income.

Although there are several farm- and micro-level studies (e.g., Lansink 1999; Vitale et al. 2009; Yu et al. 2012) and quite a few national-level studies (e.g., Barr et al. 2009; de Menezes and Piketty 2012), global-level studies are scarce. Nevertheless, cross-country analyses are conducted using a certain group of countries to determine the role of prices on agricultural supply. Peterson (1979), for instance, found agricultural supply in developing countries to be fairly responsive to crop prices (estimated long-run elasticities range between 1.25 and 1.66). On the other hand, using a sample of 58 countries between 1969 and 1978, Binswanger et al. (1987) found that agricultural supply responded weakly to price incentives but strongly to non-price factors. A more recent cross-country study by Subervie (2008), based on a sample of 25 developing countries between 1961 and 2002, found a rather small, but statistically significant, aggregate supply elasticity of 0.04. Findings from Imai et al. (2011), which used data from a panel of ten Asian countries, and other crop-disaggregated studies that found much larger supply elasticities hinted that such aggregation of crops could result in small supply elasticities.

The other scope is when supply is aggregated across countries and crops. Two related studies by Roberts and Schlenker (2009, 2013) estimated the caloric-aggregated world supply and demand of staple crops—corn, wheat, soybeans, and rice—and found supply elasticities in the range of 0.06–0.12. They used lagged weather shocks, which are approximated by deviations of yield from trend, to identify the supply elasticity of agricultural commodities. Hendricks et al. (2015) replicated Roberts and Schlenker's analysis and found little difference between their estimates, which controlled for the realized yield shock, and those of Roberts and Schlenker, which used weather shocks in the previous year as an instrument for potentially endogenous expected prices. These authors also suggested that using planted acreage as a dependent variable can reduce this endogeneity bias in the supply elasticity estimates. In line with this suggestion, Haile et al. (2014) aggregated the global acreage of staple food to estimate crop-specific world supply elasticities. The elasticities were found to fall in a range between 0.03 (for rice) and 0.34 (for soybeans).

This study differs from the literature discussed above in terms of the level of aggregation employed for the dependent variables and the proxy used for expected prices. Besides using crop acreage, yield and production as alternative proxies for the desired output supply, these variables are aggregated at the global level for each crop. Nevertheless, the aggregation retains the panel feature of the data, which enables us to control for heterogeneity across countries. For example, we made use of the country- and crop-specific planting and harvesting seasons to identify the suitable proxy for price expectation in each country and for each crop.

Our proxy for expected prices differs from those used in the literature. In this study, we used world prices during planting season as a proxy for the prices anticipated by farmers in each country; in other words, we estimated the crop supply response to changes in world prices rather than to specific domestic prices. Thus, unlike the commonly understood agricultural supply response, which estimates how output supply responds to changes in the domestic prices in the producers' own countries, we estimated the responses (in terms of production, area, and yield) to changes in international prices. These two supply response estimates are identical under the assumption of complete transmission of international prices to domestic producer prices. However, they could be different in case of incomplete price transmission—an argument which is supported by the literature (e.g., Kalkuhl 2014). Finally, with the exception of Subervie (2008), none of the abovementioned cross-country panel studies and, to our knowledge, no worldwide aggregated supply response studies, except Haile et al. (2014), have accounted for price volatility (price risk) in the respective supply models.

7.3 Conceptual Framework

The literature on supply response has gone through several important empirical and theoretical modifications, and two major frameworks have been developed. The first approach is the Nerlovian partial adjustment model, which allows for analyzing both the speed and the level of adjustment from the actual output to desired output. The second framework is the supply function approach, which is derived from the profit-maximizing framework. The framework requires detailed input price data and simultaneous estimation of input demand and output supply equations. However, input markets—in particular land and labor markets—are either missing or imperfect in many countries. Moreover, our main interest lies in the output supply function. Thus, the econometric approach used in the present study is in line with the partial adjustment framework, and the approach is enhanced with dynamic response, alternative price expectation assumptions, and the introduction of price-risk variables.

Models of the supply response of a crop can be formulated in terms of output, area, or yield response. For instance, the desired output of a certain crop in period t is a function of expected output prices and a number of other exogenous factors (Braulke 1982):

$$Q_t^{\mathrm{d}} = \beta_1 + \beta_2 p_t^{\mathrm{e}} + \beta_3 Z_t + \varepsilon_t \tag{7.1}$$

where Q_t^{d} denotes the desired output in period t; p_t^{e} is a vector of the expected price of the crop under consideration and of other competing crops; Z_t is a set of other exogenous variables, including fixed and variable input prices, climate variables, and technological change; ε_t accounts for unobserved random factors affecting crop production with zero expected mean; and β_i are the parameters to be estimated. Output (determined by area and yield) adjustments are usually delayed by one or two agricultural production cycles because of a lack of resources. To account for such time lags in agricultural supply response, it is important to apply a dynamic approach. A supply response is usually a two-stage process. Because harvest-time prices are not realized during the time of planting, producers make acreage allocation decisions conditional on expected prices at the first stage. As in the production equation above, the desired area to be cultivated for a certain crop at time $t(A_t^{\mathrm{d}})$ is determined by expected own-crop and competing crop prices and other non-price factors:

$$A_t^{\mathrm{d}} = \alpha_1 + \alpha_2 p_t^{\mathrm{e}} + \alpha_3 Z_t + \varepsilon_t \tag{7.2}$$

Given the acreage allocation for each crop, farmers then determine crop yield based on other inputs and climate conditions. During the growing period, they may make revisions to their production practices by adjusting their input quantity, input quality, and crop protection. Hence, the desired yield of each crop is defined similarly to Eqs. (7.1) and (7.2) except that the output price vector includes only the crop's own price.

It is important to emphasize that we used international prices instead of domestic prices for our empirical analysis. Given a price transmission elasticity η, we can substitute the domestic log price p_t^{e} with the transmitted international price $p_t^{\mathrm{e}} = \eta\, p_t^{\mathrm{e,int}}$ in Eqs. (7.1) and (7.2). This substitution gives:

$$Q_t^{\mathrm{d}} = \beta_1 + \beta_2 \eta\, p_t^{\mathrm{e,int}} + \beta_3 Z_t + \varepsilon_t = \beta_1 + \tilde{\beta}_2\, p_t^{\mathrm{e,int}} + \beta_3 Z_t + \varepsilon_t \tag{7.1$'$}$$

and

$$A_t^{\mathrm{d}} = \alpha_1 + \alpha_2 \eta\, p_t^{\mathrm{e,int}} + \alpha_3 Z_t + \varepsilon_t = \alpha_1 + \tilde{\alpha}_2\, p_t^{\mathrm{e,int}} + \alpha_3 Z_t + \varepsilon_t \tag{7.2$'$}$$

which are structurally equivalent to Eqs. (7.1) and (7.2). The estimated supply response elasticities $\tilde{\beta}_2$ and $\tilde{\alpha}_2$, however, implicitly consider the imperfect transmission of prices from international to domestic markets. Hence, the supply response concept used in this paper is an aggregate response that consists of two parts: the (imperfect) transmission of global prices to domestic producer prices and the genuine supply response to expected domestic producer prices. The latter is typically estimated in conventional supply response models.

7.4 Data

The econometric model relies on a comprehensive database covering the period 1961–2010. The empirical model uses global- and country-level data in order to estimate global production, acreage, and yield responses for the key staple crops in the world. Data on planted acreage were obtained from several relevant national statistical sources,[1] whereas harvested acreage, production, and yield for all countries were obtained from the Food and Agriculture Organization (FAO) of the United Nations. Area harvested serves as a proxy for planted area if data on the latter are unavailable. International spot market output prices and different types of fertilizer prices and price indices are obtained from the World Bank's commodity price database. All commodity futures prices were obtained from the Bloomberg database. The 32 countries or regions included in this study, with the rest of world (ROW) aggregated into a separate entity, are reported in Table 7.6 in Appendix.[2]

A producer may choose to cultivate different crops at planting time. Therefore, it is worthwhile to consider price, price risk, and other information available to the farmer during the planting season. Accordingly, we used crop calendar information to identify the major planting seasons in each country in order to obtain country-specific spot and futures prices, measures of price risk and yield shocks, and input prices.[3]

Because actual prices are not realized during planting, we modeled farmers' price expectations using the available relevant information about world spot and world futures prices during planting. In the empirical model, own-crop and competing crop spot prices observed in the month before the start of planting are used since they contain more recent price information for farmers. Alternatively, harvest-time futures prices quoted in the months prior to planting are used. The use of these two price series to formulate producers' price expectations makes our supply response models adaptive as well as forward-looking. Because planting pattern varies across countries and crops, both the futures and spot prices of each crop are country specific. For countries in the ROW, we used annual average spot and futures prices.

The degree of transmission of international prices to national markets, η, can vary between countries (so do the "genuine" supply elasticities α_2 and β_2). Comparisons of the global and national supply response elasticities from the literature indicated that price transmission from world to domestic prices is imperfect or absent in some countries. Consequently, producers' response to international price changes and volatility—which is the focus of this study—is expected to be smaller. Nevertheless,

[1]Data sources are available in Table 7.6 in Appendix.

[2]Countries with a global acreage share of less than half a percent are grouped in the rest-of-world category.

[3]The crop calendar for emerging and developing countries is obtained from the Global Information and Early Warning System (GIEWS) of the FAO, and the crop calendar for the advanced economies is from the Office of the Chief Economist (OCE) of the United States Department of Agriculture (USDA).

empirical evidence shows that world prices are a significant source of variation in domestic prices (Mundlak and Larson 1992). Recent empirical literature also shows that domestic markets are integrated into world markets mostly through the adjustment of domestic prices to deviations from the long-run domestic-world price relationship (Baquedano and Liefert 2014; Kalkuhl 2014). Estimating the country-specific transmission elasticity would allow us to decompose the supply response into its transmission component (η) and its "genuine" supply response (α_2 and β_2) for each country. However, as this is empirically cumbersome and requires long price series that are difficult to obtain for the country studied in this paper, we empirically estimated the average global response to international price changes, disregarding any possible heterogeneity in the price transmission and the "genuine" supply response.

We included own and cross volatility of international spot prices in order to capture output price risk. For price volatility we used the standard deviation of the log returns (that is, first differences instead of levels of log prices) in order to use the de-trended price series. The price-risk measures show country-specific output price variability in the 12 months preceding the start of the planting season of each crop in each country. Table 7.1 presents international price volatility along with the respective average real prices for all four crops. The volatility of world prices of these crops, measured by the moving standard deviation of monthly logarithmic prices, was higher in the recent decade relative to earlier periods, although it was not as high as in the 1970s. Any high degree of collinearity between the price level and volatility of a crop might be of concern for our empirical estimation; therefore, we computed both the Pearson's rank and Spearman's rank correlation coefficient for each crop, establishing a relationship between their own price and their own-price volatility. The correlation coefficients are positive and statistically significant in all cases, with wheat and corn exhibiting the highest Pearson's rank (Spearman's rank) correlation coefficients of 0.51 (0.53) and 0.45 (0.56), respectively. Further collinearity diagnostic analyses of all price and volatility variables, such as the

Table 7.1 International price volatility and levels for wheat, corn, soybeans, and rice

	Price volatility				Price level			
Period	Wheat	Corn	Soybeans	Rice	Wheat	Corn	Soybeans	Rice
1961–1970	0.062	0.069	0.082	0.104	258	220	467	594
1971–1980	0.157	0.122	0.175	0.194	267	210	502	598
1981–1990	0.089	0.135	0.121	0.125	182	140	320	331
1991–2000	0.131	0.127	0.080	0.136	149	113	256	285
2001–2010	0.153	0.142	0.148	0.127	191	133	323	328
2001–2005	0.113	0.107	0.132	0.086	160	111	273	236
2006–2011	0.214	0.193	0.163	0.160	227	169	384	423

Note: Price volatility is measured by the standard deviation of logarithmic monthly prices using the World Bank international prices. Prices are in real 2005 US dollars per metric ton. The figures in each row refer to average values of the annualized volatilities and prices over the respective decade variance inflation factor (VIF), indicate that multicollinearity is not a serious problem in our data.

We included yield shocks calculated as deviations from country- and crop-specific trends in our empirical supply models. The deviations may have been caused by weather shocks, pest infestations, or other factors; our assumption is that these deviations from the yield trends could serve as proxy for producers' yield expectations. Following Roberts and Schlenker (2009), the yield shocks are the jackknifed residuals from separate yield-on-trend regressions for each crop in each country. A positive deviation entails good yield expectations, implying a positive effect on crop supply. We aggregated the crop yields across the remaining countries in the ROW to generate yield shocks for each crop.

Fertilizer price indices are used as proxies for production costs in this paper. The weights used by the World Bank shows that the fertilizer price index considers the prices of natural phosphate rock, phosphate, potassium, and nitrogenous fertilizers. The fertilizer price index is also crop and country specific, depending on the planting pattern of a crop in a country. The fertilizer price index in the month prior to the start of planting was used in the calculations.

7.5 Econometric Model

Given the above theoretical model and assuming there are K countries observed over T periods, the supply functions of the four crops can be expressed generally as

$$Q_{ikt} = \pi_i Q_{ik,t-1} + \sum_{j=1}^{4} \alpha_{ij} p_{jk,t_{i,k}} + \sum_{j=1}^{4} \varphi_{ij} \text{vol}(p)_{jk,t_{i,k}} + \lambda_{i1} w_{ik,t_{i,k}} + \lambda_{i2} \text{YS}_{ik,t_{i,k}} + \mu_{it} + \eta_{ik} + u_{ikt} \tag{7.3}$$

where Q_{ikt} denotes the total production (or area under cultivation) of crop i ($1 = \text{wheat}$, $2 = \text{corn}$, $3 = \text{soybeans}$, and $4 = \text{rice}$), $p_{jk,t_{i,k}}$ denotes a vector of either spot or futures prices that are used as a proxy for expected own-crop and competing crop prices at planting time, $\text{vol}(p)_{jk,t_{i,k}}$ is a vector of the volatility measures for own-crop and competing crop prices, $w_{ik,t_{i,k}}$ refers to prices of variable inputs (such as fertilizer), $\text{YS}_{ik,t_{i,k}}$ refers to a yield shock for each crop, μ_{it} are time dummies to account for some structural changes or national policy changes, η_{ik} denote country-fixed effects to control for time-invariant heterogeneity across countries, and u_{ikt} is the idiosyncratic shock. π_i, α_{ij}, φ_{ij}, λ_{i1}, and λ_{i2} are parameters to be estimated. The parameter α_{ij} can, for instance, be interpreted as an own-price supply elasticity if $j = i$ and as a cross-price supply elasticity if $j \neq i$. The subscript k denotes the country. The subscripts i and k on t indicate that the lag lengths of the following are country and crop specific: the relevant futures and spot prices, output price volatility, input price, and yield shock variables.

As discussed above, the seasonality of agricultural cultivation in different countries enables us to construct international prices that are country-specific variables at the seasonally appropriate time according to a country's crop calendar. This approach is more precise than assuming all countries face the same yearly output prices. This is particularly important because planting decisions in the early months of a calendar year (or marketing year) in some countries affect the annually averaged prices and would cause an endogeneity problem in any global supply response models that use annual data. Likewise, if planting decisions are made later in a calendar or marketing year, an average annual price will contain past prices that dilute the information signal that more recent planting-time prices could convey.[4] Taking the lagged annual average price is not a good solution because producers adjust their price expectations according to more recent information (Just and Pope 2001).

As described in the conceptual model, the yield equation is specified similarly to Eq. (7.3) except that the output price and price volatility vectors do not include the price and volatility of competing crops. There is a subtle difference between the acreage response and yield response models in terms of the yield deviation measures used as proxies for yield expectations. In acreage response models, the yield deviation measures are derived from the harvest period prior to planting, but in yield response models, these measures are derived from the harvest in the previous year. Consequently, the deviations in the yield response models are lagged, whereas they are not necessarily lagged in the acreage response models if the prior harvest is in the year of planting. We therefore excluded these variables from the regressions of the production and yield response functions because they are, by definition, correlated with the respective lagged dependent variables.[5] All quantities and output and input price variables (except for price volatilities, which are rates) are specified as logarithms in the econometric models. Hence, the estimated coefficients can be interpreted as short-run elasticities.

Applying ordinary least squares (OLS) estimation to a dynamic panel data regression model, such as in Eq. (7.3) above, results in a dynamic panel bias because of the correlation between the lagged dependent variable and the country-fixed effects (Nickell 1981). Since current acreage is a function of the fixed effects (η_k), it is obvious that lagged acreage is also a function of these country-fixed effects. This violates the strict exogeneity assumption, and hence the OLS estimator is biased and inconsistent. An intuitive solution to this problem is to transform the data and remove the fixed effects. However, under the within-group transformation, the lagged dependent variable remains correlated with the error term, and therefore, the fixed-effects (FE) estimator is biased and inconsistent. While the correlation between the lagged dependent variable and the error term is positive in the simple OLS regression, the estimated coefficient of the lagged dependent variable is biased downward in the case of the FE estimator (Roodman 2009a, b).

[4]See Haile et al. (2014) for global intra-annual planting and harvesting patterns.

[5]The yield shock variables are not statistically significant in the acreage response models, and we omit them from the final regression.

Therefore, we need an estimator of the true parameter that lies in the range between the OLS and the FE estimate for the coefficient on the lagged dependent variable. Anderson and Hsiao (1982) suggested using the instrumental variable (IV) method to estimate the first-difference model. This technique eliminates the fixed-effect terms by differencing instead of within transformation. Since the lagged dependent variable is correlated with the error term, this method uses the second lagged difference as an IV. Although this method provides consistent estimates, Arellano and Bond (1991) developed a more efficient estimator, called difference GMM, in order to estimate a dynamic panel difference model using all suitably lagged endogenous and other exogenous variables as instruments in the GMM technique (Roodman 2009a). Blundell and Bond (1998) developed a further strategy named system GMM to overcome dynamic panel bias. Instead of transforming the regressors to purge the fixed effects and using the levels as instruments, the system GMM technique transforms the instruments themselves in order to make them exogenous to the fixed effects (Roodman 2009a). The estimator in the difference GMM model can have poor finite sample properties in terms of bias and precision when applied to persistent series or random-walk types of variables (Roodman 2009b). The system GMM estimator allows substantial efficiency gains over the difference GMM estimator provided that initial conditions are not correlated with fixed effects (Blundell and Bond 1998). Thus, we have chosen the system GMM method to estimate our dynamic supply models.

Several statistical tests were conducted to check the consistency of our preferred GMM estimator. First, the Arellano–Bond test for autocorrelation is used to test for serial correlation in levels. The test results, reported in the next section, indicate that the null hypothesis of no second-order autocorrelation in residuals cannot be rejected for nearly all production, acreage, and yield models, indicating the consistency of the system GMM estimators. Second, the Hansen test results cannot reject the null hypothesis of instrument exogeneity. We also conducted a test for the validity of the Blundell–Bond assumption using the Diff-in-Hansen test of the two-step system GMM. The test statistics gave p-values greater than 10 % in all cases, suggesting that past changes are good instruments of current levels and that the system GMM estimators are more efficient. Furthermore, the standard error estimates for all specifications are robust in the presence of any pattern of heteroskedasticity and autocorrelation within panels. The Windmeijer (2005) two-step error bias correction is incorporated. Following Roodman (2009a, b), we also “collapsed” the instrument set in order to limit instrument proliferation.

7.6 Results

7.6.1 Econometric Results

Tables 7.2 and 7.3 present the GMM results of the production/acreage and yield response functions, respectively. For each crop, we estimated the supply models using preplanting month spot prices and harvest period futures prices (except for

Table 7.2 Estimates of production and acreage response

Variable	Production				Acreage			
	Wheat	Corn	Soybeans	Rice	Wheat	Corn	Soybeans	Rice
Lagged dependent variable	0.961*** (0.013)	0..964*** (0.030)	0.928*** (0.036)	0.625*** (0.089)	0.990*** (0.005)	0.978*** (0.033)	0.932*** (0.029)	0.747*** (0.045)
Lagged dependent variable (2)				0.356*** (0.099)				0.244*** (0.039)
Wheat price	0.106** (0.046)	−0.015 (0.057)	−0.205*** (0.058)		0.075*** (0.027)	0.009 (0.014)	−0.034*** (0.012)	
Corn price	0.034 (0.052)	0.226** (0.113)	−0.054 (0.066)		−0.002 (0.032)	0.069*** (0.025)	−0.118*** (0.025)	
Soybean price	−0.028 (0.054)	0.050 (0.062)	0.365** (0.166)		−0.047 (0.029)	−0.038* (0.020)	0.146** (0.074)	
Rice price	−0.020 (0.023)	−0.135** (0.068)	−0.061 (0.065)	0.058*** (0.025)				0.024** (0.010)
Wheat price volatility	−0.628** (0.281)	0.074 (0.283)	0.511*** (0.162)		−0.350*** (0.124)	0.123 (0.146)	−0.110 (0.151)	
Corn price volatility	0.159 (0.438)	0.287 (0.252)	−0.374** (0.175)		0.249* (0.123)	0.135 (0.095)	0.134 (0.147)	
Soy price volatility	0.366 (0.234)	−0.608 (0.559)	0.013 (0.411)		0.279** (0.106)	−0.108 (0.128)	0.228** (0.092)	

(continued)

Table 7.2 (continued)

Variable	Production Wheat	Production Corn	Production Soybeans	Production Rice	Acreage Wheat	Acreage Corn	Acreage Soybeans	Acreage Rice
Rice price volatility				−0.197**				−0.064
				(0.106)				(0.062)
Fertilizer price	−0.068**	−0.010	0.040**	−0.014	−0.013	−0.017	0.013	−0.003
	(0.023)	(0.018)	(0.018)	(0.019)	(0.011)	(0.014)	(0.029)	(0.013)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1174	1444	1371	1332	1162	1418	1371	1332
F-test of joint significance: *p*-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Test for AR(1): *p*-value	0.015	0.013	0.020	0.101	0.100	0.004	0.010	0.002
Test for AR(2): *p*-value	0.162	0.152	0.055	0.317	0.880	0.292	0.945	0.767
Diff-in-Hansen test: *p*-value	1.000	0.991	0.991	0.753	1.000	0.980	0.970	0.980

Note: All regressions are two-step system GMM and treat the lagged dependent variable as predetermined. Two-step robust standard errors, which incorporated the Windmeijer (2005) correction, are in parentheses. Yield deviations were included in the acreage response models as additional control variables. *, **, and *** represent the 10 %, 5 %, and 1 % levels of significance. All the production and area response models are weighted by the global crop acreage share of the respective country. Sensitivity analyses, whereby elasticities were estimated using panels which excluded countries in the ROW, provide consistent results. Rice price and volatility are excluded in the non-rice acreage response models because land for rice cultivation is not usually suitable for these crops; however, competition in production is possible through input substitution

Table 7.3 Estimates of yield response

Variable	Wheat	Corn	Soybeans	Rice
Lagged dependent variable	0.920*** (0.032)	0.960*** (0.020)	0.925*** (0.034)	0.724*** (0.133)
Lagged dependent variable				0.272 (0.165)
Own-crop price	0.166*** (0.055)	0.094** (0.039)	0.146*** (0.045)	0.043** (0.018)
Own-price volatility	−0.336** (0.168)	−0.366** (0.170)	−0.467** (0.226)	−0.148** (0.070)
Fertilizer price	−0.069** (0.026)	−0.008 (0.021)	−0.050** (0.020)	−0.020 (0.017)
Time dummies	Yes	Yes	Yes	Yes
N	1174	1444	1371	1332
F-test of joint significance: p-value	0.000	0.000	0.000	0.000
Test for AR(1): p-value	0.002	0.001	0.000	0.016
Test for AR(2): p-value	0.046	0.425	0.079	0.574
Diff-in-Hansen test: p-value	0.950	0.749	0.933	0.751

Note: All regressions are two-step system GMM and treat the lagged dependent variable as predetermined. Two-step robust standard errors, which incorporated the Windmeijer (2005) correction, are in parentheses. *, **, and *** represent the 10 %, 5 %, and 1 % levels of significance

rice) as proxies for expected prices at planting time.[6] We failed to find a significant supply-price relationship using futures prices (except for soybeans); this could imply that many agricultural producers do not make use of information on futures prices in forming their price expectations. Indeed, futures prices are good proxies for expected prices for producers in countries where domestic prices are strongly linked to the futures prices—that is, where the maturity basis is constant. Although the farmers in advanced economies participate widely in futures markets and the futures prices are linked to the cash prices, this is not the case in many developing countries. Thus, we reported the results obtained from the specifications with spot prices.

Production, acreage, and yield responses to own prices are generally positive and statistically significant, and the results are consistent with economic theory. The results suggest that higher output prices induce producers to increase acreage and to invest in improving crop yields, implying that global food supply response to prices appears to occur through both acreage and yield changes. The production responses to own prices are larger than the respective acreage and yield responses (with the exception of the wheat yield response). The acreage and yield own-price elasticities are mostly similar in their order of magnitude.

[6]Rice futures markets have relatively short time series data, and local prices are unlikely to be strongly correlated with futures prices in several countries.

The results show that soybeans and corn have the largest production responses to own-crop prices, followed by wheat and rice. Conditional on other covariates, a 10 % rise in the expected own-crop price induces a production increase of about 4 % for soybeans, 2 % for corn, 1 % for wheat, and 0.6 % for rice in the short run. These production responses typically reflect the acreage and yield adjustments. An equivalent increase in the respective international crop prices induces farmers to increase their land allocated to soybean and corn cultivation by about 1.5 % and 0.7 %, respectively. The yield of soybeans and corn also respond to higher international own-crop prices in an order of magnitude similar to their respective acreage responses; the short-run elasticities are 0.15 and 0.09, respectively. Global wheat acreage and yield also respond to output prices, with short-run elasticities of 0.08 and 0.17, respectively. In line with the production response results, rice has relatively weaker acreage and yield responses to own prices. Rice cultivation in some areas requires capital investment (such as for building canals and sluices) to ensure flooding at the time of planting. These investments are long-term decisions, implying that short-run price responses are inevitably low.

Additionally, the statistically significant cross-price elasticities have negative signs, and this is consistent with economic theories. Higher wheat prices are negatively correlated with soybean production, and corn producers respond to higher international rice prices by lowering corn production. The cross-price elasticities show that corn and soybeans compete for land at the global level, with a stronger corn price effect on soybean acreage than vice versa. In addition, higher international wheat prices lead to less land for soybean production.

Unlike own-crop price levels, own-price volatility does not have a uniform effect on the supply of all crops. Price volatility seems to affect wheat and rice production most. The results reveal that an increase in the volatility of international wheat and rice prices causes producers to allocate less land to these crops and reduce yield-improving investments, resulting in a decline in wheat and rice production. To some extent, the negative wheat acreage response to own-price volatility could be offset if prices of competing crops such as corn and soybeans also exhibit such volatility. For corn, the negative supply impact of own-price volatility is due mainly to declining yields. Corn producers react to rising own-crop prices by using more inputs to improve productivity, whereas corn price risk induces producers to shift inputs away from corn production. For soybean acreage, on the other hand, the estimated coefficient of own-price volatility has a statistically positive sign. This result is consistent with previous national-level studies that found either insignificant or positive effects of price volatility on soybean acreage (e.g., de Menezes and Piketty 2012). The majority of soybean producers in the world are large, commercial holders who are likely to be well informed about price developments. Thus, they may be willing and able to absorb price risks.

It is worth mentioning that the coefficients of the price volatility variables—measured by the standard deviation of log price returns—are not elasticities, and hence they are not directly comparable with the price elasticity estimates. We computed the standardized effect sizes of price and volatility on the respective supply responses to shed light on the relative effect sizes of the mean response when compared with the volatility responses (4). The effect sizes in Table 7.4 show the

Table 7.4 Standardized effect sizes of price and volatility on supply for each crop

	Wheat price	Corn price	Soybean price	Rice price	Wheat price volatility	Corn price volatility	Soy price volatility	Rice price volatility	Fertilizer price
Production response									
Wheat	**0.045**	0.012	0.011	−0.008	**−0.025**	0.005	0.016		**−0.044**
Corn	−0.005	**0.061**	0.015	**−0.042**	0.002	0.006	−0.019		−0.005
Soybeans	**−0.065**	−0.015	**0.108**	−0.019	**0.016**	**−0.008**	0.000		**0.020**
Rice				**0.021**				**−0.008**	−0.008
Acreage response									
Wheat	**0.035**	−0.001	−0.020		**−0.015**	**0.008**	**0.013**		−0.009
Corn	0.004	**0.025**	**−0.015**		0.005	0.004	−0.005		−0.011
Soybeans	**−0.013**	**−0.040**	**0.053**		−0.004	0.003	**0.009**		0.008
Rice				**0.010**				−0.003	−0.002
Yield response									
Wheat	**0.132**				**−0.025**				**−0.084**
Corn		**0.054**				**−0.016**			−0.009
Soybeans			**0.109**				**−0.037**		**−0.062**
Rice				**0.038**				**−0.015**	−0.028

Note: The effect sizes that are statistically significant at the 10 % level or less are typed in bold global supply response for a one standard deviation change in price and volatility for every crop. In the case of the effect sizes for wheat, the negative impact of own-price volatility on production and area is roughly half of the positive impact of own-price increase. Own-price volatility is also an important factor for the yields of all four crops, with effect sizes ranging between 19 and 34 % of the yield responses to own-crop prices.

In addition to output prices, input prices are also an important factor in farmers' production decisions, as shown by fertilizer price elasticities. Higher international fertilizer prices not only have a negative effect on wheat production but also reduce the yields of nearly all crops. A doubling of international fertilizer price indices results in a 1–7 % reduction in crop productivity.

The lagged dependent variables are both statistically and economically relevant in all crop supply models.[7] The estimated coefficients indicate producers' inertia, which may reflect the adjustment costs of crop rotation, crop-specific land (and other quasi-fixed and fixed inputs), technology, and soil-quality requirements. The coefficients of the lagged dependent variables, however, may also reflect unobservable dynamic factors, and any interpretations should be made with caution (Hausman 2012). The estimated coefficients of the lagged dependent variables are close to one, indicating that agricultural supply is much more responsive to international output prices in the longer term than in the short term.

7.6.1.1 Robustness Checks

We have conducted several statistical tests to check the consistency of our preferred GMM estimator; and a number of additional sensitivity checks were performed to investigate the sensitivity of our results to alternative estimators.[8] Results are generally robust in terms of the significance and sign of the control variables in most specifications.

The coefficients on the lagged dependent variable of our preferred GMM estimator are mostly close to unity, potentially suggesting remaining residual serial correlation. To this end, we conducted the Arellano–Bond test for first- and second-order autocorrelated disturbances in the first-differenced equation. The p-values reported for AR(1) and AR(2) indicate that, as expected, there is a high first-order autocorrelation and no evidence of significant second-order autocorrelation. However, for any remaining serial correlations and whenever the p-values of AR(2) are below 0.15—for instance, in the production and yield response models for soybeans and in the latter model for wheat—we use second- and higher-order lags of the predetermined variable as instruments. Moreover, the coefficients of the lagged dependent variable can be statistically distinguished from unity in most cases. Another useful check for the validity of the dynamic panel estimates is to

[7]Rice cultivation requires capital investment to ensure flooding at the time of planting, which is a long-term investment. To account for such dynamics, we include a second lag of the dependent variable as a control variable.

[8]Alternative model results are available upon request.

determine if the estimated coefficient on the lagged dependent variable lies between the values obtained from OLS and FE estimators. All our preferred system GMM specifications result in an estimated autoregressive coefficient that lies between the two bounds.

We also report the two-step difference GMM estimates, which are mostly consistent with their system GMM counterparts. Nevertheless, the autoregressive coefficient of the difference GMM (in most cases) lies below the lower credible bound as given by the FE estimator. In addition, as discussed in the empirical model, the difference GMM estimator does not take into account the high persistence of the dependent variable. Although we do not reject the null hypothesis of the validity of the overidentifying restrictions in all the difference and system GMM estimators, the Diff-in-Hansen test results validate the additional moment restriction necessary for the system GMM.

Several things have changed over the period from which our empirical data were obtained, including the information technology available to form price expectations, general inflation, and market- and government-based institutions to provide risk management. Thus, we checked whether our estimated parameters are stable over the estimation period by estimating our supply response models with 20- and 30-year rolling windows. Additionally, we include interaction of the price variables with a dummy variable for the period after 1985–dividing the data period equally—and the period dummy to test if these additional variables are statistically different from zero. We also estimated the system GMM model on the subsample of our data after 1985; however, the estimation results are not reported for brevity. In general, the results of the recursive rolling estimation and the "Chow" test hint that the estimated coefficients are mostly stable over time and do not significantly change between the two periods. Moreover, the results from the estimations using the subsample data are mostly consistent with the results from our preferred model.

In summary, our empirical results align with previous work that showed that agricultural supply is inelastic in the short run. Table 7.5 summarizes the supply elasticities of selected countries as estimated by the Food and Agricultural Policy Research Institute (FAPRI) and in other literature; these estimates do not, however, capture the effects of price volatility on supply. The supply elasticity from Roberts and Schlenker (2009) is aggregated for all four crops in terms of their caloric content. Apart from the corn supply elasticity, which is larger in the present study, our other estimated elasticities are of similar order of magnitude to the weighted average of the national-level estimates.

Table 7.5 Summary of existing own-price supply elasticities (without considering volatility)

Country	Wheat	Corn	Soybeans	Rice
Egypt	0.25	0.09	0.03	0.16
South Africa	0.09	0.28	0.03	0.03
China	0.09	0.13	0.45	0.16
India	0.29	0.21	0.36	0.11
Pakistan	0.23	0.28	0.29	0.29
Argentina	0.41	0.7	0.32	0.24
Brazil	0.43	0.42	0.34	0.07
Turkey	0.20	0.14		0.47
Iran	0.08	0.01	0.01	0.01
EU	0.12	0.08	0.19	0.24
Russia	0.19	0.31		
Canada	0.39	0.18	0.32	
USA	0.25	0.17	0.30	0.35
Australia	0.33	0.23		0.17
Weighted average (weighted by area share)	0.18	0.14	0.31	0.07
Roberts and Schlenker (2009), Global	0.11			
Roberts and Schlenker (2013), Global	0.10	0.27	0.55	0.03
Haile et al. (2014)	0.09	0.18	0.37	0.02
This study	0.11	0.23	0.37	0.06

Source: Food and Agricultural Policy Research Institute (FAPRI), FAPRI Elasticity Database, http://www.fapri.iastate.edu/tools/elasticity.aspx. Because FAPRI only reports rice acreage elasticities for the USA, for the other crops, we used elasticities from Lin and Dismukes (2007). We also use average acreage elasticities for "other Africa" for unreported elasticities for Egypt and South Africa. Price elasticities for individual countries refer to acreage responses to domestic producer prices, while global price elasticities for this study refer to responses to world market prices

7.6.2 Simulation Results

We used the estimated coefficients of our preferred GMM estimator in Tables 7.2 and 7.3 to analyze whether the recent increase in prices and price volatility is an opportunity or a challenge to world food supply, in terms of acreage and yield changes. To this end, we calculate the differences in the predicted outcome variables under the realized prices and under a counterfactual scenario where all output prices and volatility as well as fertilizer prices after 2006 are set equal to their 1980–2005 mean values. We consider only the direct short-term impacts and neglect the influence of the autoregressive term, which would further exacerbate the changes in the long run. The results of these simulations are shown in Figs. 7.1 and 7.2.

The net impact of increasing own and competing crop prices is about a 2 % increase in the area used for cultivating both wheat and corn. The effect is higher (6 %) for rice as we included only own prices in the rice acreage. However, the effect of higher competing crop prices on soybean acreage offsets that of higher own-crop prices, resulting in a negligible net effect. In contrast, increasing fertilizer prices reduces acreage by nearly comparable amounts, except for soybeans, where

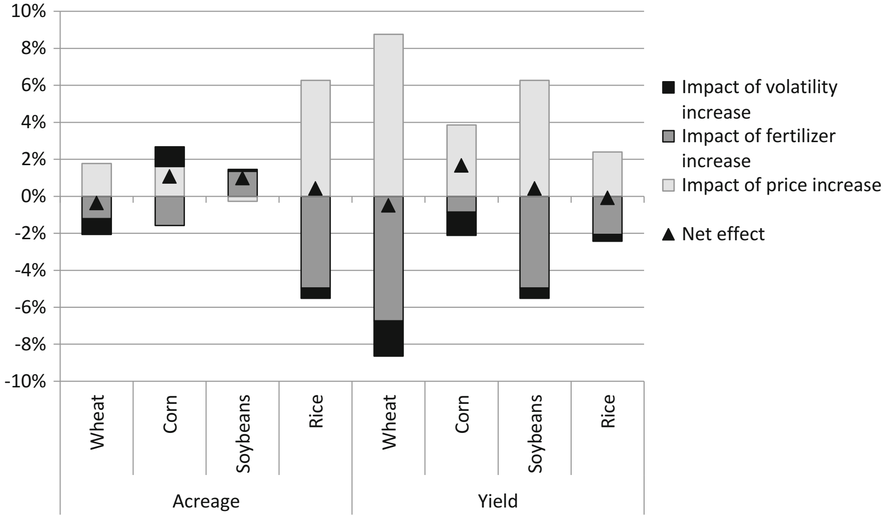

Fig. 7.1 Impacts of the 2006–2010 price dynamics on acreage and yield. *Note:* The figure shows the impact of output and fertilizer prices and output price volatility on acreage and yield compared with a counterfactual scenario where these values were set to their long-term average. The net effect is calculated as the sum of the three components. The depicted rates refer to the net impacts during the 5-year period 2006–2010. These changes are the direct short-term response, and they are the lower bounds for the longer-term effects as the coefficients of the autoregressive term are positive and closer to unity

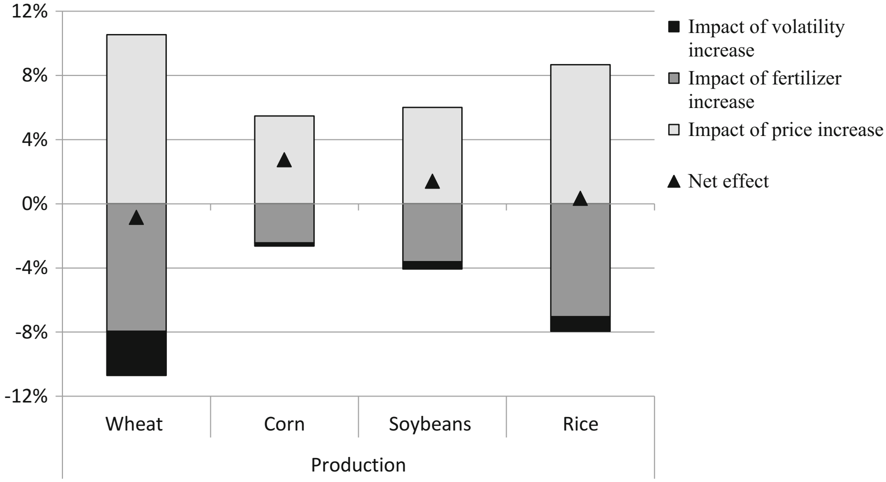

Fig. 7.2 Impacts of the 2006–2010 price dynamics on production. *Note:* See simulation assumptions detailed in Fig. 7.1

it has a positive effect.[9] The coefficient for volatility is statistically insignificant for corn, but higher volatility affects wheat acreage negatively and soybean acreage positively. The overall impact of the 2006–2010 output and input price dynamics on acreage is estimated to be, on average, positive for corn, soybeans, and rice and slightly negative for wheat. The different price dynamics have greater impacts on yields, but because of strong opposing effects, the net impact is similar in magnitude to the impact on acreage allocation decisions. The increase in own-crop price volatility during the same period dampens yield by about 1–2 % for the crops under consideration.

Analogously, we calculated the production impact of the recent price dynamics from the acreage and yield simulations by the identity that production equals acreage times yield. This way, we rely on the two-stage decision process whereby acreage and yield decisions are temporally decoupled. The respective results are shown in Fig. 7.2. According to the results, the overall net impact of the 2006–2010 price dynamics on production is about a 3 % increase for corn, a 1.5 % increase for soybeans, negligible for rice, and a 1 % decrease for wheat. Decomposing the overall effect into output price, fertilizer price, and price volatility effects reveals interesting results. The net impact of increasing own and competing crop prices ranges from about a 6 % (for corn and soybeans) to 11 % (for wheat) increase in production. In contrast, the effect of higher fertilizer price is a reduction of production that ranges from about 2 % for corn to 8 % for wheat. The effect of own-crop price and competing crop-price volatility is about a 3 % decrease in production for wheat and about 1 % for rice; it has a negative but negligible effect on the production of corn and soybeans.

In summary, the simulation results show that more volatile output prices and higher input prices have weakened the extent to which rising international agricultural commodity prices might have increased output production since the middle of the last decade.

7.7 Conclusions

Uncertainty is a quintessential feature of agricultural commodity prices. Besides the traditional causes of price fluctuations, agricultural commodities are increasingly connected to energy and financial markets, with potentially destabilizing impacts on prices (Tadesse et al. 2014). Using cross-country panel data for the period 1961–2010, this study has investigated the global supply impacts of international price levels and price volatility. Estimation of the recent supply response to input and output price levels and to output price volatility is a necessary step in predicting the effects that developments in output price levels and volatility have on the global food supply in the future. In addition to responding to price changes by reallocating

[9] One explanation for this is that soybeans require less nitrogen fertilizer than the other crops, which makes planting them more attractive when fertilizer prices are high.

acreage, producers react to expected price changes by making decisions that affect yields.

The results underscore the relevance of output price volatility for the supply of the key global agricultural staple crops. Although higher risk in prices is usually associated with higher returns, economic theory has shown that output price risk is detrimental to producers (Sandmo 1971). Coefficients for the price-risk variables are statistically and economically significant in the supply response models for wheat and rice and in the yield response models for all crops. Besides inducing producers to shift land away from wheat and rice cultivation, higher output price volatility weakens the incentive for producers to invest in yield improvement. For corn, own-crop price volatility has little or no impact on acreage allocation, but it has a negative impact on yield.

Consequently, reducing agricultural price volatility is likely to increase food supply globally and, more importantly, in developing countries. Some agricultural producers, however, do not shy away from making investments in order to obtain higher returns, which are associated with higher price risks. Such producers are not necessarily hurt by output price volatility. The findings of this paper suggest that this is the case for the majority of soybean producers in the world, indicated by the statistically significant positive coefficient of own-price volatility in the acreage response model. This result is relevant for policymakers because it suggests that a one-size-fits-all approach to price volatility management—such as through stockholding or public price risk insurance systems—may not be appropriate.

This paper has explained why the current high food prices have not brought about a large increase in global agricultural supply as one might expect. The estimated short-run supply elasticities are generally small. Agricultural supply does not increase on a par with output price increases in the short run. In other words, agricultural producers need more time to make necessary production adjustments and investments to increase supply. Furthermore, this study has assessed how much the increased latent output price uncertainty, represented by price volatility, weakens the global positive supply response.

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A.1 Appendix

Table 7.6 Countries and respective data sources

Countries	Area/production/yield data sources
Argentina	Integrated Agricultural Information System (SIIA): http://www.siia.gov.ar/_apps/siia/estimaciones/estima2.php Ministry of Agriculture, Livestock and Fisheries: http://www.minagri.gob.ar/site/agricultura/index.php
Australia	The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES): http://www.daff.gov.au/abares/pages/data
Brazil	Brazilian Institute of Geography and Statistics (IBGE): http://seriesestatisticas.ibge.gov.br/ National Food Supply Company (CONAB): http://www.conab.gov.br/
Cambodia	Ministry of Agriculture, Forestry and Fisheries (MAFF): http://www.elc.maff.gov.kh/, FAO, USDA
Canada	Canadian socio-economic information management system (CANSIM): http://www5.statcan.gc.ca/cansim
China	China Statistical Yearbook 2010
EU27	Eurostat: http://epp.eurostat.ec.europa.eu/
India	Directorate of Economics and Statistics, Department of Agriculture and Cooperation: http://eands.dacnet.nic.in/publications.htm
Japan	Ministry of Agriculture, Forestry and Fisheries: http://www.maff.go.jp/
Mexico	Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food: http://www.siap.gob.mx/
Pakistan	Pakistan Bureau of statistics: http://www.pbs.gov.pk/, http://www.finance.gov.pk/survey/chapter_12/02-Agriculture.pdf
South Africa	South African Grain Information Service (SAGIS): http://www.sagis.org.za/, http://www.daff.gov.za/docs/statsinfo/Abstract_2011.pdf, FAO, USDA
Sri Lanka	Agriculture and Environment Statistics Division of the Department of Census and Statistics: http://www.statistics.gov.lk/agriculture, FAO, USDA
Turkey	Turkish Statistical Institute: http://www.turkstat.gov.tr/
Uruguay	Uruguayan Department of Livestock, Agriculture, and Fisheries: http://portal.gub.uy/
USA	Economic Research Service: http://www.ers.usda.gov/
Other countries	FAO, USDA

Notes: Links are provided if available. They were accessed on/before August 15, 2014

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Food Crisis and Export Taxation: Revisiting the Adverse Effects of Noncooperative Aspect of Trade Policies

8

Antoine Bouët and David Laborde Debucquet

8.1 Introduction

Export restrictions are a common practice in the current world trading system. For instance, some developing countries implemented export taxes and export restrictions during the recent food crisis (2006–2008). But beyond crisis periods, export restrictions are, in fact, trade measures that are permanently adopted by some countries: export taxes implemented by Indonesia on palm oil; by Madagascar on vanilla, coffee, pepper, and cloves; by Pakistan on raw cotton; by the Philippines on copra and coconut oil; and by Argentina on crops and meat.

At a first glance, from a mercantilist point of view, it might be difficult to understand why countries implement so many export restrictions. Indeed, policymakers tend to favor exports and discourage imports. However, a more thorough analysis revealed several justifications.

In this chapter, we consider these justifications and study how export taxation may worsen a food crisis. It is important to keep in mind that reducing import duties may also amplify food crisis and that these policy options form the basis of an asymmetric game.

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We also focus on institutional aspects and, in particular, why export taxes can be so easily raised. It appears that countries have a considerably large degree of freedom when implementing such taxes as the WTO does not prohibit export taxes and other forms of export restrictions. As stated by Crosby (2008), "general WTO rules do not discipline Members' application of export taxes," but "they can agree—and several recently acceded countries, including China, have agreed—to legally binding commitments in this regard." The Uruguay Round Agreement on Agriculture only stipulates that, when implementing a new export restriction, a WTO member must (1) consider the implications of these policies on food security in importing countries, (2) give notice to the Committee on Agriculture, and (3) consult with WTO members that have an interest. The agreement does not institute any penalty for countries ignoring the rules. Restrictive export policies do not receive much attention from the public or the academic establishment.

Section 8.2 provides the various justifications for export restrictions. Section 8.3 investigates the role of export taxes in worsening a food crisis. Section 8.4 focuses on the limited institutional role of WTO in the topic of restrictive export policies. Section 8.5 concludes this chapter.

8.2 Why Do Countries Implement Export Restrictions?

Before discussing the policy justifications for export restrictions, it is noteworthy that, from a theoretical point of view, export taxes and export quotas are equivalent: quotas could raise revenue if quota allocations are not issued for free but auctioned under competitive conditions. However, in the real world, export licenses are given to domestic producers and do not generate public revenue. Therefore, export taxes and export quotas are not equivalent in the real world.[1]

The first justification is the terms-of-trade argument and the desire to increase export prices. This is perhaps the most important justification from a theoretical point of view. By restricting its exports, a country that supplies a significant share of a commodity to the world market may raise the world price of that commodity. This implies an improvement in that country's terms of trade. The reasoning behind this argument is very similar to the optimum tariff argument, which states that, by implementing a tariff on its imports, a "large" country can significantly decrease the demand for a commodity that it imports; this therefore leads to a decrease in the commodity's world price, which is again an improvement in the terms of trade (Bickerdike 1906; Johnson 1953).

When considering the final consumption of food products, the second justification is food security: export taxes reduce domestic prices. When considering a food product which is an important commodity in a country's national consumption

[1]Let us mention that export quota and export taxes are also not equivalent under retaliation, that is to say if implemented during a trade war between large countries (see Rodriguez 1974; Tower 1975).

structure and is also exported, by imposing an export tax, a government creates a wedge between the world price and the country's domestic price. This can lower the final domestic consumption price by reorienting domestic supply toward the domestic market. Piermartini (2004) cited the Indonesian government as an example. The Indonesian government frequently imposes export taxes on palm oil products, in particular on palm cooking oil, as it considers cooking oil an "essential commodity" for local households. This rationale was often used by governments during the food crisis of 2006–2008 to justify implementing export taxes and other forms of export restrictions. Some examples of which are as follows: Bangladesh, Brazil, Cambodia, China, Egypt, and India implemented restrictive policies on rice and Argentina, India, and Kazakhstan on wheat. Export restrictions are anticyclical trade policy instruments: when international prices are high, local consumers are hurt by high domestic prices; implementing export restrictions decreases local prices but contributes to the rise of international prices.

The third justification takes into account the existence of intermediate consumers (firms) of the taxed products in a country. If a raw commodity is exported and is also used by the local processing industry, imposing export taxes on this primary commodity indirectly subsidizes the local processing industry by lowering the domestic price of inputs compared to the commodity's world price, which is nondistorted. It has the same mechanism as the previous reason: export taxation gives local producers more incentive to sell their product domestically. For example, in Indonesia, an export tax on lumber promoted the development of the domestic wood-processing industry; the development was judged to be excessive for environmental reasons as it contributed to the depletion of forests (World Bank 1998). In 1988, Pakistan imposed an export tax on raw cotton in order to stimulate the development of the yarn cotton industry. Export taxes on palm oil are imposed in Indonesia and Malaysia to support the development of downstream industries (biodiesel and cooking oil; see Amiruddin 2003). According to this line of reasoning, export taxes may also be applied to a whole value chain by decreasing the level of taxation along the value chain. This is called differential export tax (DET) rates: the policy of imposing high export taxes on raw commodities and low export taxes on processed goods. This policy generates public revenues and promotes production at the later stages of a value chain. Bouët et al. (2014) studied the theoretical justification of this trade policy, and then they developed a partial equilibrium model of the global oilseed value chain and simulated the total elimination of DETs in Argentina and Indonesia and the independent removal of export taxes at various stages of production in the two countries. Their estimations showed that removing export taxes along the entire value chain in Argentina and Indonesia reduced the local biofuel production; they also point out that the DETs were implemented to raise public revenues.

The fourth justification is also a "raison d'être" for export taxes. Export taxes provide a source of revenue to developing countries that have limited capacity to rely on domestic taxation. This is a second-best argument because the imposition of lump-sum taxes is a first-best policy (Ramsey 1927; Diamond 1975). It is noteworthy that only export taxes (and not export quotas) serve this objective.

As with all trade policy, export taxes may serve the purpose of redistributing income. This is the fifth justification of this policy instrument combining different aspects from the three previous arguments. Like import tariffs, export taxes are measures that imply distribution of income. Here, this is detrimental to domestic producers of the taxed commodity but benefits domestic consumers and public revenues.

So we arrive at the first conclusion: export taxes are attractive policy instruments since they may serve different positive purposes for a government.

This is the reason why export taxes are relatively common in the current global trading system. Some studies have estimated their importance. Laborde et al. (2013) used a new detailed global data set on export taxes at the HS6 level and the MIRAGE global CGE model to assess the impact of export taxes on the world economy. They found that the average export tax on global merchandise trade was 0.48 % in 2007, with the bulk of these taxes imposed on energy products. Moreover, the removal of these taxes would increase global welfare by 0.23 %, a larger figure than the gains projected by the Doha Round. Both developed and emerging economies, such as China and India, would gain from removing export taxes. Medium and small food-importing countries without market power (such as the least-developed countries) would also benefit from the elimination of export restrictions. The export taxes implemented by the countries in the Commonwealth of Independent States on their energy sector appear to play a critical role in the overall economic impact of the removal of these taxes. However, some countries, such as Argentina, would experience income losses.

In the next section, we focus on using food security as a justification for export taxation. We show how implementing this policy instrument is a noncooperative trade policy when food prices are high. During a food crisis, governments of food-exporting countries are tempted to alleviate high food prices by restricting exports to encourage local producers to sell food items domestically and decrease local prices. But in doing so, these countries decrease the food supply on the world markets, causing world food prices to increase. This worsens the food crisis and is typically a "beggar-thy-neighbor" policy.

But in times of food crisis, restricting exports is not the only noncooperative trade policy. Food-importing countries are, at the same time, tempted to decrease domestic food prices by decreasing import duties. In doing so, they increase their national demand on the world market, reinforcing the upward pressure on world food prices. This is another noncooperative aspect of trade policies in periods of food crisis.

The combination of export taxes and reduced import duties increases the upward pressure on world prices when food prices are high. On the contrary, when world agricultural prices are low, food-exporting countries may be tempted to decrease export taxes and food-importing countries to increase import duties. This increases food supply and reduces food demand on world markets and therefore once again increases the downward pressure on world prices. It may appear that trade policies make world markets structurally more volatile.

8.3 To What Extent Does Export Taxation Amplify Food Price Volatility?

Economic literature helps to explain why large food-exporting countries implement export taxes and large food-importing countries implement import duties. The first reason is terms of trade. Bouët and Laborde (2012) designed a general equilibrium model of international trade between four countries—two large (1 and 2) and two small (3 and 4)—which trade the two commodities A (agricultural commodity) and I (industrial good). Countries 1 and 4 have a comparative advantage in A, while countries 2 and 3 have a comparative advantage in I. Import duties on the industrial good are assumed to be bound at 0, which implies that countries 1 and 4 will not use this policy instrument.

Using this simple framework, it is easy to show that if governments' objective is to maximize real income (welfare), the Nash equilibrium is a combination of a positive import duty in country 2 (the large food-importing country) and a positive export tax in country 1 (the large food-exporting country), while free trade is the best policy for both small countries. The results point out that large countries may manipulate world prices by imposing import duties or export taxes, depending on their export status. This Nash equilibrium implies a reduction in world real income, but large countries may benefit by having augmented real income. It is important to note that an import duty in the large food-importing country tends to decrease the world price of the agricultural commodity, while an export tax in the large food-exporting country tends to increase it. If at the Nash equilibrium, the world price of this commodity is increased, the small food-importing country's real income is reduced, while the small food-exporting country's real income is augmented. This teaches us that (1) export taxes on agricultural commodity improves terms of trade of large food-exporting countries and (2) when combined with import duties in large food-importing countries, world trade is drastically reduced and world real income is hurt with no policy option for small countries.

Bouët and Laborde (2012) also showed that if a government's objective is to achieve stable domestic agricultural goods prices during a food crisis, the best response is to decrease import taxes for a large food-importing country and to increase export taxes for a large food-exporting country. Both policies increase the world price of agricultural goods, thereby hurting a small food-importing country while increasing a small food-exporting country's real income.

Consequently, a collective action problem emerges from this simple theoretical framework: in case of a food price spike, governments which are concerned with establishing domestic food security and stabilizing domestic food prices are tempted to reduce import duties on food items if they are food importers and to increase export taxes on food items if they are food exporters. Both policy reactions tend to reinforce the increase in food world prices. Martin and Anderson (2012) also pointed out this inefficiency. Gouel (2014) designed a simple stochastic partial equilibrium model and concluded that countercyclical trade policies are inefficient at the global level: these trade policies increase world prices when the prices are relatively high, while they reduce world prices when the prices are relatively low.[2]

How much these trade policies amplify world price spikes remains to be known. In the same paper, Bouët and Laborde (2012) used the MIRAGE model of the world economy to evaluate this point. The study uses the static version of MIRAGE under perfect competition with 27 regions and 25 sectors.[3] They simulated a demand shock which led to a 10 % increase of the world wheat price. In the first policy scenario, countries that are net wheat exporters implement export taxes such that the real domestic price of wheat is constant. This led to additional export taxes in the range of 16–25 %. This policy reaction also caused the world wheat price to increase by 16.8 % rather than 10 %. In the second scenario, countries that are net wheat importers implemented import taxes (import subsidies are forbidden) such that the real domestic wheat price remained constant (the domestic price is not constant if the strategic rigidity—i.e., no import subsidies—is binding). Import duties are decreased by between 13 and 30 % age points, and the world price of wheat increased by 12.6 %. If both policy reactions are allowed (increasing export taxes and reducing import duties without implementing import subsidies), additional export taxes between 19 and 50 % were implemented, and the world price of wheat increased by 20.6 %: implementing these trade policies caused the world price to more than double.

Concerning countries' national real income, net wheat exporters' economic welfare is positively affected by the initial shock and their policy response (increasing export taxes), while that of net wheat importers' welfare is negatively affected. The economic welfare of Argentina as well as those of Australia, Canada, and Ukraine significantly increased under all shocks, in particular under the shock that combines endogenous export taxes and import tariffs. On the other hand, net wheat importers, such as Egypt and Eastern Africa, are significantly hurt by these shocks in terms of real income.

This collective action problem necessitates an institutional response: the next section examines to what extent the WTO may provide a framework adapted to discipline these inefficient trade policies.

[2]In case of food glut on world markets, world prices are relatively low: in the model designed by Gouel (2014), import duties may be increased in the large food-importing country and export taxes may be decreased in the large food-exporting country since governments have also an objective of domestic price smoothing.

[3]The use of a dynamic version of MIRAGE could open the door for new analyses and new policy conclusions. In the long term, export restrictions diminish sector profitability and, as such, may decrease investment in these sectors. This means less supply in following periods of time with a potentially higher risk of increased domestic price which could lead local governments to implement new export restrictions. This increases the long-term cost of these policies with the extreme situation where a net-exporting country turns into a net-importing country.

8.4 Can Export Restrictions Be Disciplined in the WTO Framework?

There is a clear trade-off between import duties and export taxes with a double asymmetry. First, in times of food crisis, export taxes are raised while import duties are reduced. Second, while increasing export taxes is clearly identified as a noncooperative policy, it is much more difficult to criticize a country when it reduces its import duties. However, both policy reactions have the same impact on world prices, and both policies hurt poor food-importing countries. While reducing import duties cannot be opposed from an institutional point of view, the policy reaction may be considered as a "beggar-thy-neighbor" policy when analyzed from an economic perspective.

The literature clearly reflects this dilemma. While Martin and Anderson (2012) and Bouët and Laborde (2012) underlined that reducing import duties also affects world price variability, Josling (2014) noted that "such impact … [is] … likely minor compared to the positive benefits for domestic consumers. Exporters … [are] also benefiting from the reduction in protection levels and it would therefore not … [make] sense to develop rules that … [inhibit] countries from making increased use of imports when domestic prices are high" (Josling 2014, p. 6). On the contrary, Gouel (2014) concluded that "export restrictions do not play a more important role … [in recent food price spikes] than tariffs. … they both contribute to shift volatility to partners' markets" (Gouel 2014, p. 18).[4]

While the WTO gives its members total freedom to decrease import duties (even import subsidies are tolerated), the institution forbids the implementation of quantitative export restrictions (Article X1:1). However, international law makes an exception for temporary export quotas in times of critical shortages of food items (Article XI:2). Export taxes are not prohibited, but the WTO requires its members to consider how their export taxes will affect their trading partners and to notify when implementing export taxes.

Anania (2014) considered that the provisions concerning export restrictions, which was included in the agricultural "modalities" issued in December 2008, reflected a broad agreement on this issue and are not ambitious. He proposed modifying Article XI.2 by limiting the export prohibitions and restrictions which are allowed under Article XI to a certain time frame. He wrote: "Existing export prohibitions and restrictions in foodstuffs and feeds under Article XI.2 (a) of GATT 1994 shall be eliminated by the end of the first year of implementation" and "any new export prohibitions or restrictions under Article XI.2 (a) of GATT 1994 should not normally be longer than 12 months, and shall only be longer than 18 months with the agreement of the affected importing Members." He also highlighted the need to

[4]However, Gouel (2014) also concludes that export restrictions may be more damaging in the real world because of the asymmetry of world price distribution (commodity prices are positively skewed).

strengthen the consultation and notification procedures so that they are performed within 90 days of introducing a new restrictive export measure.

Anania (2014) recommended two options, which he deemed realistic and can potentially be included in a low-ambition Doha Agreement. First, as proposed by many other observers, the commitment to shelter noncommercial interventions from export restrictions made by the G20 at the 2011 Cannes Summit[5] needs to be transformed into a legal commitment at the WTO. Unfortunately, at the 2011 WTO Ministerial Conference in Geneva, the proposal[6] to adopt this approach at a multilateral level was opposed by key countries including Argentina, Brazil, China, India, and South Africa[7], which are all G20 members. And without a consensus, the proposal was not adopted. Even though it is not legally binding, a statement made during a Ministerial Conference would have been the first step toward the inclusion of this basic requirement in the final Doha package—avoiding export restrictions because they adversely affect food aid. Indeed, food purchases by international organizations concern mainly key staple products and a few processed products for emergency reasons.[8] They represent a limited amount of total worldwide traded quantities of these food items. Second, making existing disciplines enforceable essentially involves clarifying the definition of the conditions under which export quantitative restrictions are allowed. The exact wording of Article XI is imprecise: "temporarily applied to prevent or relieve critical shortages of foodstuffs or other products essential to the exporting contracting party" (Article XI:2a of GATT 1994). In particular, the words "temporarily" and "critical" need to be clearly defined. However bringing discipline into the area of export restrictions is a complex issue.

Cardwell and Kerr (2014) adopted a pessimistic view on this issue. They opined that any disciplinary measures to deal with export taxes would neither be effective nor have any deterrent effects. Trade disputes, including export restrictions, occur over a different time frame than the other disputes. Any disputes arising from export restrictions during a period of high food prices are unlikely to be resolved before the prohibited restriction is lifted. Moreover, the authors also believed that retaliatory

[5]"According to the Action Plan, we agree to remove food export restrictions or extraordinary taxes for food purchased for noncommercial humanitarian purposes by the World Food Program and agree not to impose them in the future." G20 Cannes Summit, 3–4 November 2011. This commitment was based on the G20 Action Plan defined on 23 June 2011 and was based on Recommendation #5 from the international organizations report for the G20 on "Price volatility in food and agricultural markets: policy responses." Available at http://www.amis-outlook.org/fileadmin/templates/AMIS/documents/Interagency_Report_to_the_G20_on_Food_Price_Volatility.pdf.

[6]The proposal was supported by Australia, Canada, Chile, Costa Rica, the European Union, Korea, Indonesia, Japan, Mexico, Norway, Saudi Arabia, Singapore, Switzerland, and Turkey.

[7]See Bridges, Volume 15-number 37. Available at http://ictsd.org/i/news/bridgesweekly/117348.

[8]For instance, the World Food Program, in 2013, procured mainly rice, maize, wheat, wheat flour, pulses, vegetable oil, sorghum, maize meal, sugar, and blended food. The latter includes pasta, high-energy biscuits, emergency rations, and ready-to-use supplementary foods (breast milk supplement)(see http://documents.wfp.org/stellent/groups/public/documents/communications/wfp264134.pdf).

measures are difficult to design; retaliation for an export restriction in a particular sector should be carried out in another sector, and the retaliation should amount to the same value as the lost exports. This is likely difficult to implement when there is great disparity between the countries concerned, such as in the case of trade between poor net food-importing countries and countries having imposed export restrictions.

8.5 Concluding Remarks: Looking for a Solution

As discussed in Sect. 8.2, export restrictions play an important role in increasing price volatility and magnifying the impact of natural weather variability on agricultural markets. It greatly contributes to policy uncertainty and therefore undermines private investments in domestic agricultural supply, and in trade-related infrastructure and network. The binding process of import tariffs at the WTO was particularly aimed at reducing this policy instability, creating a more secure environment for the private sector and fostering investments. At the same time, it limits the possibility of a retaliation and prevents noncooperative outcomes and the so-called trade wars from emerging.[9] However, the current system is quite asymmetric at the WTO, as mentioned in Sect. 8.3, while import restrictions are severely dealt with by a set of disciplinary measures, export restrictions do not face the same constraints. On the import side, a clear framework is provided by the binding of tariffs (100 % in agriculture); tariffication and elimination of quantitative import restrictions (GATT article XI), exceptional conditions notwithstanding; and stringent rules framing the use of contingent protection (antidumping duties in GATT article 6, safeguards GATT article 19, etc.). On the export side, only quantitative export restrictions are currently disciplined, and the policy space to use them remains large, especially for food products. Because supplier countries do not face similar disciplines, this asymmetry undermines the pursuit of global integration of agricultural markets, and it strengthens the arguments of countries that do not want to reduce their tariffs and increase their reliance on world markets. Indeed, the current framework provides an unbalanced distribution of risks between importers and exporters, and it also lets suppliers increase their market power. It could potentially even have worse consequences: the overall price instability and the asymmetry in disciplinary measures could lead to the relaxation of disciplinary actions against contingent

[9] In fact, applying the game theory to trade policy leads to the conclusion that to facilitate the emergence of cooperation, there is a choice of either institutionalizing a discipline that forbids noncooperation (a world institution that forbids countries to implement beggar-thy-neighbor trade policies) or allowing countries to use retaliatory measures to prevent other countries from being noncooperative. The threat of retaliation is viewed as a powerful means of encouraging cooperation (see Axelrod 1981; Bouët 1992). The reality of the trading system today lies somewhere between these two options since the WTO forbids the use of some policy instruments (import duties) but authorizes the use of others (export restrictions). Moreover, a global institution is necessary since trading partners differ in size and capacity to hurt other countries.

import measures, as with the special safeguard mechanism introduced by the G-33, instead of strengthening regulations on contingent export restrictions.

In this context, it is important to discuss potential solutions by means of new WTO regulations or experimenting with new concepts found in some bilateral agreements. Indeed, the elimination of export restrictions can be seen as a first-best solution, but domestic political economy will make it unrealistic to attain such outcome in the short run, especially for countries with weak institutions. This is because these countries will need time to reform their tax system to replace export taxes by production taxes.

If not at the multilateral level, a solution may be reached at least on a plurilateral basis.[10] Looking at recent bilateral agreements reveals that some of these features are already included in both North–North and North–South deals. As an example of a North–North deal, the Comprehensive Trade and Economic Agreement (CETA) between the EU and Canada states its position on restrictive trade policies in certain terms; Article 7 of the agreement eliminates duties and taxes on exports: "Neither Party may maintain or institute any duties, taxes or other fees and charges imposed on, or in connection with, the exportation of goods to the other Party, or any internal taxes or fees and charges on goods exported to the other Party, that are in excess of those that would be imposed on those goods when destined for internal sale." The Dominican Republic–Central America Free Trade Agreement (CAFTA-DR) is a free trade agreement between the USA, five Central American countries, and the Dominican Republic. The agreement's key principle is to bind existing measures, granting them a "grandfathering" clause, and ban new export taxes (export bans are still subject to Article XI of the GATT); Article 3.8 of the agreement states: "[. . .]no Party may adopt or maintain any prohibition or restriction on [. . .] the exportation or sale for export of any good destined for the territory of another Party, except in accordance with Article XI of the GATT 1994." Article 3.11 indicates clearly that discriminatory practices are banned: "Export Taxes Except as provided in Annex 3.11, no Party may adopt or maintain any duty, tax, or other charge on the export of any good to the territory of another Party, unless such duty, tax, or charge is adopted or maintained on any such good: (a) when exported to the territories of all other Parties; and (b) when destined for domestic consumption."

The Economic Partnership Agreement, negotiated between the EU and some members of the Southern African Development Community (2015), also expresses its position in firm language while still maintaining some flexibility for the less-advanced economies. Article 26.1 follows the binding approach: "No new customs duties or taxes imposed on or in connection with the exportation of goods shall be introduced, nor shall those already applied be increased, in the trade between the

[10]If a plurilateral approach on all commodities is not achievable, a commodity-by-commodity approach following the sectoral initiatives could be considered. The main limit is that for most of the key staple commodities, one of the major exporters is very defensive regarding export taxes regulations (e.g., Russia, Argentina, and India on wheat).

Parties from the date of entry into force of this Agreement, except as otherwise provided for in this Article." Article 26:2 recognizes that "In exceptional circumstances, [. . .] where essential for the prevention or relief of critical general or local shortages of foodstuffs or other products essential to ensure food security Botswana, Lesotho, Namibia, Mozambique and Swaziland may introduce, after consultation with the EU, temporary customs duties or taxes imposed on or in connection with the exportation of goods, on a limited number of additional products." So, in this agreement, the largest economies (South Africa, the EU) have strong commitments to fulfill, while the others benefit from a special and differentiated treatment. Sections 6–10 of Article 26 provide an interesting framework for how to prevent products exempted from export taxes from being reexported to third parties on a bilateral basis.

So, what can be done, especially in the context of restricting contingent, short-term export restrictions? As previously discussed, humanitarian interventions should be shielded from these measures in any basic WTO decisions, but attempts to change international laws have faced strong opposition. In this context, the first basic step is to enforce a strong monitoring and notifications process,[11] aimed at reducing asymmetry of information. To keep both private and public agents informed, there are ongoing efforts to create agricultural market information systems aimed at providing updated policy changes for key agricultural commodities not only at the WTO but also at the G20, with its AMIS initiative.[12] However, the lack of automatic sanctions when countries fail to notify, which is a larger issue facing the WTO than export restrictions, is still a major problem. The second step is to develop a system that focuses on protecting small and vulnerable economies (SVEs). SVEs are generally more open and have lower income, poorer consumers, and no capacity to retaliate. Also, their demand, even when aggregated, cannot be considered as a major driver of global price increase. To ensure healthy global trade, protecting these countries and limiting negative externalities coming from other larger countries should be prioritized.

A natural way to address this issue is the "reversed" tariff quota approach. For normal import levels (e.g., the average bilateral import volume in the last 3 years), SVEs should be able to import food products without quantitative restrictions and additional export taxes. This would guarantee normal market access conditions even when world market turmoil causes major traders to change their policies. Beyond the "historical" level of imports, exporters would be free to apply short-term restrictions.

[11] This issue was emphasized in the WTO agricultural committee meeting on 21 June 2011: "These require the restricting country to take into account the impact on importing countries' food security, to notify the WTO as soon as possible, and as far in advance as possible, to be prepared to discuss the restriction with importing countries and to supply them with detailed information when asked for it."

[12] http://www.amis-outlook.org/home/en/

Another solution is to replace rigid legislation by a price mechanism and to apply a Pigouvian tax on the negative externalities of short-term surges in export restrictions. When a country, at least a G20 country, implements a new export restriction on food products, it would have to pay a fee. If more sophisticated pricing rules can be developed, a first approximation could be the historical amount of taxes collected from goods imported by an SVE from this exporter. The automaticity of the payment is ensured by the effective revenue collected by the exporting countries[13] and will address the key problems of (1) a lengthy dispute settlement at the WTO and (2) the lack of retaliation capacity by the SVE. The income generated through collecting this fee could be directly channeled toward helping SVEs pay their surging food import bills and fund their emergency safety nets. Alternatively, the income could also be used to provide the World Food Program with extra resources so that the program can cope with an increase in world food prices and develop targeted interventions. Similarly, a market for authorizing quantitative restrictions (like the "permits to pollute") can allow exporters to restrict their export quantities, while SVEs would have "importing rights" calculated based on historical import levels and could sell these licenses to exporters, thereby generating income to cover their import bills. These different measures are designed to provide an international insurance mechanism against harmful policies by reducing incentives to implement them (additional costs to exporters) and providing remedies for the most vulnerable countries.

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Part III

Commodity and Financial Market Linkages

9 Directional Volatility Spillovers Between Agricultural, Crude Oil, Real Estate, and Other Financial Markets

Stephanie-Carolin Grosche and Thomas Heckelei

9.1 Introduction

Portfolio diversification is a principal motive for financial commodity trading (Fortenbery and Hauser 1990). The fundamentals that drive the supply and demand of commodities largely differ from those of other financial assets, suggesting low or negative return correlations. And, like real estate, commodities can serve as an inflation hedge as their prices drive inflation, but holding commodities is not directly associated with inflation-threatened cash flows (Ankrim and Hensel 1993; Huang and Zhong 2013; Bodie and Rosansky 1980; Satyanarayan and Varangis 1996; Anson 1999; Gorton and Rouwenhorst 2006; Daskalaki and Skiadopoulos 2011).

The spread of electronic trading and the creation of commodity index-linked exchange-traded products (ETPs) or mutual funds have made commodity markets more accessible to financial portfolio managers (Conover et al. 2010; Daskalaki and Skiadopoulos 2011). Between 2002 and 2010, assets under the management of commodity ETPs grew from 0.1 billion to 45.7 billion US dollars (BlackRock 2011). Simultaneously, combined open interest for the Chicago Board of Trade (CBOT) corn, soybean, and wheat futures climbed from 0.7 million to 2.7 million contracts (CFTC 2013).

Attractive diversification benefits and facilitated inclusion in portfolios stimulated the use of agricultural commodities in both strategic and tactical portfolio management. While strategic portfolio management may maintain a fixed commodity share [e.g., 4–7 % according to Greer (2007)], tactical portfolio management continuously resets portfolio asset weights due to cross-market arbitrage (Büyükşahin et al. 2010) or as a response to shocks or extreme regimes in selected markets

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(cf. Conover et al. 2010; Jensen et al. 2002). Particularly during financial crises, portfolio managers may shift weights to comparatively less risky and more liquid refuge assets, a phenomenon known as “flight-to-quality” or “flight-to-liquidity” (Beber et al. 2007). Such use of commodities has been suggested, for example, by Silvennoinen and Thorp (2013) and Chong and Miffre (2010), who proposed a shift out of equity and bond markets and into commodities during crisis periods. Finally, the need to meet margin calls in distressed markets may affect weights of all other portfolio assets, if a broad range of assets needs to be sold to obtain liquidity (Büyükşahin et al. 2010).

By any of these channels, tactical portfolio allocation may create or intensify linkages between commodity and financial markets, especially during financial crises. It may also affect linkages between agricultural and energy markets as both commodity groups are included in indices such as the Standard and Poor’s (S&P) GSCI or the Dow Jones UBS (DJ UBS) Commodity index, which are replicated by index-linked products and funds. In any case, volatility, rather than returns, is the more interesting linkage due to its closer relation to information flows (Chiang and Wang 2011; Cheung and Ng 1996). Also, the development of ETP assets suggests a steadily emerging financial interest and motivates the search for a gradual change rather than a sudden structural break in market linkages.

In this chapter, we analyze time-varying short-term volatility spillovers between (1) commodity and financial markets and (2) agricultural and energy markets with rolling volatility spillover indices as introduced in Diebold and Yilmaz (2012) for the period from June 1998 to December 2013. The analyses are based on rolling generalized forecast error variance (FEV) decompositions in a vector autoregressive (VAR) model and allow us to calculate gradually changing directional volatility spillovers between any pair of included assets over the entire observation period. Volatility is measured as the daily range, based on the difference between high and low prices (Parkinson 1980).

Our analysis contributes to existing research in several aspects. First, we investigated the volatility linkages between agricultural commodities and financial assets, which remain scarcely researched. Second, we included a broad market network rather than conducting a bivariate analysis, thereby specifically taking into account the potential substitution between commodity and real estate as a result of the subprime crisis and the aforementioned parallel characteristics between the two asset classes. This also aids the investigation of agriculture-energy linkages as commodity markets are part of the global financial market network; any bivariate relation may thus be affected by the state of third markets. Finally, we do not impose any structural breakpoints; our analysis also goes beyond comparing the selected periods (e.g., before and after the recent financial crisis or before and after the introduction of biofuel mandates), also examining the gradual structural changes.

The remainder of the chapter is structured as follows: The next section focuses on existing empirical evidence on commodity-financial and agricultural-energy linkages, which is followed by a brief description of the methodology. Subsequently, we present and discuss our modeling results and compare them to previous studies. The final section concludes the analysis.

9.2 Previous Empirical Results on Market Linkages

Agriculture-energy market linkages via the use of crops in biofuel production or the use of energy as an agricultural production input are frequently researched. In comparison, research on commodity-financial market linkages is scarce and only recently gaining momentum (Chan et al. 2011).

9.2.1 Agricultural-Energy Market Linkages

We reviewed recent empirical studies which focused on volatility linkages and which covered at least part of the time period after the subprime crisis.[1] The studies typically split their data sample at around either 2006, due to a hypothesized structural change in market linkages after the introduction of biofuel mandates, or 2008, reflecting the potential effects of the financial and food price crises. Most studies used daily data, while Gardebroek and Hernandez (2012) and Du et al. (2011) used weekly data.

To investigate volatility dependencies, Nazlioglu et al. (2013) and Harri and Hudson (2009) conducted Granger causality in variance tests (cf. Cheung and Ng 1996). Nazlioglu et al. (2013) found no linkages between the volatility of daily energy and agricultural spot prices before 2005. The only exception is wheat, which Granger causes the variance of crude oil in that period. Likewise, Harri and Hudson (2009) did not detect any linkages between the volatility of daily corn and crude oil futures prices in the period before 2006. For the period after 2006, Nazlioglu et al. (2013) found volatility spillovers from crude oil to corn and bidirectional spillovers between crude oil and soybeans and between crude oil and wheat. Harri and Hudson (2009) only discovered Granger causality in mean, but not in variance, from crude oil to corn.

Du et al. (2011) used bivariate weekly stochastic volatility models to analyze corn, wheat, and crude oil futures returns for the period 1998–2009. They detected increasing volatility transmission from crude oil to both corn and wheat as well as volatility transmission between corn and wheat in the later subsample 2006–2009.

Several studies employed multivariate GARCH models. Gardebroek and Hernandez (2012) estimated both BEKK and DCC trivariate GARCH models for weekly US corn, crude oil, and ethanol spot prices for the period 1997–2011. There are some short-run volatility spillovers from corn to ethanol but no significant volatility spillovers in the other direction. Structural break tests and subsequent sample splits showed that volatility persistence is stronger in all markets after 2008. Trujillo-Barrera et al. (2011) estimated BECKK GARCH models with daily futures returns for US crude oil, ethanol, and corn for the period 2006–2011. Similar to Gardebroek and Hernandez (2012) they found that the volatility linkages between corn and ethanol increased after 2007, with significant volatility spillovers from corn to

[1]This remains a vibrant field of research. Any omissions are not deliberate.

ethanol but only modest spillovers from ethanol to corn. But they did find strong volatility spillovers from crude oil to both corn and ethanol markets. Ji and Fan (2012) and Chang and Su (2010) employed bivariate E-GARCH models. Chang and Su (2010) used daily returns to examine the relationships between crude oil, corn, and soybean futures during the period 2000–2008. Before 2004, there were no significant volatility spillovers from crude oil to either corn or soybeans; however, this changed in the 2004–2008 period. Ji and Fan (2012) used daily returns of crude oil futures and several Commodity Research Bureau (CRB) indices for the period 2006–2010 and introduced the US Dollar exchange rate as an exogenous shock. They found that volatility spillovers from crude oil to the CRB crop index decrease after the subprime crisis.

9.2.2 (Agricultural) Commodity-Financial Market Linkages

We reviewed recent empirical studies that (1) covered at least part of the period of the subprime crisis and (2) also considered corn, soybeans, wheat, or a relevant commodity index in their sample. Most studies focused on the relationships between selected US commodities and equity markets. Other financial asset classes, especially real estate, are underrepresented. In the past, the emphasis was on return linkages, but volatility dependencies are moving into focus.

Volatility relations are also mostly examined using multivariate GARCH models. Gao and Liu (2014) used bivariate regime switching GARCH models for analyzing the weekly relationships between the S&P 500 index and selected commodity indices from 1979 to 2010. The volatility linkages between the S&P 500 and both the grains and energy indices only slightly increase in the few brief periods whereby the assets shared a high volatility regime. But regime switches in the energy index appeared more closely related to equity volatility than those in the grains index. Mensi et al. (2013) estimated bivariate VAR-GARCH models for pairs of indices for the period 2000–2011; the pairs consisted of the S&P 500 and the following indices: daily wheat, beverage, gold, crude oil, and Brent oil price. Past volatility and unexpected volatility shocks to the S&P 500 have significant effects on oil, gold, and beverage markets, but not on wheat markets. For commodity-foreign exchange relations, Ji and Fan (2012) found that volatility spillovers from the US Dollar index to the CRB crop index were weaker after the subprime crisis than before it; Harri and Hudson (2009) observed Granger causality in mean but not in variance from the US Dollar exchange rate to corn futures prices in the periods before and after 2006.

Diebold and Yilmaz (2012) used their volatility spillover indices to investigate volatility linkages between the DJ UBS Commodity index and the following over the period 1999–2010: the S&P 500, US Treasuries, and the US Dollar index. They found a significant increase in linkages between the DJ UBS Commodity index and the other markets after the beginning of the subprime crisis. Volatility spillovers from the S&P 500 to the commodity index occurred throughout the crisis, while the commodity index volatility spilled over into US Treasuries and the US Dollar index during the middle of and the end of the last decade.

Multivariate GARCH models have also been used to investigate commodity-financial return linkages. Using a bivariate DCC GARCH model for the period 1991–2008, Büyükşahin et al. (2010) found that negative weekly conditional return correlations between (1) the Standard and Poor's Goldman Sachs Commodity Index (S&P GSCI), (2) its energy sub-index, and (3) the DJ UBS Commodity index and equities peaked during 2003–2004; the correlations also peaked to a lesser extent at the beginning of the subprime crisis. Correlations between the S&P 500 and the S&P GSCI agricultural index returns appeared unaffected by the crisis. Creti et al. (2013) used bivariate DCC GARCH models to examine the relationship between the daily S&P 500 returns and (1) 25 sampled commodity spot returns, and (2) the CRB index for the period 2001–2011. While they found that dynamic correlations decreased during the subprime crisis for most of the sampled commodities, return correlations between crude oil and the S&P 500 increase in times of increasing, and decrease in times of decreasing stock prices. In contrast, Silvennoinen and Thorp (2013), who used a bivariate DSTCC GARCH[2] model with weekly data between 1990 and 2009, showed that conditional weekly return correlations of equities and two commodities (corn and soybeans) increased in the period 2002–2003, while correlations of equities and two other commodities (wheat and crude oil) peaked in mid-2008. Commodity-bond relations remain relatively constant. Similarly, results from the DCC GARCH model in Huang and Zhong (2013) for the days between 1999 and 2010 and for the months between 1979 and 2010 showed that conditional correlations of the S&P GSCI and US bonds did not considerably increase during the subprime crisis. Yet, conditional rolling return correlations between the S&P GSCI and equities increased from negative to strongly positive. In addition, mean-variance spanning tests revealed that the S&P GSCI, Real Estate Investment Trusts (REITs) and US inflation-linked securities each offered unique portfolio diversification benefits, suggesting relatively weak market linkages. Finally, Bicchetti and Maystre (2013) examined rolling window bivariate intraday return correlations of equities and several commodities (corn, wheat, soybeans, and crude oil) for the period 1996–2011. The authors found an increase in correlations between all sampled commodities and equity returns after September 2008, which declined again in 2011 only in the case of crude oil.

Thus, there are some indications of increased volatility or return linkages between agricultural and energy markets, and between commodity and financial markets around 2006–2008. But, in the case of the agricultural-energy correlation, results are rather mixed. In the case of the commodity-financial correlation, the strongest effects appear to exist between US equities and crude oil. In both cases, the time-dependent dynamics and the direction of influence remain unclear. The majority of the studies focused on using multivariate GARCH models and therefore have to restrict their investigation to a bivariate or at maximum trivariate model.

[2]Dynamic Smooth Transitional Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity model.

9.3 Description of the Methodology and Data

Volatility spillover indices introduced by Diebold and Yilmaz (2009, 2012) allow a larger sample of asset markets to be included while permitting a time-dependent analysis of gradually changing volatility relations. Their computation requires externally calculating a volatility proxy variable, which is then used in the rolling VAR model estimation.

Given that there is no universally accepted best volatility measure (Engle and Gallo 2006), a choice has to be made based on informational content, interpretability, and statistical properties. We expect financial linkages between markets to mostly affect short-term volatility relations. Therefore, we used the range volatility proxy that was described in Parkinson (1980), which has also been shown to have superior statistical properties over the classical volatility proxy. The classical volatility proxy is calculated as the variance of daily returns, which may be associated with large, non-Gaussian measurement errors (cf. Parkinson 1980; Alizadeh et al. 2002; Chiang and Wang 2011). The range is calculated as:

$$\text{Range}_{it} = 0.361\left[\ln\left(\frac{\text{high}_{it}}{\text{low}_{it}}\right)\right]^2, \tag{9.1}$$

where high is the highest and low the lowest price observed on a trading day t.

9.3.1 Data

We use a sample of CBOT corn, soybeans and (soft red winter) wheat futures, New York Metal Exchange (NYMEX) WTI crude oil futures, the S&P 500 US equity index, the Dow Jones Equity all REIT index, CBOT 10-year US Treasury Note futures, and the Intercontinental Exchange (ICE) Futures US Dollar index. The REITs index consists of all US publicly traded companies within the Dow Jones stocks indices that are classified and taxed as equity REITs. The US Dollar Index is a geometrically averaged index of exchange rates of a basket of currencies against the US dollar; the basket comprises the euro, Japanese yen, British pound, Canadian dollar, Swedish krona, and Swiss franc.[3] Price and volume data were obtained from Bloomberg for trading days between 3 June 1998 and 31 December 2013.[4] Missing observations were replaced by a linear interpolation.[5] All futures prices are historical first generic price series, and expiring active futures contracts are rolled to the next deferred contract after the last trading day of the front month.[6]

[3] Weights are as follows: Euro: 57.7 %, Yen: 13.6 %, British Pound: 11.9 %, Canadian Dollar: 9.1 %, Swedish Krona: 4.2 %, Swiss Franc: 3.6 %.

[4] Data for the REIT index is not available prior to that period.

[5] Interpolation implemented with the MATLAB linear interpolation function.

[6] This corresponds to Bloomberg's "relative to expiration" rolling procedure.

9.3.2 Generalized Forecast Error Variance Decompositions

The FEV decompositions split the FEV of the range of each asset i included in a VAR model into shares stemming from own shocks and shares stemming from shocks to the range of another asset j. A VAR model with lag length p (VAR(p)) that consists of range observations for all assets is written as $y_t = A_0 + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \upsilon_t$, where y_t is a $N \times 1$ vector of range volatilities and N corresponds to the number of assets in the system. A_i is a fixed coefficient $N \times N$ matrix (including intercept terms), and u_t is a $N \times 1$ vector of white noise innovations, such that $E\left(u_t\right) = 0,\ E\left(u_t u_t{}'\right) = \Sigma$ and $E\left(u_t u_{t-s}\right) = 0$. The equivalent VAR(1) in matrix notation is given as $Y_t = c + AY_{t-1} + U_t$, where

$$Y_t = \begin{bmatrix} y_t \\ y_{t-1} \\ \vdots \\ y_{t-p+1} \end{bmatrix}; c = \begin{bmatrix} c \\ 0 \\ \vdots \\ 0 \end{bmatrix}; A = \begin{bmatrix} A_1 & A_2 & \ldots & A_{p-1} & A_p \\ I_N & 0 & \ldots & 0 & 0 \\ 0 & I_N & & 0 & 0 \\ \vdots & & \ddots & \vdots & \vdots \\ 0 & 0 & \ldots & I_N & 0 \end{bmatrix};\ U_t = \begin{bmatrix} u_t \\ 0 \\ \vdots \\ 0 \end{bmatrix}.$$

$$N \cdot p \times 1 \qquad N \cdot p \times 1 \qquad N \cdot p \times N \cdot p \qquad N \cdot p \times 1$$

The Moving Average (MA) representation of this process is $y_t = \mu + \sum_{h=0}^{\infty} \Phi_h u_{t-h}$ with $\Phi_h = JA^h J'$ and $J = [I_N : 0 : \ldots : 0]$, which is a $N \times N{\cdot}p$ selection matrix (Lütkepohl 2007, pp. 15ff.). The coefficient matrices Φ_h contain the impact multipliers of the system. Their element $\phi_{ij,h}$ describes the response of the ith asset range volatility to a shock in the jth asset range volatility, h periods ago. $\Phi_j(h)$ is the corresponding impulse response function.

The elements in u_t are correlated and estimation of the coefficient matrix Φ_h requires external coefficient restrictions. One possibility is to orthogonalize the shocks, e.g., via a Cholesky decomposition of the covariance matrix (Σ), such that the orthogonalized impulse response function traces the system's response to a *specific ceteris paribus shock* in the range of asset j over time. But this makes impulse responses sensitive to the variable ordering in the VAR model (Enders 2010, p. 309). As we investigate volatility interactions within a system of different asset markets, such an order is difficult to impose and introduces an unwanted element of subjectivity into the estimation.

Generalized impulse responses are an alternative restriction method developed by Koop et al. (1996) and extended by Pesaran and Shin (1998). The generalized impulse response function is computed as $\Phi_j^g(h) = \sigma_{jj}^{-\frac{1}{2}} \Phi_h \Sigma e_j$, where σ_{jj} is the variance of the error term in the equation for the jth range volatility and e_j is a $N \times 1$ selection vector containing 1 as its jth element and is 0 otherwise (Pesaran and Shin

1998). These impulse responses represent how the range of asset i responds to a shock in the range of asset j, taking into account the contemporaneous correlations contained in Σ (Pesaran and Pesaran 1997, p. 428). The impulse response function thus traces the system's response to a *typical composite shock* emanating from the range in asset j (Pesaran and Shin 1998). The responses are independent of variable ordering and are therefore more suitable for use in an analysis of our asset market system. Pesaran and Shin (1998) calculated generalized FEVs (θ_{ij}^{g}) as:

$$\theta_{ij}^{g}(h) = \frac{\sigma_{jj}^{-1} \sum_{l=0}^{h-1} \left(e_i' \Phi_l \Sigma e_j\right)^2}{\sum_{l=0}^{h-1} \left(e_i' \Phi_l \Sigma \Phi_l' e_i\right)}, \; i, \; j = 1, 2, \ldots, N \tag{9.2}$$

where the subscript l denotes the respective forecast period.[7] The correlated shocks lead to a non-diagonal Σ, and elements in the rows of the θ_{ij}^{g} matrix will not sum up to 1.

9.3.3 Volatility Spillover Indices

Time-varying volatility spillover indices require a rolling estimation of the VAR(p) model. A regression window of size w and T observations for the range volatilities will give a total of $T-w+1$ estimates for the θ_{ij}^{g} matrices. For a system of N assets, the elements off the main diagonal in the θ_{ij}^{g} matrices show the contributions of shocks to the range of assets $j = 1, \ldots, N$ to the h-step ahead FEV for the range of assets $i = 1, \ldots, N$, with $i \neq j$ and the diagonal elements denoting the contributions of own shocks. Analogous to the definitions as given by Diebold and Yilmaz (2012), a spillover is defined as the share of the contributions of shocks to the range of assets $j = 1, \ldots N$ in relation to the total FEV of the range of assets i with $i \neq j$. This constitutes the basis for the spillover index calculations.

First, the θ_{ij}^{g} matrices were normalized with the respective row sums such that the entries in each row sum up to 1.[8] Consequently, the total FEV across the range for all assets in the system is equal to N. The definitions and formulas to calculate the individual spillover indices according to Diebold and Yilmaz (2012) are presented in Table 9.1.

[7]The typographical error in Pesaran and Shin (1998, pp. 20 ff.), where σ_{ii} was used instead of σ_{jj}, as pointed out in Diebold and Yilmaz (2011, p. 6), has been corrected.

[8]As suggested in Diebold and Yilmaz (2012), it would also be possible to normalize with the column sums.

Table 9.1 Volatility spillover indices

Total spillover index (TOTAL)	
Sum of spillovers to the range across all asset classes in relation to the total FEV in the system	$\text{TOTAL}(h) = \frac{\sum_{i,j=1, i\neq j}^{N} \theta_{ij}^{g}(h)}{N} \times 100$
Directional spillover index from all other assets (FROM)	
Spillovers received by the range of asset i from the range of all other assets $j = 1, \ldots, N, j \neq i$, in relation to the total FEV in the system	$\text{FROM}_i(h) = \frac{\sum_{j=1, j\neq i}^{N} \theta_{ij}^{g}(h)}{N} \times 100$
Directional spillover index to all other assets (TO)	
Spillovers transmitted by the range of asset i to all other assets $j = 1, \ldots, N, j \neq i$, in relation to the total FEV in the system	$\text{TO}_i(h) = \frac{\sum_{j=1, j\neq i}^{N} \theta_{ji}^{g}(h)}{N} \times 100$
Net spillover index (NET)	
Spillovers transmitted by the range of asset i to the range of all other assets $j = 1, \ldots, N, j \neq i$ less spillovers received from the range of all other assets $j = 1, \ldots, N, j \neq i$, in relation to the total FEV in the system	$\text{NET}_i(h) = \text{TO}_i(h) - \text{FROM}_i(h)$
Net pairwise spillover index (PAIR)	
Spillovers transmitted by the range of asset i to the range of one specific asset $j, j \neq i$, less spillovers received from the range of this asset j, in relation to the total FEV	$\text{PAIR}_{ij}(h) = \left(\frac{\theta_{ji}^{g}(h) - \theta_{ij}^{g}(h)}{N}\right) \times 100$

9.4 Empirical Results

We calculated the assets' range volatilities (for detailed results, see Grosche and Heckelei 2014) and used them in the rolling VAR estimation, from which we computed the volatility spillover indices. We also discuss the results and relate the findings to the current literature.

9.4.1 Rolling VAR Estimation and Spillover Index Calculation

We used logged range volatilities and included a total of 3930 observations for each of the eight assets for a window length of 252 trading days. This reflects the volatility movements within one trading year and, at the same time, yields a sufficient number of observations to estimate the VAR. Lag length selection with the Schwartz Bayesian Criterion (SBC) yielded a VAR(5), and the FEV matrices were calculated for a forecast horizon of 10 days. The length of a forecast horizon depends on the underlying assumption regarding the time horizon of asset market

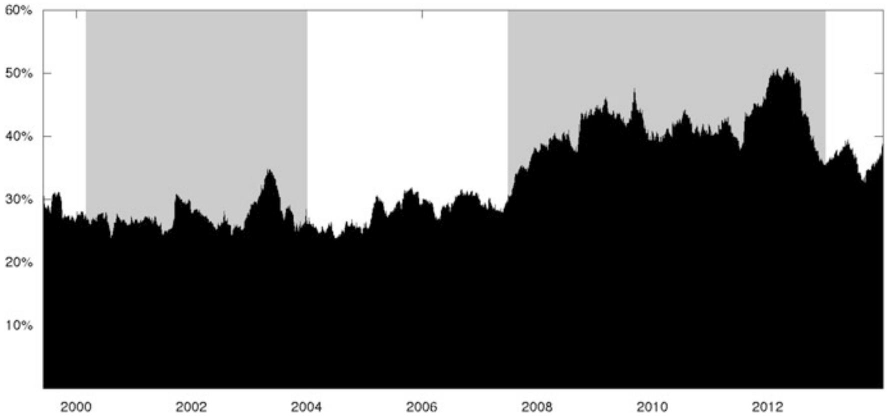

Fig. 9.1 Total volatility spillover index

linkages. A forecast horizon of 10 days is commonly used in calculating financial value at risk (Diebold and Yilmaz 2011). We obtained a total of 3679 observations for each spillover index, and the first observation corresponds to the end of the first regression window (2 June 1999). More details on the rolling VAR estimation, including verification of the robustness of the obtained results, are included in Grosche and Heckelei (2014).

Figure 9.1 shows the total volatility spillover index between 2 June 1999 and 31 December 2013. The areas shaded in gray mark the two major crisis periods of the last decade. The first period of crisis, between March 2000 and December 2003, was characterized by the burst of the dot.com bubble, the NASDAQ crash, and the overall downturn in equity markets. The real economy in the USA and the EU experienced low GDP growth rates. The events of September 11, 2001, and the wars in Afghanistan and Iraq led to political unrest. Agricultural commodity markets were influenced by (1) the continual efforts of the EU to reduce buffer stocks, (2) China's accession to the WTO in December 2001, and (3) growing US soybean exports.

The second period of crisis, between July 2007 and December 2012, started with the early events of the subprime crisis and transformed into a global liquidity crisis; it later evolved into a sovereign bond and state debt crisis. The US Federal Reserve Bank lowered interest rates 12 times successively between August 2007 and December 2008, and the real economy in the US and the EU was hit with low or even negative GDP growth rates. Agricultural commodity markets experienced further growth in soybean exports to China and were affected by the introduction of biofuel mandates in the EU and the USA. At the beginning of the period, the stock-to-use ratios for corn and wheat were at low levels of around 13 % and 18 % respectively, while the stock-to-use ratio for soybeans peaked at 21 % (USDA ERS 2012). Commodity ETP assets under management strongly increased from 6.3 billion US dollars in 2007 to 45.7 billion US dollars in 2010 (BlackRock 2011).

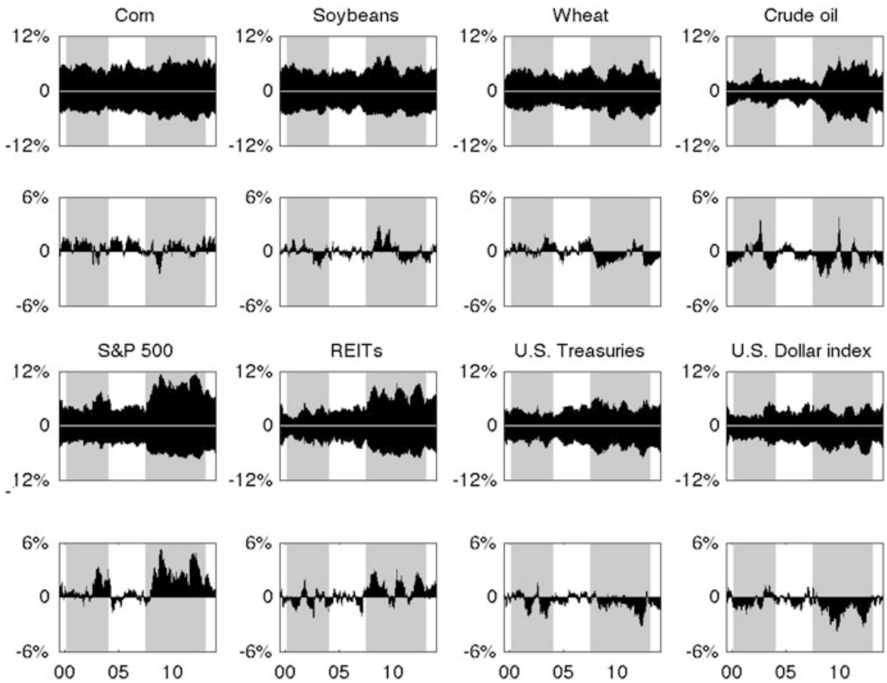

Fig. 9.2 Directional and net spillover indices. *Note*: The *upper graphs* in each pair show the spillovers from and to this asset compared to all other assets in the system. The *lower graphs* are the resulting net volatility spillover indices, where a *positive* (*negative*) value indicates that the asset is a net volatility transmitter (receiver)

Volatility spillovers were at much higher levels in the second period of crisis than the first. While there are two spikes in the first period of crisis (31 % in September 2001 and 35 % in April 2003), the average total spillover between 1 March 2000 and 31 December 2003 amounted to 26 %. In comparison, the average total spillover between 1 July 2007 and 31 December 2012 was 42 %. The index peaked at 51 % on 3 May 2012.

Directional spillovers and the resulting net spillover indices are depicted in Fig. 9.2. During the first crisis, neither of the commodity markets showed a distinct pattern and the indices moved almost horizontally into the tranquil interim period. Only crude oil and, to some extent, wheat futures have spiking directional volatility spillovers. Net spillovers from crude oil peaked at 3.4 % in August 2002, and net spillovers from wheat at 1.8 % in May 2003. In contrast, during the second crisis, volatility spillovers to and from the commodity markets were at higher levels; the net spillover patterns also differ from the previous periods. The changes in the magnitude of volatility spillovers to and from crude oil were, again, most pronounced. And, crude oil was mostly a net volatility receiver during most of the crisis period. Notable spillovers also occurred in wheat and soybean markets. The net volatility transmission from soybeans to other assets reached up to 2.9 % in September 2008. Wheat markets were net volatility receivers and peaked at 1.9 % in June 2008. Only corn market volatility spillovers appeared relatively unaffected by the crisis and showed only a slight increase in level.

Among the financial asset markets, the S&P 500 is the largest net volatility transmitter in the system, with visible increases in the period of crisis (up to 3.4 % in February 2003) and very pronounced peaks in the second crisis period (up to 5.3 % in November 2008). In contrast, the US Treasuries and the US Dollar index were both volatility receivers during the two periods of crisis. Again, the effect was more pronounced in the second crisis, whereby net spillovers to the US Treasuries reach up to 3.2 % in March 2012 and spillovers to the US Dollar index up to 3.7 % in October 2009. The REITs market showed the biggest change in volatility interaction between the two crisis periods. While the REITs market alternated between being a net volatility transmitter and being a net volatility receiver during the first crisis, it almost unexceptionally transmits volatility to of up to 3 % during the later crisis.

The pairwise spillover indices allow for the most detailed investigation of structural changes in volatility interaction between agricultural and energy commodities as well as between commodity and financial asset markets.[9] Figure 9.3 shows the pairwise indices for the agricultural commodities. Over most of the observation period, corn was transmitting volatility to the soybean market at a general magnitude of between 3 and 6 %. There was no marked difference between the first crisis and the interim tranquil period. But during the second crisis, the volatility spillover relationship was reversed. Between 2008 and 2010, soybean markets were transmitting volatility of up to 7.5 % to corn markets in September 2008. In parallel to this development, the volatility spillover relationship between soybeans and wheat also changed. Starting in 2008, soybeans became net transmitters of volatility to wheat, with a peak of 6 % in June 2009. Wheat was mostly a net volatility receiver from corn at a magnitude of up to 4.7 % in September 2002 and 6.5 % in January 2010. There were, however, exceptions occurring (1) towards the end of the first crisis, (2) shortly before the second crisis began, and, most importantly, (3) between 2010 and 2012, when wheat spillovers to corn reach up to 5.3 % in February 2011.

Figure 9.4 shows the indices for the agricultural-crude oil pairs. Corn was transmitting volatility to crude oil during most of the tranquil period, before the first crisis (up to 5 % in March 2000), and during the second crisis (up to 5.3 % in July 2009). This relation was reversed and crude oil transmitted volatility to corn in the following two periods: (1) between November 2001 and January 2003, during the first crisis, and (2) after February 2011, during the second crisis; spillovers reached up to 6.1 % in September 2002 (the first crisis) and 2.6 % in May 2011 (the second crisis). The soybean–crude oil volatility linkages almost perfectly mirrored this development. Soybeans mostly transmitted volatility to crude oil and received volatility of up to 5.2 % in July 2002, during the early crisis, and

[9] Pairwise indices for financial asset markets cannot be discussed in detail in this chapter, but are available from the authors upon request.

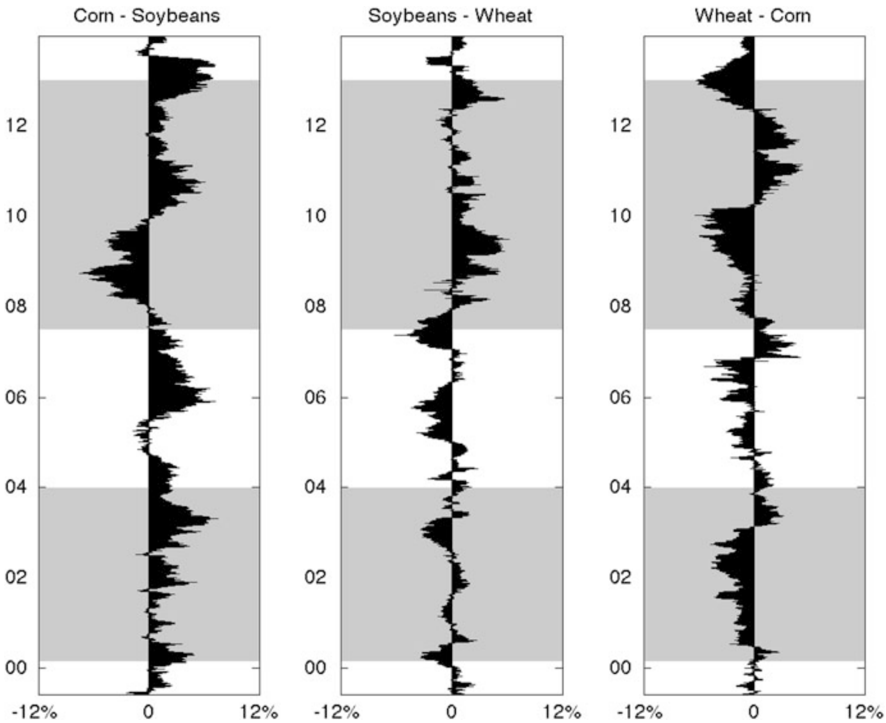

Fig. 9.3 Pairwise spillover indices: agricultural commodities

up to 4.5 % in May 2011, during the later crisis period. While wheat was also mostly transmitting volatility to rather than receiving volatility from crude oil, the magnitude of interaction between the markets' volatility is generally lower than in the case of corn and soybeans. But there was one notable spillover spike of up to 12 % in June 2003. And during the tranquil period, we observed some stronger spillovers from wheat to crude oil of up to 5.4 % in June 2006.

Figure 9.5 shows the pairwise indices for the commodities and the financial asset markets. During the early crisis, volatility from the S&P 500 predominantly spilled over into corn and wheat markets, with a high of 6.4 % in February 2003 for corn and 4.3 % in November 2002 for wheat. Soybean markets, in contrast, were mostly net transmitters of volatility to the S&P 500 during that period. While crude oil markets received some spillovers, they also transmitted volatility to the S&P 500 during November 2001 and October 2002, with a strong magnitude of up to 10.6 % in August 2002. But during and after the second crisis, there was a notable change in this volatility spillover relationship, both in direction and in magnitude. Crude oil mostly received volatility from the S&P 500, peaking at 10.8 % in December 2010. A less pronounced but nevertheless visible change occurred in corn and wheat markets, whereby net spillovers from the S&P 500 increased in magnitude around the time of the subprime crisis, with peaks of 5.3 % in October 2008 for corn and of

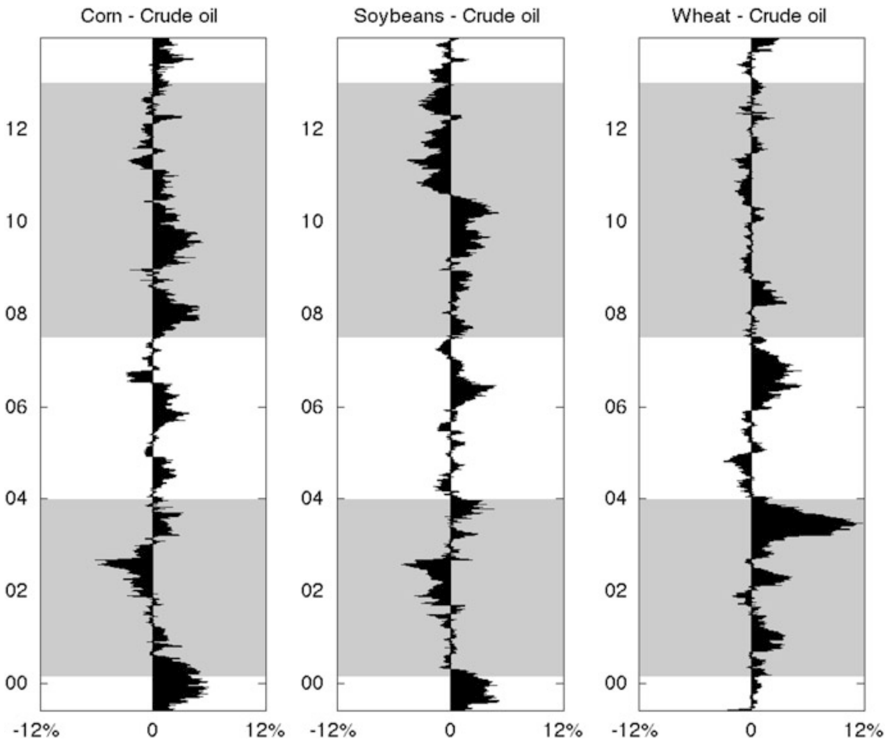

Fig. 9.4 Pairwise spillover indices: agriculture—crude oil

6.7 % in April 2008 for wheat. Soybean markets showed no change in the magnitude of spillover relationships, but in contrast to the crisis in the early 2000s, they became mostly net volatility receivers from the S&P 500.

While the REITs market was a net volatility transmitter to all commodities during parts of the first crisis, this tendency continued for most commodities (except soybeans) into the tranquil interim period. During the crisis, spillovers rose to 4.7 % in January 2003 for corn, 3.8 % in October 2001 for wheat, 4.7 % in January 2003 for soybeans, and 4.5 % in January 2002 for crude oil. For the agricultural commodities, there was no marked difference in spillover patterns during the later crisis. But, in parallel to the developments in the volatility relation with the S&P 500, crude oil started to receive markedly higher net spillovers from the REITs market of up to 9.3 % in February 2009. There was only a short period of reversed transmission between July 2009 and April 2010.

Net spillover between commodities and US Treasuries occurred bidirectionally during both the early crisis and the tranquil period. But there were some exceptions. Around December 2001, there was a period in which volatility of up to 7.2 % spilled over from soybean markets into Treasuries. In the second crisis, corn and wheat markets were almost exclusively net receivers of volatility from the US Treasury

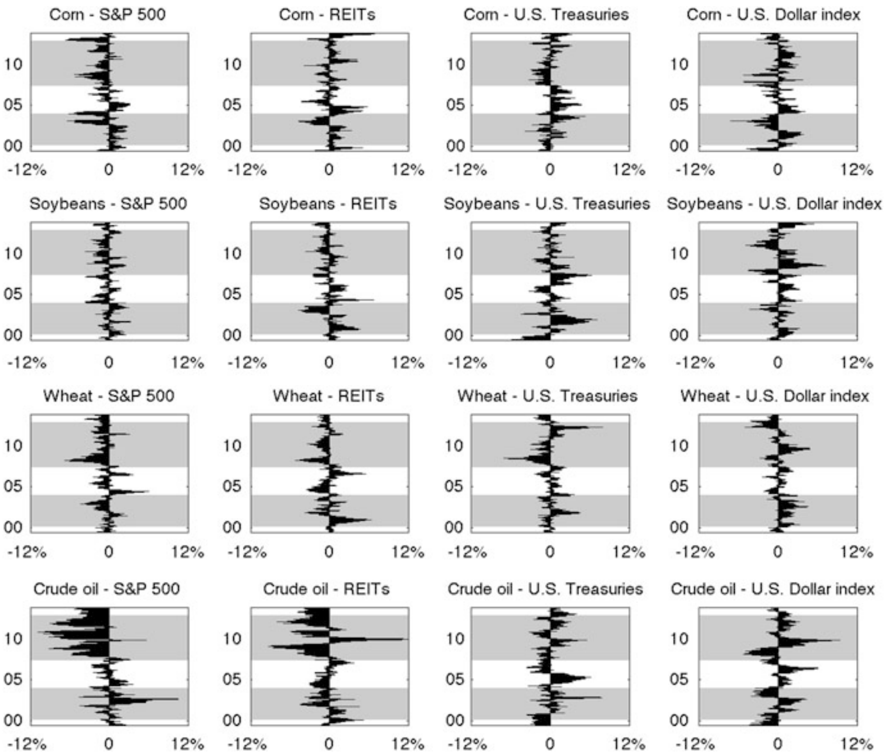

Fig. 9.5 Pairwise spillover indices: commodity—financial assets

(up to 3.2 % in March 2008 for corn and 7 % in July 2008 for wheat), while for soybeans and crude oil, the patterns were less distinct.

Towards the end of the first crisis, the US Dollar index transmitted volatility to the corn, soybean, and crude oil markets: up to 7.1 % in February 2003 (corn), 4.3 % in March 2003 (soybeans), and 4 % in December 2002 (crude oil), while during almost the entire crisis period wheat was a net volatility transmitter to the index with a peak of 4.6 % in August 2002. During the second crisis, however, soybeans, crude oil, and wheat markets transmitted net volatility to the US Dollar index: up to 7.2 % in August 2008 (soybeans), 4.9 % in September 2009 (wheat), and 9.4 % in December 2009 (crude oil), while the net volatility transmission of corn markets was lower and had a less clear direction.

9.4.2 Discussion of Results

The analysis of the above volatility spillover indices does not permit any direct causal attribution of single spillovers. Nevertheless, it is interesting to examine the results in the light of the political and economic developments on the markets and in relation to existing empirical findings about volatility linkages.

The total volatility spillover index shows a distinct increase in range volatility interdependence between the markets during the second period of crisis. While the levels of individual range volatilities were also high at the height of the subprime crisis, the total spillover index peaked only in May 2012, when the volatility levels of individual markets decreased again. In comparison, during the first crisis, there were only two smaller volatility spillover spikes despite high volatility levels in some markets. Thus, over the course of the subprime crisis, the movements of individual volatilities became increasingly synchronized with each other, and they also experienced significant parallel jumps. On the other hand, the period of increased volatility interdependence stretched beyond the period of individual volatility jumps, pointing to a generally higher degree of market interaction.

Directional and net volatility spillover indices showed that the S&P 500 was the strongest volatility transmitter among the assets during the financial crises. Thus, the drivers behind the S&P 500 range volatility would likely also influence the range volatility in other markets. The magnitude of spillovers to and from the other financial asset markets was much lower. Although REITs are also a component of the S&P 500, the stand-alone REITs spillover indices can better illustrate the volatility linkages during the subprime crisis, when REITs were strong net volatility transmitters and remained so until the end of the observation period. US Treasuries, in contrast, are traditionally refuge assets, towards which liquidity is shifted during general economic recessions and individual market crises (e.g., equity or real estate). This effect is visible on the spillover indices, whereby US Treasuries were net volatility receivers during both crisis periods. Unsurprisingly, net spillovers were especially high during the sovereign bond crisis at the end of the second crisis period. The US economy experienced an economic recession during both crisis periods, which affected demand for the US dollar. But the US dollar is also the most important currency for international monetary reserves. While the US Dollar index is a net volatility receiver during both crisis periods, the levels of spillovers increased in the second period, at a time when both the need to adjust monetary reserves and to allocate liquidity to comparably safer US Treasuries was high.

9.4.2.1 Agricultural: Energy Linkages

Corn appeared to be the strongest volatility transmitter among the agricultural commodities, with significant spillovers into both wheat and soybeans. This is plausible as (1) the USA is the world's largest producer of corn and a significant acreage area is allocated to growing corn, and (2) trading volumes of corn futures were much higher on the CBOT than of soybean and wheat futures. Therefore, information is most likely disseminated from corn markets to other affected futures markets rather than in the opposite direction. While seemingly unaffected by the early crisis, the corn–soybean relationship reversed between 2008 and 2010. During that time, soybeans also transmitted volatility to wheat. This effect could be related to China's surging demand for soybeans, which shocked the soybean market and also affected corn and wheat through substitution effects.

The pairwise agriculture-energy spillover indices show that the magnitude of spillovers between both corn and soybeans and crude oil is higher than for wheat. The level of spillovers did not considerably change after 2006; therefore, this effect cannot be clearly attributed to biofuel production. In fact, the spillover indices do not yield any convincing evidence that an increase in spillovers from the energy to relevant commodity markets was a result of the biofuel mandates. While there were some spillovers from crude oil markets to both corn and soybeans markets in the first crisis, between 2006 and 2010, both markets transmitted volatility to crude oil rather than receive it. Only soybeans experienced a clear reversal in that relationship after 2010.

These results are mostly in line with the findings of Gardebroek and Hernandez (2012), who, based on weekly conditional volatility over the period 1997–2011, did not discover evidence of energy volatility spilling over to corn price volatility. And while Ji and Fan (2012) did find significant linkages in the conditional daily volatility between crude oil and the crop index (which includes corn, wheat, soybeans, soft commodities, livestock, and cotton), they also found a decrease in spillovers during the subprime crisis. On the other hand, the results contradict the findings of, e.g., Nazlioglu et al. (2013), Du et al. (2011), and Chang and Su (2010). Using their respective models and volatility measures, they showed that volatility spillovers between crude oil and (1) corn, (2) wheat, and (3) soybeans increased after 2006. But Nazlioglu et al. (2013) also found bidirectional spillovers between (1) crude oil and soybeans and (2) crude oil and wheat after 2006, which is again closer to the results obtained from the spillover indices.

The extraordinary spike (up to 12 %) in the volatility spillovers from wheat into crude oil in June 2003 would merit a closer (causal) investigation. There could be some connection to the end of the UN Iraq oil-for-food program in 2003, which was used by the Iraqi government to secure wheat supplies in exchange for crude oil. It is interesting that Nazlioglu et al. (2013) also found Granger causality in variance from wheat to crude oil before 2005, but it could not be found after 2005.

Thus, there is little indication that short-term daily range volatility linkages in the corn, soybean, and wheat markets were affected by biofuel policies. This is in contradiction to some findings derived using the GARCH-type models. The contradictions could stem from the choice of sample splits and restricting sample size to two or three markets. In this chapter, the volatility spillovers were calculated for a more comprehensive system of asset markets; some of the apparent bivariate volatility spillovers may be absorbed by other markets. Also, structural breaks were not exogenously imposed. Instead, more gradual structural changes were permitted.

9.4.2.2 Commodity: Financial Linkages

The linkages between commodity and financial markets vary strongly depending on the commodity and financial asset class involved. In the first crisis, there were few instances of S&P 500 volatility spilling over to commodities, and the spillovers were low magnitude. However, there were some spillovers from crude oil *into* the S&P 500, which could be explained in terms of fundamentals with the wars in Afghanistan and Iraq. Our findings thus lend strength to the results of Diebold and Yilmaz (2012), who speculated that the range volatility spillover between DJ UBS Commodity index and the S&P 500 during that time were linked to the Iraq war. During and after the second crisis, however, all commodity markets were net S&P 500 spillover receivers. This is again similar to and an extension of the findings in Diebold and Yilmaz (2012) about the DJ UBS Commodity index. Our results generated from data on individual commodity markets allowed for further disaggregation of the spillovers and showed that most net spillovers reached the crude oil market. Yet, corn and wheat also received some transitory spiking net spillovers. All commodities, and especially crude oil, have strong fundamental and financial linkages with US equities because they are inputs in production and components of all important commodity indices, in which crude oil is generally given higher weights than corn, soybeans, or wheat. An increase in short-term range volatility linkages was observed during a time when both commodity index-linked products became more widespread and commodity trading volume increased. This provided evidence in favor of the hypothesis that the financial linkage factor became more important in the second crisis period.

Our results lend strength to the existing results about volatility linkages between the S&P 500 and commodities. Mensi et al. (2013) have shown that volatility shocks to the S&P 500 can significantly affect the oil market; the results of their study are also confirmed for range volatility spillovers. Gao and Liu (2014) found that correlations between energy and grains indices and the S&P 500 increase in periods of volatility, which is also in line with the results above. But, in their model, US energy indices and grains indices did not frequently share common volatility regimes with the S&P 500, and this led the authors to conclude that commodities remain an attractive portfolio diversifier. Yet, the spillover indices show stronger volatility relationships, especially between the S&P 500 and crude oil, which may in fact decrease diversification benefits. In addition, our results for spillovers complement the evidence of increased dynamic conditional return correlations between commodities and the S&P 500 during and after 2008 (e.g., Huang and Zhong 2013; Bicchetti and Maystre 2013; Büyükşahin et al. 2010). The observation made by Creti et al. (2013) that oil-S&P 500 return correlations increase with increasing stock prices could not be confirmed for daily range volatility spillovers (rather, it increase with decreasing stock prices).

The fundamental connection between REITs and commodity markets is much weaker than the connection between commodities and the S&P 500. Nevertheless, volatility spillovers from REITs into crude oil were high in the early 2000s and surged in the late 2000s crisis. This provides additional evidence in favor of the financial linkage hypothesis. But agricultural commodities appear to have much weaker linkages to REITs markets. Volatility spillovers between commodities and US REITs have barely been analyzed in the literature. Somewhat related to our results, Huang and Zhong (2013) showed that commodities and REITs (along with inflation-protected securities) each offer unique diversification benefits that tend to disappear during a financial crisis.

In contrast to the S&P 500 and REITs, the magnitude of range volatility spillovers between commodities and US Treasuries generally appears unaffected by either of the crisis periods. This confirms results of Huang and Zhong (2013), who also found that conditional correlations between the S&P GSCI and US Treasuries did not significantly increase during the subprime crisis. The net spillovers from the DJ UBS Commodity index to US Treasuries identified by Diebold and Yilmaz (2012) were further disaggregated in our model, and they appear to stem mostly from crude oil and soybeans as both wheat and corn markets are net receivers of volatility from US Treasuries during that period.

The US Dollar index receives net volatility spillovers from wheat, soybeans, and crude oil during both crisis periods. But spillovers increased in magnitude during the late 2000s crisis. This could be related to China importing more soybeans and crude oil and the associated changes in the demand for the US dollar. Another explanation is foreign activities on US commodity futures markets. The corn-US Dollar index relationship is less clear, and during the second crisis period, corn transmits less volatility to the US Dollar index than the other commodities. Linkages could have decreased following the drop in US corn exports. Corn was increasingly used for the domestic biofuel production in the USA. The findings of Diebold and Yilmaz (2012) about the spillovers between the DJ UBS Commodity index and the US Dollar index are substantiated for most individual commodities, and crude oil does not appear to be the main driver of the spillover. Ji and Fan (2012) found that volatility spillovers from the US Dollar index to the CRB crop index became weaker after the subprime crisis. When compared with the respective volatility spillover indices, their results only match the ones for corn but not that for soybeans or wheat.

9.5 Conclusions

This chapter has investigated directional time-varying range volatility spillovers using a new method developed by Diebold and Yilmaz (2009, 2012). The chapter focuses on short-term volatility interaction effects within a system which comprises agricultural products, crude oil, and selected financial asset markets over the period between 3 June 1998 and 31 December 2013. We especially emphasized the comparison between the two periods of financial and economic crises, whereby the later crisis period is also characterized by an increased use of commodities as financial investment.

During and after the subprime crisis, individual range volatilities moved increasingly in synchrony, with significant parallel jumps. Also, the total volatility spillover index shows stronger volatility interdependence. This suggests an overall higher degree of market interaction. The S&P 500 was the strongest net volatility transmitter in the system and spillovers peaked during the crisis periods. REITs net volatility transmission starts to rise only with the beginning of the subprime crisis.

The pairwise agriculture-energy volatility spillover indices do not provide significant evidence for an increase in spillovers from the energy to relevant commodity markets as a consequence of biofuel mandates. While this is in line with the findings of some previous studies, such as Gardebroek and Hernandez (2012), it stands in contrast to the results of other related studies. This discrepancy could be because (1) the index uses the full sample rolling approach instead of exogenously introducing structural breaks and (2) the system was extended to include financial assets that could have absorbed some of the volatility spillovers. Yet, our results do not permit the conclusion that biofuel mandates did not have any effects on the volatility (or return) relation between crude oil and biofuel crops. Due to the focus on short-term range volatility, we did not capture any longer-term structural changes arising from events such as reallocating land to be used for biofuel crops as a consequence of a high or volatile oil price.

The pairwise commodity-financial volatility spillover indices show that the volatility interaction between commodity and US Treasury markets appeared relatively unaffected by the crisis periods, but spillovers from commodities to the US Dollar index increased (except in the case of corn). Yet, the most profound shift in volatility interaction occurred between the S&P 500, US REITs, and commodity markets. Crude oil received high net spillovers from both financial asset markets during and after the second period of crisis. Agricultural commodities are less affected than crude oil, although there were some spikes in the spillovers into corn and wheat markets during the second crisis.

The volatility spillover patterns into and from commodities observed in the second period of crisis were more apparent than in the first crisis. While it is not possible to directly attribute causes to the discrepancy, the results do provide evidence in favor of the hypothesis that there were increased financial linkages between the markets. There are two important implications: First, shocks to financial asset markets, which have no direct fundamental connections to commodity markets, may increasingly affect short-term commodity market volatility. Second, if commodities find themselves increasingly being used as portfolio diversifiers and refuge assets, their diversification benefits may be reduced, especially in times of crisis.

Thus, future research should be directed towards investigating the underlying structural relationships behind the volatility linkages. And, as also suggested by Diebold and Yilmaz (2012), a theoretical and empirical comparison of the spillover indices with multivariate GARCH models could be useful. The focus should be put on the relationship between short-term conditional volatility and range volatility. A starting point could be the range volatility-based GARCH models such as the E-GARCH model used in Brandt and Jones (2006) and the conditional autoregressive range model used in Chiang and Wang (2011). In any case, the volatility spillover indices are a useful addition to the hitherto GARCH-centered analysis of volatility relationships. The indices should be further used to investigate alternative asset systems.

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10 A Roller Coaster Ride: An Empirical Investigation of the Main Drivers of Wheat Price

Bernardina Algieri

10.1 Introduction

In recent years, food commodity prices have increased at an unusually rapid pace, and wheat prices in particular have experienced marked upsurges, only briefly interrupted by the global financial crisis. These trends can be particularly detrimental because they could amplify the incidence of poverty (IMF 2011; von Braun and Tadesse 2012; Dethier and Effenberger 2012; Benson et al. 2013), hamper economic growth in poor countries (Jacks et al. 2011), and cause worldwide unrest, such as those documented in several sub-Saharan African regions. Unrest in these regions occur because people living there spend a larger share of their income on food (about 50 %) than urban residents in other parts of the world (about 30 % and 15 % in middle- and high-income countries, respectively) (Portillo and Zanna 2011). Given that Africans depend on a small number of staple crops, increases in cereal prices can be particularly destructive. Spending more consumer money on food means fewer purchases of services, such as sanitation, health, and education (The Economist 2011). In addition, the Middle East and North Africa regions are the world's largest importers of cereals, particularly wheat, making them more vulnerable to higher international cereal prices. This can lead to substantial terms-of-trade shocks, which affect countries' internal and external balances, with higher non-accelerating inflation rates of unemployment and balance of payments deficits.

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In this context, the present study tries to shed light on the main drivers of wheat prices by identifying the influence of the fundamental factors of supply and demand and the behavior of investors in the financial markets. In light of the steep hikes in the price of several commodities, it has become especially important to investigate the underlying factors that exert an influence on the wheat market.

Specifically, the study divides the drivers of wheat prices into market specific variables, broad macroeconomic variables, financial factors, and weather conditions. An empirical analysis was conducted based on monthly data for the period between January 1980 and January 2012 and the subperiod between January 1995 and January 2012. The quadrangulation of the drivers will allow us to better understand commodity price patterns.

The paper makes several contributions to the existing literature. It explicitly examines the case of the wheat market, merging different strands of the literature. Empirical analyses of the factors influencing wheat spot prices are quite scant (Borensztein and Reinhart 1994; Westcott and Hoffman 1999). Some studies about wheat are more descriptive in nature. For instance, Trostle (2008) and Mitchell (2008), after carrying out a graphical inspection, suggested that wheat prices increased due to a large demand for biofuels, high transportation costs, and a severe decline in global wheat supplies. Other analyses considered demand and supply factors while leaving out the role of financialization or other broad macroeconomic factors (Goodwin and Schroeder 1991; Westcott and Hoffman 1999). This study tries to extend the discussion about the wheat market by singling out specific factors behind price swings within a cointegration framework. Another novel contribution is the comparison of two long-run relationships—before and after the "financialization" of the commodity markets—to identify their similarities and differences. The last important element of this study is the ability to analyze price dynamics at a higher resolution through the use of monthly data. Most existing studies based their analysis on annual or quarterly data (Westcott and Hoffman 1999).

The rest of the chapter is organized as follows: Sect. 10.2 reviews literature about the key factors influencing commodity price; Sect. 10.3 introduces the variables of the model; Sect. 10.4 presents the VECM estimation and discusses the results; Sect. 10.5 concludes this chapter.

10.2 Literature Review

The roller-coaster ride experienced by commodity prices over the recent years has triggered a vivacious discussion regarding the causes of these fluctuations.

Some observers argued that the run-ups in commodity prices reflect strong changes in economic fundamentals, with price fluctuations moderated by the participation of nonuser speculators[1] and passive investors in commodity futures markets. Others pointed to the role of broader macroeconomic factors as the main drivers of rising prices. Finally, there are also other observers who argued that commodity prices have been exuberant and divorced from market fundamentals. The first view can be dubbed the "fundamentalist" view, the second the "broad" macro-view, and the third the "financialization" view.

According to the market "fundamentalist" view (Irwin et al. 2009; Irwin and Sanders 2010; Krugman 2010a, 2011; Yellen 2011; Dwyer et al. 2011, 2012), the price of any goods or assets should be driven by demand and supply in the absence of "irrational exuberance." In this context, any shocks to demand and supply which lead to rising global demand and disruption of global supply cause relevant price swings. Negative shocks to agricultural commodity supplies, which cause commodity prices to surge, are mainly the result of adverse weather conditions or collapses in the stock-to-use ratios. In other words, extreme weather conditions are likely to damage existing cropping areas, resulting in greater yield variability and negatively affecting price changes. Additionally, when stock-to-use ratios are low, the market is less able to cope with a significant decline in supply or a drastic increase in demands and thus drives prices significantly upwards (Williams and Wright 1991; Gilbert and Morgan 2011). Preexisting stocks are thus a fundamental source of stability in commodity markets. According to a report by the FAO (2009) about the prerecession spike in food commodity prices, stock levels have been decreasing by an average of 3.4 % per year since the mid-1990s, and the highest prices were registered during a period in which the stock-to-use ratios were at historical lows. Low food stocks and low crop stocks exacerbate the effects of weather disruptions on prices. For instance, wheat prices increased by 47 % in 2010, which was largely attributable to droughts in Russia and China and to floods in Canada and Australia.

With respect to demand, the process of income catch-up (convergence) between developing and advanced countries has triggered a growth in demand for commodities and hence drove up commodity prices. More than 90 % of the augmentation in demand for agricultural commodities in recent years has originated from developing countries, mainly from India and China (Heap 2005; Coxhead and Jayasuriya 2010; Fawley and Juvenal 2011; Cevik and Sedik 2011). In Krugman's words (2010b), rising commodity prices are a sign that "we are living in a finite world, in which the rapid growth of emerging economies is placing pressure on limited supplies of raw materials, pushing up their prices." However, it should be noted that in real terms, the price of food commodities has increased by 75 % between 2003 and 2008 (Erten and Ocampo 2013). This pattern is a reversal of the strong downward trends experienced since the 1980s, but it is still too early to assess if the reversal implies a long-term change (shift) in the direction of the trend, a pronounced short-run food

[1]A rational expectations model predicts that the existence of a futures market would reduce the fluctuation of spot prices for reasonable value of input parameters.

commodity price spike around the long-run trend, or a commodity price super-cycle (Rogers 2004; Heap 2005; Jacks 2013).

According to the "broad" macro-view, other macroeconomic determinants—such as exchange rates, monetary policies, inflation, energy price, global economic activity, and the "thinness" of markets—could have affected price levels and their fluctuations via demand or supply channels. For instance, exchange rates can influence commodity prices through several conduits, such as international purchasing power and the effects on margins for producers with non-US dollar costs (Mussa 1986; Gilbert 1989; Borensztein and Reinhart 1994; Roache 2010; Manera et al. 2013). This means that dollar depreciation increases costs to US producers and consumers in areas where the US dollar is the currency of trade. A change in the US dollar exchange rate thus affects prices measured in US dollar terms, but its effect will be nullified if prices are measured in terms of a weighted basket of currencies. Monetary policies, including interest rate maneuvers, can affect a number of demand and supply channels as well (Orden and Fackler 1989; Frankel 2008; Calvo 2008; Bakucs et al. 2009), leading to greater movements in real commodity prices when changes in real interest rates become frequent. This occurs particularly when interest rates are low and when there is an incentive to hoard physical commodities as an investment vehicle, causing prices to go up. Inflation is a common driver of prices of different commodities. Oil prices have also been mentioned as an additional factor in causing food price shocks via demand channels (Mercer-Blackman et al. 2007; Thompson et al. 2009). This is because a surge in oil prices leads to an increase in demand for grains as biofuels, and this subsequently causes food commodity prices to rise.[2]

Market "thinness," which is defined as the combined share of imports and exports relative to the size of global consumption or production, also significantly affects commodity price movements. In thinner markets, in which domestic prices do not closely follow international market movements, world market prices have to vary more to accommodate an external shock to traded quantities (OECD 2008).

Some observers doubt that fundamental shocks could be used as a reason to fully justify the price run-ups. Instead, they point to the "financialization" of commodity markets and speculation as the main causes of the drifts and fluctuations of commodity prices (Masters 2008; Stewart 2008; Hamilton 2009; Gilbert and Morgan 2011; Tang and Xiong 2012). "Financialization" refers to the large flow of capital into commodity markets, more specifically into long-only commodity index funds (Acworth 2005; Domanski and Heath 2007; Miffre 2011; Miffre and Brooks 2013). Speculation involves buying, holding, and selling of stocks, bonds,

[2]To reduce oil dependence as the main source of energy, several countries, including the USA, have adopted new energy policies to promote the use of biofuel. The 2005 US energy bill mandated that 7.5 billion gallons of ethanol be used by 2012. The 2007 energy bill further raised the mandate to 36 billion by 2022. The mix of increasing ethanol subsidies and high oil prices determined a rapid growth of the ethanol industry, which consumes about one-third of the US maize production. The rise of the ethanol industry might have led prices of maize, and other close substitutes such as soybeans and wheat, to co-move with oil prices (Roberts and Schlenker 2010; EPA 2012).

commodities, or any valuable financial instruments to profit from fluctuations in their price. This is in contrast to market participants buying these assets for use, dividends, interest income, or hedging purposes (Robles et al. 2009). Speculation thus may take the form of speculative stockholding, speculative purchase and the sales of commodity futures, or other derivative contracts.

Similarly, a report by the US Senate's Permanent Subcommittee on Investigations (USS/PSI 2009, p. 2) argued that commodity traders and futures contracts were disruptive forces, pushing prices away from fundamentals, and inducing excessive price movements.

In this context, some believe that a speculative bubble is forming in commodities as a consequence of the highly accommodative stance of the US monetary policy. Some of the accommodative policies include the maintenance of the target federal funds rate at exceptionally low levels (Hamilton 2009) and extremely high flows of investment funds into commodity futures. Loose monetary policies influence commodity prices by reducing the cost of holding inventories or by encouraging "carry trades" and other forms of speculative behavior (Frankel 2013). However, the "fundamentalist" view points to the fact that stocks of agricultural products have generally been falling between 2006 and 2008 as evidence that undermines the hypothesis that speculators contributed to the spike in prices.

The financialization hypothesis suggests that prior to the recession, the surge in commodity prices was accompanied by a large inflow of funds. According to Barclays, index fund investment in commodities increased from $90 billion in 2006 to about $200 billion by the end of 2007; in July 2011, the amount of investment reached a historical peak of $431 billion. In this context, the large-scale speculative buying of index funds during the boom caused commodity future prices to far exceed fundamental values, thus creating a "bubble." However, people who hold the fundamentalist view again argued against the "speculation theory," pointing out that commodities without futures markets have experienced approximately as much fluctuations as commodities with a derivative market.

10.3 Variables and Data

In order to empirically examine the causes of price fluctuation, wheat spot prices were considered. The sample consists of monthly wheat spot prices for the period 1980–2012, and a subperiod is defined as 1995–2012. The subsample starts in 1995 due to the unavailability of some financial data before that year. To identify the key drivers, the different strands of the existing literature were merged, and the driving forces behind wheat prices were divided into four dimensions: market specific variables, broad macroeconomic variables, speculative components, and weather conditions. A detailed description of the data can be found in the Annex.

The focus is on the spot market rather than the futures market for two main reasons. First, it is important to understand the interconnections between the two markets and assess how trading activities in the futures markets affect the patterns of spot prices for their economic and welfare consequences. Second, the existing analyses are mainly focused on commodity futures markets and less on the cash markets.

Wheat spot prices were taken from the IMF International Financial Statistics, via Datastream. The prices are expressed in US dollars, averaged from daily quotations, and have been deflated by the US consumer price index to obtain their real values. The prices were then converted into an index (2000 = 100).

Market Specific Variables include inventory-to-consumption and the "thinness" of markets.

Inventory-to-Consumption
(−)

Inventory stock levels have a crucial role in commodity pricing (Williams and Wright 1991; Pindyck 2001; Krugman 2011). As in manufacturing industries, inventories are used to reduce costs of adjusting production over time in response to fluctuations in demand and to shrink marketing costs by facilitating timely deliveries and preventing stock-outs. Producers can reduce their costs over time by selling out of inventories during high-demand periods and replenishing inventories during low-demand periods. Since inventories can be used to ease production and marketing costs despite fluctuating demand conditions, they lower the degree of short-run market price fluctuations. Therefore, price levels and their fluctuations are expected to increase when the level of inventories is lower.

Because inventory holdings can change, production at any period does not need to be equal to consumption. As a result, the market-clearing price is determined not only by current production and consumption but also by changes in inventory holdings.

Aggregate world stocks at the end of a year were expressed as a proportion of the aggregate world consumption from the previous year. This ratio is also referred to as the stock-to-use ratio (Fig. 10.1). The inventory data are the predicted end-

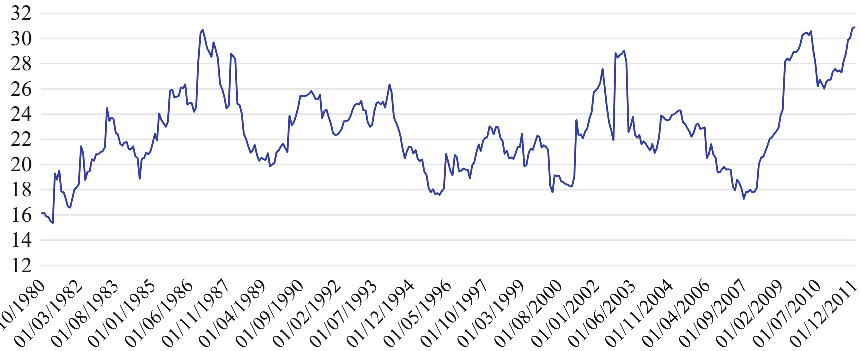


Fig. 10.1 End stock-to-use ratio (in %)

of-season global wheat inventories as published in the monthly USDA reports. Therefore, the inventories are the projected quantities of grain reserves carried over from the ongoing marketing year to the new marketing year. The definition of a marketing year is based on the aggregate of local marketing years. The largest trader of wheat in the international market is the USA, where the marketing season starts at the beginning of June and ends at the end of May. The consumption data are the projected season's consumption levels. The data was obtained from the United States Department of Agriculture (USDA).

International Thinness of Markets
(+)/(−)

The "thinness" of a market refers to the share of the imports and exports of a specific commodity relative to the size of global consumption or production (OECD 2008). This ratio describes the extent to which agricultural products are internationally traded.[3] The thinness of the wheat market can be expressed as follows:

$$TH \equiv \left(\frac{EX_w + IM_w}{Cons_w} \right) \tag{10.1}$$

A low ratio means that the market is "thin," while a high ratio implies "fatness" of the market. Hence, a thin market is characterized by low trading volume.

The thinness of a market could exert two opposite effects on prices. Higher trading volume may lead to higher demand for commodities; this could result in a price run-up. Conversely, trade could help smooth production and consumption across space by moving goods from regions with surplus to those with deficit, thus mitigating the effects of price movements. In this context, more trade implies more stability and price drops, while a lack of trade implies high movements and price increases (Jacks et al. 2011). Increased trade integration would thus facilitate the stabilization of food prices and the reduction of prices for consumers (The World Bank 2012).

In regards to volatility, thin markets, characterized by low trading volumes, tend to show high fluctuations (illiquid), while fat markets display high trading volumes and high liquidity. It is often argued that agricultural markets are "thin"; the ratio of trade flows to global production/consumption is considered low as a consequence of protectionist measures or because a commodity is mostly consumed in their country of production, as in the case of rice (Timmer 2009). This causes price swings that are larger than those expected in more liquid or deeper markets. In the case of wheat,

[3] The construction of this measure includes exports and imports to be conceptually parallel to the degree of openness of an economy. As imports equal exports at a global level, the thinness index could also be represented by either exports or imports.

a change in thinness can be considered as a more direct proxy for changes in trade policy since wheat is consumed independently from where it is produced, and the market dimension is more linked to the existence of restrictive or expansive trade policies.

When markets are thinner and prices in domestic markets do not follow those in international trade because of insulating policies or market imperfections, world market prices must change to better accommodate an external shock to the traded quantities, if all else is equal. Trade thus is an important buffer against localized fluctuations originating from the domestic market and could also be useful for leveling out local supply shocks around the globe.

Broad macroeconomic variables include global economic activity, interest rates, real exchange rates, oil price, and inflation.

Global Economic Activity

(+)

The monthly global industrial production index was considered when measuring the global economic activity. The index was chosen because real world GDP data is not available on a monthly basis but only at quarterly frequency. Initially, industrial production data for advanced and emerging economies were considered separately when analyzing the impact of aggregate demand growth; however, these data are available only at annual frequency, and in any case, world figures have the advantage of including emerging countries such as China and India. This is in line with the study by Frankel and Rose (2009).

Interest Rate and Yield Curve

(−) & (+)/(−)

Real interest rates can influence commodity prices in several ways, as explained by Frankel (2006, 2012, 2013). For instance, the prices of storable commodities rise as interest rates fall because, by decreasing the cost of carrying inventories, lower rates stimulate inventory demand for commodities. On the other hand, a rise in interest rates reduces inventory demand since it increases the cost of carrying inventories. This, in turn, lessens commodity prices.

Another mechanism by which real interest rates affect commodity prices relates to financial speculation in commodity markets. Commodities can be thought of as financial assets; thus when real interest rates are very low, investors are more prone to take open positions in the financial market for commodities, thereby pushing commodity prices up. Conversely, an increase in interest rates encourages speculators to shift from spot commodity contracts to Treasury bills, and this curbs commodity prices. Following this line of thought, Calvo (2008) put forward that increases in commodity prices mostly stem from the combination of low central bank interest rates, the growth of sovereign wealth funds, and the consequent lower demand for liquid assets.

In order to account for the effects of monetary policies, the US money market rate (federal funds) deflated by the consumer price was considered. The interest rate is thus expressed in real values.

In addition, to gain insights into the expected future path of the short-term interest rates, the US interest rate spread has been included, constructed as the difference between the 10-year Treasury bonds and the federal funds. This spread, or difference between long and short rates, is often called the yield curve. It can be considered as an indicator of the stance of monetary policy and general financial conditions because it rises (falls) when short rates are relatively low (high). A negative yield curve (i.e., short rates are higher than long rates) is historically a particularly strong indicator of recession. In short, it is a leading indicator which signals changes in the direction of aggregate economic activity.

The expected relationship between yield spread and commodity prices is uncertain. If risk premiums on Treasury Bond represent a reward to investors for their exposure to economy-wide macroeconomic risks, then we should expect a strong positive linkage between variation in commodity spot prices and measures of risk in Treasury bond markets. This indicates that higher yield spreads, which signal a declining risk tolerance in the Treasury bond market, mean higher commodity prices, which indicate an increasing risk tolerance in the commodity markets. This pattern is consistent with the thesis that asset classes are being treated as substitutes in diversified portfolios.

If risk aversion is instead expressed in a similar way across the Treasury and commodity markets during the period, then rising Treasury yields are correlated with lower commodity prices. This pattern is consistent with the thesis that asset classes are being treated as complements in diversified portfolios.

Oil Spot Price

(+)

The oil price is a critical factor contributing to the increase in production costs of agricultural commodities and food (costs of processing, transportation, and distribution) and consequently to the increase in their market prices. Additionally, an increase in oil price provides an incentive to produce biofuels, thus exerting a further upward pressure on food commodity prices. Therefore, wheat prices and oil prices are expected to be positively related.

Crude oil prices were obtained from Cushing, Oklahoma West Texas Intermediate (WTI) Spot Price FOB (Dollars per Barrel) via Datastream. To obtain the real values, the average petroleum spot price was deflated using the US CPI.

Real Effective Exchange Rate

(+)/(−)

Many agricultural commodities (as with oil) are traded in the US dollar; this implies that the effective exchange rate of the US dollar affects commodity prices as perceived by countries other than the USA. Therefore, a change in the dollar exchange rate can change the demand for and supply of agricultural commodities and consequently their prices. A real exchange rate appreciation (depreciation) can be positively or negatively related to prices.

On the one hand, dollar depreciation tends to reduce the commodity prices in domestic currencies for countries and regions with floating exchange rates, such as the euro area, Japan, the Philippines, and South Korea. This leads to an increase in the demand for commodities in these areas. Therefore, dollar depreciation has a positive impact on the demand for commodities and should contribute to rising commodity prices. Conversely, dollar appreciation makes exports less competitive and decreases the demand for commodities, causing dollar-denominated international commodity prices to diminish. This has a neutral effect for countries that peg their currency to the US dollar, like Oman, Saudi Arabia, Eritrea, and Hong Kong.

On the other hand, if uncertainty increases, both the demand for the dollar and commodities will increase, causing commodity prices to rise.

Inflation

(+)

Since commodities are considered to have the ability to store value, demand for commodities, for use as financial assets or as stocks, increases with inflation. Inflation tends to affect commodity prices through the portfolio choices of financial investors; this occurs because holding commodities can hedge investment portfolios against inflation risks (Roache 2010). The inflation rate is computed using changes in the US consumer price index.

To account for *Financial Variables*, a measure of financialization and speculation in the wheat market has been included.

Financialization and Speculation

(+)/(−)

Commodity markets have seen a progressive financialization over time. This is evident in the evolution of the level of open interest. Open interest describes the total number of long (purchased contracts outstanding) or short (sold contracts outstanding) futures contracts for a given commodity in a delivery month or market that has been entered into but not yet (1) liquidated by an offsetting transaction or (2) fulfilled by the delivery of the commodity.[4] Open interest is hence a widely used measure of the size of a commodity futures market. Specifically, Fig. 10.2 shows the open interest disaggregated by the type of traders and the nature of contracts in the wheat market; that is, it considers the long and short open interests for commercial traders, noncommercial traders, and non-reportables.

Commercial traders, also known as hedgers, hold positions in the underlying commodity and attempt to offset their risk exposure using future transactions. Noncommercial traders, also called speculators, only hold positions in futures

[4]In analytical terms, the market's total open interest is the sum of reporting and non-reporting positions: $TOT\ OI = [NCL + NCS + 2 \times NCSP] + [CL + CS] + [NRL + NRS]$, where noncommercial open interest (NC) is distinguished in long (NCL), short (NCS), and spreading (NCSP), while for commercials (C) and non-reportables (NR) open interest is divided in long and short.

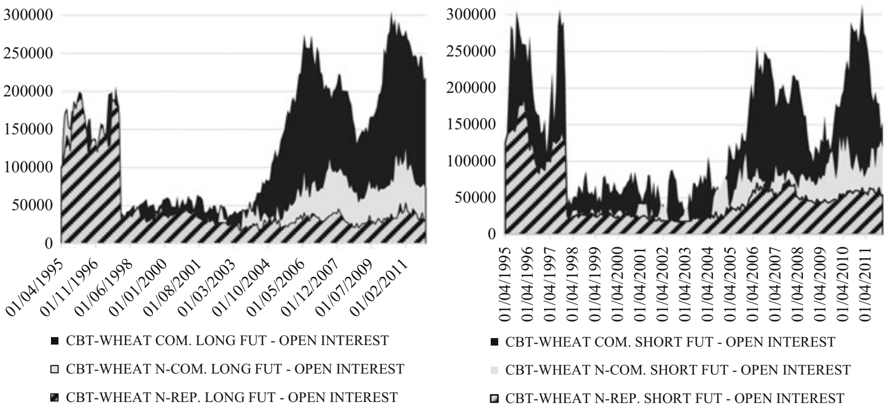


Fig. 10.2 Role of commercials, noncommercials, and non-reportables in wheat market (Chicago Board of Trade). *Source*: Own Elaboration on Datastream

contracts and are not involved in the physical commodity trade. Commercial and noncommercial traders are defined as reportable traders because they hold positions in futures and options at or above specific reporting levels set by the US Commodity Futures Trading Commission (CFTC). Non-reportables refer to small traders who do not meet the reporting thresholds set by the CFTC. Traders could take either long (buy) or short (sell) positions in commodity futures markets, depending on whether commodity prices are expected to appreciate or depreciate.

It is worth noting that although wheat futures can also be traded on the Kansas City Board of Trade (KCBT), and the Minneapolis Grain Exchange (MGEX), figures in this chapter come from the Chicago Board of Trade (CBOT) because it is the world's oldest futures and options exchange and the largest commodity exchange in the world. Founded in 1848, it accounts for about half of the turnover in futures contracts in the USA and the bulk of the world's grain futures trading.

As shown in Fig. 10.2, open interest recorded significant gains from 2003 onward, only registering a drop during the financial crisis but surged again soon afterwards. The fact that the long and short positions of all types of investors in the wheat market have increased over time suggests a rise in the financialization of commodity futures markets.

In a well-functioning futures market, hedgers, who want to lower their exposure to price risks, will have to find a counterparty. In the absence of any speculative activity, long hedgers have to find short hedgers with an equal and opposite position. Since long and short hedgers do not always trade simultaneously or in the same contract amount, there is unmet hedging demand, which speculators can satisfy. Speculators thus reduce searching costs by taking the opposite positions when long and short hedgers do not perfectly match each other's demand (Büyükşahin and Harris 2011). This follows Friedman's (1953) argument: speculators stabilize prices by buying low and selling high so as to bring prices closer to fundamentals. However, it turns out that speculative activities often exceed the level required to offset any unbalanced hedging, thus destabilizing markets. According to De Long et al. (1990), rational speculators set price trend and lead short-term prices away from fundamentals by anticipating the buy/sell orders of trend followers.

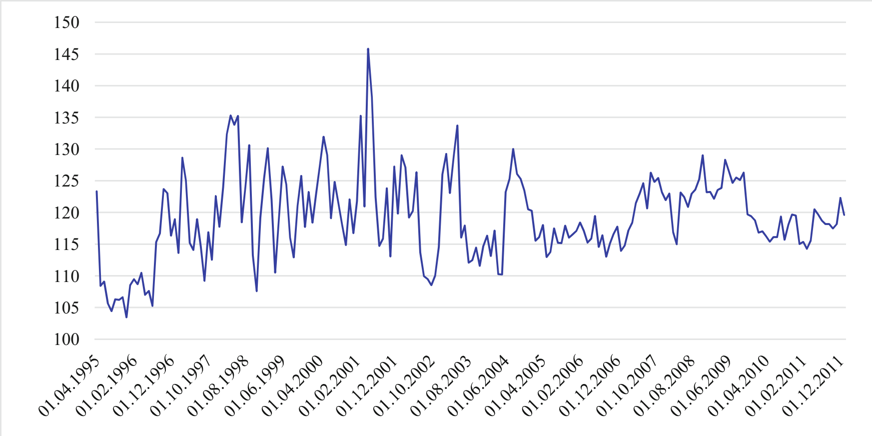
In short, the financialization of commodity markets has brought about an increase in speculative activities, which could have positive or negative effects on commodity markets, and consequently on prices.

Since the share of net long positions of noncommercial traders is frequently used as a variable to capture the activity of financial investors in commodity markets (IMF 2006; Micu 2005; Domanski and Heath 2007), an excessive-speculation index has been constructed following Working (1953). This metrics is a good measure of speculative activities in futures markets since it assesses the relative importance of speculative positions with respect to hedging positions. And as Working suggested, the level of speculation is meaningful only when compared with the level of hedging in the market. The Working index has been used also by Sanders et al. (2010) and Büyükşahin and Harris (2011) to examine the adequacy or excessiveness of speculative participation in the commodity futures markets. The excessive-speculation index is expressed as:

$$\text{ESPI} \equiv \begin{cases} \left[1 + \frac{\text{NC OI Short}}{(\text{C OI Short}+\text{C OI Long})}\right] \times 100 \; \textit{if C OI Short} \geq \textit{C OI Long} \\ \left[1 + \frac{\text{NC OI Long}}{(\text{C OI Short}+\text{C OI Long})}\right] \times 100 \; \textit{if C OI Short} < \textit{C OI Long} \end{cases} \quad (10.2)$$

where NC OI Short = open futures position of short speculators, NC OI Long = open futures position of long speculators, C OI Short = open futures position of short hedgers, and C OI Long = open futures position of long hedgers. In other words, the nominator denotes the short and long speculative positions. The denominator is the total amount of futures open interest resulting from hedging activity.

Figure 10.3 shows the excessive-speculation index in the wheat market and its descriptive statistics.

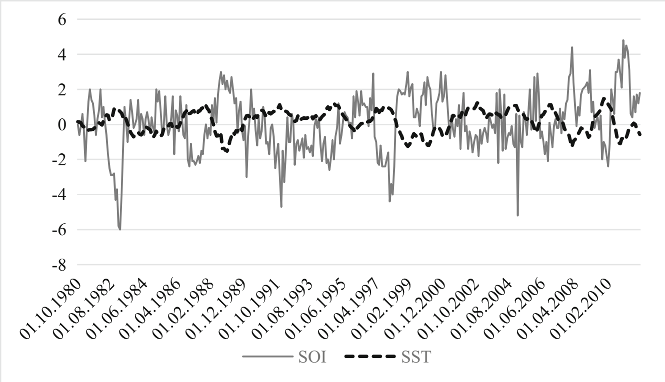


Excessive speculation index					
Mean	119.206	Std. Dev.	6.836	Skewness	0.396
Median	118.429	Sum	24079.670	Kurtosis	3.711
Maximum	145.822	Sum Sq.	9393.373	Jarque-Bera	9.525
Minimum	103.445	Observations	202	Probability	0.008

Fig. 10.3 Excessive-speculation index. Wheat CBOT

Finally, the model controls for *Global weather conditions*. To account for weather conditions, the following two indicators have been considered:

- The sea surface temperature anomalies (SST) for the El Niño region 3.4 (a central region of the Pacific Ocean). This index measures the deviations between the sea surface temperatures in the El Niño region 3.4 and its historical average, and it is calculated by the National Climatic Data Center US Department of Commerce and the NOAA Satellite and Information Service using the extended reconstructed sea surface temperature.
- The Southern Oscillation Index anomalies (SOI), which measures the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes (i.e., the state of the Southern Oscillation). It is a standardized index based on the observed sea-level pressure differences between Tahiti, French Polynesia, and Darwin (Australia). In general, a negative phase of the SOI represents below-normal air pressure at Tahiti and above-normal air pressure at Darwin. SOI data are taken from the National Oceanic and Atmospheric Administration National Climatic Data Center.



	SOI	SST		SOI	SST
Mean	0.070	0.164	Std. Dev.	1.693	0.632
Median	0.100	0.290	Coef. of variation	24.052	3.864
Maximum	4.800	1.470	Jarque-Bera	10.292	15.876
Minimum	-6.000	-1.520	Probability	0.006	0.000

Note. Observations: 375

Fig. 10.4 Weather proxies

Although the events described by these indices arise in the Pacific Ocean, they have strong effects on the world's weather and an important influence on the global production and price of primary non-oil commodities (Brunner 2002). Monitoring both the SOI and the SST allows for a better understanding of global climatic fluctuations, enabling us to clearly distinguish between the atmosphere's and the ocean's influence on yield, and thus prices. In addition, evaluating both variables together significantly improves the accuracy of weather forecast when compared to using them separately (Russell et al. 2010).

The dynamics of the SST index and the SOI are reported in Fig. 10.4. With regard to the SST index, positive anomalies (index values above zero) are related to abnormally warm ocean waters across the eastern tropical Pacific typical of an El Niño event, and negative anomalies are related to a cool phase typical of a La Niña episode. Conversely, prolonged periods of positive SOI values (values above zero) coincide with La Niña events during which water becomes cooler than normal; the opposite is true for prolonged periods of negative SOI values. SOI values below zero mirror El Niño episodes, during which water becomes warmer than normal. La Niña events are associated with increased instances of drought throughout the mid-latitudes, where much of the global wheat and other grains (such as corn and soybeans) are produced, thus decreasing their global yield (Hurtado and Berri 1998) and driving up prices. For this reason, La Niña episodes have historically been associated with global food crises. El Niño is associated with an increased likelihood of droughts in tropical land areas, which mainly affects crops such as sugar and palm oil.

It is worthwhile to note that the SST index and the SOI tend to have opposite signs and that the SOI has a higher variability than the SST index as computed by the coefficient of variation shown below.

10.4 Empirical Evidence

10.4.1 Preliminary Unit Root Test

Prior to testing for cointegration, the time series examined in Sect. 10.3 were transformed into logarithms, and their properties were carefully investigated. The transformation of the time series into logarithm is of advantage as the coefficients can be interpreted as elasticities. Inspecting the data graphically (Fig. 10.5) reveals that most of the series resemble a random walk, with some "trending" upward and others downward, and with fluctuations. Therefore, the Augmented Dickey–Fuller (ADF) (1981) and the Philips Perron (P–P) (1988) tests have been conducted for each variable to formally test for the presence of *unit roots*. The critical values for the rejection of the null hypothesis of a unit root are those computed according to the MacKinnon criterion (1991). The lag length for the ADF test is based on the Schwarz information criterion (SIC). The lag structure for the P–P is selected using the Bartlett Kernel with automatic Newey–West bandwidth. The two tests have been carried out with a constant and a linear trend (Table 10.1).

The ADF and P–P tests show that all the independent and dependent variables are integrated of order one I(1), i.e., the series become stationary after being differentiated for the first time. This occurs because the computed values do not exceed the Mac Kinnon critical values. The only exceptions are for the US Fed spread and the SST index, which produced different results according to the two tests.[5] However, it is acceptable to consider the series integrated of order

[5] Although Engle and Granger's (1987) original definition of cointegration refers to variables that are integrated of the same order, Enders (2009) argued that: "It is possible to find equilibrium relationships among groups of variables that are integrated of different orders." Asteriou and Hall (2007) also explained that in cases where a mix of I(0) and I(1) variables are present in the model, cointegrating relationships might exist. Similarly, Lütkepohl and Krätzig (2004) explain: "Occasionally it is convenient to consider systems with both I(1) and I(0) variables. Thereby the concept of cointegration is extended by calling any linear combination that is I(0) a cointegration

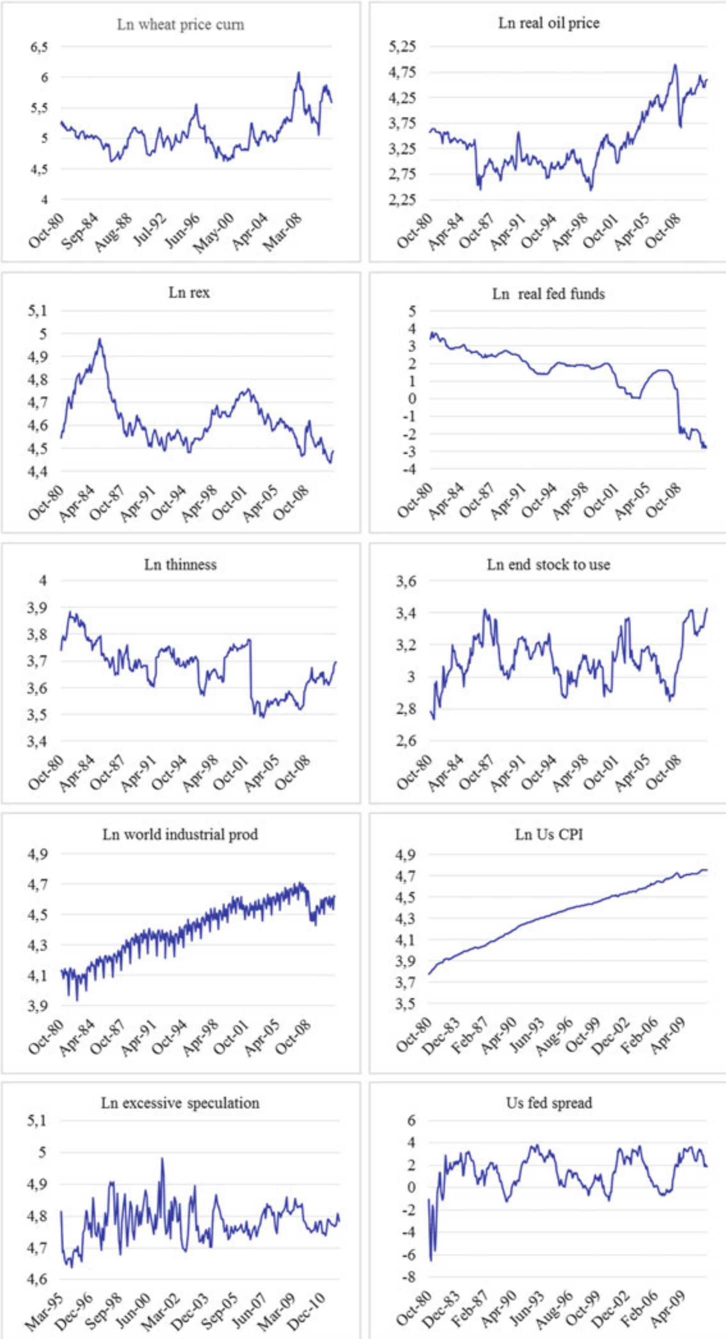


Fig. 10.5 Variables developments

Table 10.1 Unit root tests

	ADF level		ADF first difference		PP Level		PP first difference	
	t-stat	Prob.	*t*-stat	Prob.	*t*-stat	Prob.	*t*-stat	Prob.
ln real p	−2.992	0.1357	−14.911	0.0000	−2.758	0.2142	−14.856	0.0000
ln real poil	−2.431	0.3627	−14.537	0.0000	−2.173	0.5029	−14.026	0.0000
ln real fed fund	−1.068	0.9316	−11.719	0.0000	−0.940	0.9489	−11.642	0.0000
ln rex	−2.355	0.4028	−13.605	0.0000	−2.339	0.4111	−13.544	0.0000
ln end stock to use	−3.066	0.1162	−18.986	0.0000	−3.124	0.1022	−18.986	0.0000
sst	−4.111	0.0066			−3.853	0.0150	−12.365	0.0000
soi	−5.796	0.0000			−9.232	0.0000		
ln us cpi	−2.674	0.2480	−11.595	0.0000	−3.129	0.1010	−10.555	0.0000
ln world ind prod	−1.775	0.7150	−6.058	0.0000	1.850	0.9848	−44.358	0.0000
us fed spread	−4.484	0.0018			−3.363	0.0580	−13.339	0.0000
ln thinness	−2.636	0.2645	−18.783	0.0000	−2.900	0.1637	−18.782	0.0000
ln speculation	−6.668	0.0000			−6.766	0.0000		

Note: test equation includes trend and intercept. Mac Kinnon crit-values. The sample consists of monthly observation spanning the period from 1980 to 2012. The sample refers to the period 1995–2012 only with regard to speculation. Null hypothesis: there is a unit root. Real p = real wheat price, real poil = real oil price, real fed fund = real federal fund, rex = real effective exchange rate, sst = sea surface temperature anomalies, soi = Southern oscillation index anomalies, us cpi = US inflation rate, world ind prod = world industrial production, US fed spread = US bond yield, thinness = thinness of the market, speculation = excessive speculation

one because the series was confirmed by a supplementary Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test (1992). The outcomes of the tests are reported in Table 10.1. The presence of non-stationarity implies that standard time-series methods are no longer suitable. And consequently, a cointegration analysis is required (Enders 2009).

To have a broader indication on the variables of interest, the correlation matrix has been computed[6] (Table 10.2).

relation, although this terminology is not in the spirit of the original definition because it can happen that a linear combination of I(0) variables is called a cointegration relation." Therefore, even in the presence of a set of variables which contains both I(1) and I(0) variables, cointegration analysis is applicable, and the presence of a long-run linear combination denotes the existence of cointegrated variables. Hence, it is possible to find long-run equilibrium relationships among a set of I(0) and I(1) variables if their linear combination reveals a cointegrating relationship.

[6]On the basis of the variance inflation factor, the variable ln us cpi was excluded from the model because it is highly correlated with the world industrial production. Further, the inclusion of the inflation rate would have caused a clear problem of endogeneity.

Table 10.2 Correlation matrix

Correlation	ln real poil	ln real fed funds	ln rex	ln end-stock-to-use	SST	SOI	ln us cpi	ind prod	us fed spread	ln thinness	ln speculat.
ln real poil	1										
ln real fed funds	−0.231	1									
ln rex	0.020	0.464	1								
ln end-stock-to-use	−0.066	−0.514	−0.100	1							
SST	−0.114	−0.082	−0.132	0.313	1						
SOI	0.138	−0.216	−0.110	−0.109	−0.678	1					
ln us cpi	0.094	−0.811	−0.540	0.201	0.054	0.242	1				
ln world ind prod	0.020	−0.646	−0.500	0.077	0.011	0.252	0.943	1			
us fed spread	−0.075	−0.510	−0.022	0.600	0.289	−0.160	0.254	0.104	1		
ln thinness	−0.023	0.499	0.439	−0.185	−0.162	−0.289	−0.134	−0.633	−0.139	1	
ln specul.	0.038	−0.079	0.241	0.146	−0.105	0.001	0.167	0.197	0.025	0.117	1

Notes: the monthly observations in the sample were made between 1980 and 2012. The sample refers to the period 1995–2012 only with regards to speculation. Real p = real wheat price, real poil = real oil price, real fed fund = real federal fund, rex = real effective exchange rate, sst = sea surface temperature anomalies, soi = Southern oscillation index anomalies, us cpi = US inflation rate, world ind prod = world industrial production, US fed spread = US bond yield, thinness = thinness of the market, speculat. = excessive speculation

10.4.2 Johansen and Juselius Analysis

The Johansen and Juselius methodology (1990), based on maximum-likelihood estimation, allows for the simultaneous evaluation of equations involving two or more variables and for determining whether the series are cointegrated; that is to say, whether there is a long-term relationship among variables. Furthermore, this technique controls for endogeneity and enables us to assess and test for the presence of more than one cointegrating vector. Finally, this methodology performs better than other estimation methods by including additional lags, even when the errors are non-normal distributed or when the dynamics are unknown, and the model is over-parameterized (Gonzalo 1994).

Consider a p-dimensional vector autoregressive model, which in error correction form is given by:

$$\Delta x_t = \Pi x_{t-p} + \sum\nolimits_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t \tag{10.3}$$

where Δ is the difference operator, and $x_t = (k \times 1)$ is the vector of nonstationary I(1) variables, explicitly:

$$\begin{aligned} x_t = {} & [\text{wheat price}_t;\ \text{market specific variables}_t;\ \text{broad macro variables}_t; \\ & \text{weather}_t;\ \text{speculation}_t] \end{aligned} \tag{10.4}$$

and:

$$\Pi = \sum\nolimits_{i=1}^{p} A_i - I \qquad I = a\,(k \times k)\ \text{identity matrix} \tag{10.5}$$

$$\Gamma_i = \sum\nolimits_{j=1}^{i} A_j - I \qquad A = a\,(k \times k)\ \text{matrix of parameters} \tag{10.6}$$

The variable St contains a constant term and a time trend, and ξ is a vector of Gaussian, zero mean disturbances. Γ_i are $(k \times k)$ dimensional matrices of autoregressive coefficients. The long-run matrix $\prod$ can be decomposed as the product of α and β, two $(k \times r)$ matrices each of rank r, such that $\prod = \alpha\beta$', where β' contains the r cointegrating vectors and α represents the adjustment parameters, which reflect the speed of adjustment of the particular variables with respect to a disturbance in the equilibrium relationship. Therefore, Eq. (10.3) becomes:

$$\Delta x_t = (\alpha\beta)\, x_{t-p} + \sum\nolimits_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t \tag{10.7}$$

The maximum-likelihood approach makes it possible to test the hypothesis of r cointegrating relations among the elements of x_t,

$$H_0 : \Pi = \alpha\beta \tag{10.8}$$

where the null of no cointegration relation ($r = 0$) implies $\prod = 0$. If $\prod$ is of rank k, the vector process is stationary. If rank $(\prod) = 1$, there is a cointegrating vector; for other cases in which $1 < \text{rank}\ (\prod) < k$, there are multiple cointegrating vectors.

10.4.3 Empirical Results

A VAR system of variables was constructed to test whether real wheat prices are cointegrated with specific market variables, broad macroeconomic factors, speculation, and weather events. To identify the proper model, the five possibilities considered by Johansen (1995) were tested, specifically: (1) the series have no deterministic trends, and the cointegrating equations do not have intercepts; (2) the series have no deterministic trends, and the cointegrating equations have intercepts; (3) the series have linear trends, but the cointegrating equations only have intercepts; (4) both series and the cointegrating equations have linear trends; and (5) the series have quadratic trends, and the cointegrating equations have linear trends. Following the Pantula test (Pantula 1989), the third and the fifth models are the most appropriate for two samples. To identify the lag length, the Aikaike information criterion (AIC) and the SIC were implemented. The chosen lag structure is three (the smallest value) for the complete sample and five for the subsample, following the AIC. A number of dummies have been included in the cointegration test to take into account periods of social and economic instability and structural breaks.[7]

The results of the Johansen test for cointegration are shown in Table 10.3, which reports the hypothesized number of cointegration equations in the first column on the left, the eigenvalue, the trace[8] statistics, the max eigenvalue statistics,[9] and the 5 % critical values. The asterisks indicate the rejection of the hypothesis.

[7]Specifically, outliers were detected by looking at the graphs of the residuals. Five dummies relative to 1998, 2007, 2008, 2010, and 2011 were inserted in the short-sample wheat price equation. The effects of including dummy variables to capture structural breaks in cointegration models have been analyzed in Kremers et al. (1992), and Campos et al. (1996).

[8]The trace statistic of r cointegration relations is a sequence of likelihood ratio tests, computed as $\lambda_{\text{trace}}(r) = -T\sum_{i=r+1}^{k} \ln\left(1 - \widehat{\lambda}_i\right)$, where λ_i is the estimated value of the characteristic roots (also called eigenvalue) obtained from the estimated long-run Π matrix, and T is the number of usable observations.

[9]The max eigenvalue statistic is calculated as $\lambda_{t\ \max}(r) = -T\ln\left(1 - \widehat{\lambda}_{r+1}\right)$.

Table 10.3 Johansen cointegration tests

Sample (adjusted). Included observations: 365 after adjustments Trend assumption: Quadratic deterministic trend				
Unrestricted cointegration rank test (trace)				
Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	5 % Critical value	Prob.**
None*	0.172	233.630	219.402	0.0090
At most 1	0.111	164.650	179.510	0.2206
At most 2	0.097	121.810	143.669	0.4306
At most 3	0.077	84.592	111.780	0.6913
At most 4	0.050	55.509	83.937	0.8503
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level				
Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	5 % Critical value	Prob.**
None*	0.172	68.980	61.034	0.0071
At most 1	0.111	42.839	54.966	0.4688
At most 2	0.097	37.219	48.877	0.4742
At most 3	0.077	29.083	42.772	0.6531
At most 4	0.049	18.565	36.630	0.9422
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				
Sample (adjusted). Included observations: 173 after adjustments. Trend assumption: Linear deterministic trend				
Unrestricted cointegration rank test (trace)				
Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	5 % Critical value	Prob.***
None*	0.362	350.632	285.142	0.0000
At most 1*	0.304	272.774	239.235	0.0006
At most 2*	0.296	210.063	197.371	0.0100
At most 3	0.248	149.364	159.530	0.1561
At most 4	0.167	100.126	125.615	0.5978
Trace test indicates three cointegrating eqn(s) at the 0.05 level				
Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	5 % Critical value	Prob.***
None*	0.362	77.858	70.535	0.0091
At most 1	0.304	62.711	64.505	0.0736
At most 2*	0.296	60.699	58.433	0.0294
At most 3	0.248	49.239	52.363	0.1010
At most 4	0.167	31.672	46.231	0.6786
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				

*Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon et al. (1999) *p*-values
***MacKinnon et al. (1999) *p*-values. Estimations include significant dummies

Elaborating on the trace statistic, the first row of the trace statistic tests the hypothesis of no cointegration, the second row tests the hypothesis of one cointegrating relation, the third row tests the hypothesis of two cointegrating relations, and so on. All hypotheses were tested against the alternative hypothesis of full rank (i.e., all series in the model are stationary). For the longer sample, the λ_{trace} test and the λ_{max} statistic indicate the presence of one cointegrating equation at the 5 % level. For the shorter sample, the λ_{trace} test indicates the presence of three cointegrating equations at the 5 % level. The λ_{max} statistic does not confirm this result. The null hypotheses of no cointegrating vector ($r = 0$) can be rejected at the 5 % level, but the null of $r = 1$ cannot be rejected. So, it can be concluded that there is one cointegrating vector in the system at the 5 % level.

Although the results of trace tests and maximum eigenvalue tests point to different outcomes, we can conclude for one cointegrating vector since as Johansen and Juselius note, "one would, however, expect the power of this procedure [the trace test] to be low, since it does not use the information that the last three eigenvalues have been found not to differ significantly from zero. Thus, one would expect the maximum eigenvalue test to produce more clear-cut results" (1990, p. 19).

To extract the cointegrating vectors, a VEC representation has been adopted. Convergence was reached after few iterations for the entire sample and the small sample. The restricted cointegrating vectors and the speed of adjustment coefficients are reported in Table 10.4.

Table 10.4 Vector error correction estimations

Cointegrating vector β	1981:1–2012:1	1995:1–2012:1
ln real poil	0.231(4.44)	0.294(2.84)
ln real fed funds	−0.132(−2.55)	−0.207(−6.03)
ln rex	−0.771(−3.12)	−0.726(−9.77)
ln end-stock-to-use	−0.999(−3.94)	−0.436(−1.99)
sst	−0.244(−3.50)	−0.248(−4.54)
soi	0.166(5.71)	0.104(4.26)
ln world ind prod	3.290(2.80)	1.807(2.63)
us fed spread	0.045(1.99)	0.021(1.09)
ln thinness	−1.008(−2.56)	0.340(1.42)
ln speculation		0.715(7.14)
Constant	27.990	25.800
Trend	0.006(3.51)	0.001(2.01)
Speed of adjustment α		
dln real price index	−0.069(−4.87)	−0.085(−2.07)

Regressand: ln real wheat price index. *t*-stat in brackets. ln stands for logarithm

10.4.4 Discussion of Results and implications

The cointegration analysis suggests that real wheat prices were cointegrated with market specific variables, broad economic variables, weather events, and speculation. In particular, the columns of β in Table 10.4 are interpreted as long-run equilibrium relationships between variables, and the matrix α is used to determine the speed of adjustment towards this equilibrium. The estimated speeds of adjustment coefficients had the expected signs and were statistically significantly different from zero. This means that the cointegrating vectors converged towards their long-run equilibrium in the presence of a shock to the system. Expressly, 6.9 % of the disequilibrium was eliminated in 1 month for the complete sample, and this figure was 8.5 % for the subsample; that is, it took 14.5 months (1/0.069) and 11.7 months (1/0.085), respectively, to restore the equilibrium after a shock.

More specifically, Table 10.4 provides evidence to suggest that higher oil prices have led to an increase in wheat prices due to greater use of petroleum-based inputs in the wheat market. In other words, on the supply side, a rise in oil prices exerts an upward pressure on the input costs (such as fertilizers, irrigation, and transportation costs), which consequently leads to a decline in profitability and production. This results in a shift of the supply curve to the left and a rise in wheat prices. The result provides evidence that energy and agricultural prices are interwoven. A 10 % increase in international oil prices is statistically associated with an approximately 2.3 % rise in wheat prices for the longer sample and a 2.9 % increase for the shorter sample, all other things being equal. This result is in line with the studies by Tang and Xiong (2012) and Chen et al. (2010), who found an increasing correlation between agricultural commodities and oil price.

In addition, wheat prices appear to be sensitive to fluctuations in the real exchange rate. The sensitivity to fluctuation is almost the same for the two samples, both before and after the financialization of the wheat market. Specifically, the elasticity of about −0.7 suggests that a real dollar depreciation causes wheat prices to rise as wheat prices are denominated in the US dollar. The coefficients of the real exchange rate fell in a range between 0 and −1, just as predicted by the economic theory (Gilbert 1989; Borensztein and Reinhart 1994).

The real federal fund variable is negatively linked to the real wheat price, thus confirming the presence of the monetary policy effect. A loose monetary stance (with a lower interest rate of 1 %) implies that the price level will increase by about 0.1 and 0.2 %. When the real interest rate is high, as in the 1980s, money will flow out of commodities and therefore prices shrink. This confirms the studies by Dornbusch (1976), Frankel (2008), Svensson (2008), and Anzuini et al. (2012). The studies highlighted the high responsiveness of agricultural prices to monetary policy changes. The spread variable has a positive sign, signaling that the future expectations of tightened monetary policies do not have a depressing effect on wheat prices and that the Treasury bond market and the wheat commodity market are treated as substitutes asset classes for portfolio diversification. In other words, when the long-term interest rate is higher than the short-term interest rate, it signals an increase in the financial and macroeconomic risk linked to Treasury bonds. This causes investors to shift from the bond market to the commodity market, which in turn raises commodity prices. A 10 % increase in the spread increased prices by about 0.5 %; this value decreased to 0.2 % in the short sample and became insignificant.

The stocks-to-use ratio is used to capture the effects of market supply and demand factors on price determination (Westcott and Hoffman 1999). The variable shows a negative relationship with the wheat price. When usage grows faster than ending stocks, it would imply that demand growth outpaces supply growth, which puts an upward pressure on prices. Specifically, a reduction in the stocks-to-use ratio by 1 % caused real prices to surge by 0.9 % for the longer sample and 0.4 % for the shorter sample. This means that the combined effects of market supply and demand are factors in determining prices. It also means that a rise in the stocks-to-use ratio of a commodity translates into an almost proportional drop in the commodity's price in the longer sample, while the effect is less pronounced in the shorter sample.

As expected, bad weather conditions negatively affected wheat prices. Specifically, La Niña weather patterns tended to lower wheat yields and lift prices. It should be noted that the sea surface temperature anomalies had a larger impact than the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes. However, since the variability of SOI is larger than SST, the SOI could have more detrimental effects for wheat production and prices.

A 1 % increase in industrial production produced a significant rise in wheat prices by about 2–3 %. This implies, in accordance with the studies by Svensson (2008) and Wolf (2008), that the global demand is an important determinant of commodity prices.

The thinness of the market, while negative and significant for the longer sample, turned out to be not significant for the shorter sample. This implies that trade restriction policies could exert a detrimental effect as they tend to push wheat prices further up.

Finally, the speculation variable that is included only in the shorter sample indicates that the financialization of markets has contributed to pushing up prices. In traded markets, when futures traders seek exposure to commodities without holding the underlying commodities and speculate on future price movements of the commodity, they amplify price fluctuations on cash markets. This implies that speculative behaviors in the wheat futures market affect the associated spot market. According to our model, a 1 % increase in financial speculation increased cash prices by about 0.7 %.

In summary, the estimated coefficients showed that market specific variables, broad macroeconomic variables, speculative components, and weather conditions have a significant effect on real wheat prices, and thus the existing theories complement rather than contradict one another. The key to understanding the findings of this study is that commodities have multiple uses: they are both consumption goods and financial assets for investments. The positive effect of world demand on wheat commodity prices showed that wheat is used as consumption goods. The positive impact of open interest and yield curve on wheat price demonstrated that wheat is also used as financial assets.

An increasing demand was a dominant factor in driving up wheat prices, together with inventories for the longer sample; excessive speculation turned out to be significant and a relevant factor behind the price swings for the shorter sample. Pressures on real prices were alleviated by restrictive monetary policies, a real dollar appreciation, and, to some extent, expansive trade policies.

The properties of the residuals of the estimated model have been carefully analyzed. A battery of tests revealed that the residuals were stationary, homoskedastic, and uncorrelated. The estimated model was also "dynamically stable".[10]

10.5 Conclusions

The roller-coaster ride which commodity prices have experienced over the last decade has generated considerable interest among academics, policy makers, and investors in its effects on the real economy and thus on economic growth, food security, and investment decisions. In this context, the present study has tried to shed light on the key factors affecting the price movements of wheat, one of the major food grains in the world. The analysis was carried out for the period 1980–2012 and the subperiod 1995–2012, using monthly data.

The results of the study indicated that all the theories about drivers of commodity price do not necessarily contradict, but rather complement, each other. In fact, the results showed that a complex amalgamation of factors have caused prices to rapidly increase in the wheat markets, including speculation in futures markets, macroeconomic fundamentals, market specific variables, and weather conditions.

Wheat prices have been pushed up by a myriad of factors: loose monetary policies (as evident in low real interest rates), higher levels of industrial production (a proxy for strong economic activities), and speculative pressure. An increase in the stock-to-use ratio and a real appreciation has a curbing or dampening effect on

[10]The residual analysis, including details about stability, and the short-run dynamics are not reported for brevity but are available upon request. The impulse response function representation based on the Cholesky decomposition method indicates that short-run wheat price patterns in response to a shock are rich, and the impact of the shock is long-lasting. The variance decomposition based on Monte Carlo repetitions confirmed that there is a long-run relationship between the variables, and that all the determinants are meaningful in predicting real wheat prices when considered as a whole.

wheat prices. The thinness of a market turns out to be insignificant in the short sample, but it plays a role in the long sample, exerting an upward pressure on prices when trade diminishes.

Furthermore, the study has shown that an additional factor behind the rise in wheat prices is the increase in oil prices. Higher oil prices makes wheat production more expensive by raising the cost of inputs like fertilizers, irrigation, and transportation, thereby decreasing the profitability and production of wheat and raising wheat prices.

The variables with the largest effects on price movements over the period 1995–2012 are the global demand, speculation, and the real effective exchange rates. This showed that financial and wheat markets are becoming increasingly interwoven. It also showed that "speculation" which involves trading futures contracts on commodity markets (to profit from price fluctuations) is an important determinant of price dynamics. The wider and more unpredictable price changes are caused by greater possibilities of realizing large gains by speculating on future price movements of the commodity in question. Although the presence of "speculators" on derivatives markets is a necessary condition for a well-functioning market and efficient hedging, price fluctuations can also attract significant speculative activities and destabilize markets, which are both the cause and the effect of increased prices.

The adopted model satisfied the stability conditions as well as other residuals properties, and it indicated that cointegrating vectors will converge towards their long-run equilibrium in the presence of a shock to the system after 14.7 months and 11.7 months for the two sample periods, respectively.

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Annex

Market price for wheat	This is a market price series for wheat, with values expressed in US dollars and averaged from daily quotations. The commodity and market specifications are: US No. 1 hard red winter, ordinary protein, prompt shipment, FOB Gulf of Mexico ports. The series was collected from Datastream
Real effective exchange rate	The US real effective exchange rate series take into account not only changes in market exchange rates but also variations in relative price levels (using consumer prices). The data was taken from Datastream USOCC011
Oil spot prices	This variable has been collected from EIA database and refers to Cushing, Oklahoma WTI (West Texas Intermediate) Spot Price FOB (Dollars per Barrel), Datastream USWTIOIL
Stock-to-use	Data was taken from the USDA http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194
El Niño region 3.4 sea surface temperature anomalies (SST)	Data was taken from the National Climatic Data Center US Department of Commerce and NOAA Satellite and Information Service using the extended reconstructed sea surface temperature; http://www.ncdc.noaa.gov/ersst/ftp://ftp.ncdc.noaa.gov/pub/data/cmb/ersst/v3b/pdo ftp://ftp.ncdc.noaa.gov/pub/data/cmb/ersst/v3b/pdo/el_nino.dat
The southern oscillation index (SOI)	Data was taken from National Oceanic and Atmospheric Administration National Climatic Data Center;http://www.ncdc.noaa.gov/teleconnections/enso/indicators/soi.php http://www.cpc.ncep.noaa.gov/data/indices/soi
Real federal funds	The US money market rate (federal funds) deflated by the consumer price. The Series refers to the weighted average rate at which banks borrow funds through New York brokers. Monthly rate is the average of rates of all calendar days. Data was collected from Datastream
US interest rate spread	It has been constructed as difference between the 10 year treasury bonds and the federal fund
Global activity	It is measured as industrial production index taken from IMF, IFS, via Datastream
Thinness	It was computed using data provided by the USDA http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194

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Relative Prices of Food and the Volatility of Agricultural Commodities: Evidence for a Panel of Developing Economies

11

Carlos Martins-Filho and Maximo Torero

11.1 Introduction

Increases in relative prices of food items may have severe negative impact for consumer welfare. This can be particularly acute in low income countries where the share of household expenditure on food items is high. Recently, various time series on prices and returns for major agricultural commodities (rice, maize, soybeans, and wheat) have exhibited periods of increased price variability or high absolute values of returns. Whereas the negative link between high relative food prices and consumer welfare is empirically well documented in low income economies [see, e.g., conceptually (Deaton 1989), and for short-term effects (de Hoyos and Medved 2011; Ivanic and Martin 2008; Ivanic et al. 2012; Jacoby 2013; Wodon and Zaman 2010)], the potential link between high returns on major agricultural commodities and consumer welfare is, to our knowledge, poorly understood. Most of the existing work has focused on traditional measures of transmission of global price volatility to price volatility at the country level (see, e.g., Ceballos et al. 2015; Hernandez et al. 2014; Minot 2014; Zhao and Goodwin 2011). Moreover, the link between high absolute value of returns (volatility) of agricultural commodities at the global level and their impact on local prices of foodstuffs and consumer welfare has not been analyzed in the literature.

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Looking at volatility at the global level is important because although the food price spikes of 2008 and 2011 did not reach the heights of those during the 1970s, price volatility (measured in various ways) has arguably been at its highest level in the past 15 years (see Torero 2012). Wheat and maize prices have been particularly volatile. For soft wheat, for example, there were an average of 41 days of excessive price volatility per year between December 2001 and December 2006 (according to a measure of price volatility recently developed at IFPRI).[1] From January 2007 to June 2011, the average number of days of excessive volatility was more than doubled to 88 per year (see Fig. 11.1).

High and volatile food prices are two different phenomena with distinct implications for consumers and producers. High food prices may harm poorer consumers because they need to spend more money on their food purchases and therefore may have to cut back on the quantity or quality of the food they buy. They may also be

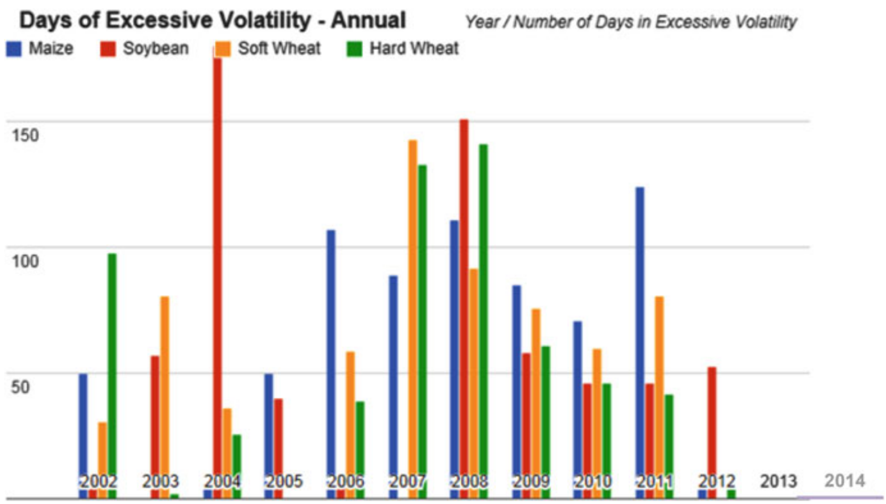

Fig. 11.1 Number of days with excessive volatility in commodity markets. *Source*: The number of days of excessive volatility is calculated using the Nonparametric Extreme Quantile (NEXQ) model for the dynamic evolution of daily returns based on historical data going back to 1954. This model is then combined with extreme value theory to estimate higher-order quantiles of the return series, allowing for classification of any particular realized return (that is, effective return in the futures market) as extremely high or not. A period of time characterized by extreme price variation (volatility) is a period of time in which we observe a large number of extreme positive returns. An extreme positive return is defined to be a return that exceeds a certain pre-established threshold. This threshold is taken to be a high-order (95 %) conditional quantile, (i.e., a value of return that is exceeded with low probability: 5 %). One or two such returns do not necessarily indicate a period of excessive volatility. Periods of excessive volatility are identified based on a statistical test applied to the number of times the extreme value occurs in a window of consecutive 60 days. See Martins-Filho et al. (2015)

[1] See Martins-Filho et al. (2013, 2015).

forced to economize on other needed goods and services. For food producers, higher food prices could raise their incomes—but only if they are net sellers of food—if increased global prices feed through to their local markets, and if the price changes on global markets do not also increase their production costs.

Apart from these effects of high food prices, price volatility also has significant effects on food producers and consumers. Greater price volatility can lead to increased losses for producers because it implies price changes that are larger and occur faster than what producers can adjust to. Uncertainty about prices makes it more difficult for farmers to make sound decisions about how and what to produce. For example, which crops should they produce? Should they invest in expensive fertilizers and pesticides? Should they purchase high-quality seeds? Without a realistic idea of how much they will earn from their products, farmers may become more pessimistic in their long-term planning and dampen their investments in areas that could otherwise improve their productivity. The positive relationship between price volatility and producers' expected losses can be modeled in a simple profit maximization model assuming producers are price takers. Still, it is important to mention that there is no uniform empirical evidence of the behavioral response of producers to volatility. By reducing supply, such a response could lead to higher prices, which in turn would hurt consumers.

It is important to remember that in rural areas the line between food consumers and producers is blurry. Many households both consume and produce agricultural commodities or foodstuffs. Therefore, if prices become more volatile and these households reduce their spending on seeds, fertilizer, and other inputs, this may affect the amount of food available for their own consumption. Even when the households are net sellers of food, producing less and having less to sell will reduce their household income and thus still impact their consumption decisions.

Finally, increased price volatility over time can also generate larger profits for investors, drawing new players into the market for agricultural commodities. Increased price volatility may thus lead to increased—and potentially speculative—trading that in turn can exacerbate price swings further, increasing volatility.

Despite the importance that price volatility may have for consumers, its impact on consumer welfare is notoriously difficult to measure due to income effects associated with price changes. In addition, the fact that in many low income countries economic agents are concomitantly consumers and producers of food creates added concerns and complications. Besides the inherent difficulties in adequately measuring consumer welfare, most empirical models for the dynamic evolution of returns for major agricultural commodities lack flexibility in modeling the conditional volatility (conditional standard deviation) of returns. Restrictive modeling of volatility can produce inconsistent return forecasts and inaccurate assessments and policy recommendations regarding the link between volatility and consumer welfare.

Since the empirical link between high relative food prices and consumer welfare is fairly well established, herein we propose an econometric/statistical model that attempts to model the relationship between conditional return volatility of major agricultural commodities and relative prices of food items/groups in a collection of low income countries. Our goal is to better understand the transmission of global volatility to local relative prices and therefore start to unveil its potential welfare effects.

11.2 Methodology

11.2.1 Relative Food Prices at Country Level

We are interested in understanding if, and how, changes in relative food prices (defined for certain groups of foodstuff) are related to volatility of agricultural commodities in global markets. To construct our variable of interest we use a Laspeyres price index for country $j = 1, \ldots, J$ in time period $t = 0, \ldots, T$. Let N be the number of elements in a collection of goods and services that form a consumption basket and $p_{tj} = \left(p_{tj1} \cdots p_{tjN}\right)'$ be the corresponding vector of prices at time period t in country j. We denote a representative consumption basket for this collection by the vector $q_{tj} = \left(q_{tj1} \cdots q_{tjN}\right)'$. The share of expenditures devoted to the nth element of the consumption basket at time t in country j is given by $s_{tjn} = p_{tjn}q_{tjn}/(p'_{tj}q_{tj})$, where $p'_{tj}q_{tj} = \sum_{n=1}^{N} p_{tjn}q_{tjn}$. Similarly, for a set $I_F = \{i_1, \ldots, i_F\}$ that indexes F elements from the representative basket, we define the share of expenditure on the food group I_F by

$$s_{tj,I_F} = \frac{p'_{tj,I_F}q_{tj,I_F}}{p'_{tj}q_{tj}},$$

where $p_{tj,I_F} = \left(p_{tji_1} \cdots p_{tji_F}\right)$, $q_{tj,I_F} = \left(q_{tji_1} \cdots q_{tjI_F}\right)'$ and $p'_{tj,I_F}q_{tj,I_F} = \sum_{n\in I_F} p_{tjn}q_{tjn}$. We note that $0 \leq s_{tj,I_F} \leq 1$. The Laspeyres price index for country j from time period $t-1$ to time period t can be written as

$$L(p_{tj}, p_{t-1,j}, q_{t-1,j}) = \sum_{n=1}^{N} \frac{p_{tjn}}{p_{t-1,jn}} s_{t-1,jn} \text{ for } t = 1, \ldots, T,$$

and the relative share of the Laspeyres price index associated with food group I_F of the consumption basket is given by

$$Y_{tjI_F} = \frac{\sum_{n\in I_F} \frac{p_{tjn}}{p_{t-1,jn}} s_{t-1,jn}}{L(p_{tj}, p_{t-1,j}, q_{t-1,j})} \text{ for } t = 1, \ldots, T.$$

Clearly, $Y_{tjI_F} \in (0, 1)$ and represents the share of price index variations from time period $t-1$ to t that correspond to the food group defined by the set I_F in the consumption basket. If Y_{tjI_F} is large, say in the vicinity of 1, the set I_F in the consumption basket accounts for a large share of the price variability of the entire consumption basket N. In this case, most of the price changes in the consumption basket from time period $t-1$ to time period t can be attributed to price variations on the elements in I_F.

If the consumption share in period $t-1$ of each element of the food group I_F—$s_{t-1,jn}$—is fixed through time at $s_{0,jn}$ for all n in I_F, then all changes in Y_{tjI_F} can be attributed to changes in relative prices of food items that belong to I_F. Otherwise, the observed variability in Y_{tjI_F} may result from both changes in relative prices and changes in expenditure shares. Throughout this paper, we will fix the share of goods and services through time at $s_{0,jn}$ and take Y_{tjI_F} as our main variable of interest for defined sets of food groups I_F. In Sect. 11.3.1 we define the sets I_F that we consider in our empirical model.

11.2.2 Conditional Global Volatility and Its Relation to Country Level Relative Food Prices

As mentioned above, we are interested in the impact that volatility of returns on agricultural commodities in global markets may have on Y_{tjI_F}. Hence, a key component of our empirical model is a measure of volatility. To obtain such a measure, we follow Martins-Filho et al. (2013) and envision the evolution of a commodity (rice, maize, soybeans, and wheat) price P as a discretely indexed stochastic process $\{P_t\}_{t=0,1,...}$. As such, the observation of a time series of commodity prices that extends from a certain time in the past up to the present time represents a realization of many possible collections of values that a stochastic process may take. We let the one-lag log-returns associated with such time series be denoted by $r_t = \log \frac{P_t}{P_{t-1}}$ and assume that

$$r_t = h^{1/2}(r_{t-1}, \ldots, r_{t-L})\varepsilon_t, \tag{11.1}$$

where $h(r_{t-1}, \ldots, r_{t-L}) = h_0 + \sum_{j=1}^{L} h_j(r_{t-j})$, $L \in \mathbb{N}$ represents the maximum lag on r_t to be included as determinants of the conditional variance (squared volatility) of the process, h_j are smooth non-negative functions that are otherwise unrestricted, $\varepsilon_t \sim IID(0, 1)$ and $E(h_j(r_{t-j})) = 0$ for all j, $h_0 > 0$.[2]

The model in (11.1) assumes that the dynamic evolution of log-returns for agricultural commodities can be described as a conditional location-scale model with conditional mean equal to zero and conditional volatility given by $\left(h_0 + \sum_{j=1}^{L} h_j(r_{t-j})\right)^{1/2}$, which is a function of L lagged returns. Here, rather than assuming that volatility takes on a specific parametric structure, as in autoregressive conditional heteroscedastic (ARCH) or generalized autoregressive conditionally heteroscedastic (GARCH) models (Engle 1982; Bollerslev 1986), we flexibly model the impact of lag returns on volatility via the nonparametric functions h_j as

[2]The requirement that $E(h_j(r_{t-j})) = 0$ for all j is an identification condition for the conditional expectation $E(r_t^2 | r_{t-1}, \ldots, r_{t-L}) = h_0 + \sum_{j=1}^{L} h_j(r_{t-j})$.

in Fan and Yao (1998) and Martins-Filho et al. (2013). In this model, a measure of (conditional) volatility—a function of time—is obtained by estimating h_0, h_j nonparametrically from a time series $\{r_t\}$.

A general stochastic model that relates Y_{tjI_F} to the volatility of agricultural commodities can be expressed as

$$E(Y_{tjI_F}|h^{1/2}(r_{t-1}, \ldots, r_{t-L}), W_t) = g^{-1}(m(h^{1/2}(r_{t-1}, \ldots, r_{t-L}), W_t)) \tag{11.2}$$

for $t = L+1, \ldots, T$, where $W_t \in \mathbb{R}^K$ is a collection of suitably defined (exogenous) conditioning variables, g is a strictly monotonic *link* function $g(x) : (0,1) \to \mathbb{R}$, m is a smooth function $m(x) : \mathbb{R}^{K+1} \to \mathbb{R}$. Note that in (11.2) g^{-1} takes values in $[0, 1]$, which guarantees that the regression takes values in $(0, 1)$, a constraint that must hold given that $Y_{tjI_F} \in (0, 1)$. It would be desirable to impose as little structure as possible on the functional m and the link g, however letting m and g be nonparametric functions creates difficulties both for estimation and for deriving practical empirical conclusions. As will be described shortly, we prefer a parametric specification that explicitly accounts for the fact that $Y_{tjI_F} \in (0, 1)$, which has important implications for stochastic modeling.

11.2.3 Beta Regression

As described above, our variable of interest—Y_{tjI_F}—takes values in $(0, 1)$ and an appropriate parametric statistical model must reflect its range. A flexible univariate parametric (unconditional) density that accounts for such range is the beta density. The beta density associated with a random variable Y is given by

$$\pi(y; p, q) = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} y^{p-1}(1-y)^{q-1} \text{ for } p, q > 0, 0 < y < 1.$$

If $\mu = \frac{p}{p+q}$ and $0 < \phi = p + q$, then $0 < E(Y) = \mu < 1$ and $V(Y) = \frac{\mu(1-\mu)}{1+\phi}$. Here, we follow Ferrari and Cribari-Neto (2004) and consider a *conditional* beta density where $\mu(\cdot)$ is a function of a collection of conditioning variables $X_t' \in \mathbb{R}^K$ with K a natural number, such that for all t

$$g(\mu_t) = \sum_{k=1}^{K} X_{tk}\theta_k = X_t\theta \tag{11.3}$$

θ is a parameter vector taking values in a compact subset of $\mathbb{R}^K$ and $g(\mu_t) = \log \frac{\mu_t}{1-\mu_t}$. This specific form for g can be promptly recognized as the much used logit-link.

It is easily verified that for a random sample $\{(Y_t, X_t)\}_{t=1}^{T}$, the log-likelihood function associated with the conditional beta model is given by $\ell(\theta, \phi) = \sum_{t=1}^{T} \ell_t(\mu_t, \phi)$, where

$$\ell_t(\mu_t, \phi) = \log\Gamma(\phi) - \log\Gamma(\mu_t\phi) - \log\Gamma((1-\mu_t)\phi) + (\mu_t\phi - 1)\log Y_t \\ + ((1-\mu_t)\phi - 1)\log(1 - Y_t).$$

The score vectors associated with the parameters of the distribution are given by

$$\ell_\theta(\theta, \phi) = \phi X' D(Y^* - \mu^*),$$

$$\ell_\phi(\theta, \phi) = \sum_{t=1}^{T} \left(\mu_t(Y_t^* - \mu_t^*) + \log(1 - Y_t) - \psi((1-\mu_t)\phi) \right. \\ \left. + \psi(\phi)\right),$$

where Y^* is a vector with tth element given by $Y_t^* = \log \frac{Y_t}{1-Y_t}$, μ^* has tth element $\mu_t^* = \log \frac{\mu_t}{1-\mu_t}$, $\psi(\cdot)$ is the digamma function, $D = \text{diag}\{1/g^{(1)}(\mu_t)\}_{t=1}^{T}$, and $X' = \left(X_1' \cdots X_T'\right)$, and $g^{(1)}(\cdot)$ denotes the first derivative of g. The values $\hat{\phi}$ and $\hat{\theta}$ that satisfy

$$\ell_\theta(\hat{\theta}, \hat{\phi}) = 0 \text{ and } \ell_\phi(\hat{\theta}, \hat{\phi}) = 0 \tag{11.4}$$

are the maximum likelihood estimators for θ and ϕ. Ferrari and Cribari-Neto (2004) obtained the Fisher Information for this model, which is given by

$$F(\theta, \phi) = \begin{pmatrix} F_{\theta\theta} & F_{\theta\phi} \\ F_{\phi\theta} & F_{\phi\phi} \end{pmatrix},$$

where $F_{\theta\theta} = \phi X' W X$, $F_{\theta\phi} = F_{\phi\theta}' = \phi X' D c$, $F_{\phi\phi} = \text{trace}(D)$ with

$$W = \text{diag}\left\{\phi\left(\psi^{(1)}(\mu_t\phi) + \psi^{(1)}((1-\mu_t)\phi)\right)(g^{(1)}(\mu_t))^{-2}\right\}_{t=1}^{T},$$

$$D = \text{diag}\left\{\psi^{(1)}(\mu_t\phi)\mu_t^2 + \psi^{(1)}((1-\mu_t)\phi)(1-\mu_t)^2 - \psi^{(1)}(\phi)\right\}_{t=1}^{T}, \text{ and}$$

$$c = (c_1, \ldots, c_T)', \text{ with } c_t = \phi\left(\psi^{(1)}(\mu_t\phi)\mu_t - \psi^{(1)}((1-\mu_t)\phi)(1-\mu_t)\right).$$

Following standard arguments for obtaining the asymptotic distribution of maximum likelihood estimators (see Newey and McFadden 1994), we obtain for sufficiently large T the following approximation

$$\begin{pmatrix} \hat{\theta} \\ \hat{\phi} \end{pmatrix} - \begin{pmatrix} \theta \\ \phi \end{pmatrix} \sim N\left(0, F^{-1}(\theta, \phi)\right), \tag{11.5}$$

which allows for asymptotically valid hypothesis testing on the parameters θ and ϕ.

It is desirable to obtain an expression for the first partial derivatives of $E(Y_t|X_t)$ with respect to the conditioning covariates X_{tk}. Given (11.3) and the logit-link, we have

$$\frac{\partial}{\partial X_{tk}} E(Y_t|X_t) = \theta_k \frac{\exp\left(\sum_{k=1}^{K} X_{tk}\theta_k\right)}{1 + \exp\left(\sum_{k=1}^{K} X_{tk}\theta_k\right)}. \tag{11.6}$$

11.3 Data, Empirical Model, and Estimation

11.3.1 Data

We have constructed a panel data set for nine Latin American countries: Costa Rica, El Salvador, Guatemala, Honduras, Ecuador, Peru, Mexico, Nicaragua and Panama, and one Asian country, India. Our variable of interest—Y_{tjI_F}—was constructed for four food groups. They are: (i) Breads and cereals, (ii) meat, (iii) milk and other dairy products, and (iv) other foods. That is, there are four elements in I_F and $I_F = \{Breads\ and\ cereals, Meat, Milk\ and\ other\ dairy\ products, Other\ foods\}$. These food groups were defined based on the international agricultural commodity groups rice, corn and wheat, and on standard grouping for food price indices, which is based on similarities in expenditure shares and market structure. Y_{tjI_F} for (i)–(iv) were constructed using detailed data sets obtained from the national statistical institutes of each country. They included a price index of approximately 200 food and nonfood items that constitute a standard consumption basket, and their corresponding relative importance (weights) in the general consumption price index (CPI).

As components of X_t in the previous section, we included a measure of the overall economic activity in the country given by a "Monthly index of economic activity." This is a Laspeyres index. It measures the evolution of economic activity, approximating the aggregated value of the industries included in the calculation of the gross domestic product (GDP). The index is given by $I_t = \sum_{i=1}^{n} I_{it} w_{i0}$ where I_t is the general index in period t; I_{it} is the index of industry i (manufacturing, agricultural, etc.) in month t; w_{i0} is the weight associated with industry i in the calculation of GDP in the baseline period; n is the number of industries; GDP is the aggregation of all the aggregated values of the productive activities. Activities included in the calculation of the IMAE (Indice Mensual de Actividad Economica—Monthly Index of Economic Activity) include: agricultural and livestock; mining; manufacturing; construction; water and electricity; trade; transport and communication; services for enterprises; services for financial intermediation; and hotel business. This variable was obtained from the Central Banks from each country. This index measures the total value of all different industries included in the calculation of the GDP. Additionally we included total imports, returns on oil prices, the monetary value (in US dollars) of liquid assets (M1) in circulation, and of course, our main conditioning variables of interest, the estimated volatility of international commodity prices (see the Appendix for a detailed list of sources for these variables in each country).

The volatility of returns for agricultural commodities was estimated using a sequence of returns based on prices for future contracts closest to maturity for: wheat CBOT (Chicago Board of Trade), wheat KCBT (Kansas City Board of Trade), corn, soybeans, and rice. From 01/28/1987 until 8/31/2009, daily data was taken from a historic file bought from the CME Group. From 09/01/2009 to 08/20/2013 daily data was obtained from daily updates, from CME and KCBT. The first observation for the time series estimation is for 01/03/1995.

11.3.2 Empirical Model and Estimation

Since $Y_{tjI_F} \in (0,1)$, we consider the following empirical specification for $g(\mu_t)$ in Sect. 11.2.3,

$$g(\mu_t) = \theta_0 + \sum_{l=1}^{4} W_{tl}\theta_l + \sum_{l=5}^{9} \theta_l h_l^{1/2}(r_{l,t-1}, r_{l,t-2}), \qquad (11.7)$$

where $h_l^{1/2}(r_{l,t-1}, r_{l,t-2})$ must be estimated based on a time series of returns $\{r_{lt}\}$ on each of the five agricultural commodities given above, and W_{t1}, W_{t2}, W_{t3}, and W_{t4} represent the monthly indicator of economic activity, total imports, M1 and return on oil prices, respectively. As in Sect. 11.2.3, we specify $g(\mu_t) = \log \frac{\mu_t}{1-\mu_t}$.

Each $h_l^{1/2}(r_{l,t-1}, r_{l,t-2})$ is estimated nonparametrically by noting that from (11.1), we have for each l,

$$E(r_{tl}^2 | r_{l,t-1}, r_{l,t-2}) = h_0 + h_{l1}(r_{l,t-1}) + h_{l2}(r_{l,t-2}).$$

Hence, for each l we conduct a nonparametric additive regression estimation using the procedure discussed in Kim et al. (1999). The data we use on r_{tl} has daily frequency, and all other data has monthly frequency. Thus, we aggregate our daily estimated conditional volatility to produce monthly estimates. We have experimented with the following measures of monthly volatility: (a) monthly means; (b) monthly medians; and (c) monthly inter-quartile ranges. There was little qualitative change in the results from using either of these measures. The results reported in Tables 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11.8, 11.9, 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, 11.17, 11.18, 11.19 and 11.20 in the Appendix are for monthly means. These estimates of (monthly) volatility, denoted by $\hat{h}_l^{1/2}(r_{l,t-1}, r_{l,t-2})$, are then used as covariates for the maximum likelihood estimation of (11.7).

The maximum likelihood procedure requires the numerical solution of the homogeneous system of nonlinear equations given in (11.4). We use the Marquardt algorithm (see Marquardt 1963) to obtain a solution. The procedure requires initial values for the parameters ϕ and θ, which we choose as suggested by Ferrari and

Cribari-Neto (2004).[3] Convergence of the algorithm is attained very quickly for all 40 (four food groups in ten countries) beta-regressions we have estimated. After obtaining $\hat{\theta}$ and $\hat{\phi}$ for all food groups and for all countries we estimated Fisher's information by $F(\hat{\theta}, \hat{\phi})$ using the expressions given in Sect. 11.2.3. $F(\hat{\theta}, \hat{\phi})$ is used to calculate the z-statistics reported in Tables 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11.8, 11.9, 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, 11.17, 11.18, 11.19 and 11.20 that appear in the Appendix. Also reported in these tables are the estimated marginal impact of the various covariates on the conditional expectation of Y_{tjI_F}. These are obtained using the estimates $\hat{\theta}$ to obtain estimated partial derivatives as given in (11.6).

11.3.3 Discussion

We first note that proportion of the variation on the general Laspeyres price index attributed to "Breads and Cereals," "Meats," and "Milk and other dairy products" is fairly small across all countries. These proportions vary from 0.02 to 0.10 for "Breads and Cereals," 0.02 to 0.09 for "Meats," and 0.03 to 0.06 for "Milk and other dairy products." As expected, the price variation of the catchall category "Other foods" is a much larger proportion of the variation on the general Laspeyres price index. It varies from proportion 0.05 to 0.26.

For illustrative purposes, Figs. 11.2 and 11.3 provide Rosenblatt-kernel estimates of the density of the proportion of the general Laspeyres price index attributed to the food group "Bread and cereals" and "Meat" in Honduras and India. Figure 11.4 provides the Rosenblatt-kernel estimate of the density of the proportion of the general Laspeyres price index attributed to the food group "Milk and other dairy products" in Peru, and Fig. 11.5 provides the Rosenblatt-kernel estimate of the density of the proportion of the general Laspeyres price index attributed to the food group "Other foods" in Nicaragua. The estimated unimodal densities presented here are typical across the countries, but cases of bimodal densities do exist.

The results for all regressions are given in Tables 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11.8, 11.9, 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, 11.17, 11.18, 11.19 and 11.20 in the Appendix. The tables contain parameter estimates, z-statistics for the null hypothesis that $\theta_k = 0$ against the alternative that $\theta_k \neq 0$ as well as the estimated marginal impact of each covariate evaluated at its average sample value. In addition, we provide pseudo-R^2 values for each regression. We can perceive some general regularities. For all food groups and for all countries, the precision parameter ϕ and the intercept θ_0 are significant at the 5 % level, with $\phi > 0$ and $\theta_0 < 0$. Also, the pseudo-R^2 for the regressions are generally large, varying from 0.56 to 0.98, indicating a reasonable overall fit for the models we have specified.[4]

[3] All codes for estimation were written using MATLAB and are available upon request.

[4] The exception is the regression for the Meat group in Costa Rica, where the pseudo-R^2 is 0.21.

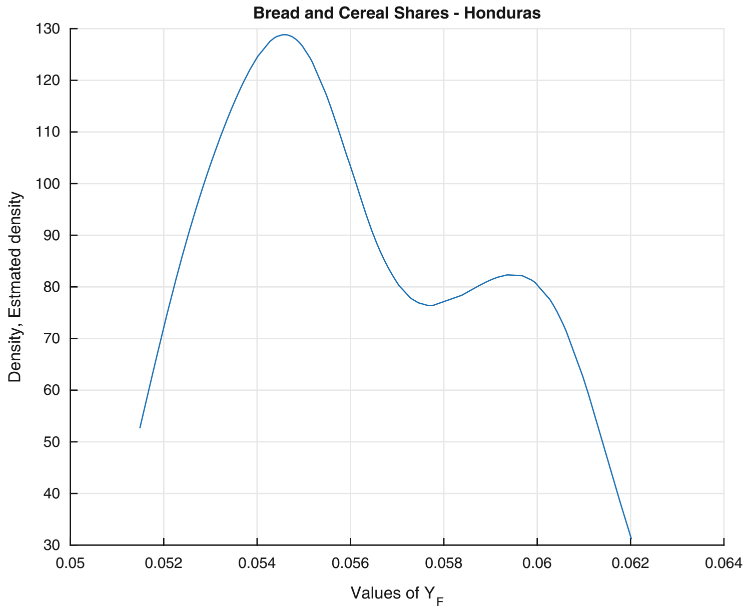

Fig. 11.2 Rosenblatt density estimate of the density of the proportion of general Laspeyres price index attributed to "Breads and cereals" in Honduras

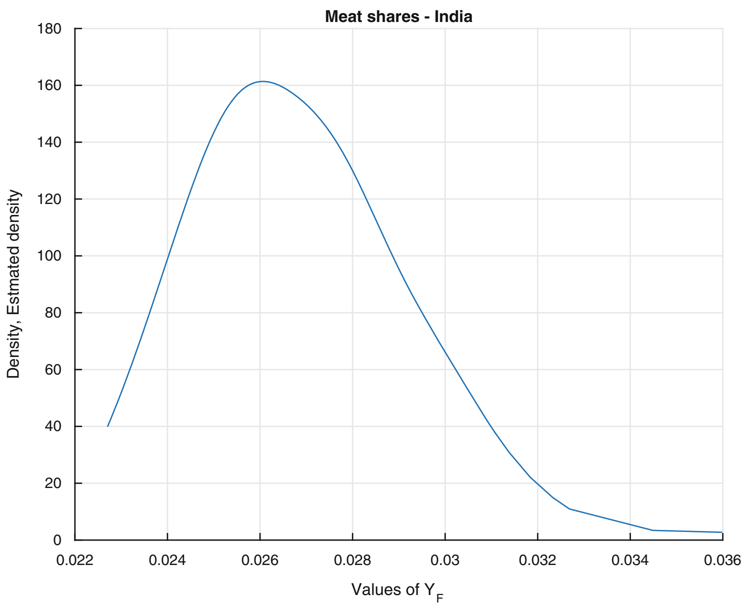

Fig. 11.3 Rosenblatt density estimate of the density of the proportion of general Laspeyres price index attributed to "Meat" in India

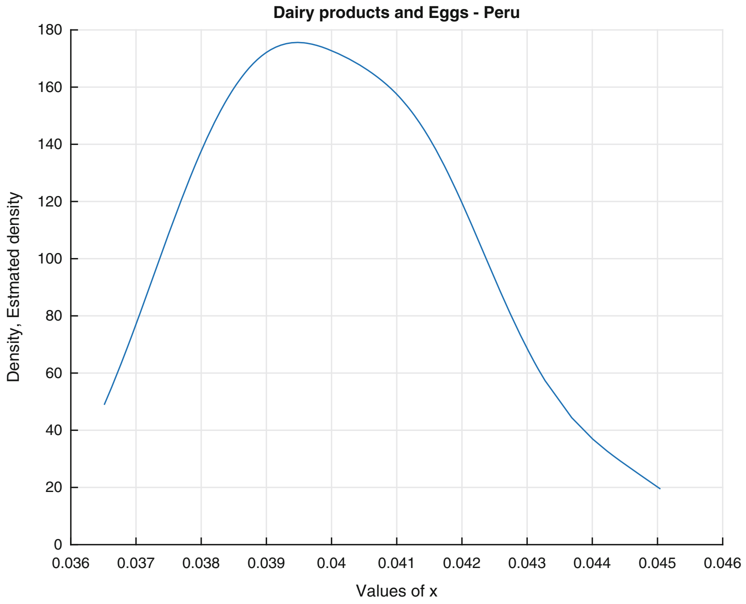

Fig. 11.4 Rosenblatt density estimate of the density of the proportion of general Laspeyres price index attributed to "Milk and dairy products" in Peru

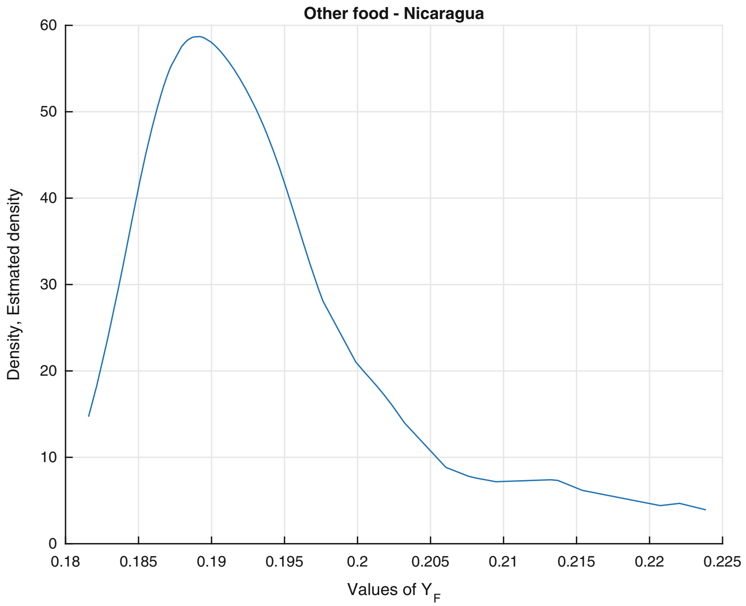

Fig. 11.5 Rosenblatt density estimate of the density of the proportion of general Laspeyres price index attributed to "Other foods" in Nicaragua

In addition, for most regressions, plots of standardized residuals against the indices of the observations show no discernible pattern that may suggest misspecification. Figures 11.6 and 11.7 provide such plots for Honduras and India. The case of Honduras is quite typical, but the figure for India reveals that some observations may have significant leverage on the estimation. We chose to keep these observations in our calculations, but their removal normally boosts the estimated value of ϕ.

For the food group "Breads and cereals" and for all countries, with the exception of El Salvador, Guatemala, and Nicaragua, the parameters associated with the volatility of wheat (either KCBT or CBOT) are positive and significant, mostly at the 5 % level, and in Honduras and Mexico at the 10 % level.[5] Whenever the estimated parameter values associated with either of these volatilities is negative, it is insignificant at either the 5 or 10 % level. Thus, there seems to be evidence that increased volatility of prices of wheat in global markets correlates with an increased proportion of the variation on the general Laspeyres price index that is attributed to the food group "Breads and cereals." Put differently, increased volatility on wheat markets may increase the relative prices of "Breads and cereals" in most countries. Accordingly, policies or market forces that mitigate volatility in these global markets

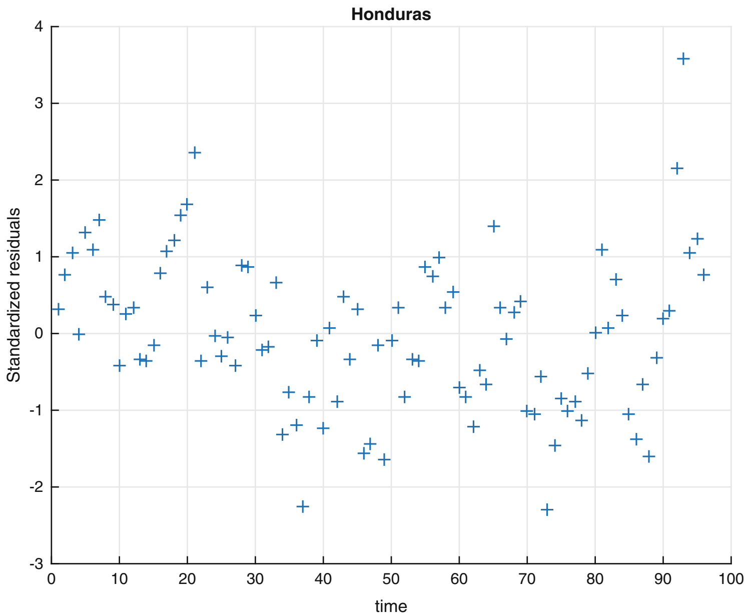

Fig. 11.6 Standardized residuals against the time index of the observations for "Other foods" for Honduras

[5]In El Salvador and Nicaragua the parameters associated with global wheat market volatility are statistically insignificant, and in Guatemala the parameter associated with the volatility of hard wheat (VolWCBOT) is negative and significant at the 10 % level.

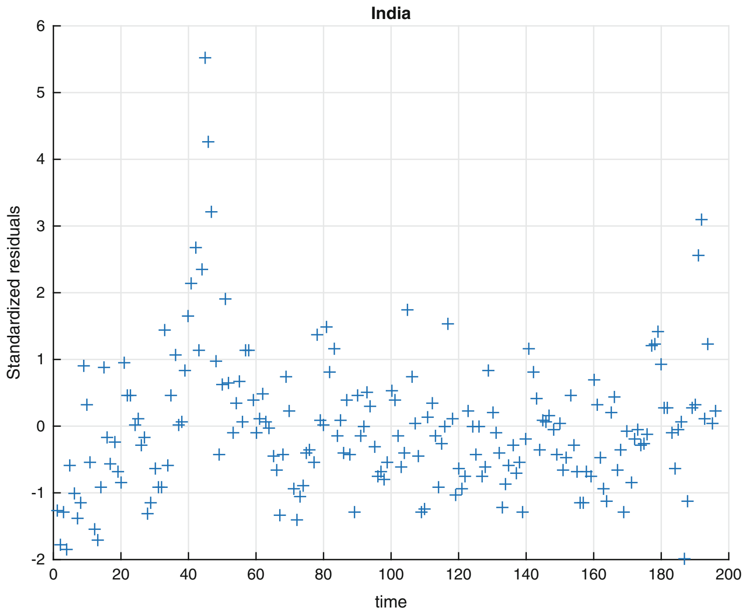

Fig. 11.7 Standardized residuals against the time index of the observations for "Other foods" for India

may help curb the share of general price movements that is attributable to "Breads and Cereals," therefore lessening the impact of changing prices on the budgets of households where this food group accounts for a larger share of expenditures.

The parameter associated with the index of economic activity is, whenever significant, negative for most food groups and countries (19 out of 24 cases). The exceptions are Costa Rica, El Salvador, and Guatemala where the parameter is positive and significant for the food groups "Breads and cereals," "Milk and other dairy products," and/or the catchall category "Other foods." Hence, there seems to be some evidence that increased economic activity dampens the proportion of the variation on the general Laspeyres price index that is attributed to most food groups. Thus, growth seems to lighten the impact of changing prices on the budgets of households where food accounts for a larger share of expenditures.

The parameter associated with the returns on oil prices is insignificant for virtually all food groups across all countries. The exceptions are "Breads and cereals" in India and "Meat" in Ecuador. The parameter associated with M1 is mostly positive and significant, or insignificant in most countries across all food groups. In addition, the absolute value of the estimated parameters associated with M1 is quite small, with values that are less than or equal to 10^{-4}. Similarly, the estimated parameters associated with imports are also very small in absolute value. For this covariate, in most countries in Latin America, it has a statistically significant positive impact on the proportion of the variation on the general Laspeyres price index that is attributed to most food groups. In India the impact of this covariate is significant, but negative.

For the food group "Meats" and for most countries the parameter associated with the volatility of corn is positive and significant at either the 5 or 10 % level. The exceptions are Costa Rica, where the parameter is negative and insignificant, and Nicaragua, Panama, and Peru where the parameters are always positive but not significant at the 10 % level. Hence, there seems to be some evidence that increased volatility of prices of corn in global markets correlates with an increased proportion of the variation on the general Laspeyres price index that is attributed to the food group "Meats."

We note that the marginal impact of changes in covariates on $E(Y_{tjI_F}|\cdot)$ is relatively small across countries and food groups. This impact is rarely above 1 in absolute value, with exceptions for volatility of wheat in India and Costa Rica and volatility of rice in Peru for the "Other foods" group, volatility of rice in El Salvador and volatility of wheat, corn, and soy in Guatemala for the "Breads and cereals" group, and volatility of rice for the "Meat" group in Mexico. Thus, changes in volatility produce, at average values, changes on $E(Y_{tjI_F}|\cdot)$ of smaller magnitude.

11.4 Conclusion

The global food price crises of 2007/2008 and 2010/2011 led to economic difficulties for the poor, contributed to political turmoil in many countries, and in the long run could undermine confidence in global food markets, thereby hampering these markets' performance in balancing fundamental changes in supply, demand, and production costs. More important, food price crises can result in unreasonable or unwanted price fluctuations (volatility) that can harm the poor. Price volatility can have significant effects on food producers and consumers but the potential link between the volatility of returns for major agricultural commodities at the global level and welfare at the household level was not well understood. In this paper we took advantage of the fact that there is already important evidence on the effects of price levels on welfare and therefore focus on reducing the knowledge gap of the relationship between price volatility at the global level and relative prices of food items/groups in low income countries. Specifically, to close this gap we specify an empirical model that describes the dynamic evolution of the relative share of various food items in a Laspeyres price index as a function of the global volatility of returns for major agricultural commodities and a collection of observed covariates and relate it to the volatility of returns of agricultural commodities emerging from a fully nonparametric location-scale stochastic process as in Martins-Filho et al. (2015).

Our results show evidence for most countries of a relationship between relative prices and price volatility for the food group "Breads and cereals" with the volatility of wheat (either KCBT or CBOT). Thus, increased global volatility on wheat markets may increase the relative prices of "Breads and cereals" in most countries.

Similarly, for the food group "Meats" for most countries the parameter associated with the volatility of corn is positive and significant being possibly the transmission mechanism for animal feed based on corn. Hence, and similarly to the case of wheat and breads and cereals, there also seems to be some evidence that increased volatility of prices of corn in global markets correlates with an increased proportion of the variation on the general Laspeyres price index that is attributed to the food group "Meats."

Accordingly, policies or market forces that mitigate volatility in these global markets may help curb the share of general price movements that is attributable to "Breads and cereals" and "Meat" at the country level lessening the impact of changing prices on the budgets of households where these food groups account for a larger share of expenditures. These results are of extreme relevance for the food price crises of 2007/2008 because volatility was, as initially mentioned, at its highest level during that period of time relative to the past 50 years. Even more the volatility was the highest for wheat and corn. For soft wheat there were an average of 41 days of excessive price volatility per year between December 2001 and December 2006 while from January 2007 to June 2011, the average number of days of excessive volatility more than doubled to 88 per year.

The question is then what countries can do to cope with excessive volatility. In this light, many countries try to stabilize prices through trade policies and management of food reserves. With respect to reserves, international experience in the management and use of so-called strategic grain reserves is mixed, with frequent concerns about operational inefficiencies, financial costs, and disincentives for private traders to perform normal arbitrage functions. Some of the problems with grain reserves can be overcome by establishing clear and open rules for market interventions, including the private sector in the tendering for supplies for the reserves, combining grain and financial reserves to reduce costs. However, instead of domestic buffer stocks, some authors posit the advantages of holding reserves at the international level or regional level. Among other reasons, this type of intervention can reduce storage costs and, if managed by an international intelligence unit, can reduce governments' political management of the resources. Albeit compelling, an international or regional reserve poses other important obstacles. Politically, it requires multinational coordination and sound governance. Economically, it might disincentive private grain storage. Operationally, it is important to establish clear triggers for market intervention. Similarly, there is important evidence showing that using trade policies to reduce price volatility is not effective and on the contrary could have important welfare costs as shown by Martin and Anderson (2011) and Anderson and Nelgen (2012).

On the other hand, there is evidence that improved transport infrastructure helps reduce price variability. Roads are useful means to spread out regional shocks; if a certain region is hit by a shock (weather or other), it can import food from another region. For example, during the food crisis of 2007/2008, it is shown that regions with better infrastructure in Indonesia were not hit as hard as those poorly connected. In this line, the World Bank (2010) argues that after controlling for exchange rates and world prices, remote provinces appear to have higher levels of price volatility than well-connected provinces. It confirms the importance of investment in infrastructure. In particular, it demonstrates that the constraints created by geography and remoteness to the transmission of price signals can be alleviated by improving the quality of infrastructure. This result is consistent with the fact that in our analysis we also find some evidence that increased economic activity dampens the proportion of the variation on the general Laspeyres price index that is attributed to most food groups. Thus, growth seems to lighten the impact of changing prices on the budgets of households where food accounts for a larger share of expenditures.

In summary, price volatility is likely to remain an important challenge in the medium and long run and, as was shown, a link exists between the volatility of returns for major agricultural commodities and relative prices of certain food groups. It is in this sense that further research is needed to understand alternative policies at the global, regional, and local level that could help countries to cope with excessive volatility.

Appendix

Tables

Table 11.1 Model: Y_{tI_F}—India, $n = 196$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	8322.0225	9.8975		8052.0188	9.8966	
θ_0(Intercept)	−3.3859	−45.8605	−0.1181	−3.4186	−40.4528	−0.0918
θ_1(EconAct)	−0.0001	−0.4041	0	−0.0012	−2.9929	0
θ_2(Imports)	0	−4.1538	0	0	−3.8414	0
θ_3(M1)	0	0.8828	0	0	5.1483	0
θ_4(Return on Oil)	0.1347	2.5937	0.0047	0.0363	0.6084	0.001
θ_5(VolCorn)	3.7597	1.6468	0.1311	4.8465	1.8106	0.1302
θ_6(VolSoy)	−7.9867	−2.9294	−0.2785	−11.1097	−3.5301	−0.2985
θ_7(VolRice)	−8.0383	−3.8538	−0.2803	−12.6843	−5.209	−0.3408
θ_8(VolWCBOT)	24.7865	3.972	0.8644	11.699	1.6275	0.3143
θ_9(VolWKCBT)	−7.448	−1.3926	−0.2597	−2.8586	−0.4622	−0.0768
Pseudo-R^2	0.61				0.63	

Table 11.2 Model: Y_{tI_F}—India, $n = 196$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	18,235.638	9.8986		2959.3164	9.8965	
θ_0(Intercept)	−3.3944	−67.3571	−0.115	−2.8103	−27.592	−0.1442
θ_1(EconAct)	−0.0006	−2.5677	0	−0.0012	−2.374	−0.0001
θ_2(Imports)	0	−6.9294	0	0	−1.9511	0
θ_3(M1)	0	5.2652	0	0	2.9808	0
θ_4(Return on Oil)	0.0456	1.2867	0.0015	−0.1576	−2.1992	−0.0081
θ_5(VolCorn)	0.9446	0.5976	0.032	2.2964	0.7103	0.1178
θ_6(VolSoy)	−6.1414	−3.3173	−0.2081	−8.4597	−2.2293	−0.434
θ_7(VolRice)	−0.9646	−0.6754	−0.0327	−12.9179	−4.4025	−0.6627
θ_8(VolWCBOT)	7.9036	1.8516	0.2678	20.5499	2.3618	1.0542
θ_9(VolWKCBT)	2.1534	0.5863	0.073	−5.2261	−0.6984	−0.2681
Pseudo-R^2	0.58				0.58	

Table 11.3 Model: Y_{tI_F}—Costa Rica, $n = 161$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	26,075.522	8.9718		45,212.82	8.9719	
θ_0(Intercept)	−3.6305	−98.3296	−0.1566	−3.173	−106.2465	−0.1228
θ_1(EconAct)	0.0004	1.8016	0	−0.0001	−0.7093	0
θ_2(Imports)	−0.0001	−2.1393	0	0	2.0016	0
θ_3(M1)	0	4.0094	0	0	−0.2263	0
θ_4(Return on Oil)	−0.0237	−0.8253	−0.001	−0.0045	−0.195	−0.0002
θ_5(VolCorn)	−3.0216	−1.7949	−0.1304	−0.1286	−0.0974	−0.005
θ_6(VolSoy)	9.0852	6.4816	0.392	0.2527	0.2246	0.0098
θ_7(VolRice)	2.3734	1.636	0.1024	−0.4263	−0.3762	−0.0165
θ_8(VolWCBOT)	7.5157	2.0229	0.3243	−3.4331	−1.1423	−0.1329
θ_9(VolWKCBT)	8.689	2.2975	0.3749	1.4881	0.4892	0.0576
Pseudo-R^2	0.94				0.21	

Table 11.4 Model: Y_{tI_F}—Costa Rica, $n = 161$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	6196.3183	8.9698		10,060.627	8.9724	
θ_0(Intercept)	−4.6539	−56.4141	−0.168	−2.1065	−64.0618	−0.3418
θ_1(EconAct)	0.0034	6.6053	0.0001	0.0009	4.6255	0.0002
θ_2(Imports)	−0.0001	−1.7584	0	−0.0001	−3.7474	0
θ_3(M1)	0	0.1881	0	0	4.0935	0
θ_4(Return on Oil)	−0.0455	−0.7101	−0.0016	−0.0074	−0.2882	−0.0012
θ_5(VolCorn)	3.3943	0.884	0.1225	3.4899	2.3559	0.5663
θ_6(VolSoy)	8.2956	2.633	0.2994	−0.0698	−0.0557	−0.0113
θ_7(VolRice)	9.0529	2.7014	0.3268	2.2767	1.7793	0.3694
θ_8(VolWCBOT)	6.7551	0.8206	0.2438	3.2624	0.9848	0.5294
θ_9(VolWKCBT)	15.4374	1.8353	0.5572	6.8953	2.0505	1.1189
Pseudo-R^2	0.93				0.94	

Table 11.5 Model: Y_{tI_F}—Ecuador, $n = 101$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	17,823.992	7.105		17,059.821	7.1061	
θ_0(Intercept)	−4.4994	−40.662	−0.0942	−3.0999	−46.642	−0.1984
θ_1(EconAct)	0.0003	1.3192	0	−0.0003	−2.5424	0
θ_2(Imports)	0	−0.0158	0	0	−0.2144	0
θ_3(M1)	0	0.9764	0	0	3.264	0
θ_4(Return on Oil)	0.0387	0.6157	0.0008	0.0665	1.7533	0.0043
θ_5(VolCorn)	−5.7378	−1.1672	−0.1201	9.0724	3.0926	0.5807
θ_6(VolSoy)	15.704	4.1448	0.3288	−3.8565	−1.6903	−0.2468
θ_7(VolRice)	5.1702	0.8926	0.1083	11.269	3.2368	0.7212
θ_8(VolWCBOT)	−5.5333	−0.6799	−0.1159	3.5782	0.7259	0.229
θ_9(VolWKCBT)	20.9795	2.5906	0.4393	3.5107	0.7179	0.2247
Pseudo-R^2	0.83				0.86	

Table 11.6 Model: Y_{tI_F}—Ecuador, $n = 101$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	91,687.291	7.1062		15,227.761	7.1065	
θ_0(Intercept)	−3.2196	−94.4869	−0.1429	−1.6972	−39.1194	−0.3331
θ_1(EconAct)	0	−0.6612	0	−0.0001	−1.4768	0
θ_2(Imports)	0	4.1872	0	0	2.2185	0
θ_3(M1)	0	0.0493	0	0	8.2742	0
θ_4(Return on Oil)	0.0004	0.0218	0	0.0034	0.1382	0.0007
θ_5(VolCorn)	−1.4647	−0.9732	−0.065	−4.4661	−2.3233	−0.8767
θ_6(VolSoy)	0.0609	0.052	0.0027	2.9095	1.9523	0.5711
θ_7(VolRice)	2.8649	1.6069	0.1272	6.1867	2.7241	1.2144
θ_8(VolWCBOT)	0.1769	0.0699	0.0079	1.1011	0.3418	0.2161
θ_9(VolWKCBT)	4.0488	1.6159	0.1797	1.2828	0.4018	0.2518
Pseudo-R^2	0.85				0.96	

Table 11.7 Model: Y_{tI_F}—El Salvador, $n = 158$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	5561.2261	8.888		12,950.628	8.8873	
θ_0(Intercept)	−2.1186	−28.6153	−0.1978	−2.5586	−36.4601	−0.1052
θ_1(EconAct)	−0.0015	−3.8894	−0.0001	−0.0011	−2.9273	0
θ_2(Imports)	0	0.6865	0	−0.0001	−1.9564	0
θ_3(M1)	0.0001	1.6496	0	0	−0.5514	0
θ_4(Return on Oil)	0.0263	0.5228	0.0025	0.0079	0.1643	0.0003
θ_5(VolCorn)	3.5452	1.8955	0.331	5.0484	2.819	0.2075
θ_6(VolSoy)	4.9424	2.0159	0.4614	−13.2289	−5.384	−0.5438
θ_7(VolRice)	−11.1869	−6.2487	−1.0444	−6.4993	−3.7905	−0.2672
θ_8(VolWCBOT)	2.2313	0.37	0.2083	−11.5973	−2.0402	−0.4767
θ_9(VolWKCBT)	2.9245	0.6448	0.273	5.62	1.3124	0.231
Pseudo-R^2	0.56				0.85	

Table 11.8 Model: Y_{tI_F}—El Salvador, $n = 158$

Parameter	Milk and other dairy products			Other foods		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	30,430.033	8.8881		5667.8556	8.8887	
θ_0(Intercept)	−2.549	−70.1824	−0.1738	−1.6938	−30.9319	−0.322
θ_1(EconAct)	0.0005	2.4619	0	0.0001	0.3237	0
θ_2(Imports)	−0.0002	−6.41	0	0.0001	1.0381	0
θ_3(M1)	0	−1.6455	0	0.0001	4.3691	0
θ_4(Return on Oil)	0.0062	0.2515	0.0004	−0.0103	−0.2802	−0.002
θ_5(VolCorn)	−0.9513	−1.0251	−0.0649	−0.2598	−0.1873	−0.0494
θ_6(VolSoy)	−1.1632	−0.9433	−0.0793	4.208	2.3415	0.8
θ_7(VolRice)	−4.3038	−4.8952	−0.2935	−1.2858	−0.9834	−0.2444
θ_8(VolWCBOT)	7.5635	2.5548	0.5157	4.292	0.9573	0.8159
θ_9(VolWKCBT)	−2.8503	−1.2763	−0.1944	−2.7598	−0.8161	−0.5247
Pseudo-R^2	0.88				0.81	

Table 11.9 Model: Y_{tI_F}—Guatemala, $n = 87$

Parameter	Breads and cereals			Meat		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	4298.7881	6.5953		146,788.96	6.5954	
θ_0(Intercept)	−2.9855	−24.5471	−0.3232	−2.4889	−96.4172	−0.1709
θ_1(EconAct)	−0.0008	−0.6875	−0.0001	0.0001	0.6322	0
θ_2(Imports)	0.0002	1.7144	0	0	−1.1404	0
θ_3(M1)	0.0002	11.7713	0	0	−6.0762	0
θ_4(Return on Oil)	0.0757	0.9064	0.0082	−0.0175	−1.0212	−0.0012
θ_5(VolCorn)	−11.8679	−3.44	−1.2849	1.8097	2.6906	0.1242
θ_6(VolSoy)	22.4028	7.5817	2.4255	−0.9991	−1.605	−0.0686
θ_7(VolRice)	8.2857	2.5947	0.8971	−1.567	−2.5122	−0.1076
θ_8(VolWCBOT)	−18.6606	−1.9522	−2.0204	1.1373	0.5625	0.0781
θ_9(VolWKCBT)	5.419	0.5968	0.5867	−2.4823	−1.3201	−0.1704
Pseudo-R^2	0.98				0.93	

Table 11.10 Model: Y_{tI_F}—Guatemala, $n = 87$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	65,680.907	6.5953		25,657.83	6.5955	
θ_0(Intercept)	−3.3321	−64.5307	−0.1212	−1.4485	−36.6358	−0.2782
θ_1(EconAct)	0.0002	0.3783	0	0.0009	2.5545	0.0002
θ_2(Imports)	0	−0.7157	0	0	−1.1066	0
θ_3(M1)	0	−1.4175	0	0	−2.6884	0
θ_4(Return on Oil)	−0.0183	−0.5276	−0.0007	0.0335	1.2704	0.0064
θ_5(VolCorn)	0.0587	0.043	0.0021	1.775	1.7126	0.3409
θ_6(VolSoy)	−1.6323	−1.2926	−0.0594	−4.0444	−4.2128	−0.7768
θ_7(VolRice)	−3.3057	−2.6103	−0.1202	0.9904	1.0305	0.1902
θ_8(VolWCBOT)	8.1127	2.0038	0.295	3.9504	1.2751	0.7588
θ_9(VolWKCBT)	2.8203	0.7445	0.1025	−4.0736	−1.4118	−0.7825
Pseudo-R^2	0.58				0.73	

Table 11.11 Model: Y_{tI_F}—Honduras, $n = 96$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	14,598.789	6.9279		48,382.299	6.9281	
θ_0(Intercept)	−2.585	−26.1313	−0.1452	−2.3455	−43.8583	−0.1391
θ_1(EconAct)	−0.0053	−7.3732	−0.0003	−0.0017	−4.43	−0.0001
θ_2(Imports)	0.0005	4.8968	0	0.0001	2.1388	0
θ_3(M1)	0.0001	0.8068	0	0	−1.0715	0
θ_4(Return on Oil)	−0.0571	−1.0855	−0.0032	−0.0273	−0.9683	−0.0016
θ_5(VolCorn)	−1.0199	−0.4448	−0.0573	3.9446	3.212	0.234
θ_6(VolSoy)	−2.084	−0.8758	−0.117	−8.0223	−6.2669	−0.4759
θ_7(VolRice)	−2.5027	−1.2808	−0.1406	−1.8207	−1.7399	−0.108
θ_8(VolWCBOT)	7.9671	0.9622	0.4474	−3.7906	−0.8517	−0.2249
θ_9(VolWKCBT)	10.1606	1.6438	0.5706	−4.2284	−1.2683	−0.2508
Pseudo-R^2	0.75				0.90	

Table 11.12 Model: Y_{tI_F}—Honduras, $n = 96$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	34,209.087	6.928		13,181.435	6.9283	
θ_0(Intercept)	−2.6426	−37.6436	−0.1261	−1.3638	−20.9949	−0.2263
θ_1(EconAct)	−0.0037	−7.2297	−0.0002	−0.0032	−6.957	−0.0005
θ_2(Imports)	0.0003	4.0397	0	0.0003	4.3367	0.0001
θ_3(M1)	0.0002	3.8116	0	0.0001	2.3503	0
θ_4(Return on Oil)	−0.0496	−1.334	−0.0024	−0.0525	−1.5292	−0.0087
θ_5(VolCorn)	−1.5597	−0.9562	−0.0744	1.3954	0.9295	0.2315
θ_6(VolSoy)	−4.8124	−2.8469	−0.2297	−1.6185	−1.048	−0.2685
θ_7(VolRice)	−1.5132	−1.0887	−0.0722	−2.8316	−2.2052	−0.4698
θ_8(VolWCBOT)	−7.0353	−1.1958	−0.3358	0.4223	0.0777	0.0701
θ_9(VolWKCBT)	4.877	1.1178	0.2328	0.2002	0.0496	0.0332
Pseudo-R^2	0.77				0.71	

Table 11.13 Model: Y_{tI_F}—Mexico, $n = 159$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	18,585.355	8.9154		5369.5718	8.915	
θ_0(Intercept)	−3.5081	−32.6184	−0.1168	−1.9976	−13.1078	−0.1125
θ_1(EconAct)	0.0002	0.118	0	−0.0071	−3.3766	−0.0004
θ_2(Imports)	0	2.6326	0	0	3.5931	0
θ_3(M1)	0	−1.9315	0	0	−5.1358	0
θ_4(Return on Oil)	0.0704	1.5813	0.0023	−0.0194	−0.3014	−0.0011
θ_5(VolCorn)	1.8294	1.1281	0.0609	6.605	2.8381	0.3718
θ_6(VolSoy)	−2.6105	−1.2018	−0.0869	−1.784	−0.5532	−0.1004
θ_7(VolRice)	−6.2146	−3.7211	−0.2069	−17.8027	−7.3128	−1.0022
θ_8(VolWCBOT)	9.193	1.8751	0.3061	0.2148	0.0305	0.0121
θ_9(VolWKCBT)	−1.1962	−0.2925	−0.0398	−2.0003	−0.3489	−0.1126
Pseudo-R^2	0.63				0.88	

Table 11.14 Model: Y_{tI_F}—Mexico, $n = 159$

Parameter	Milk and other dairy products			Other foods		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	8191.7135	8.9149		8349.1367	8.9159	
θ_0(Intercept)	−2.5171	−17.6153	−0.1044	−2.2455	−20.5959	−0.1644
θ_1(EconAct)	−0.0065	−3.3301	−0.0003	−0.0024	−1.6152	−0.0002
θ_2(Imports)	0	4.4809	0	0	3.3767	0
θ_3(M1)	0	−6.0912	0	0	−6.1153	0
θ_4(Return on Oil)	0.0212	0.3538	0.0009	-0.0103	−0.2262	−0.0008
θ_5(VolCorn)	3.7388	1.7097	0.1551	2.3254	1.3982	0.1702
θ_6(VolSoy)	−7.3896	−2.4292	−0.3066	−8.1107	−3.5465	−0.5936
θ_7(VolRice)	−14.9432	−6.5592	−0.62	−7.112	−4.1495	−0.5205
θ_8(VolWCBOT)	10.5947	1.6134	0.4396	6.3139	1.2587	0.4621
θ_9(VolWKCBT)	−0.6629	−0.1234	−0.0275	−0.627	−0.152	−0.0459
Pseudo-R^2	0.86				0.81	

Table 11.15 Model: Y_{tI_F}—Nicaragua, $n = 88$

Parameter	Breads and cereals			Meat		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	23,124.049	6.6331		28,388.756	6.6331	
θ_0(Intercept)	−2.9785	−61.2473	−0.2098	−2.557	−55.4856	−0.18
θ_1(EconAct)	0.0002	0.8483	0	0.0001	0.3479	0
θ_2(Imports)	0.0004	4.291	0	0.0001	1.7132	0
θ_3(M1)	0.0005	5.2454	0	0	0.3868	0
θ_4(Return on Oil)	0.0511	1.2112	0.0036	−0.03	−0.7928	−0.0021
θ_5(VolCorn)	−1.4927	−0.8725	−0.1052	2.3858	1.5672	0.1679
θ_6(VolSoy)	7.6796	5.1633	0.541	−3.8797	−2.8563	−0.2731
θ_7(VolRice)	−2.4418	−1.6053	−0.172	3.5647	2.6457	0.2509
θ_8(VolWCBOT)	1.3202	0.2667	0.093	−2.5505	−0.5616	−0.1795
θ_9(VolWKCBT)	4.8302	1.0473	0.3403	−4.9979	−1.2009	−0.3518
Pseudo-R^2	0.94				0.88	

Table 11.16 Model: Y_{tI_F}—Nicaragua, $n = 88$

	Milk and other dairy products			Other foods		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	8894.0985	6.6327		12,171.234	6.6334	
θ_0(Intercept)	−2.8914	−32.9862	−0.168	−1.6241	−36.4102	−0.3154
θ_1(EconAct)	−0.0002	−0.6858	0	0.0002	0.9527	0
θ_2(Imports)	−0.0005	−2.9821	0	0.0003	3.8202	0.0001
θ_3(M1)	0.0007	4.0906	0	0.0003	4.1596	0.0001
θ_4(Return on Oil)	0.1163	1.5761	0.0068	0.0444	1.1844	0.0086
θ_5(VolCorn)	−10.1085	−3.3629	−0.5872	2.7707	1.8333	0.538
θ_6(VolSoy)	−4.7079	−1.7503	−0.2735	0.3458	0.2589	0.0672
θ_7(VolRice)	−3.62	−1.3816	−0.2103	0.1308	0.0975	0.0254
θ_8(VolWCBOT)	17.1722	1.9661	0.9976	−4.24	−0.9516	−0.8234
θ_9(VolWKCBT)	3.447	0.4277	0.2002	1.7843	0.4344	0.3465
Pseudo-R^2	0.88				0.81	

Table 11.17 Model: Y_{tI_F}—Panama, $n = 79$

	Breads and cereals			Meat		
Parameter	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	42,836.899	6.2847		27,901.146	6.2848	
θ_0(Intercept)	−3.3296	−48.3513	−0.1477	−2.5388	−39.1479	−0.2065
θ_1(EconAct)	−0.0012	−2.3271	−0.0001	0.0008	1.6198	0.0001
θ_2(Imports)	0.0001	3.0469	0	0	−0.6296	0
θ_3(M1)	0.0001	6.2054	0	0	1.0226	0
θ_4(Return on Oil)	0.0334	1.1603	0.0015	0.0145	0.5335	0.0012
θ_5(VolCorn)	−4.9734	−2.2377	−0.2207	3.0768	1.4729	0.2502
θ_6(VolSoy)	3.9587	2.7148	0.1757	−0.2289	−0.1686	−0.0186
θ_7(VolRice)	0.2367	0.1261	0.0105	1.5116	0.8705	0.1229
θ_8(VolWCBOT)	13.9842	3.0451	0.6205	−4.0673	−0.9367	−0.3308
θ_9(VolWKCBT)	−1.0518	−0.2336	−0.0467	−1.3298	−0.3149	−0.1081
Pseudo-R^2	0.95				0.70	

Table 11.18 Model: Y_{tI_F}—Panama, $n = 79$

Parameter	Milk and other dairy products			Other foods		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	30,599.764	6.2845		19,812.572	6.285	
θ_0(Intercept)	−3.9488	−41.1289	−0.1244	−2.0358	−34.6196	−0.3042
θ_1(EconAct)	0.001	1.4929	0	0.0006	1.5135	0.0001
θ_2(Imports)	0	0.2854	0	−0.0001	−3.8037	0
θ_3(M1)	0.0001	3.3279	0	0	4.291	0
θ_4(Return on Oil)	−0.0364	−0.9104	−0.0011	−0.037	−1.5032	−0.0055
θ_5(VolCorn)	−12.6476	−4.0779	−0.3984	−1.4221	−0.7495	−0.2125
θ_6(VolSoy)	8.5396	4.2007	0.269	4.6104	3.7345	0.6888
θ_7(VolRice)	1.7534	0.6661	0.0552	0.7373	0.4654	0.1102
θ_8(VolWCBOT)	−0.5952	−0.0932	−0.0187	2.2778	0.5795	0.3403
θ_9(VolWKCBT)	16.9397	2.705	0.5336	3.5562	0.9275	0.5313
Pseudo-R^2	0.94				0.92	

Table 11.19 Model: Y_{tI_F}—Peru, $n = 152$

Parameter	Breads and cereals			Meat		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	10,649.305	8.7177		5867.4867	8.7175	
θ_0(Intercept)	−2.2777	−51.2681	−0.2132	−1.7373	−28.2889	−0.1568
θ_1(EconAct)	−0.0007	−2.2116	−0.0001	−0.0031	−6.8838	−0.0003
θ_2(Imports)	0.0001	6.9847	0	0.0003	10.029	0
θ_3(M1)	0	−1.39	0	0	−6.4168	0
θ_4(Return on Oil)	0.0446	1.2385	0.0042	0.0391	0.7958	0.0035
θ_5(VolCorn)	−2.4112	−1.8183	−0.2257	2.2836	1.2644	0.2061
θ_6(VolSoy)	8.627	4.9168	0.8076	−7.3505	−2.9558	−0.6634
θ_7(VolRice)	−5.3316	−3.9281	−0.4991	−12.0382	−6.4187	−1.0865
θ_8(VolWCBOT)	−6.1178	−1.5146	−0.5727	−5.9913	−1.0871	−0.5407
θ_9(VolWKCBT)	7.8244	2.268	0.7325	10.5296	2.2921	0.9503
Pseudo-R^2	0.81				0.87	

Table 11.20 Model: Y_{tI_F}—Peru, $n = 152$

Parameter	Milk and other dairy products			Other foods		
	Estimate	z-statistic	Marginal impact	Estimate	z-statistic	Marginal impact
ϕ	25,927.176	8.7173		4281.78	8.7186	
θ_0(Intercept)	−2.9624	−69.5966	−0.1187	−0.7408	−15.7126	−0.1931
θ_1(EconAct)	−0.002	−6.502	−0.0001	−0.0017	−4.9396	−0.0004
θ_2(Imports)	0.0001	6.299	0	0.0001	3.3777	0
θ_3(M1)	0	−3.1206	0	0	0.4413	0
θ_4(Return on Oil)	0.0555	1.622	0.0022	0.0059	0.157	0.0015
θ_5(VolCorn)	2.0215	1.6189	0.081	3.1737	2.3028	0.827
θ_6(VolSoy)	−1.4678	−0.8619	−0.0588	−3.3824	−1.8061	−0.8814
θ_7(VolRice)	−5.5173	−4.266	−0.2211	−7.4991	−5.2855	−1.9542
θ_8(VolWCBOT)	−1.7307	−0.4505	−0.0694	−1.0336	−0.2425	−0.2693
θ_9(VolWKCBT)	8.6824	2.6816	0.348	−0.681	−0.1887	−0.1775
Pseudo-R^2	0.77				0.70	

Data Sources

For oil prices the source is always U.S. Energy Information Administration (EIA), and for the volatility of international commodities the source is the estimation procedure described in the text.

- Costa Rica—Share of Laspeyres index: Instituto Nacional de Estadistica y Censos de Costa Rica (INEC); Monthly Index of economic activity: Banco Central de Costa Rica; Imports: Banco Central de Costa Rica.
- El Salvador—Share of Laspeyres index: Direccion General de Estadística y Censos (DIGESTYC); Monthly Index of economic activity: Banco Central de Reserva de El Salvador; Imports: Banco Central de Reserva de El Salvador.
- Guatemala—Share of Laspeyres index: Instituto Nacional de Estadistica Guatemala (INE); Monthly Index of economic activity: Banco de Guatemala; Imports: Banco de Guatemala.
- Honduras—Share of Laspeyres index: Instituto Nacional de Estadistica, Honduras (INE); Monthly Index of economic activity: Banco Central de Honduras; Imports: Banco Central de Honduras.
- Ecuador—Share of Laspeyres index: Instituto Nacional de Estadística de Ecuador (INEC); Monthly Index of economic activity: Banco Central del Ecuador; Imports: Banco Central del Ecuador.
- Peru—Share of Laspeyres index: Instituto Nacional de Estadistica e Informatica (INEI); Monthly Index of economic activity: Banco Central de Reserva del Peru; Imports: Banco Central de Reserva del Peru.

- Mexico—Share of Laspeyres index: Instituto Nacional de Estadistica y Geografia (INEGI); Monthly Index of economic activity: Banco de Mexico; Imports: Banco de Mexico.
- Nicaragua—Share of Laspeyres index: Instituto Nacional de Informacion de Desarrollo (INIDE); Monthly Index of economic activity: Banco Central de Nicaragua; Imports: Banco Central de Nicaragua.
- Panama—Share of Laspeyres index: Contraloria General de la Republica; Monthly Index of economic activity: Contraloria General de la Republica; Imports: Contraloria General de la Republica.
- Dominican Republic—Share of Laspeyres index: Oficina Nacional de Estadistica (ONE); Monthly Index of economic activity: missing; Imports: Banco Central de la Republica Dominicana.

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How Strong Do Global Commodity Prices Influence Domestic Food Prices in Developing Countries? A Global Price Transmission and Vulnerability Mapping Analysis

12

Matthias Kalkuhl

12.1 Introduction

Major global food commodities experienced unexpected price spikes in 2007/2008 and again in 2010. This raised serious concerns about the impact of global price shocks and volatility on food security in developing countries. There have been several attempts to investigate the impacts of price shocks on income and poverty as well as nutrition indicators. Some of these papers quantified the number of people who were pushed below the poverty line due to increased food prices (and decreased real incomes) at 105–150 million (de Hoyos and Medvedev 2011; Ivanic and Martin 2008); Tiwari and Zaman (2010) estimated that 63 million people became food insecure, as measured by the number of people who consume less than 1810 calories/day. However, as these studies used either domestic food prices, whereby the linkage to global prices is not directly clear (de Hoyos and Medvedev 2011), or the ad hoc assumption that price transmissions from global markets are uniform (Ivanic and Martin 2008; Tiwari and Zaman 2010), they cannot provide a satisfactory answer about the impacts of global price shocks. The heterogeneous degree of price transmission from international to domestic markets has to be considered explicitly for ex-post impact analysis as well as early warning and information systems, which are aimed at identifying upcoming food security risks.

There are some controversies about the role of international commodity prices in the local food security of developing countries. A common explanation for the low integration of developing countries, in particular African countries, in

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global markets is that many of them import only small amounts of the commodity they consume and that trade does not take place continuously. Additionally, transaction costs due to transportation costs and trade barriers, like tariffs and quotas, are considered to reduce price transmission. Existing research has therefore come to different conclusions regarding the degree of price transmission, depending on the considered domestic market, crop and international reference price.

So far, a comprehensive analysis of the extent of price transmission for the 1.2 billion people worldwide living below the poverty line is missing: We neither have an estimation of how many poor people are affected by global market-induced food price changes nor do we know the heterogeneous extent of price transmission. While the recent FAO report on the State of Food Insecurity in the World (FAO 2013) attempted to provide an aggregate picture of the extent of price transmission, it used regionally aggregated food price indices which showed only weak linkages to global prices and price volatility.[1] The use of regionally aggregated price indices, however, masks the heterogeneity of countries and commodities: combining prices from markets with high market integration and low (or missing) market integration will give an average low transmission that distracts from the serious impacts of international price shocks on *some* markets.

This paper aims to fill this gap by providing a globally comprehensive but nationally differentiated analysis of price transmission which maps transmission elasticities to the size of the vulnerable population. The result will be a Lorenz-type curve showing how many poor people are affected by international price shocks and how strong these effects are. The paper also provides a pragmatic way to deal with the heterogeneity of local food staples by creating a domestic grain price index which is highly relevant to the poor and vulnerable population. Our grain price index is preferable to the food price indices from national statistical agencies used in FAO (2013), Cachia (2014), and Ianchovichina et al. (2012) because the latter often contain processed and luxury food items that are of little relevance to the poor. As for these products, material costs play a minor role; therefore, using official food price indices would likely result in an underestimation of the degree of price transmission to the costs of the food basket of poor people. On the contrary, using individual crop prices instead of price indices – as in most existing studies – inflates the reported results of the empirical analysis, neglects possible substitution effects between grains, and complicates the interpretation of the severity of price transmission.

The market integration of developing countries is a highly relevant topic for policymakers and international organizations. Market integration presents both opportunities and risks. The larger a market is, the better its capability to diversify

[1]Cachia (2014) provides a more detailed overview on methods and data on regional price transmission.

(uncorrelated) shocks; this generally has a stabilizing effect on prices, benefitting producers as well as consumers. In contrast, integration into global markets makes domestic markets vulnerable to "external" shocks that are beyond the control of the national government, in particular, international price volatility (Kornher and Kalkuhl 2013). Market liberalization may further be incompatible with domestic price stabilization schemes, such as buffer stocks.

In this paper, we do not attempt to assess the costs and benefits of market integration. Leaving the normative debate aside, we address the descriptive question of the extent of market integration, which forms the basis of not only further normative analyses but also an appropriate impact assessment of global price shocks. Mapping price transmission with vulnerable population is one important step toward a better understanding of the impacts of recent global food price spikes since 2007. Additionally, our mapping analysis helps to identify the crucial international reference prices that should be monitored carefully in early warning and food security information systems. Finally, the calculated transmission elasticities can be used for forecasting the partial effect of international commodity price dynamics on local food prices and thus food security.

The paper is structured as follows: Section 12.2 provides an overview on existing literature on price transmission and market integration. Section 12.3 establishes the theoretical framework by drawing on basic trade and storage models from the literature. This section in particular helps to explain price transmission when trade is (temporarily) absent.[2] Section 12.4 describes the empirical model to estimate price transmission. Section 12.5 presents the price data used and the calculation of a domestic grain price index as an alternative reference price for the costs of the food basket of the poor. Section 12.6 discusses the results of the transmission analysis, including some robustness checks for different specifications. Section 12.7 summarizes the findings and concludes the chapter with policy and research implications.

12.2 Existing Work on Price Transmission

In the wake of the large swings in international commodity prices, there have been various researches on market integration and price transmission. Using staple prices on several sub-Saharan African markets, Minot (2010) calculated that the price increase in the region was on average 71 % of the corresponding world market increase in 2007/2008. Because static correlations between prices might be spurious and no compelling evidence for market integration exists (Ravallion

[2] Götz et al. (2013) provided an analysis on the price transmission of Ukraine and Russia during different trade regimes. The authors find that price transmission was also present during times of tight export quotas and high export taxes but stronger during liberal trade regimes.

1986), Minot (2010) extended the correlation analysis by applying a vector error correction model (VECM). This model, however, suggests that only one-fifth of the considered domestic price series have a long-run relationship to international prices. The estimated price elasticities range from 16 to 97 %. In general, rice prices seem to be more integrated than maize prices.

Robles (2011) estimated price transmission with an autoregressive distributed lag (ADL) model for some Latin American and three Asian countries using retail prices (Latin America) and wholesale prices (Asia) between 2000 and 2008. Transmission to processed food items is reported to be lower than to raw commodities. The average transmission from international wheat to domestic bread and pasta prices is 20 % and 24 %, respectively. In contrast, transmission of rice and wheat prices in Asia to the raw commodity prices varies a lot among the considered cities, but values higher than 50 % are reported for several cities.

Using a similar econometric approach but considering food price indices instead of commodity prices, Ianchovichina et al. (2012) analyzed price transmission to Middle East and North Africa countries. They report transmission for several countries in the range of 20–40 %. Greb et al. (2012) attempted to investigate price transmission and made some observations about the extent and determinants of market integration by assessing existing literature and by an own analysis based on FAO GIEWS price data. In their meta-analysis, they found that rice markets are more integrated than maize markets. They reported substantial price transmission to domestic markets (long-run price transmission coefficient of 75 %).

Most recently, Baquedano and Liefert (2014) calculated short- and long-run transmission coefficients for several commodities in developing countries within a single-equation error correction model (SEECM). They found that most consumer markets in developing countries are co-integrated with world markets although their speed of equilibrium adjustment is rather low. Cachia (2014) provided an overview of different concepts and models of price transmission and estimated market integrations and price transmission between the FAO (global) food price index and regionally aggregated food price indices (based on consumer price indices from national statistical agencies). His findings suggest limited market integration and rather slow transmission, which might be related to the use of aggregated food price indices as discussed above.

12.3 Theoretical Framework

Domestic prices are linked to world market prices primarily through trade. If a commodity is imported, its domestic price p_t^{D} equals its international price p_t^{G} plus the transaction costs $\tau_t^{I,E}$ for import I and export E. Depending on the trade balance (a positive T_t denotes exports, a negative T_t imports), we can therefore distinguish the three cases (Samuelson 1952)[3]:

$$p_t^{\mathrm{D}} = p_t^{\mathrm{G}} + \tau_t^I \quad \text{if } T_t < 0 \tag{12.1a}$$

$$p_t^{\mathrm{D}} = p_t^{\mathrm{G}} - \tau_t^E \quad \text{if } T_t > 0 \tag{12.1b}$$

$$p_t^{\mathrm{D}} = D\left(Q_t^{\mathrm{D}}, Y_t^{\mathrm{D}}\right) \quad \text{if } T_t = 0, \tag{12.1c}$$

where $D\left(Q_t^{\mathrm{D}}, Y_t^{\mathrm{D}}\right)$ is the inverse of the domestic demand function, which depends on consumption Q_t^{D} and income Y_t^{D}. Equations (12.1a)–(12.1c) imply that the domestic price is independent from the global price if and only if it is neither profitable to export nor to import the commodity, that is if

$$p_t^{\mathrm{G}} - \tau_t^E < D\left(Q_t^{\mathrm{D}}, Y_t^{\mathrm{D}}\right) < p_t^{\mathrm{G}} + \tau_t^I \tag{12.2}$$

Spatial arbitrage through trade links domestic and global prices immediately. There exists, however, also another form of arbitrage through storage which links current prices to expected (future) prices. Assuming rational expectations, current prices are a function of expected futures prices (Wright and Williams 1991):

$$p_t = \beta E_t\left[p_{t+1}\right] \quad \text{if } I_t > 0, \tag{12.3a}$$

$$p_t > \beta E_t\left[p_{t+1}\right] \quad \text{if } I_t = 0, \tag{12.3b}$$

where p_t is the price of the commodity at time t; $\beta = (1-\delta)/(1+r)$ contains the interest rate r and rate of deterioration δ; $E_t[\cdot]$ refers to the expectation at time t; and I_t denotes the inventory of grains. When there are no inventories ($I_t = 0$), current and future prices are not directly linked through intertemporal arbitrage.

Consider now the case of a country which has a zero or negative trade balance (that may change over time) but which is never in an exporting state. Combining Eqs. (12.1a) and (12.3a) for the domestic and global markets and assuming positive storage on both, for exactly s consecutive periods without trade, we obtain:

$$p_t^{\mathrm{D}} = \gamma^s p_t^{\mathrm{G}} + \left[\beta^{\mathrm{D}}\right]^s E\left[\tau_{t+s}\right] \quad \text{if } I_{t+j}^{\mathrm{D,G}} > 0,\ T_{t+j} = 0 \text{ for } 0 < j < s, \tag{12.4}$$

where $\gamma := \frac{\beta^{\mathrm{D}}}{\beta^{\mathrm{G}}} = \frac{(1-\delta^{\mathrm{D}})(1+r^{\mathrm{G}})}{(1-\delta^{\mathrm{G}})(1+r^{\mathrm{D}})}$. Equation (12.4) indicates that domestic prices depend on global prices even when there is *no trade* in a sequence of s periods. If

[3]In the subsequent theoretical analysis, we will assume that all transaction costs are unit costs and independent of the price level p_t^{G}. Considering ad-valorem transaction costs ς_t^I (e.g., due to transport insurance, value-added tax, or ad-valorem tariffs), Eq. (12.1a) would change to $p_t^{\mathrm{D}} = p_t^{\mathrm{G}}\left(1+\varsigma_t^I\right) + \tau_t^I$. As the ad-valorem component has no impact on the transmission elasticity (it cancels out after taking the derivatives), we have omitted it to shorten the formal analysis.

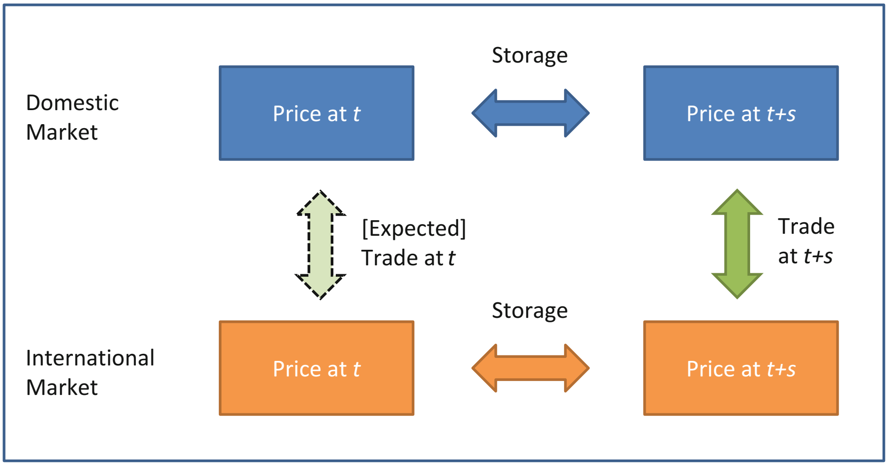

Fig. 12.1 Linkage between domestic and international prices through storage, trade, and expectations. *Source*: Own elaboration, based on Eqs. (12.1)–(12.4)

trade is expected in future periods (which brings domestic and global prices back to equilibrium), current domestic prices are adjusted according to intertemporal arbitrage. The relation between domestic and international markets for the direct trade regime and the indirect transmission regime (expected trade, with storage) is depicted in Fig. 12.1.

In the case of trade, prices at t are directly linked. In the case of no trade at t but expected trade at $t+s$, prices at t are indirectly linked through storage and expected trade arbitrage.

Inserting Eq. (12.4) into the transmission elasticity $\eta := \frac{\partial p^{\mathrm{D}}}{\partial p^{\mathrm{G}}} \frac{p^{\mathrm{G}}}{p^{\mathrm{D}}}$, we get[4]:

$$\eta = \frac{p_t^{\mathrm{G}}}{p_t^{\mathrm{G}} + [\beta^{\mathrm{G}}]^s E[\tau_{t+s}]}$$

Building partial derivatives of η, we obtain $\eta'\left(p_t^{\mathrm{G}}\right) > 0$, $\eta'\left(\beta^{\mathrm{G}}\right) < 0$, $\eta'\left(E[\tau_{t+s}]\right) < 0$, and $\eta'(s) > 0$. Thus, transmission increases in the global price level, and it decreases in the storage discount factor β^G and in expected transaction costs $E[\tau_{t+s}]$. Transmission increases, however, in the distance s to the next trade period: the longer the period of no trade, the stronger domestic prices respond to global prices (if storage domestic and global stocks are strictly positive during that period).

Table 12.1 gives an overview of the different possible trade and storage regimes and how they determine domestic prices and price transmission. In the case of trade,

[4]For $s = 0$, the transmission elasticity collapses to the standard form (direct transmission in case of trade) $\eta = p_t^{\mathrm{G}} / \left(p_t^{\mathrm{G}} + \tau_t\right)$. As argued above, any ad-valorem transaction costs cancel out in the price transmission.

Table 12.1 Domestic prices and price transmission for different trade and storage regimes

Trade T_t	Domestic storage	Global storage	Domestic price p_t^{D}	Transmission elasticity η
Yes	Yes/no	Yes/no	$p_t^{\mathrm{G}} + \tau_t$	$\frac{p_t^{\mathrm{G}}}{p_t^{\mathrm{G}}+\tau_t}$
None, but expected	Yes	Yes	$\gamma^s p_t^{\mathrm{G}} + \left[\beta^{\mathrm{D}}\right]^s E\left[\tau_{t+s}\right]$	$\frac{p_t^{\mathrm{G}}}{p_t^{\mathrm{G}}+\left[\beta^{\mathrm{G}}\right]^s E\left[\tau_{t+s}\right]}$
None, but expected	Yes	No	$\left[\beta^{\mathrm{D}}\right]^s E_t\left[p_{t+s}^{\mathrm{G}} + \tau_{t+s}\right]$	For p_t^{G} : 0 For $E_t\left[p_{t+s}^{\mathrm{G}}\right]$ $\frac{E_t\left[p_{t+s}^{\mathrm{G}}\right]}{E_t\left[p_{t+s}^{\mathrm{G}}+\tau_{t+s}\right]}$
None, but expected	No	Yes/no	$D\left(Q_t^{\mathrm{D}}, Y_t^{\mathrm{D}}\right)$	0
None and not expected	Yes	Yes/no	$\beta^s E_t\left[D\left(Q_{t+s}^{\mathrm{D}}, Y_{t+s}^{\mathrm{D}}\right)\right]$	0
None and not expected	No	Yes/no	$D\left(Q_t^{\mathrm{D}}, Y_t^{\mathrm{D}}\right)$	0

Source: Own elaboration

or in case of expected (future) trade, and positive domestic and global stocks, there is always a positive price transmission from global to domestic markets. However, if global stocks are zero[5] (i.e., if global prices are not in an intertemporal equilibrium), current global prices do not affect current domestic prices. Nevertheless, current domestic prices are in equilibrium with the *expected* global prices (which might, in turn, be a function of current global prices). Only in the remaining cases whereby all stocks are zero or whereby there will never be trade, domestic prices are completely decoupled from global prices. In these cases, domestic prices are solely determined by the conditions of domestic supply and demand, and price transmission is zero.

The theoretical analysis revealed two further interesting insights: For each trade regime, the transmission elasticity η is not affected by ad-valorem transaction costs (which include ad-valorem taxes and tariffs), and it is furthermore independent of the traded amount. In other words, the transmission elasticity will be the same for a country with small and large imports as long as the (unit) transaction costs are the same. Finally, the formal analysis emphasizes the role of storage in price transmission. Traditionally, storage is seen as a buffer against supply shocks, and this buffer reduces price fluctuations. As (private) storage, however, links current and future prices via expectations, it links domestic prices to global prices even if no trade occurs. Hence, storage could make a country more vulnerable against international price shocks because domestic prices are additionally linked to international prices through expectations.

While trade and storage link domestic prices to international prices of the same commodity, substitution effects might also link non-traded commodities to international prices if they are substitutes for traded commodities. The magnitude of substitution effects is expressed in the cross-price elasticity of demand, relating the percentage change in a commodity price to the percentage change in the price of a substitute. Hence, we would also expect price transmission to non-traded local products if they are substitutes for traded commodities. This is in particular the case for staples or different edible oils.

12.4 Empirical Model

As we are interested in the transmission of global shocks to domestic prices, any empirical analysis should consider intra-annual prices. However, many of the variables that determine price transmission (like grain stocks and trade) are only observable on an annual basis and suffer additionally from substantial measurement

[5]Zero stocks refer here to the theoretical model. In real-world settings, stocks become rarely zero because a certain amount of grains will be always stored for operational purposes. This "operational stock," however, is not part of the intertemporal arbitrage dynamics as it is used to ensure deliveries and does not respond to (expected) prices.

errors and data quality problems.[6] While there are models that allow data of different frequencies to be combined [e.g., GARCH-MIDAS for analyzing volatility, see Engle et al. (2013)], estimating them requires typically a large sample size. Because most of our price series start after the year 2000, we used a pure time-series approach to quantify country- and crop-specific “average” transmission elasticities instead of estimating the underlying fundamental model parameters, like the transaction costs, trade flows, and storage levels.

Time-series models are often confronted with the problem of nonstationary data series, which generates biased estimates and high R^2 due to spurious regression of explanatory variables with trends which leads to the overestimation of t-values in the case of autocorrelation. The typical approach to deal with a nonstationary time series is to differentiate the data until it becomes stationary. If the time series is also co-integrated (i.e., there exists a linear combination of the series that is integrated of order one), it is possible to estimate the long-run relationship between trended variables within an error correction model (ECM) (Engle and Granger 1987). If the time series is integrated to the order of one but not co-integrated, one can analyze the first-differenced, stationary time series within an autoregressive distributive lag model (ADL). If the time series is stationary, the ECM can be made equivalent to an ADL (De Boef and Keele 2008).

An ECM would be the favorable model to test for market integration (i.e., co-integration of domestic and international price series). However, the transmission of short-term shocks in international prices to domestic prices, which is the focus of this paper, does not require co-integrated time series. Relying on co-integrated time series only could exclude countries with significant transmission of shocks.[7] Using an ADL for this set of countries would be one option. As the estimated short-run transmission elasticities of the ADL are not directly comparable to the ECM, which controls for error correction, we prefer to use the same econometric model for all countries and series. Hence, we used an ADL with stationary first-differenced logarithmic prices, which is suitable for all countries and price series.[8] Our basic model estimates the relative change of the domestic food price index as follows:

$$\begin{aligned}\Delta p_{it}^{\mathrm{d}} = &\sum\nolimits_{j=1}^{l} \alpha_i^{dw} \Delta p_{it-j}^{d} + \sum\nolimits_{j=1}^{k} \beta_{ij}^{dw} \Delta p_{t-j}^{w} + \sum\nolimits_{j=1}^{k} \gamma_{ij}^{dw} \Delta e_{it-j} \\ &+ \sum\nolimits_{j=1}^{k} \zeta_{ij}^{dw} \Delta p_{t-j}^{\mathrm{oil}} + \delta_{im}^{dw} + c_i^{dw} + \varepsilon_{i,t}^{dw},\end{aligned} \tag{12.5}$$

[6]Stocks data is, for example, lacking for many countries. Published stock data (e.g. on the USDA-PSD database) is for many developing countries based on rough estimates and balance sheet calculations rather than original survey data.

[7]Additionally, testing for a unit root process, a necessary condition for the ECM, is problematic due to the low performance of unit root tests. Hence, the use of the ADL avoids the risk of using a misspecified ECM.

[8]The stationarity of all domestic and international price series was tested using the Augmented Dickey-Fuller test. While only a few of the original series are stationary, all first-differenced series are stationary with a test statistic below the 1 % critical value. Results are available upon request.

where $\Delta x_t = x_t - x_{t-1}$ is the difference operator, $p_{i,t}^{d}$ denotes the domestic reference price d (or price index) in country i (all prices in logs) at time t, p_{t-j}^{w} is a world market reference price (or price index), $e_{i,t-j}$ the exchange rate (in US dollars) of country i, p_t^{oil} is the oil price, $\delta_{i,m}$ a monthly country-specific dummy to account for seasonality, and c_i^{dw} is a (country and commodity specific) constant. We chose the lag structure $l = 3$ and $k = 3$ in our base model, but we also explored different lag structures (including optimal lags using information criteria) as a robustness check. Although oil prices are neglected in most other studies, we considered them important as they influence domestic production and transportation costs as well as import costs (Minot 2010).

Controlling for seasonality (Helmberger and Chavas 1996) and oil prices may allow us to consider important determinants of food and grain prices in particular countries; it might, however, also weaken the reliability of the model due to decreased degrees of freedom for countries in which seasonality or oil prices are irrelevant. Therefore, to automatically select the appropriate model specification for each country and commodity, we applied the Akaike information criterion to (1) the full model, (2) a model which ignores oil prices, (3) a model which ignores seasonality, and (4) a model which ignores both oil prices and seasonality.

We ran the regression in Eq. (12.5) separately for each country i, each international reference price p_t^w and each considered domestic food price p_t^d. With the estimated coefficients, we calculated the short-run transmission $\beta_i^{dw} = \sum_{j=1}^{k} \beta_{ij}^{dw}$ and the pass-through θ (i.e., the equilibrium effect of a marginal world price change on the domestic food price index) of international price w to domestic price d in country i as:

$$\theta_i^{dw} = \frac{\sum_{j=1}^{k} \beta_{ij}^{dw}}{1 - \sum_{j=1}^{l} \alpha_{ij}^{dw}},$$

where $\beta_i^{dw} = \sum_{j=1}^{k} \beta_{ij}^{dw}$ and $\alpha_i^{dw} = \sum_{j=1}^{l} \alpha_{ij}^{dw}$; both terms are set to zero if they are not significant at the 5 % level (F-test with Newey-West estimated standard errors).[9] While β_i^{dw} gives the direct (short-term) price transmission within 1–3 months, the autoregressive term α_i^{dw} further amplifies price changes in the subsequent periods. The total effect is therefore given by the pass-through θ_i^{dw}. As we estimated β_i^{dw} and θ_i^{dw} separately for each country and international commodity price (index), we obtained a matrix of transmission elasticities and pass-throughs for every domestic food price index d.

[9]Significance levels of 10 % and 1 % were also employed to check robustness (see below). The Newey-West estimator corrects for heteroskedasticity and autocorrelation. We use a lag length of 6 months. The standard OLS procedure gives similar results (see below).

12.5 Data

This study differs from other related studies because it used an extensive dataset of international commodity prices and price indices, ranging from spot prices at important export destinations to prices of relevant futures contracts.

Table 12.3 in the Appendix lists the prices that were used as international reference prices and price indices. The main sources of information are the FAO and the FAO GIEWS for the international food prices and price indices, the World Bank (2013b) for important international spot prices, and Bloomberg for futures prices. We also calculated indices over futures prices in order to better capture price dynamics on commodity exchanges. For all futures prices, a time series consisting of the respective active contract was used. All price series are monthly data (for daily price series, like futures prices, monthly averages were calculated).

The food price indices (FPI), a part of the national consumer price indices (CPI), served as reference database for the domestic prices. These data are available from the LABORSTA database for 200 countries in the world in a monthly or quarterly frequency (ILO 2013). We drop those countries which only report quarterly food price indices and consider the years 2000–2012.[10] While the LABORSTA database has the advantage of covering many countries, the calculation of the food price indices is not transparent for many countries. In particular, CPIs may suffer from urban bias as price collection in urban area is less expensive than in remote rural areas. Additionally, the weights in a CPI might reflect the consumption and spending patterns of the urban lower-middle class rather than the very poor households that spent up to 70 % of their expenditures on staple food (James 2008). For example, dramatic changes in staple prices, which affect the real income of poor households, might only lead to small changes in the domestic food price index, which consists of processed foods as well as luxury food and beverages.

Because FPI data might be inadequate to monitor the food costs for poor people, we developed an alternative staple grain price index which consists of the retail prices of wheat, maize, rice, sorghum, and millet. We used several sources to compile this retail price database and calculate the national average price in US$ across different markets for each of the commodity prices. We used prices in US$ to avoid the problem of strong inflationary shocks, which are difficult to control for, but provided robustness checks for prices in nominal and CPI-deflated local currencies. We combined the different commodity prices into a price index according to their share of the domestic per capita food supply [taken from FAOSTAT (2013)]:

$$p_{it}^{GPI} = \sum\nolimits_{j} \alpha_{ij} p_{itj},$$

[10] These countries are (20 in total) AIA, ASM, AUS, BLZ, BTN, COK, CYM, FRO, GUM, JEY, KIR, MHL, MNP, NFK, NIU, PNG, SHN, SPM, TUV, and VUT.

Table 12.2 Domestic food price indices

d	Variable	Description	Source
FPI	Food price index (FPI)	National food price index (nominal); 2000–2012	ILO (2013)
GPI	Domestic grain price index (GPI)	Index of the national average retail prices (nominal US$) of five staple grains for 2000–2012: wheat, maize, rice, sorghum, and millet; weighted according to domestic per capita food supply for 2000–2009	Own calculation; domestic per capita food supply from FAO; retail prices from FEWS NET, FAO GIEWS, WFP Price Monitor, and national sources

Exchange rates were obtained from the IMF database. For the oil price, we consider the "average oil price" of WTI, Brent and Dubai prices quoted at World Bank Commodities Price Database.
Source: Own elaboration

where $\alpha_{ij} = C_{ij}/C_j$ is the *j*-th crop's share of the total consumption of the considered grains in country *i* in kg over the period 2000–2009 and p_{itj} is the corresponding crop price at month *t* in US$ per kg. We used national average prices if available in one of the databases (shown in Table 12.2); otherwise, we calculated an (unweighted) national average price using all the markets price data available (again, using the sources shown in Table 12.2). Our self-constructed grain price index accounts on average for 45 % of the average national calorie consumption in many countries. As the diet of poor people consists of a higher share of staples, our grain price index is likely to cover more than the national average number for poor people which increases its relevancy.

One drawback of the grain price index is the limited data availability. Contrary to the food price index from national statistical offices, retail grain prices were available for 65 countries only. Yet, as will be discussed later, the considered countries are home to more than 90 % of the global poor, who live with an income below $1.25 per day. Thus, the coverage with respect to poor people is much larger than the "geographical" coverage. Another drawback of the grain price index is that it is likely irrelevant to the countries where staples other than those grains considered in this study are consumed as part of their diet (e.g., roots and tubers in Uganda). Because of the advantages and disadvantages of both food price indices and grain price indices, we considered both in our analysis. Table 12.2 summarizes the characteristics and data sources for the domestic price indices.

12.6 Results

This section presents and discusses the calculated transmission elasticities. For policymakers as well as for establishing early warning information systems, it might be relevant to know whether a country's food prices are linked to at least one international commodity price. Subsequently, a country's policymakers can access the database on transmission elasticities to find out which particular commodity prices are transmitted from the international market to the domestic market of that particular country. We therefore calculated a country-specific transmission *vulnerability indicator* V_i^d as the maximum transmission over the pass-throughs of different commodities from the set Ω:

$$V_i^d = \max_{w \in \Omega} \left\{ \theta_i^{dw} \right\} \tag{12.5}$$

If this indicator is zero, domestic food markets are with a high degree of certainty not vulnerable to global price shocks.[11] If the indicator is high, there is high transmission for at least one international commodity price (or price index), which implies that the country is generally vulnerable to global market price changes. As we will see, the vulnerability indicator provides an important benchmark for single international prices or price indices, like the FAO food price index. We further calculated the vulnerability indicator for subsets Ω of commodities, for example, we calculated V_i^d as maximum pass-through overall international rice prices.

12.6.1 Transmission from the FAO Food Price Index

We first considered the transmission from the FAO food price index – an international reference price index – which is often used as an indicator for global food market dynamics. We ran regressions for the transmission to domestic food prices as well as to domestic grain prices. The magnitude of the aggregate transmission elasticity β (if significant at the 5 % level) is depicted in Fig. 12.2 for both the domestic food price index (Fig. 12.2a) and the domestic grain price index (Fig. 12.2b). The maps indicate that there was no significant transmission for several developing countries in Asia, Latin America, and Africa. Where there was statistically significant transmission, it tended to be particularly high. These findings are consistent with the other studies mentioned above but provide a more comprehensive country coverage.

The map showing global transmission to domestic food price indices, for which data is available for almost all countries in the world, reveals another interesting finding: Several developed countries (North America, Europe) show a statistically significant but low price transmission, while transmission to developing countries is either insignificant (i.e., zero) or relatively high. An explanation for this finding is that the food basket in developed countries consists of many processed food items; commodity costs constitute only a very small share of the final price of process food items. Thus, a price increase in a raw commodity translates only into a very small price increase in the final product. This explains why price transmission to the US domestic market is very low – although several of the international reference prices used are quoted from US markets. The transmission from world to domestic

[11]However, they might still be co-integrated with world markets (through rather slow adjustment process) as we do not test for co-integration.

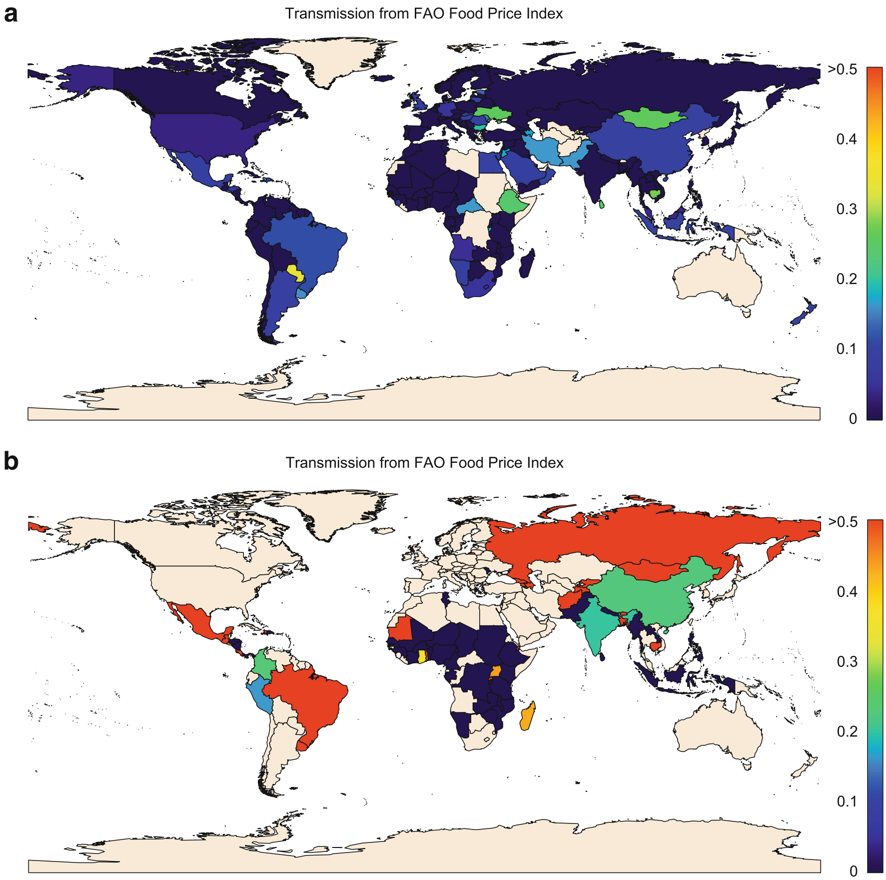

Fig. 12.2 (**a**) Transmission from the FAO food price index to the domestic food price index (FPI). (**b**) Transmission from the FAO food price index to the domestic grain price index (GPI)

markets showed high variance among developing countries because some of them are not integrated into the world market due to high transaction costs. If a country is integrated, price transmission to its domestic market is relatively high because raw commodity costs are a major part of the price of many food items.

The FAO food price index is a much more aggregated price index. It uses weights according to the export share on the global market of the considered commodities. While this gives an appropriate average price index for globally traded commodities, trade patterns may differ greatly among countries. For example, a country might predominantly import rice, but rice prices have a very low weight in the FAO food price index. By adding further international price indices and concentrating on the vulnerability indicator (maximum transmission) for all the grain prices in our database, we got a map which reveals a different result. Many Asian, African, and Latin American countries experience significant and high price transmission

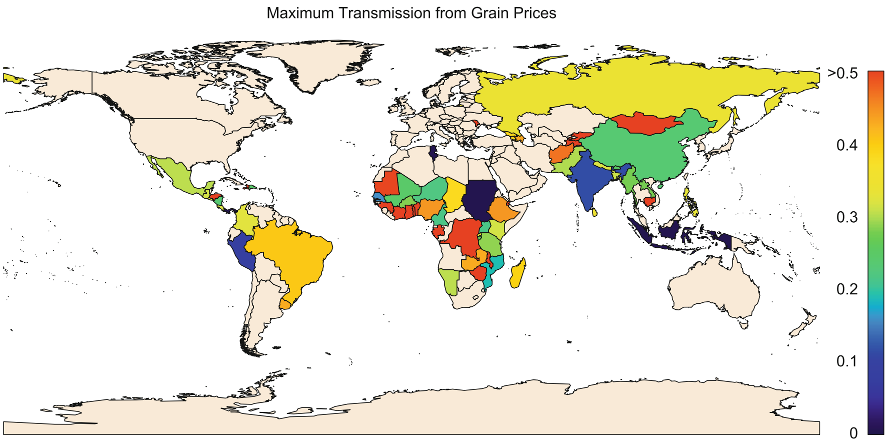

Fig. 12.3 Transmission to the domestic grain price index – vulnerability indicator over international grain prices. *Note*: Maximum transmission to the domestic grain price index using all international grain prices in Table 12.3

(Fig. 12.3). For example, some of the West African countries showed high price transmission to their domestic grain price index, which is primarily driven by international rice prices as these countries import a large amount of rice. Note that a low transmission elasticity of even as low as 20 % may have remarkable implications: doubling of commodity prices (e.g., as was experienced for wheat in 2007/2008) increases the costs of the *entire food or staple commodity basket* by 20 %. This is an important difference when compared with other studies: transmission elasticities for a single commodity do not reveal how important the commodity is for the population. Using a price index, in contrast, weights the price transmission in relation to the importance of the commodity to the diet of a country's population, and it also takes into account any potential substitution effects.

The use of the vulnerability indicator emphasizes that considering the FAO food price index exclusively might lead to serious biases in the assessment of price transmission downward. Thus, it is important to consider a larger set of reference prices and price indices rather than only relying on the FAO food price index. However, the FAO food price index remains a pragmatic alternative when only a single international price (index) can be used.

12.6.2 Vulnerability Mapping: How Many Poor People Are Affected by Global Price Changes?

To assess the impacts of global price changes, it is important to know how many poor people live in countries with high price transmission. Price changes have often heterogeneous impacts on the welfare of households, depending on their production structure and market access (von Braun et al. 2013). High agricultural commodity prices can increase the income of poor rural households who produce cash crops (Tefera et al. 2013). Nevertheless, such beneficial impacts are often realized in the medium or long term when households adjust their production by growing high-value crops. However, existing empirical analyses have concluded that sudden price spikes negatively affect not only poor consumers and the landless but also farmers who buy many food items as they cannot quickly adjust their production in the short run (Aksoy and Isik-Dikmelik 2008; Anríquez et al. 2013).

To assess how strongly poor people are exposed to global price changes, we took the following steps: The transmission elasticities β of the countries (e.g., regarding the Chicago corn price or the vulnerability indicator containing the maximum transmission by grain prices) were sorted in descending order. Next we calculated the number of people living below the extreme poverty line of \$1.25 per day[12] using poverty share and population data from the World Development Indicators (World Bank 2013a).[13]

Figure 12.4 shows the transmission from different international grain prices to the domestic grain price index. We calculated the maximum transmission (vulnerability indicator) according to Eq. (12.1b) for each of the three commodities: wheat, corn, and rice. Hence, the wheat line shows the maximum transmission for each country from all the available wheat price series shown in Table 12.3. We calculated the total vulnerability indicator as the maximum over the commodity indicators (blue line).

Regarding the extent of transmission, Fig. 12.4 clearly shows that rice prices are most strongly transmitted; this has also been highlighted by other studies (e.g., Robles 2011; Baquedano and Liefert 2014). While wheat prices experience lower transmission elasticities than rice prices for many countries, the tail is much longer due to its impact on India, where one-third of the globally poor live. The all-grain vulnerability indicator revealed that more than 1.06 billion poor people live in countries with significant price transmission of 10 % or higher – which constitute 96 % of the poor in the countries studied in this chapter and 89 % of the poor globally. More than 360 million poor people (one-third of the poor) live in countries with transmission elasticities of 30 % or higher; about 44 million poor people live in countries with transmission elasticities of 50 % or higher.

We decomposed the transmission further into the individual price series (see Appendix, Figs. 12.8, 12.9, 12.10, 12.11 and 12.12) to identify the most relevant international reference price for each of the commodities. Prices of futures contracts at the Chicago Board of Trade (CBOT) are the most relevant for wheat, in particular regarding the number of people affected. Transmission elasticities from CBOT prices are, however, topped by transmission rates from Canadian wheat and Argentinian spot prices for some countries (e.g., Nigeria, Ethiopia, or Kenya). For maize, US spot and futures prices were transmitted at rates ranging from 15 to

[12]Using the "moderate poverty line" of \$2 per day gives qualitatively similar results. Quantitatively, however, roughly double as many people are affected.

[13]Poverty rates are not available for every year. We use therefore the most recent number and multiplied it with the 2012 number of total population.

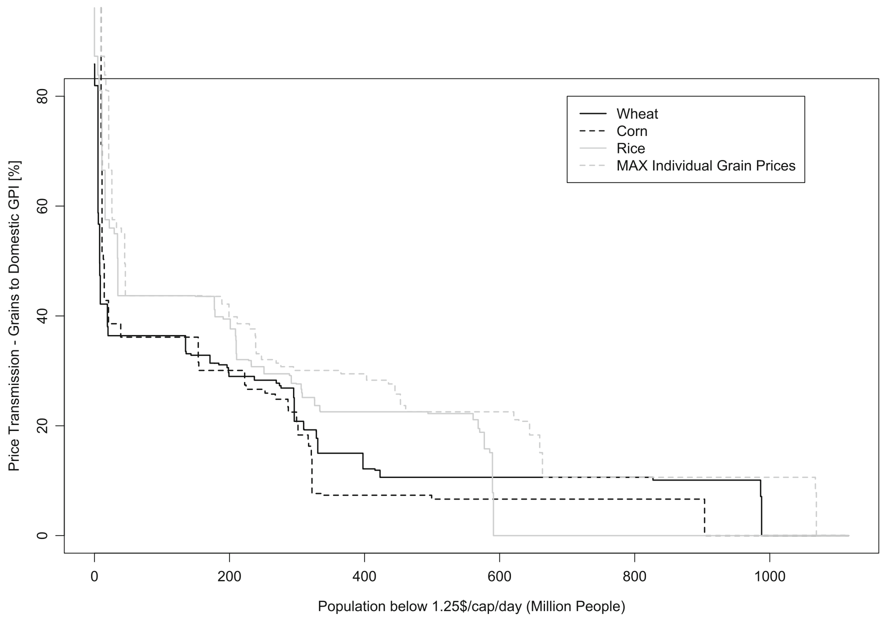

Fig. 12.4 Number and extent of poor people potentially affected by international price changes (change of grain price index). *Note*: The figure shows the transmission elasticities over all countries in descending order mapped to the number of people below the extreme poverty line in the particular country. *Source*: Own illustration

50 % for 150 million poor people. Yellow and white maize prices at the South African Futures Exchange (SAFEX) are strongly transmitted to Malawi at rates higher than 70 %. There is no clear reference price emerging for rice. IGC rice prices and Pakistani and Thai prices transmit at different rates to different countries, with Nigeria experiencing high transmission, in particular from Thai prices and the IGC price index.

Comparing the transmission indicated by the all-grain vulnerability indicator with several other price indices emphasizes that using individual price index alone would cause the size of the affected population to be underestimated. For example, the FAO food price index, a popular international reference price, suggests that 700 million poor could be affected by global price shocks (due to its significant transmission to India and China); the FAO cereals price suggests that 350 million people could be affected – far below the numbers obtained from the all-grain vulnerability indicator. The FAO food price index shows a higher transmission elasticity than most indices that are based only on grain prices because the FAO food price index has a lower variability.[14]

[14]The FAO food price index also contains meat and oils, which are processed food items that typically fluctuate less than commodity prices. Comparing the FAO food price and cereals price

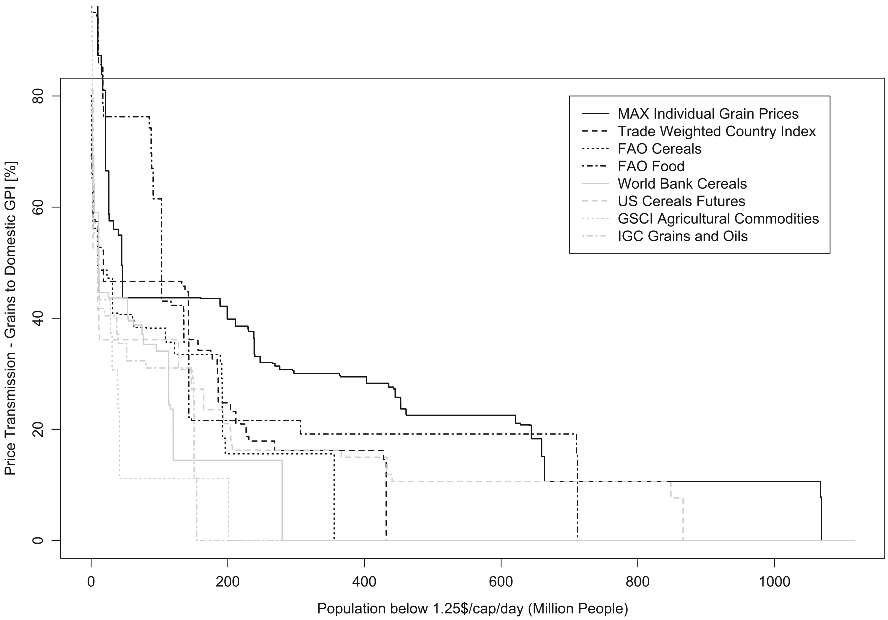

Fig. 12.5 Number and extent of poor people potentially affected by changes of international price indices. *Source*: Own illustration

Figure 12.5 further illustrates that about 850 million poor people might be affected by price changes in US cereals futures contracts (140 million with transmission rates of 30 % or higher), which is particularly relevant for the debate on speculation and financialization (Tadesse et al. 2014; von Braun et al. 2013). The transmission elasticities from commodity prices and price indices for countries with at least one million people living below the poverty line are listed in Table 12.4 in the Appendix.

The calculations shown in Figs. 12.4 and 12.5 require an important qualification: They represent the likely upper bound of the number of people affected. More precisely, they show the number of poor people living in countries affected by a specific price transmission. Not all poor people in a country with positive price transmission experience international price changes. In developing countries, in particular Africa, poor people in remote rural areas lack access to markets due to bad infrastructure (Barrett 2008; Nelson 2008). As discussed previously, food price indices from national statistical agencies could exhibit biases because of their focus on urban centers, making them less relevant for the rural population

index between 1990 and 2011, the former shows an average change rate of ±0.8 % per month, while the latter changes ±1.3 % per month. We would therefore expect a roughly 60 % higher transmission from FAO food prices for an identical commodity composition compared to cereals prices.

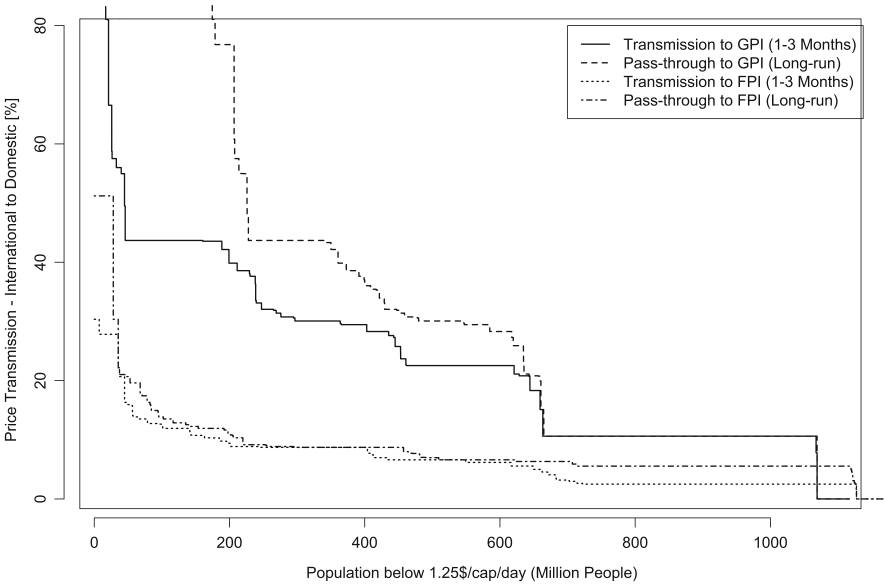

Fig. 12.6 Comparison of transmission and pass-through. *Source*: Own illustration

in remote areas. A transmission analysis based on food price indices from national statistical agencies would overstate the number of affected poor as one would expect lower price transmission from international prices to remote rural markets. The use of the grain price index which also considers grain prices from rural markets is an important alternative because it is constructed independent of the FPI using alternative price data. Nevertheless, the markets considered in this study are far from comprehensive, and prices for many rural areas are missing. The number of poor people in affected countries therefore only indicates the potential number of people affected (which would be the same if domestic markets were perfectly integrated).

12.6.3 Pass-Through and Equilibrium Effects

While the sum of the coefficients of international prices β gives the relative magnitude of price transmission 1–3 months after a spike, the pass-through θ considers long-run equilibrium adjustments due to the autoregressive term (see Sect. 12.4 above). Figure 12.6 depicts the vulnerability indicator (maximum overall international grain prices) for both transmission and pass-through to the domestic food price index as well as to the domestic grain price index. Consistent with Figs. 12.2 and 12.3, we found that transmission elasticities are considerably higher for the domestic grain price index than for the domestic food price index. The long-run equilibrium effect of international price spikes is substantially higher: For high vulnerable countries, the long-run effect is approximately twice as high as the short-run effect. The discrepancy between short-run transmission and long-run pass-though is higher when domestic grain prices instead of domestic food prices are considered. This is due to the more important role of the auto-regressive dynamics.

12.6.4 Robustness Checks

The outcome of our econometric analysis depends on not only the chosen model specification but also the considered significance levels. We therefore discuss the implications of different model specifications for our findings. We confine our discussion only to the vulnerability indicator for grain prices, in particular, with regard to its mapping to affected poor people (as shown in Fig. 12.4).

12.6.4.1 Significance Levels

If the null hypothesis of zero transmission cannot be rejected at the 5 % level, we set the transmission to zero; otherwise, we use the point estimate for the calculation of the transmission. Changing the significance level to 10 % increases the likelihood of erroneously detecting transmission to a country's domestic market when there is none; it reduces, however, the possibility of wrongly concluding that there is no price transmission in the case that the F-test does not reject the null hypothesis of zero transmission. We therefore employed two different significance levels (at 10 % and 1 %) to check the sensitivity of our results. As shown in the Appendix, a significance level of 10 % has only marginal impacts on the extent of price transmission and the number of poor people affected (Fig. 12.7). For a stricter significance level of 1 %, the transmission is lower relative to the poor population: Many countries on the right tail (with low transmission rates) do not pass the stricter significance test. Nevertheless, transmission elasticities for the 550 million poor people in countries with significant transmission hardly changed when compared with the lower significance levels.

12.6.4.2 CPI-Deflated Food Prices

It is often argued that nominal price changes are less relevant because monetary inflation might change the overall price level and therefore the purchasing power of money. To study welfare impacts of price changes, one would ideally deflate nominal prices with (nominal) income for consumers. This information is, however, hardly available.[15] Using the consumer price index (CPI) is a pragmatic alternative, although CPIs do not measure the income or wage of people but rather the costs of goods a consumer who is representative of the population buys. For some countries (e.g., Bangladesh), food items have a share over 50 % of the CPI (ILO 2013). Thus, even without any monetary inflation and without any increases in wages or prices of other consumption goods, an increase in food prices by 10 % would increase the CPI by more than 5 %. Deflating the food price change with the CPI would then

[15] For households with substantial income from selling their agricultural produce, prices of inputs need also to be considered (Dorward 2011).

result in a "real" price change of 5 %, although wages and other consumer prices would remain constant. Deflating the food price index with the CPI would in such cases understate the impact on welfare due to price changes.

Due to the lack of monthly wage or income data, we resorted to deflating food prices by the CPI despite knowing its shortcomings. As our grain price index used prices in the US dollar, which shows very low monthly inflation rates, we performed this robustness check only for the domestic food price analysis. As expected, the transmission to CPI-deflated food price indices was lower than to nominal food prices (Fig. 12.7). The transmission-population curves obtained are similar to our standard model, although slightly lower to the right tail (in particular, for India which experiences high inflation). Using nominal prices in the local currency also gave results similar to our standard model. The robustness of our findings regarding the choice of the currency and deflator is probably due to the use of first differences of log prices, which cancel out inflation, and the use of heteroskedasticity-corrected standard errors by the Newey-West method.

12.6.4.3 OLS Versus Newey-West

To check the robustness of the Newey-West approach with time lags of 6 months, we also included regressions based on the standard OLS, whereby homoskedasticity is assumed for calculating standard errors and thus significance levels. The OLS method allows for a much faster calculation of the standard errors; this becomes important when applying the method to many country and commodity time series. As indicated in Fig. 12.7, OLS gives similar results, although transmission rates were slightly lower as high transmission elasticities for some commodities did not pass the *t*-test at the 5 % level anymore.

12.7 Conclusions

The aim of this paper is to better understand the transmission of shocks from international prices to domestic food prices. Our analytical model emphasized that international price changes can be transmitted through intertemporal arbitrage of storage even if no trade takes place. Our empirical analysis suggests that focusing only on the FAO Food or Cereal Price Indices might cause the vulnerability of the poor to international price changes to be understated. Likewise, food price indices from national statistics might be biased, being more representative of (on average wealthier) urban consumers, who buy and consume relatively more processed staples and luxuries. To avoid these shortcomings, we used a comprehensive database on international reference prices and constructed a domestic grain price index based on retail prices in developing countries and the considered commodities' share of the total consumption. Our price database allows for almost universal country coverage, in particular, with respect to countries where poor people live. For the first time therefore, we were able to estimate how many poor people live in countries where international price changes are transmitted to domestic prices.

Our empirical analysis illustrated that the vast majority of the poor (over 90 %) live in countries where food prices are linked more or less strongly to international prices *in the short term* that is within 1–3 months. For 360 million poor people, international prices transmit to their country at rates of 30 % or higher. The empirical analysis considered seasonality and oil prices (endogenous model selection). The findings were robust at different significance levels and for different price deflators.

Because of our chosen lag structure of 3 months, we expect that international price shocks will translate to domestic price shocks rather quickly. Existing research on the impact of price changes on the welfare of poor consumers has paid more attention to the differentiated and heterogeneous effects of price changes, depending on the production and consumption structure. While higher prices can benefit net sellers of the affected crops, they make poor consumers, net buyer farmers and rural landless worse off in the short term. Several quantitative estimates concluded that the negative effects overweigh the positive effects, for example, with respect to the number of people falling below the poverty line – at least in the short term when production is not able to respond flexibly to higher prices (Ivanic and Martin 2008; Tiwari and Zaman 2010; de Hoyos and Medvedev 2011; Anríquez et al. 2013). There are also concerns that price increases affect poor consumers more than the effect of a symmetric price decrease on producers of food: While poor consumers can run into serious problems because they cannot afford sufficient food, producers may still have enough (self-grown) food to eat, even though their income may be significantly reduced (Kalkuhl et al. 2013).

Although our analysis focused on the transmission of price levels rather than price risk or volatility, one can expect that high international volatility (measured in the fluctuations of *monthly* prices) would also increase domestic food price volatility (see also Chap. 13). While the impacts of price changes on welfare are as yet unclear, higher volatility may have negative effects on welfare because of an increase in the production risks for farmers and, thus, undermining long-term food supply (Haile and Kalkuhl 2013; Haile et al. 2013).

The transmission analysis and the estimated elasticities could be used in early warning systems to detect vulnerable countries in times of high international price swings. It could further be extended to explain the different degrees of price transmission by using other explanatory variables like transportation costs, trade, GDP, or grains stocks.

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Appendix

International Reference Prices and Price Indices

Table 12.3 Considered international reference prices and price indices

w	Variable	Description	Source
1	FAO food price index	Consists of 55 commodity quotations considered as representing the international prices of food commodities; weighted by export share	FAO
2	FAO cereals price index	Consists of wheat, maize, and rice prices; weighted by export share	FAO
3	FAO oil/fat price index	Consists of 12 different oils (including animal and fish oils); weighted by export share	FAO
4	FAO sugars price index	Index form of the International Sugar Agreement prices with 2002–2004 as base	FAO
5	FAO meat price index	Consists of poultry, bovine meat, pig meat, and ovine meat products; weighted by export share	FAO
6	FAO dairy price index	Consists of butter, skimmed milk powder, whole-milk powder, cheese, and casein prices; weighted by export share	FAO
7	WB grain price index	Includes barley, maize, rice, and wheat	World Bank
8	WB fats and oils price index	Includes coconut oil, groundnut oil, palm oil, soybeans, soybean oil, and soybean meal	World Bank
9	Wheat (HRW) US	No. 1, hard red winter, ordinary protein, export price delivered at the US Gulf port for prompt or 30 days' shipment	World Bank
10	Wheat (SRW) US	No. 2, soft red winter, export price delivered at the US Gulf port for prompt or 30 days' shipment	World Bank
11	Wheat CAN	Wheat (Canada), no. 1, western red spring (CWRS), in store, St. Lawrence, export price	World Bank
12	Wheat AUS	Australian soft white, Australia, f.o.b.	USDA/IGC
		Australia Eastern States Standard White Wheat FOB Spot (for 10/2007–09/2008 where USDA/IGC series has missing entries)	Bloomberg
13	Barley	Barley (Canada), feed, western no. 1, Winnipeg Commodity Exchange, spot, wholesale farmers' price	World Bank
14	Sorghum US	Sorghum (US), no. 2 milo yellow, f.o.b. Gulf ports	World Bank
15	Corn US	Maize (US), no. 2, yellow, f.o.b. US Gulf ports	World Bank
16	Soybeans	Soybeans (US), c.i.f. Rotterdam	World Bank
17	Soybean oil	Soybean oil (Any origin), crude, f.o.b. ex-mill Netherlands	World Bank
18	Soybean meal	Soybean meal (any origin), Argentine 45/46 % extraction, c.i.f. Rotterdam beginning 1990; previously US 44 %	World Bank

(continued)

Table 12.3 (continued)

w	Variable	Description	Source
19	Rice Thai A1	Rice (Thailand), 100 % broken, A.1 Super from 2006 onward, government standard, f.o.b. Bangkok; prior to 2006, A1 Special, a slightly lower grade than A1 Super	World Bank
20	Rice Thai 5 %	Rice (Thailand), 5 % broken, white rice (WR), milled, indicative price based on weekly surveys of export transactions, government standard, f.o.b. Bangkok	World Bank
21	Rice Thai 25 %	Rice (Thailand), 25 % broken, WR, milled indicative survey price, government standard, f.o.b. Bangkok	World Bank
22	Rice Vietnam	Vietnamese rice, 5 % broken	World Bank
23	Palm oil	Palm oil (Malaysia), 5 % bulk, c.i.f. N. W. Europe	World Bank
24	Groundnut oil	Groundnut oil (any origin), c.i.f. Rotterdam	World Bank
25	Coconut oil	Coconut oil (Philippines/Indonesia), bulk, c.i.f. Rotterdam	World Bank
26	Fishmeal	Fishmeal (any origin), 64–65 %, c&f Bremen, estimates based on wholesale price, beginning 2004; previously c&f Hamburg	World Bank
27	Beef	Meat, beef (Australia/New Zealand), chucks and cow forequarters, frozen boneless, 85 % chemical lean, c.i.f. US port (East Coast), ex-dock, beginning 11/2002; previously cow forequarters	World Bank
28	Chicken	Meat, chicken (US), broiler/fryer, whole birds, 2½–3 pounds, USDA grade "A," ice-packed, Georgia Dock preliminary weighted average, wholesale	World Bank
29	Sheep	Meat, sheep (New Zealand), frozen whole carcasses prime medium (PM) wholesale, Smithfield, London, beginning 01/2006; previously Prime Light (PL)	World Bank
30	Wheat/CBT	#2 Soft red winter at contract price, #1 Soft red winter at a 3 cent premium, Chicago Board of Trade	Bloomberg
31	Corn/CBT	#2 yellow at contract price, #1 yellow at a 1.5 cent/bushel premium, #3 yellow at a 1.5 cent/bushel discount, Chicago Board of Trade	Bloomberg
32	Soybeans/CBT	#2 Yellow at contract price, #1 yellow at a 6 cent/bushel premium, #3 yellow at a 6 cent/bushel discount, Chicago Board of Trade	Bloomberg
33	Soybean oil/CBT	Crude soybean oil meeting exchange-approved grades and standards, Chicago Board of Trade	Bloomberg
34	Soybean meal/CBT	48 % protein soybean meal, Chicago Board of Trade	Bloomberg

(continued)

Table 12.3 (continued)

w	Variable	Description	Source
35	Rough rice/CBT	US no. 2 or better long grain rough rice with a total milling yield of not less than 65 % including head rice of not less than 48 %, Chicago Board of Trade	Bloomberg
36	Feeder cattle/CME	650–849 pound steers, medium-large #1 and medium-large #1–2, Chicago Mercantile Exchange	Bloomberg
37	Live cattle/CME	55 % choice, 45 % select, yield grade 3 live steers, Chicago Mercantile Exchange	Bloomberg
38	Lean hogs/CME	Hog (barrow and gilt) carcasses, Chicago Mercantile Exchange	Bloomberg
39	Wheat/KCBT	Hard red winter wheat, no. 2, at contract price; no. 1 at a 1½-cent premium; Kansas City Board of Trade	Bloomberg
40	Wheat/MGEX	Hard red spring wheat, no. 2 or better Northern spring wheat with a protein content of 13.5 % or higher; Minneapolis Grain Exchange	Bloomberg
41	White maize/SAFEX	South African Futures Exchange; starting in 08/1996	Bloomberg
42	Yellow maize/SAFEX	South African Futures Exchange; starting in 08/1996	Bloomberg
43	Wheat/SAFEX	South African Futures Exchange; starting in 11/1997	Bloomberg
44	Soybean/SAFEX	South African Futures Exchange; starting in 04/2002	Bloomberg
45	Sunflower seeds/SAFEX	South African Futures Exchange; starting in 02/1999	Bloomberg
46	Palm oil/MDEX	Malaysia Derivatives Exchange; starting in 03/1995	Bloomberg
47	GSCI agriculture	Price index over active futures with the 2012 S&P GSCI weights on wheat (CBT), wheat (KCBT), corn, soybeans, lean hogs, live cattle and feeder cattle (all CBT)	Own calculation
48	Trade weighted country index	Price index over US corn, US HRW and Thai 5 % spot prices according to the trade shares (imports plus exports of commodity divided by imports plus exports of all three commodities) of each country	Own calculation
49	Rice/Vietnam	Vietnam, rice (25 % broken), export	FAO GIEWS
50	Rice/Vietnam	Vietnam, rice (5 % broken), export	FAO GIEWS
51	Rice/Pakistan	Pakistan, rice (25 % broken), export	FAO GIEWS
52	Rice/Pakistan	Pakistan, rice (Basmati ordinary), export	FAO GIEWS
53	Rice/USA	USA, rice (US long grain 2.4 %), export	FAO GIEWS

(continued)

Table 12.3 (continued)

w	Variable	Description	Source
54	Rice/USA	USA, rice (US California medium grain), export	FAO GIEWS
55	Rice/Thailand	Thailand: Bangkok, rice (25 % broken), export	FAO GIEWS
56	Rice/Thailand	Thailand: Bangkok, rice (5 % broken), export	FAO GIEWS
57	Rice/Thailand	Thailand: Bangkok, rice (fragrant 100 %), export	FAO GIEWS
58	Rice/Thailand	Thailand: Bangkok, rice (glutinous 10 %), export	FAO GIEWS
59	Rice/Thailand	Thailand: Bangkok, rice (parboiled 100 %), export	FAO GIEWS
60	Rice/Thailand	Thailand: Bangkok, rice (Thai 100 % B), export	FAO GIEWS
61	Rice/Thailand	Thailand: Bangkok, rice (Thai A1 Super), export	FAO GIEWS
62	Wheat/Argentina	Argentina, wheat (Argentina, up river, trigo pan), export	FAO GIEWS
63	Maize/Argentina	Argentina, maize (Argentina, up river), export	FAO GIEWS

Source: Own elaboration

Robustness Checks for Transmission to Grain Price Index

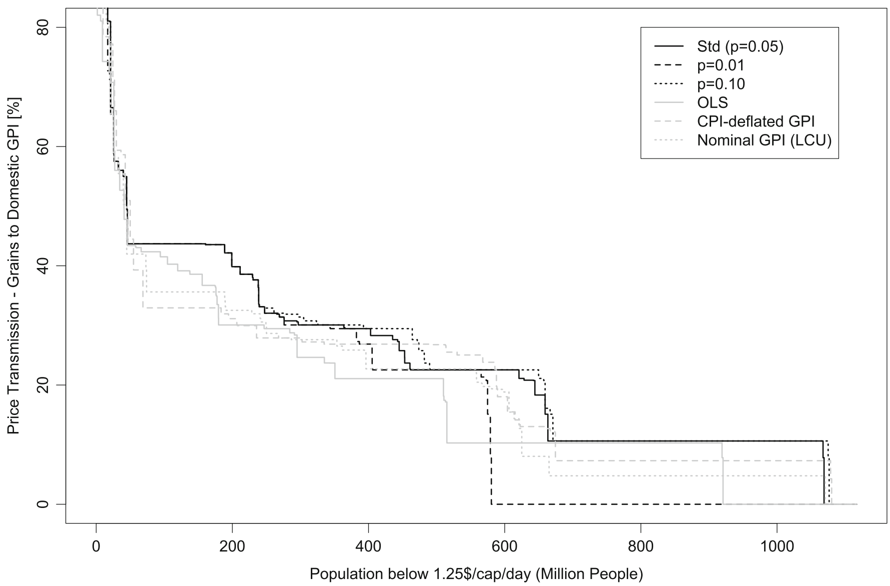

Fig. 12.7 Global price transmission to the domestic grain price index under different significance levels and model specifications. *Source*: Own elaboration

Price Transmission from Individual Grain Prices

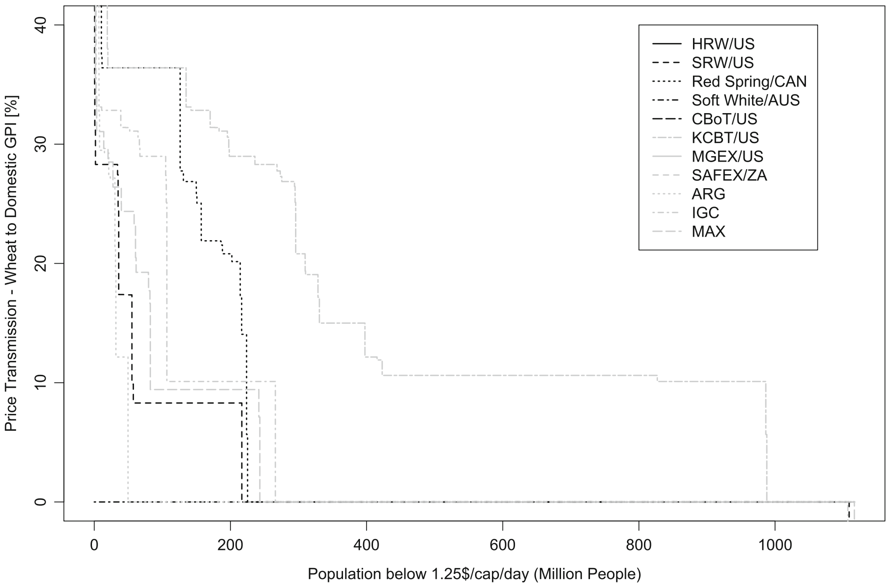

Fig. 12.8 Transmission from several international wheat prices to the domestic grain price index and affected people

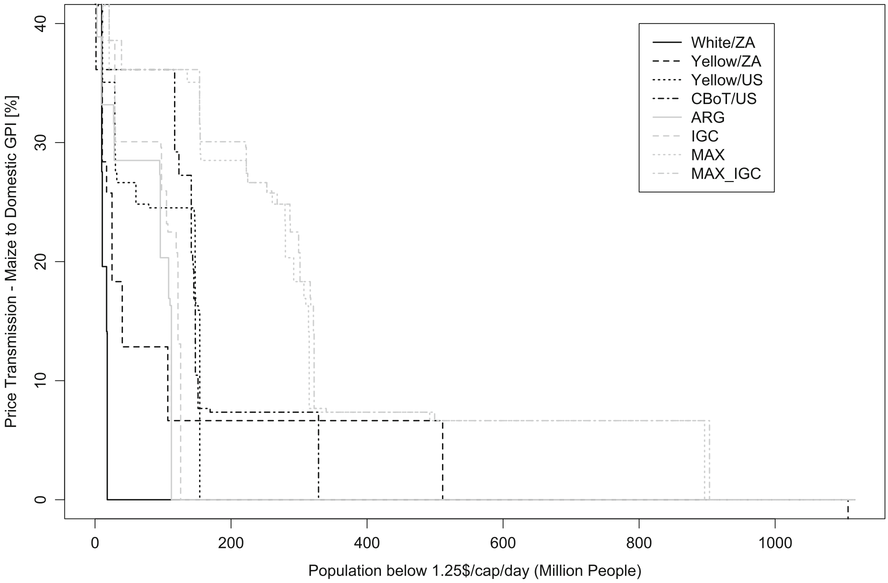

Fig. 12.9 Transmission from several international maize prices to the domestic grain price index and affected people

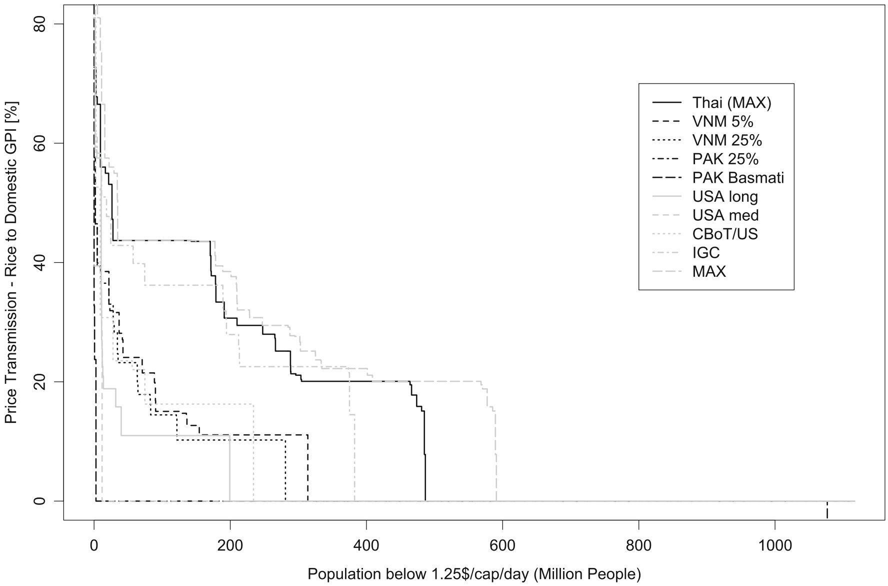

Fig. 12.10 Transmission from several international rice prices to the domestic grain price index and affected people

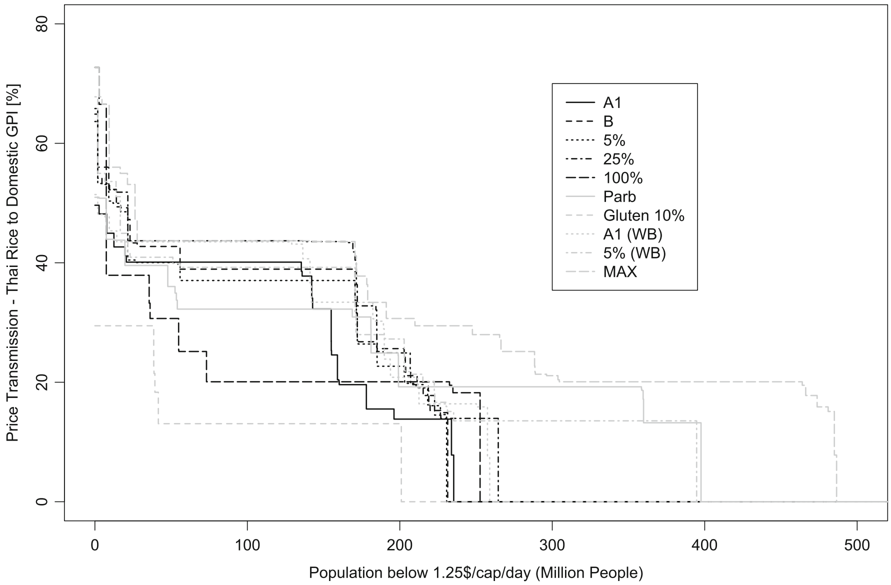

Fig. 12.11 Transmission from Thai rice prices (export) to the domestic grain price index and affected people

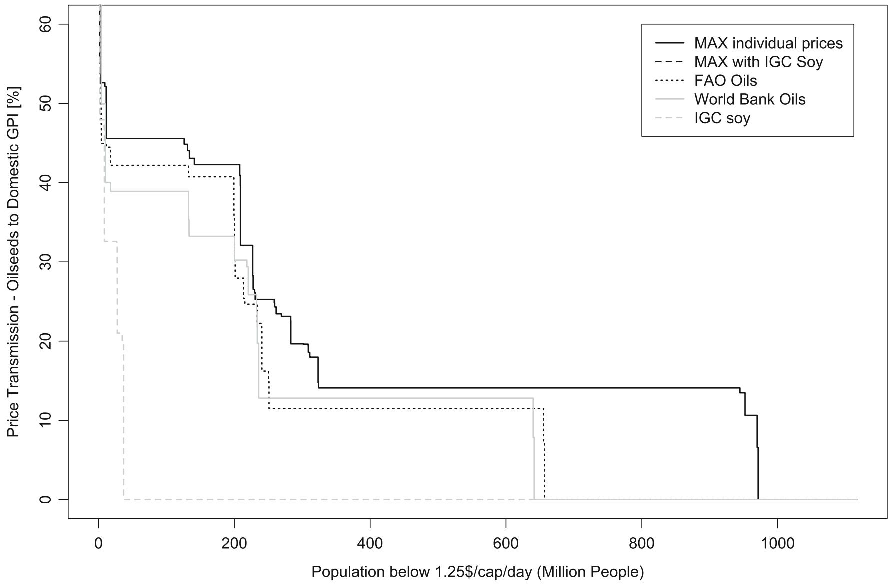

Fig. 12.12 Transmission from several international oilseed prices to the domestic grain price index and affected people

Table 12.4 Transmission elasticities of grain prices and price indices to domestic grain prices for countries with more than one million people below the poverty line

ISO3	Poor pop (Mio)	Wheat	Maize	Rice	Max (grains)	Max (US cereals futures)	FAO food	FAO cereals	WB grains	IGC grains/oils
AFG		0.30	0.46	0.37	0.46	0.28	0.71	0.52	0.50	0.51
BDI	8.0	0.00	0.26	0.16	0.26	0.00	0.00	0.00	0.00	0.00
BEN	4.8	0.28	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00
BFA	7.3	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
BGD	66.9	0.15	0.30	0.22	0.30	0.15	0.76	0.33	0.00	0.31
BRA	12.2	0.31	0.22	0.40	0.40	0.00	0.61	0.36	0.39	0.35
CHN	159.4	0.10	0.07	0.23	0.23	0.16	0.42	0.32	0.32	0.00
CIV	4.7	0.00	0.00	0.67	0.67	0.00	0.00	0.00	0.00	0.00
CMR	2.1	0.18	0.21	0.00	0.21	0.17	0.00	0.32	0.24	0.29
COL	3.9	0.00	0.16	0.32	0.32	0.10	0.22	0.18	0.24	0.11
ETH	28.1	0.33	0.27	0.44	0.44	0.24	0.00	0.71	0.78	0.61
GHA	7.3	0.00	0.00	0.56	0.56	0.00	0.36	0.00	0.00	0.00
GIN	5.0	0.82	0.00	0.87	0.87	0.00	0.00	0.00	0.00	0.00
GTM	2.0	0.31	0.27	0.29	0.31	0.21	0.67	0.40	0.37	0.37
HND	1.4	0.00	0.71	0.81	0.81	0.42	0.00	0.65	0.78	0.77
HTI	6.3	0.31	0.43	0.58	0.58	0.53	0.86	0.56	0.59	0.57
IDN	40.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IND	404.1	0.11	0.07	0.00	0.11	0.11	0.19	0.00	0.00	0.00
KEN	18.7	0.27	0.25	0.31	0.31	0.31	0.00	0.41	0.35	0.00
KHM	2.8	0.00	0.00	0.81	0.81	0.81	0.74	0.00	0.00	0.00
LAO	2.3	0.27	0.00	0.19	0.27	0.00	0.00	0.00	0.00	0.00
MDG	18.1	0.19	0.39	0.25	0.39	0.27	0.42	0.38	0.34	0.40

(continued)

Table 12.4 (continued)

ISO3	Poor pop (Mio)	Wheat	Maize	Rice	Max (grains)	Max (US cereals futures)	FAO food	FAO cereals	WB grains	IGC grains/oils
MLI	7.5	0.12	0.00	0.24	0.24	0.12	0.00	0.00	0.00	0.00
MMR		0.27	0.25	0.27	0.27	0.27	0.00	0.00	0.31	0.34
MNG		0.55	0.37	0.32	0.55	0.34	0.88	0.69	0.53	0.64
MOZ	15.0	0.00	0.18	0.00	0.18	0.00	0.00	0.00	0.00	0.00
MWI	9.8	0.00	1.17	0.00	1.17	0.00	0.00	0.00	0.00	0.00
NER	7.5	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	0.00
NGA	114.8	0.36	0.36	0.44	0.44	0.36	0.00	0.00	0.00	0.00
NPL	6.8	0.31	0.00	0.19	0.31	0.00	0.00	0.00	0.00	0.00
PAK	37.7	0.29	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.00
PER	1.5	0.07	0.00	0.08	0.08	0.00	0.40	0.00	0.00	0.00
PHL	17.8	0.12	0.08	0.32	0.32	0.08	0.00	0.00	0.00	0.00
RUS		0.33	0.26	0.28	0.33	0.21	0.95	0.47	0.40	0.42
RWA	7.2	0.33	0.26	0.28	0.33	0.21	0.95	0.47	0.40	0.42
SDN	7.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEN	4.1	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	0.00
TCD	7.7	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.00	0.00
TGO	1.9	0.57	0.51	0.84	0.84	0.00	0.59	0.00	0.44	0.38
TZA	32.4	0.28	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00
UGA	13.8	0.21	0.00	0.00	0.21	0.00	0.43	0.49	0.45	0.00
ZMB	10.5	0.42	0.00	0.39	0.42	0.00	0.00	0.41	0.00	0.00
ZWE		0.00	0.00	1.54	1.54	0.00	0.00	0.00	0.00	0.00

Note: "Poor pop" refers to the number of people below the poverty line (estimated in 2012) – blank entries denote missing data. Wheat, maize, and rice refer to the maximum transmission of the commodity prices at different international markets or of different types in each of the commodity group; max(grains) is the vulnerability indicator – showing the maximum transmission over the different grain prices; max (US cereals futures) is the vulnerability indicator over commodity prices at US futures exchanges. WB refers to the World Bank's grain price index

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13 Transmission of Food Price Volatility from International to Domestic Markets: Evidence from Africa, Latin America, and South Asia

Francisco Ceballos, Manuel A. Hernandez, Nicholas Minot, and Miguel Robles

13.1 Introduction

The global food crisis of 2007–2008 was characterized by a sharp spike in grain and other commodity prices. These price increases have been attributed to supply shortages, increased biofuel production, reduced stock-to-use ratios, export bans by major grain exporters, and panic buying by some major importers (Gilbert 2010). Commodity prices rose rapidly again in 2010, 2011, and 2012. Since 2007, global grain markets have seen an overall increase in price volatility, which is defined as the standard deviation of monthly price returns. For example, comparing the 27-year period before the crisis (1980–2006) with the 4-year period during and after the crisis (2007–2010), the unconditional volatility of international prices rose by 52 % for maize, 87 % for rice, and 102 % for wheat (Minot 2014).

To the extent that this price volatility is transmitted to markets in developing countries, it may have serious implications for farmers and low-income consumers. First, low-income consumers spend a large share of their income on food in general and on staple foods in particular, thereby making them more vulnerable to food price volatility. For instance, in some countries, such as Tanzania, Sri Lanka, and Vietnam, low-income households allocate more than 60 % of their budgets to food (Seale et al. 2003). Second, food price volatility affects poor, small-scale farmers who rely on food sales for a significant part of their income and possess limited capacity for timing their sales. Third, price volatility is likely to inhibit agricultural investment and reduce agricultural productivity growth—especially in the absence of efficient risk-sharing mechanisms—with long-run implications for poor consumers and farmers.

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A key question, however, is whether food price volatility in world grain markets is indeed transmitted to local markets in developing countries. If so, efforts to reduce excessive price volatility should perhaps be focused on concerted regional and international actions through the World Trade Organization or other multilateral bodies. Alternatively, if food price volatility in developing countries is mostly attributed to domestic factors, then the most effective policy remedies would likely be solutions at the local level which are targeted at the most vulnerable groups.

One approach to answering this question is to examine the transmission of prices (in levels) from world markets to local markets.[1] Although it seems reasonable to assume that markets with high transmission of prices could also be characterized by high transmission of volatility, this may not necessarily be the case. For example, prices from highly volatile world markets may only be transmitted to local markets with a 1- to 6-month lag, thus insulating local markets from international turmoil and resulting in less volatile local prices. Alternatively, even if there were no direct price transmission, it would still be possible for local market volatility to be determined by the degree of uncertainty among local traders, which could be influenced by a sudden increase in the volatility on world markets.

The objective of this paper is to directly estimate the transmission of grain price volatility from world markets to local markets in developing countries. In particular, we focus on the effect of the changes in the world price of maize, rice, wheat, and sorghum on 41 domestic prices of grain products in 27 countries in Latin America, Africa, and Asia. The price data are monthly, and mostly cover the period from January 2000 to December 2013, though there is some variation in the starting and ending points. The analysis is based on a multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) model using the BEKK specification proposed by Engle and Kroner (1995).[2]

The main contribution of this paper is that it is one of the first studies to estimate the transmission of food price volatility from international markets to local markets across several developing countries and regions. As will be discussed later, other studies have examined the transmission of (mean) price levels from global markets to developing countries. However, studies on the transmission of price volatility have mainly focused on examining volatility dynamics across different commodities and international markets. In addition, by focusing on market interactions in terms of the conditional second moment and allowing for volatility spillovers, better insight into the dynamic price relationship of international and domestic markets can be gained.

The remainder of the paper is organized as follows. Section 13.2 provides a review of recent research on transmission of prices and volatility. Section 13.3 details the methodology used in the study. Section 13.4 describes the data. Sec-

[1] Section 13.2 discusses the relatively large body of research examining price transmission.

[2] The BEKK acronym comes from the synthetized work on multivariate GARCH models by Baba et al. (1990).

tion 13.5 presents and discusses the estimation results, and Sect. 13.6 summarizes the findings and draws some conclusions for future research.

13.2 Previous Research on Transmission of Prices and Volatility

There is a large body of research on the transmission of prices between markets within developing countries (see Baulch 1997; Abdulai 2000; Rashid 2004; Lutz et al. 2006; Negassa and Myers 2007; Van Campenhout 2007; Myers 2008; Moser et al. 2009). Most of these studies used cointegration analysis in the form of error correction models, although some of the more recent studies applied threshold cointegration models and asymmetric response to positive and negative price shocks (e.g., Meyer and von Cramon-Taubadel 2004). Fewer studies have examined the transmission of prices from world markets to local markets. Mundlak and Larson (1992) estimated the transmission of world food prices to domestic prices in 58 countries using annual price data. They found very high rates of price transmission, but the analysis was carried out in levels rather than first differences, so the results probably reflected spurious correlation due to nonstationarity. Quiroz and Soto (1995) repeated the analysis of Mundlak and Larson (1992) using cointegration analysis and an error correction model. They found no relationship between domestic and international prices for 30 of the 78 countries examined. Conforti (2004) examined price transmission in 16 countries, including 3 in sub-Saharan Africa, using an error correction model. In general, the degree of price transmission in sub-Saharan African countries was lower than in Asian and Latin American countries. Minot (2010) analyzed the transmission of prices from world grain markets to 60 markets in sub-Saharan Africa and found a statistically significant long-term relationship in only 13 of the 62 prices examined. He also found that African rice prices are more closely linked to world markets than maize prices, presumably because most African countries are close to self-sufficiency in maize product but import a large share of their rice requirements.

Another set of studies has focused on the co-movement of world commodity prices. In their seminal paper, Pindyck and Rotemberg (1990) found "excessive co-movement" of seven commodity prices, which they attributed to herd behavior among traders in financial markets. The hypothesis of excess co-movement, however, was challenged by Deb et al. (1996) and Ai et al. (2006). These studies argued that the results obtained by Pindyck and Rotemberg suffered from misspecification and that fundamental supply and demand factors were sufficient to explain the co-movement.[3] In the case of international agricultural prices, Gilbert (2010) indicated that shocks to individual commodity prices are often supply related, whereas joint price movement can be explained by macroeconomic and monetary conditions.

[3]See Saadi (2010) for an extensive review of commodity price co-movement in international markets.

Fewer studies have examined the co-movement of conditional price volatility. As noted by Gallagher and Twomey (1998), dynamic models of conditional volatility, like MGARCH models, which are widely used in empirical finance, can provide a better understanding of the dynamic price relationship between markets by evaluating volatility spillovers. Volatility transmission between commodity markets may occur through substitution effects or as a result of common underlying factors, such as uncertainty in financial markets.

Some of the recent studies that examined market interactions between agricultural commodities using MGARCH models include Le Pen and Sévi (2010), Zhao and Goodwin (2011), Hernandez et al. (2014), Beckmann and Czudaj (2014), and Gardebroek et al. (2014). Le Pen and Sévi (2010) used different multivariate models, including a factor model and a Dynamic Conditional Correlation (DCC) model, to examine the interrelationship between eight agricultural and nonagricultural commodities and find moderate co-movement in prices and volatility. Zhao and Goodwin (2011) found important volatility spillovers between corn and soybean future prices based on a BEKK model. Using both a BEKK and a DCC model, Hernandez et al. (2014) showed significant volatility spillovers within corn, wheat, and soybean futures exchanges in the United States, Europe, and Asia as well as an increase in their interdependence in recent years. Beckmann and Czudaj (2014) also showed evidence supporting short-run volatility transmission between futures prices of corn, wheat, and cotton, based on bivariate GARCH-in-mean VAR models. Lastly, Gardebroek et al. (2014) used different MGARCH models and found little evidence of price transmission in levels between corn, wheat, and soybean spot markets. However, they found significant transmission in price volatility, particularly at weekly and monthly frequencies.

13.3 Methodology

We followed an MGARCH approach to evaluate the dynamics of volatility in monthly price returns from major agricultural international commodities to key domestic products in Africa, South Asia, and Latin America.[4] In particular, we estimated a bivariate T-BEKK model, proposed by Engle and Kroner (1995), which allowed us to model volatility transmission from international to domestic markets since the model is flexible enough to take into account both volatility spillovers and persistence across markets.[5]

The T-BEKK approach involves modeling both a conditional mean equation and a conditional variance equation for each price return series considered in the analysis. In our case, we defined price returns as $r_{mt} = \ln(p_{mt}/p_{mt-1})$, where p_{mt} is

[4] See Bauwens et al. (2006) and Silvennoinen and Teräsvirta (2009) for an extensive overview of different MGARCH models.

[5] The T acronym refers to the student's t density used in the model estimation in order to better control the leptokurtic distribution of the price returns series.

the price of a certain product (commodity) in market m at month t, and $m = 1$ refers to the domestic market while $m = 2$ to the international market. The logarithmic transformation is a standard measure for net returns in a market and is generally applied in empirical finance to obtain a convenient support for the distribution of the error term in the estimated model.

For those cases in which the pair of price returns are not found to be cointegrated, the conditional mean equation is simply modeled as a vector autoregressive (VAR) process such that

$$r_t = a_0 + \sum_{s=1}^{k} a_s r_{t-s} + \varepsilon_t,\ \varepsilon_t \Big| I_{t-1} \sim (0, H_t) \tag{13.1a}$$

where r_t is a 2×1 vector of price returns for the corresponding product (commodity) in the domestic and international market at month t, i.e., $r_t = \begin{pmatrix} r_{1t} \\ r_{2t} \end{pmatrix}$; a_0 is a 2×1 vector of constants; a_s, $s = 1,..,k$, are 2×2 matrices of parameters capturing own and cross lead-lag relationships between markets at the mean level; and ε_t is a 2×1 vector of innovations with zero mean, conditional on past information I_{t-1}, and conditional variance-covariance matrix H_t.[6] In order to determine the number of lags (k), we relied on the Schwarz Bayesian Information Criterion (SBIC). The number of lags in the conditional mean equation varied between zero and two lags, with only one case requiring three lags.

For those cases where the pair of price returns are found to be cointegrated, the conditional mean equation is modeled as a vector-error correction (VEC) model such that

$$r_t = a_0 + \sum_{j=1}^{k} a_j r_{t-j} - \lambda \mathrm{ECT}_{t-1} + \varepsilon_t,\ \varepsilon_t \Big| I_{t-1} \sim (0, H_t) \tag{13.1b}$$

where ECT_{t-1} is the lagged error correction term resulting from the cointegration relationship, i.e., $\mathrm{ECT}_{t-1} = lnp_{1,t-1} - \beta_0 - \beta_1 lnp_{2,\,t-1}$, and λ is a 2×1 vector of parameters that measure the adjustment of each (log) price series to deviations from the long-run equilibrium.

[6]Other control variables were excluded from the conditional mean (and variance) equations to capture dynamic price relationships across markets in their purest form. As with any autoregressive process, the state of the process (mean or variance) in the previous period is assumed to account for all relevant information prior to the realization of the mean or variance in the current period.

The conditional variance-covariance matrix H_t at time t (with one-time lag) is, in turn, given by

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}A + G'H_{t-1}G, \tag{13.2}$$

where C is a 2×2 upper triangular matrix of constants c_{ij}, A is a 2×2 matrix whose elements a_{ij} capture the direct effect of an innovation in market i on the current price return volatility in market j, and G is a 2×2 matrix whose elements g_{ij} measure the direct influence of past volatility in market i on the current volatility in market j (persistence). If we expand Eq. (13.2), the resulting conditional variance equation for the domestic market is defined as

$$\begin{aligned} h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + g_{11}^2 h_{11,t-1} \\ +2g_{11}g_{21}h_{12,t-1} + g_{21}^2 h_{22,t-1} \end{aligned} \tag{13.3}$$

This variance-covariance specification allows us to characterize the magnitude and persistence of volatility transmission from international to domestic markets. Moreover, similar to Gardebroek and Hernandez (2013) and Hernandez et al. (2014), we derived impulse response functions for the estimated conditional volatilities to assess how a shock or innovation is transmitted from the international market to the domestic market and obtain the elasticity of domestic price volatility with respect to international price volatility.

13.4 Data

We compiled a large dataset of monthly prices of maize, rice, sorghum, wheat, and wheat products for 41 markets in 27 countries. We obtained domestic price data from two sources. Our main source was the Famine Early Warning Systems Network (FEWS NET), which tracks the nominal prices of several staple food commodities across several key domestic markets on a monthly basis. This service is provided as part of their Price Bulletin product and is only available for countries in which the network has a presence—mostly African and Central American economies. Our second source was the Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization (FAO), which relies on price information from a number of local primary sources across FAO's 190 member countries. We relied on this source to obtain domestic prices in Asian, South American, and some additional Central American countries.

Out of all the price series available from these sources, we considered the domestic prices of the most important food staples in each country, which are defined as those constituting the highest share of the local diet. Moreover, prices from the main local market—generally the capital city—were chosen to be representative of each product. We also included prices observed in more than one market for a few countries (in India, for example, prices from both the Mumbai and the New Delhi markets were considered). As prices are denominated in local currency, each price series was converted into the US dollar using monthly exchange rates from the IMF's International Financial Statistics (IFS) database. Normalizing all prices to the US dollar allowed us to take into account the potential impact of the exchange rate on the international-domestic price transmission analysis. We excluded price series with less than 100 observations (i.e., months) or with a high number of missing or repeated values. Missing values in the remaining series were approximated through linear interpolation between the two closest available data points. Appendix Table 13.3 shows the details for each of the price series used, including its source (FEWS NET or GIEWS), the corresponding local market, whether it is a retail or a wholesale price, and its unit of measurement.

International monthly price series are compiled by the FAO International Commodity Prices database (FAOSTAT). These prices are expressed in terms of US dollars per tonne. The maize price is for No. 2 yellow maize, U.S. Gulf; the rice price is for A1 super, white broken rice, Bangkok, f.o.b.; the sorghum price is for No. 2 yellow sorghum, U.S. Gulf; and the wheat price is for No. 2 hard red winter wheat (ordinary protein), U.S. Gulf, f.o.b. Appendix Table 13.4 shows the details of each of the international price series used.

Figure 13.1 shows the evolution of international monthly prices for maize, rice, sorghum, and wheat over the 2000–2014 period. In general, prices had been rising in a relatively stable way until the spikes experienced during the food crisis of 2007–2008; price spikes were subsequently observed between 2010 and 2012. Interestingly, the figure shows a large degree of co-movement between the prices for the four commodities during the past years. The price movement of sorghum

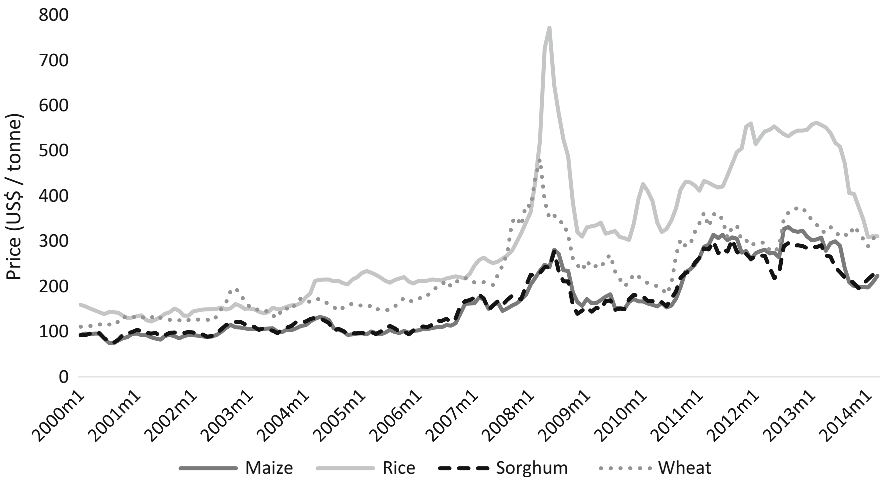

Fig. 13.1 International commodity prices—2000–2014. *Note*: this figure shows the evolution of the monthly international prices of maize, rice, sorghum, and wheat during the 2000–2014 period. Prices are expressed in US$ per tonne

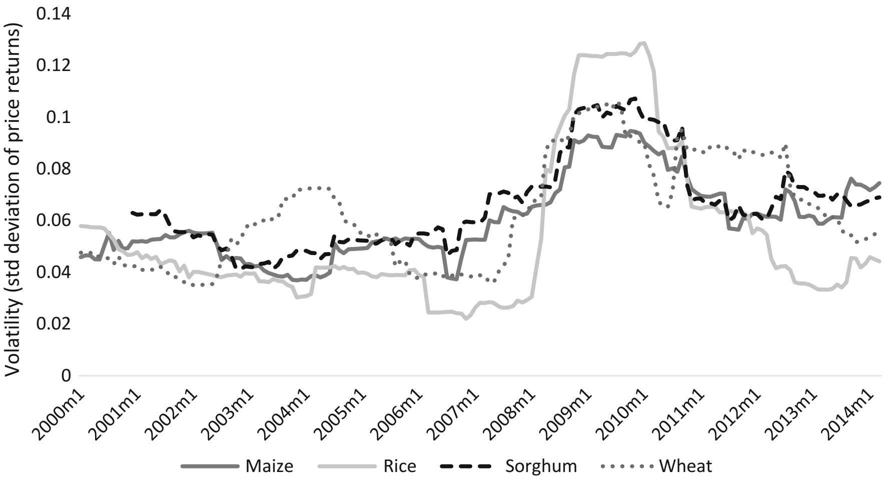

Fig. 13.2 Volatility of international grain prices (2-year moving window)—2000–2014. *Note*: this figure shows the evolution of the volatility of monthly international prices of maize, rice, sorghum, and wheat during the 2000–2014 period. The monthly volatility was calculated as the standard deviation of the monthly price returns observed during that month and the previous 23 months

and maize showed striking similarities; this is also true of wheat price movement—though to a lesser extent.

International prices of different food commodities also seem to co-move in terms of volatility. Figure 13.2 shows the evolution of price volatility (the standard deviation of monthly price returns) for these four commodities over a 2-year moving window from 2000 to 2014.[7] The price volatility of these commodities seems to have followed a similar pattern during most of the period of analysis, with a considerable increase during and following the 2007–2008 food crisis, followed by a decrease—even though price volatility after the decrease was still higher than prior to the crisis. This is more clearly observed in Fig. 13.3, which compares price volatility before (2000–2006) and after the crisis (2008–2014). Except for sorghum, which showed only a moderate increase, sample standard deviations for the rest of the commodities increased by more than 30 % after the crisis, indicating a much higher variation (fluctuation) of international agricultural prices in recent years.

As discussed above, the main purpose of this study is to analyze volatility transmission from international to domestic markets. As a first step, it is useful to analyze the dynamics of the volatility of domestic prices vis-à-vis that of the international reference prices. Figure 13.4a–d plots the evolution of price volatility (the standard deviation of international and domestic price returns) by commodity over a 2-year moving window, similar to Fig. 13.2. The results were mixed. In the

[7]For instance, the number for January 2000 reflects the standard deviation of the monthly realized price returns from February 1998 until January 2000.

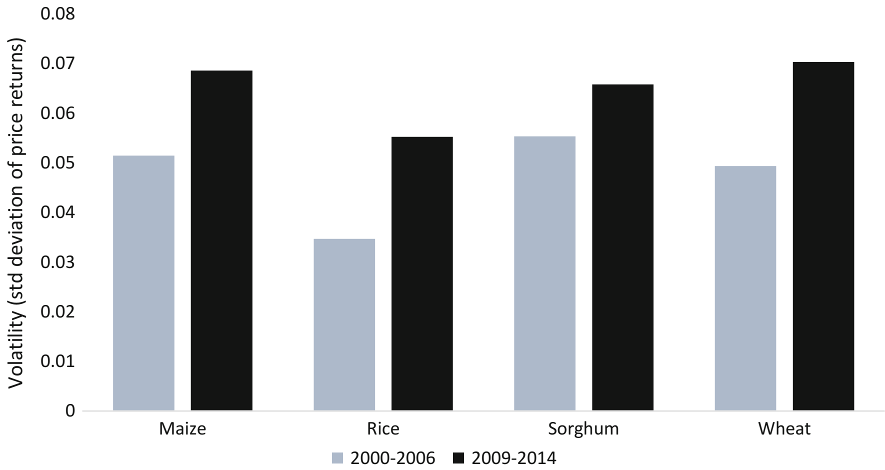

Fig. 13.3 Volatility of international grain prices before and after the 2007–2008 crisis. *Note*: this figure shows the volatility of monthly international prices of maize, rice, sorghum, and wheat before and after the 2007–2008 food crisis. The "before" period spans 2000–2006 while the "after" period spans 2009–2014. The volatility for each period is calculated as the standard deviation of the observed monthly price returns for each commodity

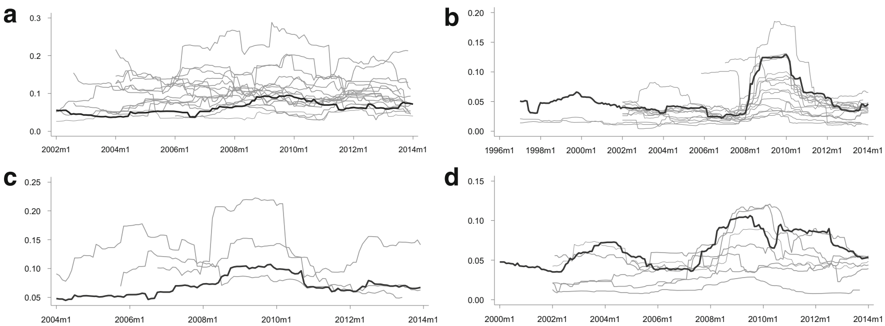

Fig. 13.4 Volatility (2-year moving window) of domestic and international prices for (**a**) maize, (**b**) rice, (**c**) sorghum, and (**d**) wheat. *Note*: Figures (**a**)–(**d**) show the evolution of the volatility of monthly domestic and international prices of maize, rice, sorghum, and wheat during the 2000–2014 period. The volatility for every month is calculated as the standard deviation of the monthly price returns observed during that month and the previous 23 months. The *line* in *bold* represents the volatility of each international price series

case of rice and wheat, there seems to be a substantial co-movement in the volatility of domestic and international prices, particularly in the case of rice. The volatility of international sorghum prices also showed some evidence of co-movement with the volatility of domestic sorghum-related prices. The volatility pattern of prices in domestic maize markets, in contrast, did not generally resemble the volatility pattern exhibited by international maize prices. The volatility dynamics between domestic

Table 13.1 Summary statistics and selected normality, autocorrelation, and stationarity tests

	Maize	Rice	Sorghum	Wheat	Total
Panel A: domestic price series					
Number of domestic price series	16	15	3	7	41
Mean price returns (%)	0.42	0.33	0.47	0.46	0.40
% of series with kurtosis > 3	100.0	100.0	100.0	100.0	100.0
% of series rejecting Jarque-Bera test's H_0	93.8	100.0	100.0	100.0	97.6
% of series rejecting Ljung-Box test's H_0 on squared returns (5 lags)	31.3	66.7	0.0	71.4	48.8
% of series rejecting Ljung-Box test's H_0 on squared returns (10 lags)	31.3	73.3	33.3	71.4	53.7
% of series rejecting AC Q test's H_0 on squared returns (first lag)	37.5	73.3	33.3	71.4	56.1
% of series rejecting AC Q test's H_0 on squared returns (second lag)	43.8	80.0	33.3	85.7	63.4
% of series rejecting ADF test's H_0 on logarithm of price in levels (5 lags)	56.3	13.3	0.0	57.1	36.6
% of series rejecting ADF test's H_0 on price returns (5 lags)	100.0	100.0	100.0	100.0	100.0
Panel B: international price series					
Mean price returns (%)	0.52	0.39	0.54	0.62	
Standard deviation of price returns (%)	6.44	6.18	6.74	6.65	
Jarque-Bera statistic	28.68*	273.10*	39.46*	39.37*	
Kurtosis	4.84	9.15	5.27	5.11	
Ljung-Box statistic on squared returns (5 lags)	1.58	53.74*	4.42	7.25	
Ljung-Box statistic on squared returns (10 lags)	11.86	80.14*	8.71	11.86	
AC Q statistic on squared returns (first lag)	0.09	0.35*	0.08	0.17*	
AC Q statistic on squared returns (second lag)	0.03	0.34	0.01	0.09*	
ADF statistic—logarithm of price in levels (5 lags)	−1.40	−1.58	−1.47	−1.78	
ADF statistic—price returns (5 lags)	−5.88*	−5.74*	−5.74*	−4.68*	

Note: This table presents summary statistics and selected normality, autocorrelation, and stationarity tests for domestic (panel A) and international (panel B) price return series for maize, rice, sorghum, and wheat. An asterisk indicates that the null hypothesis is rejected at the 5 % level of confidence

and international price returns requires further examination, as will be discussed in the next section.

Table 13.1 provides some descriptive statistics for the domestic and international price returns used in the analysis. First, the Jarque-Bera test indicated that the returns for almost every domestic price and all four international prices did not follow a normal distribution. The kurtosis in all of the analyzed markets was greater than 3, further pointing to a leptokurtic distribution of returns. These results revealed the need to use a Student's t density for the estimation of the BEKK models below.

Second, both the Ljung-Box (LB) statistics for up to five and ten lags and the Portmanteau (Q) statistics for the first- and second-order autocorrelation coefficients generally rejected the null hypothesis of no autocorrelation for the squared returns.

This autocorrelation suggests the existence of nonlinear dependencies in several of the price returns, which motivates the use of MGARCH models to better capture own- and cross-market interdependencies between domestic and international markets.

Third, the Augmented Dickey-Fuller (ADF) test suggested that several of the domestic and international prices (in natural logarithms) were non-stationary. As explained in the methodology section, for all these cases, a cointegration test was first conducted to determine if a potential long-run relationship between the corresponding domestic and international price needs to be taken into account by applying a vector-error correction model. Finally, the ADF test confirms the stationarity of all the domestic and international price returns series.

13.5 Results

In this section, we describe our estimates of volatility transmission from international commodity markets to domestic food markets across countries and commodities. Due to space limitations, we did not provide detailed estimation results of the BEKK model for each of the 41 country-commodity combinations; instead, we assessed the reliability of our estimations by comparing model predictions to sample statistics. In particular, we compared the volatility of each domestic price sample (standard deviation of domestic price returns) with the corresponding predicted volatility from our estimated model. Since the BEKK model explicitly formulates a law of motion for the conditional variance of price returns, the estimated variance are not individual values but rather a series of monthly estimated conditional variances. In addition, we can estimate the implied steady-state (or unconditional) volatility and compare it with the sample volatility. In practice, we estimate the following for each domestic price return:

The sample volatility: $\left(h_{11}^{sample}\right)^{0.5} = \sqrt{\frac{\sum_{t=1}^{n}(r_t - \bar{r})^2}{n}}$

The steady-state volatility $\left(h_{11}^{SS}\right)^{0.5}$ which satisfies the following expression: $H^{SS} = C'C + G'H^{SS}G$

The average of the predicted conditional volatilities: $\widehat{\overline{h_{11}}} = \frac{\sum_{t=1}^{n}\hat{h}_{11.t}^{0.5}}{n}$

Figure 13.5a–c compare the sample values and model estimates of the domestic price volatility. First, note that the sample volatilities of maize prices are, on average, higher than those of rice and wheat. The sample maize price volatilities ranged from 4.3 % (in Mexico) to 20.8 % (in Malawi), with an average of 10.4 % for our full set of countries. Sorghum also showed volatility levels which are similar to or even higher than maize, although we only obtained data for three countries. In the case of rice and wheat, the sample volatilities are on average 4.7 % and 4.8 %, respectively. Interestingly, African countries have the highest sample volatilities (an average of 11.3 %), while Asia and Latin America countries have averages which are less than half of the African average.

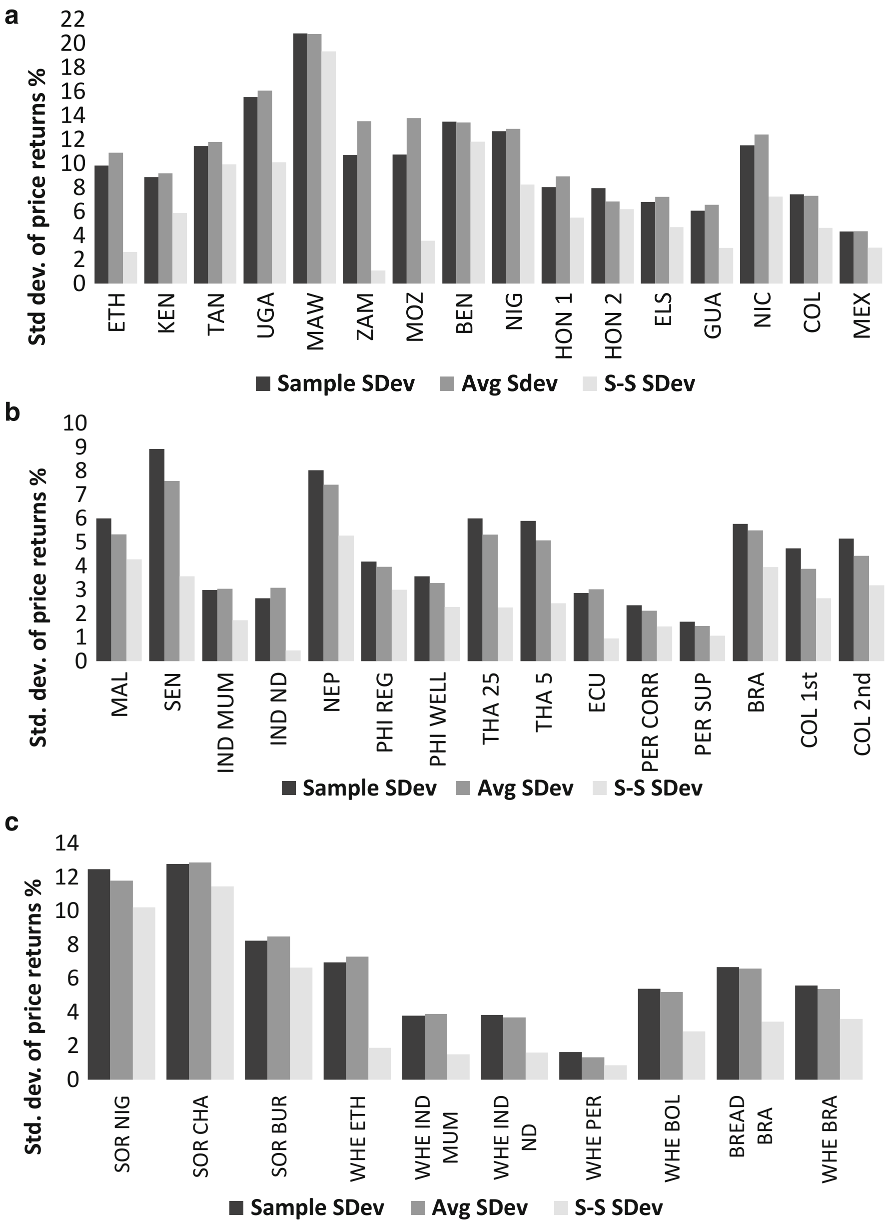

Fig. 13.5 Volatility of monthly prices (in %) sample, average, and steady state for (**a**) maize, (**b**) rice, and (**c**) sorghum/wheat. *Note*: Figures (**a**)–(**c**) compare the sample, average, and steady-state volatilities of monthly price returns. Sample volatility is defined as the standard deviation of the domestic price returns. Average and steady-state volatilities were derived from the results of the conditional variance estimation. The average volatility is the average of the squared roots of the estimated domestic variance terms. The steady-state volatility is the squared root of the domestic variance term after the estimated system reaches a hypothetical steady state. See Sect. 13.5 of the main text for details.

Our estimated steady-state and predicted volatilities yielded similar conclusions when comparing commodities and regions. On average, volatilities estimated by our model for maize prices are larger than those for rice and wheat, with the last two being quite similar. Across regions, estimated food price volatility was around twice as high in Africa than Asia and Latin America. Comparing steady-state volatility with sample volatility, the former is consistently lower than the latter. In particular, steady-state volatility estimates are on average 60 % of the sample estimates, and these differences range from 10 % for maize in Zambia to 93 % for maize in Malawi. Steady-state estimates are expected to be consistently lower than sample estimates because steady-state estimates reflect the standard deviations to be reached over time in the absence of shocks to price volatility. This finding is also consistent with results reported by Gardebroek et al. (2014).

When comparing the average predicted volatility from the estimated models with the sample volatility, we also observed that our estimated models exhibited a relatively good predictive performance. The ratio of the average predicted volatility to the sample volatility is on average 0.99 for the full set of countries and commodities. This ratio ranged from 0.81 for wheat in Peru (the largest underestimation) to 1.28 for maize in Mozambique (the largest overestimation). Across commodities, the model predictions on average slightly overestimated the sample value in the case of maize (average ratio of 1.05) and underestimate it for rice and wheat (average ratios of 0.92 and 0.96). These average predicted volatilities further reaffirm that maize prices are much more volatile than rice and wheat prices.

To estimate the degree of volatility transmission from international markets to domestic markets, we carried out the following two steps for each estimated model (one per country-commodity):

We estimated the size of a shock in the international market ($\overline{\varepsilon}_2$) such that the steady-state variance of the international price return increases by 1 % after one period:

$$\frac{H_{1,22}\left(\overline{\varepsilon}_2\right) - H_{0,22}}{H_{0,22}} = 0.01$$

We introduced the shock $\overline{\varepsilon}_2$ into Eq. (13.2), estimated the percentage change in the variance of the domestic price return (with respect to its steady-state value), and compute our volatility transmission VT indicator according to:

$$\mathrm{VT} = \frac{H_{1,11} - H_{0,11}}{H_{0,11}} \div 0.01$$

In other words, our volatility transmission indicator compares the reaction (after one period and assuming the system is at a steady state) of the domestic price return variance and the reaction of the international price return variance to a shock in the international market. If our volatility transmission indicator is equal to 1, it means that the domestic price return variance increases by the same proportion as

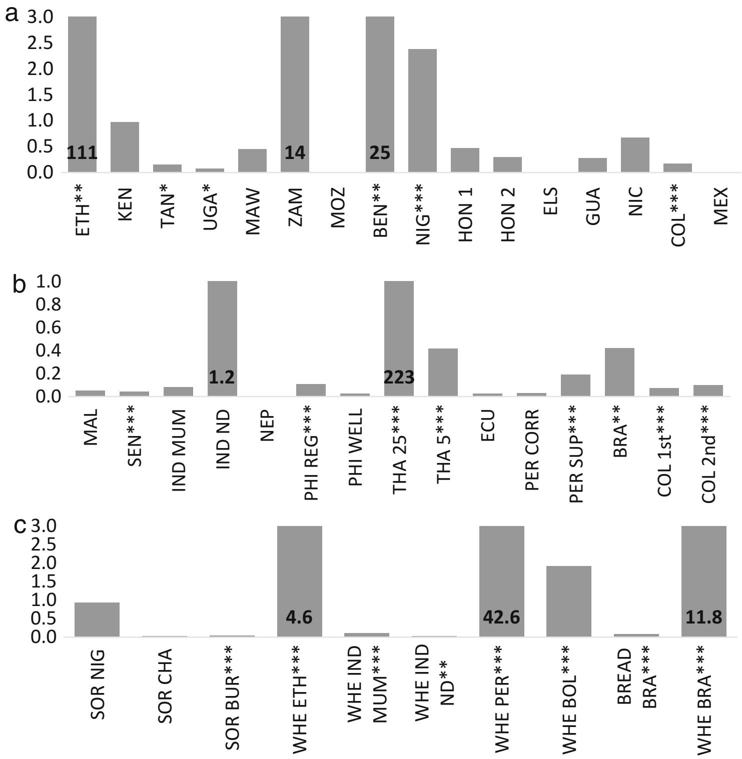

Fig. 13.6 Price return volatility transmission estimates for (**a**) maize, (**b**) rice, and (**c**) sorghum/wheat. *Note*: Figures (**a**)–(**c**) show estimates for the elasticity of price volatility transmission from international markets to domestic markets for each available country and commodity. Panel (**a**) focuses on volatility transmission of the international maize price, panel (**b**) on volatility transmission of the international price of rice, and panel (**c**) on volatility transmission of the international prices of sorghum (first three country-commodities) and wheat. The elasticity of price volatility is defined as the percentage change in the variance of the domestic price return (with respect to its steady-state value) relative to that of the international price return variance (see Sect. 13.5 of the main text for details). The figure is truncated to preserve scale; outlier values are indicated in *bold*. *, **, and *** denote statistically significant estimates at the 1 %, 5 %, and 10 % level, respectively

the international price return variance in one period, after introducing a shock to the international market.

We present our volatility transmission estimates for each country and commodity in Fig. 13.6a–c, together with a measure of their statistical significance. Aggregated medians and frequencies across commodities and regions are shown in Table 13.2.[8]

[8]We measured statistical significance by implementing the Wald test for the joint significance of α_{21} and g_{21} in the conditional variance equation, where α_{21} is the short-term effect of an

Table 13.2 Price return volatility transmission, by commodity and region

	Median	Volatility transmission (elasticity)				Not significant (at 5 % level)
		Lower than 0.1	Between 0.1 and 1	Higher than 1	Total	
Total	0.172	6	6	8	20	21
By commodity						
Maize	0.372	0	1	3	4	12
Rice	0.082	3	4	1	8	7
Sorghum	0.035	1	0	0	1	2
Wheat	1.919	2	1	4	7	0
By region						
Africa	0.450	2	0	4	6	9
Asia	0.103	1	3	1	5	4
Central America and Caribbean	0.288	0	0	0	0	6
South America	0.172	3	3	3	9	2

Note: This table shows the estimates of the elasticity of price volatility transmission from international markets to domestic markets by commodity and region. The first column presents the median elasticity of all estimates, while columns 2–4 show the number of statistically significant cases (at the 5 % level) for which the estimated elasticity falls between certain values. The last column shows the number of cases for which the estimated volatility transmission was not statistically significant at the 5 % level. The elasticity of price volatility is defined as the percentage change in the variance of the domestic price return (with respect to its steady-state value), relative to that of the international price return variance (see Sect. 13.5 of the main text for details)

Overall, we found volatility transmission that was statistically significant at the 5 % level in about half of the cases, with most of the estimates within reasonable values.[9]

In the case of maize, the median volatility transmission from international to domestic markets was 0.37, but just 4 of the 16 countries exhibited a relationship that is significant at the 5 % level: Ethiopia, Benin, Nigeria, and Colombia.

Our estimates indicated that the volatility transmission of rice prices was lower than that of maize and wheat. The median volatility transmission was less than 0.1, and in seven out of eight statistically significant cases, our volatility transmission estimates are below 0.5. On the other hand, more than half of the estimates of volatility transmission for rice are statistically significant, compared to just one-fourth for maize. Across regions, evidence of transmission was observed mostly in Asia and Latin America, with the highest levels in Thailand and Brazil.

international price shock on domestic volatility (innovation effect) and g_{21} is the short-term effect of changes in international price volatility on domestic volatility (persistence effect).

[9]Our estimates showed extreme values larger than 10 only in 6 of the 41 cases.

In the case of wheat, the median volatility transmission (1.92) is larger than for any other commodity, and all of our estimates are statistically significant. However, there does not seem to be a clear pattern across countries. Volatility transmission was very low (below 0.2) in three of the seven cases: Mumbai wheat, New Delhi wheat, and Brazilian bread. In contrast, volatility transmission was quite high (above 4) in three other cases: wheat in Peru, Brazil, and Ethiopia. Finally, volatility transmission for sorghum was estimated for just three economies, all in Africa, and only one of these (Burkina Faso) was statistically significant.

In terms of regional patterns, while we found no evidence of price volatility transmission in any Central American and Caribbean countries, there was a significant relationship between the volatility of international prices and domestic prices in a large proportion of South American economies. In the case of Africa and Asia, the evidence was mixed, with statistically significant volatility transmission in around one-third of the African cases and one-half of the Asian cases.

13.6 Discussion

We expect price transmission and volatility transmission to be greatest when (1) the international trade in the commodity is large relative to domestic production or consumption, (2) trade restrictions (particularly quantitative restrictions) are low, (3) the government does not intervene to stabilize the domestic price of the commodity, and (4) the transport costs between the country and international markets are low. Some of these factors, particularly the ratio of trade to domestic production, are helpful in explaining the volatility transmission results obtained in this study, but some of the findings were unexpected.

In the case of maize, it is unsurprising that Colombia was the only Latin American country for which our estimate of volatility transmission was statistically significant: Colombian maize imports are equivalent to 64 % of its domestic production, as shown in Appendix Table 13.5. In the other five Latin American countries, the proportion ranges from 15 % to 38 %. And the African countries are not expected to have statistically significant volatility transmission because they are almost self-sufficient in maize production (net trade is 0–9 % of domestic production). The only unexpected finding was the statistically significant volatility transmission in Ethiopia, Nigeria, and Benin.

Turning to rice markets, it is unsurprising that volatility transmission was statistically significant in Thailand, which exports 70 % of its domestic rice production, and Senegal, whose imports are equivalent to 82 % of its domestic output (see Appendix Table 13.5). The lack of volatility transmission to domestic markets in Mali, India, Nepal, and Ecuador is expected given that these countries import an equivalent of no more than 16 % of their domestic production. However, there was evidence of volatility transmission to the domestic markets of Peru, Brazil, and Colombia despite these countries relying minimally on rice imports.

In the case of sorghum, the three countries examined have negligible trade in this commodity, so the volatility transmission in Burundi was unexpected, but the lack of transmission in the other two countries was expected.

As mentioned above, all of the seven wheat prices tested showed statistically significant transmission of volatility. This was expected in the cases of Peru, Bolivia, and Brazil, whose wheat imports are equivalent to 88 %, 72 %, and 56 % of domestic production, respectively. And it is perhaps also understandable in the case of Ethiopia, whose imports are equivalent to 32 % of domestic output. However, it is less clear why international volatility is transmitted to Indian wheat markets given that wheat trade is equivalent to just 2 % of its domestic production.

Overall, it appears that price volatility is (is not) transmitted from international to domestic markets when the ratio of traded volume to domestic production is above (below) 40 %. In our analysis, 29 of the 41 prices (71 %) follow this pattern.

13.7 Conclusions

Food price volatility in developing countries is economically and politically important. In these economies a large share of household budgets is spent on food, so food price levels and volatility have a direct and large impact on welfare. Food price volatility also affects poor, small-scale farmers who rely on crop sales for a significant part of their income. Food price volatility is also likely to inhibit agricultural investment and reduce the growth in agricultural productivity, with long-run implications for poor consumers and farmers. Hence, it is important to better understand the sources of food price volatility and whether the volatility is mostly transmitted from international agricultural commodity markets or largely determined by domestic factors. This in turn will help design better global, regional, and domestic policies to cope with excessive food price volatility and to protect the most vulnerable groups.

The objective of this paper is to estimate the transmission of grain price volatility from world markets to local markets in developing countries, as these estimates have been generally absent in the literature. In particular, we focused on the effect of the world price of maize, rice, wheat, and sorghum on 41 prices of grain products in 27 countries across Latin America, Africa, and Asia. Monthly price data were used, and the data mostly covered the period from January 2000 to December 2013. The analysis was based on a MGARCH approach using a BEKK model.

We assessed the reliability of our estimations by comparing model predictions to sample statistics. In particular, we compared sample food price volatility to average predicted conditional volatility and estimated steady-state volatility. Our model predictions did a good job in replicating sample data patterns. For our full set of commodity/countries, the ratio of the average predicted volatility to the sample volatility was 0.99, and as in the data, the average predicted volatility is higher for maize prices than for rice and wheat prices. Across regions, the estimates showed that the average food price volatility in African countries was around double those in South Asia and Latin America. Furthermore, as expected, our estimated steady-state price volatilities were consistently lower than the sample price volatilities.

We proposed a volatility transmission estimator (or elasticity) that shows the reaction of domestic price return variance relative to the reaction of international price return variance to a one-time shock in the international market (after one period and assuming the system is at steady-state).

We found that most of our estimates were within reasonable values. About half (20 of 41) of the volatility transmission estimates were statistically significant, but the proportion varies by commodity: all seven wheat prices show volatility transmission, but just half of the rice prices and one-fourth of the maize prices did so. Volatility transmission of a commodity's price appears to be linked to the importance of trade in that commodity to the country in question. When the ratio of trade to domestic production is over (under) 40 %, price volatility is (is not) transmitted from world markets to local markets. This rule could explain 29 of the 41 prices examined (71 %). All 12 exceptions to this rule are cases in which trade is minimal but volatility is transmitted from world markets. This could occur through transmission of volatility between closely related commodity markets or perhaps as a result of transmission of "anxiety" from international markets to domestic markets. Further research is needed to examine these alternative explanations.

Acknowledgements The authors acknowledge funding from the European Commission within the FoodSecure Research Project.

Appendix

Table 13.3 Domestic price series' sources and information

International commodity		Country	Local product	Market	Abbreviation	Units	Price type	Start date	End date	Num. of obs.	Region	Source
1	Maize	Benin	Maize (white)	Cotonou	BEN	FCFA/kg	Retail	2003–10	2013–12	123	Africa	FEWSNET
2	Maize	Ethiopia	Maize (white)	Addis Ababa	ETH	ETB/100 kg	Wholesale	2004–01	2013–12	120	Africa	FEWSNET
3	Maize	Kenya	Maize (white)	Nairobi	KEN	KES/90 kg	Wholesale	2000–01	2013–12	168	Africa	FEWSNET
4	Maize	Malawi	Maize (white)	Lunzu	MAW	MWK/kg	Retail	2004–01	2013–12	120	Africa	FEWSNET
5	Maize	Mozambique	Maize (white)	Maputo	MOZ	MZN/kg	Retail	2002–01	2013–12	144	Africa	FEWSNET
6	Maize	Nigeria	Maize (white)	Ibadan	NIG	NGN/kg	Retail	2003–10	2013–12	123	Africa	FEWSNET
7	Maize	Tanzania	Maize (white)	Dar es Salaam	TAN	TZS/100 kg	Wholesale	2002–01	2013–12	144	Africa	FEWSNET
8	Maize	Uganda	Maize (white)	Kampala	UGA	UGX/kg	Wholesale	2002–01	2013–12	144	Africa	FEWSNET
9	Maize	Zambia	Maize (white)	Lusaka	ZAM	ZMW/kg	Retail	2002–01	2013–12	144	Africa	FEWSNET

(continued)

Table 13.3 (continued)

	International commodity	Country	Local product	Market	Abbreviation	Units	Price type	Start date	End date	Num. of obs.	Region	Source
10	Maize	El Salvador	Maize (white)	San Salvador	ELS	USD/pound	Retail	2000–08	2013–12	161	Central America and Caribbean	FEWSNET
11	Maize	Guatemala	Maize (white)	Guatemala City	GUA	GTQ/pound	Retail	2005–08	2013–12	101	Central America and Caribbean	FEWSNET
12	Maize	Honduras	Maize (white, mkt 1)	Tegucigalpa	HON 1	HNL/5 pounds	Retail	2001–09	2013–12	148	Central America and Caribbean	FEWSNET
13	Maize	Honduras	Maize (white, mkt 2)	Tegucigalpa	HON 2	HNL/5 pounds	Retail	2001–09	2013–12	148	Central America and Caribbean	FEWSNET
14	Maize	Mexico	Maize (white)	Mexico City	MEX	Peso/kg	Wholesale	2000–01	2014–03	171	Central America and Caribbean	GIEWS
15	Maize	Nicaragua	Maize (white)	Managua	NIC	NIO/pound	Retail	2000–08	2013–12	161	Central America and Caribbean	FEWSNET

(continued)

Table 13.3 (continued)

	International commodity	Country	Local product	Market	Abbreviation	Units	Price type	Start date	End date	Num. of obs.	Region	Source
16	Maize	Colombia	Maize (white)	Bogotá	COL	Peso/kg	Wholesale	2000–01	2012–10	154	South America	GIEWS
17	Rice	Mali	Rice (local)	Bamako	MAL	FCFA/kg	Retail	2003–11	2013–12	122	Africa	FEWSNET
18	Rice	Senegal	Rice (imported)	Dakar	SEN	FCFA/kg	Retail	2003–10	2013–10	121	Africa	FEWSNET
19	Rice	India	Rice (Mumbai)	Mumbai	IND MUM	Rupee/kg	Retail	2000–01	2014–03	171	Asia	GIEWS
20	Rice	India	Rice (New Delhi)	New Delhi	IND ND	Rupee/kg	Retail	2000–01	2014–03	171	Asia	GIEWS
21	Rice	Nepal	Rice (coarse)	Kathmandu	NEP	USD/kg	Retail	2005–01	2014–02	110	Asia	GIEWS
22	Rice	Philippines	Rice (regular milled)	Metro Manila	PHI REG	USD/kg	Retail	2000–01	2014–02	170	Asia	GIEWS
23	Rice	Philippines	Rice (well milled)	Metro Manila	PHI WELL	USD/kg	Retail	2000–01	2014–02	170	Asia	GIEWS
24	Rice	Thailand	Rice (25 % broken)	Bangkok	THA 25	Baht/tonne	Wholesale	2000–01	2014–02	170	Asia	GIEWS
25	Rice	Thailand	Rice (5 % broken)	Bangkok	THA 5	Baht/tonne	Wholesale	2000–01	2014–02	170	Asia	GIEWS

(continued)

Table 13.3 (continued)

	International commodity	Country	Local product	Market	Abbreviation	Units	Price type	Start date	End date	Num. of obs.	Region	Source
26	Rice	Brazil	Rice	São Paulo	BRA	Real/kg	Retail	2000–01	2014–03	171	South America	GIEWS
27	Rice	Colombia	Rice (first quality)	Bogotá	COL 1st	Peso/kg	Wholesale	2000–01	2014–03	171	South America	GIEWS
28	Rice	Colombia	Rice (second quality)	Bogotá	COL 2nd	Peso/kg	Wholesale	2000–01	2014–03	171	South America	GIEWS
29	Rice	Ecuador	Rice (long grain)	Quito	ECU	Usd/kg	Wholesale	2005–01	2014–03	111	South America	GIEWS
30	Rice	Peru	Rice (milled, corriente)	Lima	PER CORR	Nuevo sol/kg	Retail	1995–01	2013–09	225	South America	GIEWS
31	Rice	Peru	Rice (milled, superior)	Lima	PER SUP	Nuevo sol/kg	Retail	1995–01	2013–09	225	South America	GIEWS
32	Sorghum	Burkina Faso	Sorghum (white)	Ouagadougou	SOR BUR	FCFA/kg	Retail	2003–10	2013–12	123	Africa	FEWSNET
33	Sorghum	Chad	Sorghum (red)	N'Djamena	SOR CHA	FCFA/kg	Retail	2002–01	2013–12	144	Africa	FEWSNET
34	Sorghum	Nigeria	Sorghum (mixed)	Ibadan	SOR NIG	NGN/kg	Retail	2004–10	2013–12	111	Africa	FEWSNET
35	Wheat	Ethiopia	Wheat	Addis Ababa	WHE ETH	ETB/100 kg	Wholesale	2004–01	2013–12	120	Africa	FEWSNET

(continued)

Table 13.3 (continued)

	International commodity	Country	Local product	Market	Abbreviation	Units	Price type	Start date	End date	Num. of obs.	Region	Source
36	Wheat	India	Wheat (Mumbai)	Mumbai	WHE IND MUM	Rupee/kg	Retail	2000–01	2014–03	171	Asia	GIEWS
37	Wheat	India	Wheat (New Delhi)	New Delhi	WHE IND ND	Rupee/kg	Retail	2000–01	2014–03	171	Asia	GIEWS
38	Wheat	Bolivia	Wheat (pealed)	La Paz	WHE BOL	Boliviano/kg	Wholesale	2003–01	2014–03	135	South America	GIEWS
39	Wheat	Brazil	Bread (French)	São Paulo	BREAD BRA	Real/kg	Retail	2000–02	2014–03	170	South America	GIEWS
40	Wheat	Brazil	Wheat (flour)	São Paulo	WHE BRA	Real/kg	Retail	2000–01	2014–03	171	South America	GIEWS
41	Wheat	Peru	Wheat (flour)	Lima	WHE PER	Nuevo sol/kg	Retail	2000–01	2013–09	165	South America	GIEWS

Table 13.4 International price series' sources and information

International commodity	Description	Country	Market	Units	Source
Maize	No. 2 yellow	United States	U.S. Gulf	US$/tonne	FAOSTAT (primary source: USDA)
Rice	A1 super, white broken	Thailand	Bangkok	US$/tonne	FAOSTAT (primary source: Jackson Son & Co. (London) Ltd.)
Sorghum	No. 2 yellow	United States	U.S. Gulf	US$/tonne	FAOSTAT (primary source: USDA)
Wheat	No. 2 hard red winter	United States	U.S. Gulf	US$/tonne	FAOSTAT (primary source: International Grains Council)

Table 13.5 Ratio of imports minus exports over domestic production, average 2007–2013

	Maize (%)	Rice (%)	Sorghum (%)	Wheat (%)
Benin	0	85	0	95
Chad	8	2	4	91
Ethiopia	1	49	3	32
Kenya	9	86	10	70
Malawi	0	3	8	108
Mali	1	16	0	103
Mozambique	9	77	1	95
Nigeria	0	37	0	98
Senegal	30	82	1	100
Tanzania	0	9	0	100
Uganda	−2	29	7	94
Zambia	−7	46	35	10
India	−13	−5	−1	−2
Nepal	3	5	109	1
Philippines	4	12	97	104
Thailand	−6	−70	−3	105
Bolivia	1	3	−1	72
Brazil	−18	3	−1	56
Colombia	64	6	52	98
Ecuador	33	−5	44	100
El Salvador	38	72	1	100
Guatemala	32	71	0	97
Honduras	37	83	1	97
Mexico	25	76	32	44
Nicaragua	15	35	−1	100
Peru	50	5	99	88
Mean abs. value	16	36	22	72

Note: Data obtained from FAOSTAT online (accessed on May, 2015)

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Part IV

National and Regional Responses to Food Price Volatility

India's Food Security Policies in the Wake of Global Food Price Volatility

14

Shweta Saini and Ashok Gulati

Abbreviations

APMC	Agricultural Produce Market Committee
BE	Budget estimates
C&F	Cost and freight
CACP	Commission for Agricultural Costs and Prices
CAGR/CARG	Compound annual growth rate/compound annual rate of growth
CAP	Cover and plinth
CCI	Cotton Corporation of India
CIF	Cost insurance and freight
CoP	Cost of production
CSO	Central Statistics Office
CV	Coefficient of variation
DAC	Department of Agriculture and Cooperation
DARE	Department of Agricultural Research and Education
DES	Directorate of Economics and Statistics
DFPD	Department of Food and Public Distribution
DGCIS	Directorate General of Commercial Intelligence and Statistics
DGFT	Directorate General of Foreign Trade
ECA	Essential Commodities Act, 1955

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F&V	Fruits and vegetables
FAO	Food and Agriculture Organization
FAQ	Fair average quality
FCI	Food Corporation of India
FFPI	FAO Food Price Index
FOB	Free on board
FY	Financial year
GCF	Gross capital formation
GDP	Gross domestic product
KMS	Kharif marketing season
MEP	Minimum export price
MSP	Minimum support price
MSR	Marketed surplus ratio
MMT	Million metric tonnes
NFSM	National food security mission
NWRs	Negotiable warehouse receipts
OGL	Open general license
OMSS	Open market sale scheme
OWSs	Other welfare schemes
PDS	Public distribution system
PMEAC	Prime Minister's Economic Advisory Council
PSS	Price support scheme
Qtl	Quintal
SEZs	Special Economic Zones
STC	State Trading Corporation
TE	Triennium ending
TFP	Total factor productivity
TRQ	Tariff rate quota
USDA	United States Department of Agriculture
WDRA	Warehousing Development and Regulatory Authority
WTO	World Trade Organization

14.1 Backdrop

In a country which has a population of 1.25 billion and which still has the largest number of poor and malnourished people in the world, ensuring food security for the masses is one of the prime concerns of the government policy.

It may be worth noting that an average Indian household still spends about 45 % of its total expenditure on food (NSSO 2013). The decade of the 2000s saw the overall GDP grow by an average annual growth rate of more than 7 %. With population growing by less than 1.5 % per annum, per capita incomes consequently rose by more than 5.5 % per annum, thus exerting pressure on food demand, and the pressure is only going to amplify in the foreseeable times. If India can raise its domestic food production at a pace faster than its domestic demand, it can at least have food available to feed its population from domestic sources. Otherwise, India would have to increasingly rely on food imports.

India is already importing more than half of its edible oil consumption and about 15–20 % of pulse consumption from global markets. Any abrupt increase in the global prices of these commodities will therefore directly affect their domestic prices and consumption and thereby elements of food security. Domestic prices of important food commodities are also affected when the commodities are exported. India, for example, has been the largest exporter of rice from financial year (FY) 2011–2012 to 2014–2015, and its domestic prices are affected by what is happening in the global rice market.

Against this backdrop, this paper looks at the issue of food security in India in the wake of recent global food price volatility, especially the price spikes of 2007–2008 and the price surge in early 2011, when global food price index exceeded the previous peak from 2008. How did India react to global food price spikes of 2007–2008? Could it protect its poor? What were the likely implications of India's policy choices on global prices? What lessons can we learn from that experience in terms of providing reasonable stability in food prices, locally and globally, so that food security can be ensured for the masses? These are some of the questions that will be addressed in this paper.

The paper is organized as follows: In Sect. 14.2, we study the global rice and wheat markets and how India is placed in it. Section 14.3 elaborates on the policy landscape of rice and wheat, the two primary staples in India. The section is subdivided into two parts where both the trade and the domestic policies are given. After elaborating on India's policy response to the global food crisis of 2007–2008, we use the interconnectedness of the global and the domestic food prices to illustrate India's competitiveness in the global markets. The subsection about domestic grain policies highlights the domestic grain dynamics and the major policy changes in the domain. The last section encapsulates the things that could be learned from the analysis in this paper and gives suggestions for the future with regard to the Indian grain trade market.

14.2 Global Rice and Wheat Markets and India

Only 9 % of the total rice production was globally traded between 2013 and 2014 (see Figs. 14.1 and 14.2). This indicates a rather thin global rice market compared to wheat and corn, where 23 % and 13 % of the production was traded respectively. The rice supply in global markets is also highly concentrated: in 2013–2014, 80.4 % of the global rice supply came from five countries, namely, Thailand, Vietnam, the United States, Pakistan, and India.

Globally, the production of all three staples is going up. The markets are expanding and so are the demands. Between 2011–2012 and 2013–2014, global exports of rice, wheat, and corn increased by 9 %, 5.4 %, and 24.9 %, respectively. This increase may also be due to the markets liberalizing after the 2007–2008 global food crisis, in which the major food exporters like India and Thailand restricted

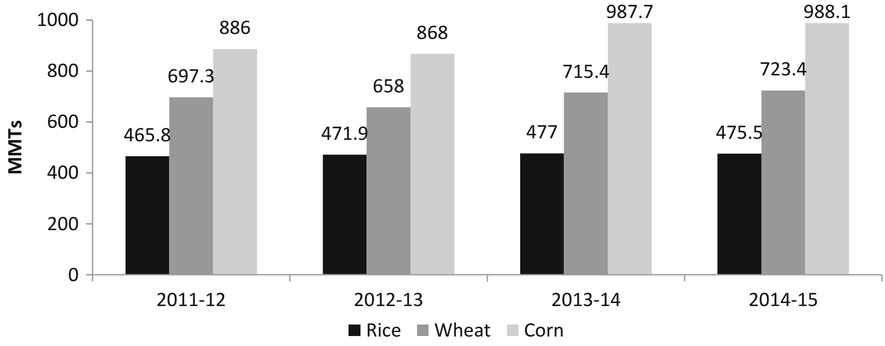

Fig. 14.1 Global production trend of the three staples—rice, wheat, and corn since FY 2011–2012. *Source*: USDA

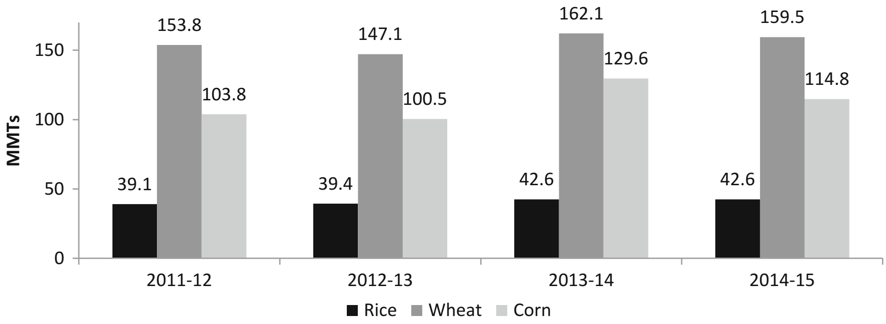

Fig. 14.2 Trends in world exports (MMT). *Source*: USDA

their food supplies and thus triggering an unprecedented global food price spike in history.

As a net food exporter, India was bound to benefit from such global trend. We next examine the performance of the Indian agriculture exports.

India exported more than US $42.6 billion worth of agricultural exports in 2013–2014, while it imported agricultural commodities worth US $15.9 billion; India's agriculture trade account had therefore a net surplus (Fig. 14.3). According to the WTO, India's share in the total global export of agricultural products increased from 0.8 % in 1990 to 2.6 % in 2012. India emerged as the world's largest exporter of rice.

India has a gross cropped area between 190 and 200 million ha, depending upon the amount of rainfall during the monsoons. In 2013–2014, India produced about 106 million metric tonnes (MMTs) of rice from roughly 43 million ha (m ha) of rice planting area and 96 MMT of wheat from 29 m ha of wheat planting area. India's share of rice and wheat production globally is roughly 22 % and 13 %, respectively (FAO, stat).

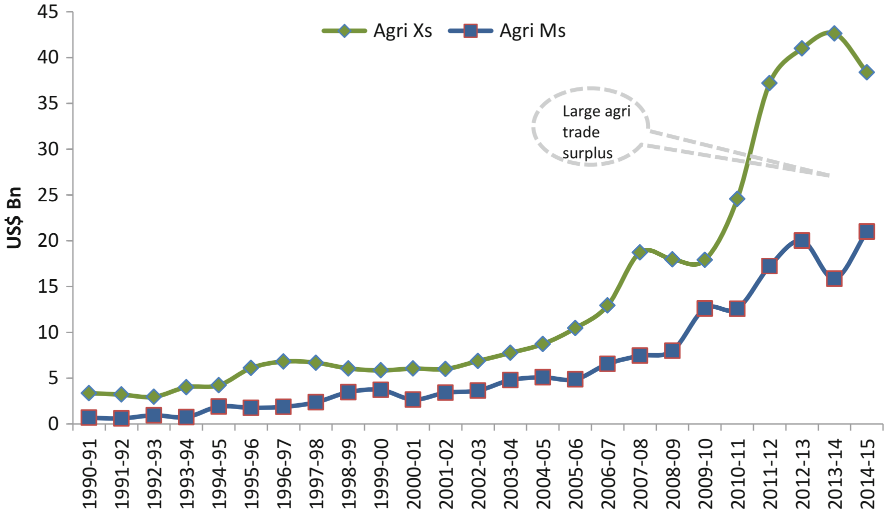

Fig. 14.3 India's exports and imports of agricultural commodities. *Source*: Agricultural Statistics at a glance (various issues) and the Department of Commerce. *Note*: Figures for 2014–2015 are estimates

Rice and wheat are staple crops of the country and help in meeting a significant proportion of the daily caloric needs of the people. Close to 22 % of the population still live below the poverty line, as estimated by the Planning Commission based on Tendulkar poverty line (Planning Commission 2014). By international definition of US $1.9/day/capita, almost 21.3 % of the people in India lived below poverty line in 2011 (World Bank 2014). The largest mass of poor and malnourished people in the world live here (World Bank 2013). Roughly about one-sixth of the world's people and one-third of the world's poor are Indians. One in every three malnourished children in the world is from India (HUNGaMA 2011). Thus, anything affecting food prices, and rice and wheat in particular, is important for Indians, especially for those hovering around the poverty line. It is no wonder that the government monitors food prices very closely.

The Indian government supports both the cereal producers as well as its consumers. By providing price support mechanisms for paddy and wheat using minimum support price (MSP) and by reducing their effective costs of production (input subsidies mainly for fertilizers, electricity, and irrigation), the government supports and incentivizes cereal (rice and wheat) production. The government also supports the consumers by ensuring that prices of wheat and rice remain low and stable through its public distribution system (PDS). It provides identified beneficiaries with subsidized (and sometimes free) food under its various food-based welfare schemes. The government also utilizes the Open Market Sale Scheme Domestic (OMSS-D) to smoothen any inter-/intra-year fluctuations by actively regulating the market grain supply and thereby ensuring price stability.

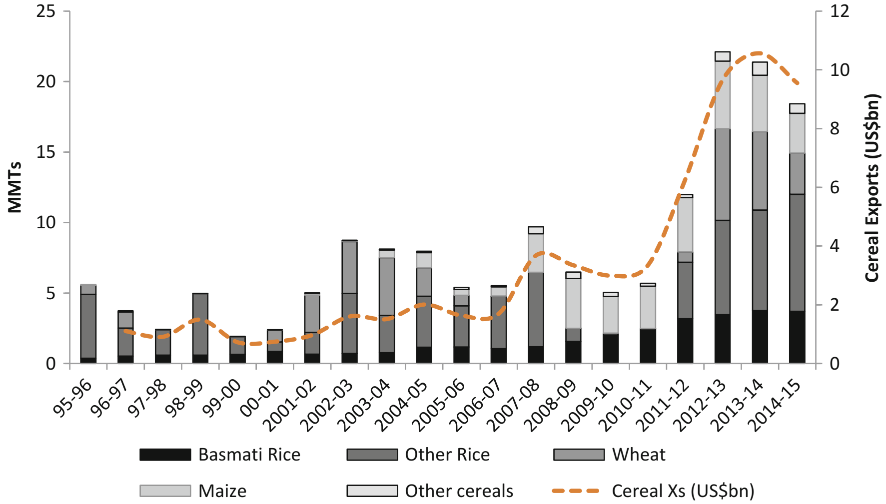

Fig. 14.4 Trends in cereal exports quantity and values. *Source*: DGCI&S

India is a net exporter of agricultural commodities, whereas it is a net importer in the overall trade (CACP, Kharif Report 2013–2014). Both in terms of quality and cost, Indian rice has a comparative advantage in the global market. Nevertheless, India's agricultural trade policies are somewhat conservative and subject to frequent bans/restrictions. Nevertheless, in the last 3 years since FY 2012–2013, India exported a total of approximately 62 MMTs of cereals, and around 53 % (i.e., 33 MMTs) of this consisted of rice exports. The country earned close to US $30 billion from these cereal exports (Fig. 14.4).

What could explain such a massive increase in cereal exports? Open trade policy regime (more recently for common rice), overflowing government granaries owing to production gains, and global price (cost) competitiveness could explain the phenomenon. We will look at the factors individually.

14.3 Rice and Wheat Policy: Trade and Domestic

Historically, India has been a country of droughts and famines. It is an agrarian economy with large dependence on rains for irrigating its crops. 54 % of its gross cropped area and 40 % of the rice planting area are still rainfed. With close to 1.25 billion people to feed, including the highest number of the global poor, opening the trade of its staple crops, like rice, is still a decision to be made with extreme caution. A significant proportion of the Indian population is still rice eating. Because of growing concerns regarding the high level of malnutrition and food security issues in the country, the government has always been cautious in liberalizing the rice and wheat trade. Therefore, the government has always first met the consumption needs and maintained *enough* buffer stocking before letting the "residual" determine the nature of trade policy.

India has come a long way since the mid-1960s, when it was living from "ship to mouth" through PL 480 imports from the USA to today when it has become the largest rice exporter globally and a net agricultural exporter. Still India's rice and wheat trade policy is highly cautious and sometimes even unpredictable as we will see in the section below.

14.3.1 Grain Policy: Trade

India exports mainly two types of rice: basmati and common rice (raw or par boiled). While the former is a finer quality rice meant for niche markets in the Gulf, Europe, and the USA, the latter is comparable to the type of rice supplied by Thailand, Vietnam, and others. India's trade policies for both types of rice are different from each other. While there has been no restriction on the export of basmati rice, trade restrictions, such as minimum export price (MEP), export quotas, and even complete bans, have been imposed on the common rice export. Until 1991, the common rice export was completely restricted; with quotas and MEP in place. Overvalued exchange rate and export restrictions taxed the Indian farm sector before 1991. The devaluation of the Indian rupee in 1991 contributed immensely to making the expensive basmati rice more price competitive in the global market, and thus its export surged.

Common rice exports were banned until October 1994 despite being highly price competitive globally. The government finally decided to open common rice exports in FY 1995–1996. As a result, the net exports of the common rice surged from 0.9 MMTs in 1994–1995 to 4.9 MMTs in 1995–1996 (Fig. 14.5), making India the second largest exporter of rice in the world. Encouraged by the phenomenal growth in rice exports, India opened its wheat exports in May 1995. However, increasing exports squeezed domestic market supplies thus building pressures on the domestic prices. Within a year, the rising prices of staple crops like rice and wheat drove the policymakers to reverse the trade decision and completely ban the rice and wheat exports in 1996–1997 (Hoda and Gulati 2008).

Increased production incentivized by rising minimum support prices (MSPs), falling global grain prices owing to many factors like the 1997 East Asian crisis, falling PDS grain offtakes due to the "targeted" focus of the system in 1997, and export bans were among the many factors that resulted in the overaccumulation of grain stocks in the coming years in the country. This forced the government to remove the bans on rice and wheat exports in 2000.

But it was not before 2005–2006 when Indian wheat regained its competitiveness because global prices had improved from their trough in around 2001–2002 (Hoda and Gulati 2008). Wheat exports were expected to rise; however, contrary to expectations, the government had to import wheat in 2006 to refill its plummeting wheat stocks in the Food Corporation of India (FCI) granaries. The FY 2006–2007 was an interesting year for the food sector of the country. Owing to farmers (mainly wheat) getting a better price for their produce from the private market, the FCI was unable to meet its annual procurement targets, and thus its granaries fell below the

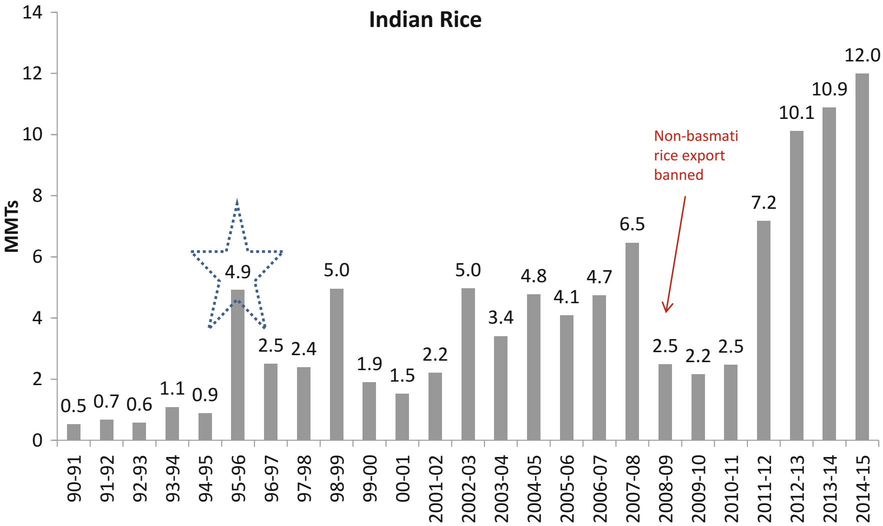

Fig. 14.5 India's exports of rice from 1990–1991 to 2014–2015. *Source*: Ministry of Commerce, GoI

desired stock norm level. Consequently, the government imported wheat amounting to 5.6 MMTs in that year. This is when India decided first to ban wheat exports in February 2007 (Sharma 2011).

14.3.2 The 2007–2008 Global Price Hikes and India's Response

From the point of view of Indian policymakers, India's withdrawal from the international rice and wheat markets in 2007 was a well-calibrated response. However, it appeared like a knee-jerk reaction to outsiders. Some of the alarming concerns driving the Indian policymakers' response to the global food crisis included food insecurity at the household level, impacting millions of vulnerable people, continued volatility in agricultural production caused by weather changes, fear of political unrest in times of high and sticky food inflation, and the need to feed a large PDS. In this section, we discuss India's policy response to the crisis, mainly for the rice and wheat markets.

Export Restrictions on Rice To stop the global price hikes from being transmitted to the domestic market and to strengthen the government's grain stocks, the country started imposing export restrictions on common rice. In October 2007, they imposed an MEP on common rice of US $425/ton; but by December 2007, this MEP was increased to $500/ton. Nevertheless, the exports of rice continued unabated. In March 2008, the government finally imposed a complete ban on common rice exports. The exports of rice dropped from 6.5 MMT in 2007–2008 to only 2.5

MMT in 2008–2009 (and these were mainly basmati rice exports). This decision to ban exports of common rice in the wake of surging global prices came under severe criticism from several rice-importing countries. In response, India opened a window to export common rice at "concessional" prices compared to prevailing global prices of rice to some neighboring countries, like Bangladesh and Bhutan, and also to some low-income African countries. However, not much rice was actually exported. The government eventually lifted the export ban on common rice in September 2011. Since then, India has exported record quantities of rice, especially in 2014–2015, when 12 MMT of rice was exported (Fig. 14.5).

The share of common rice in the total rice export earnings increased from 4 % in 2010–2011 to 42.6 % in 2 years. During the period in which the export ban on common rice was in place, India's basmati rice exports constituted 2.5 % (2008–2009) and 2.4 % (2009–2010) of the total rice production in India. Today, after the ban has been removed, the country is exporting close to 10 % of its annual production (Fig. 14.6).

The 1990–1991 Indian rice export basket comprised mainly basmati rice. With the opening of the common rice trade, the share of basmati rice exports in the total rice export decreased over time to less than 35 % in 2012–2013.

India has emerged as the world's largest rice exporter since 2011, closely competing with Thailand. Despite the export competiveness, the country imposes, contrary to expectations, high import duty on rice: –70 % on semi-milled or wholly milled rice and 80 % on paddy, brown rice, and broken rice. Such a high import duty is ineffective when the country is quite export competitive in rice and has been exporting more than 10 MMT of rice annually since 2012–2013.

Export Restrictions on Wheat India is the world's second largest wheat producer after China, producing about 12 % of the global wheat. It has, however, not been

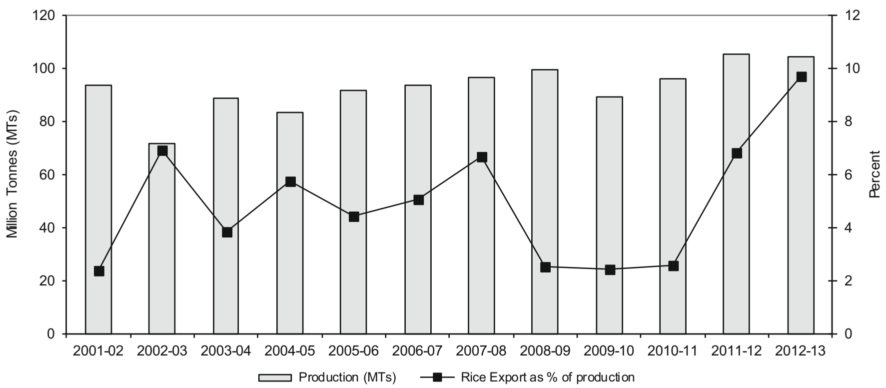

Fig. 14.6 India's exports as a percentage of rice production. *Source*: Agricultural Statistics at a Glance, Various Issues

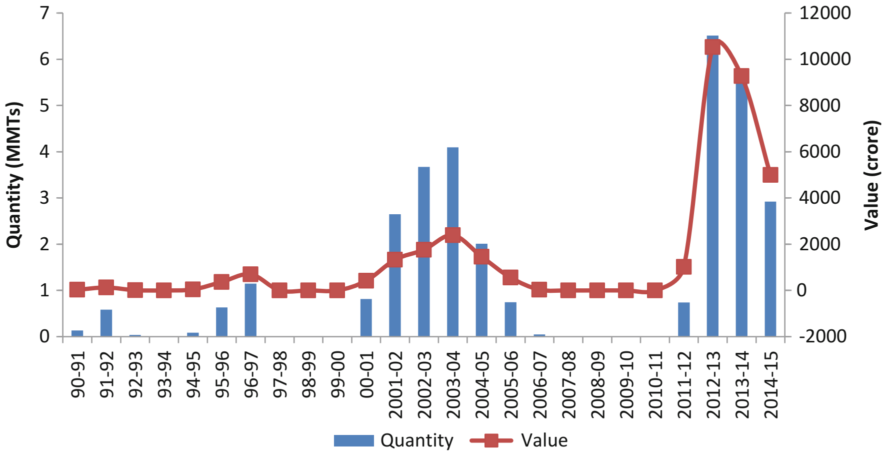

Fig. 14.7 India's exports of wheat from 1990–1991 to 2013–2014. *Source*: Ministry of Commerce, GoI

among the largest wheat exporters (accounting for about 3 % of total world exports) because the country consumes more than 90 % of its production, and it even had to import wheat in some of years (India was the fourth largest importer of wheat in 2006–2007). India imposed a complete ban on wheat exports in February 2007 (Fig. 14.7) in reaction to rising prices and supply fears, both domestically and globally.

Since India has a very small share in the global wheat market, its restrictions on wheat exports did not have any significant effect on international prices. But the imposition of the ban pulled domestic prices of wheat down from US $283/ton in February to US $225/ton by April (Fig. 14.8).

The export ban also helped the domestic market to remain stable and insulated from the steep hike in international prices in the first half of 2008; in April 2008, when the wheat price in the global market touched US $380/MT, the domestic wheat price in India was less than US $280/MT (Fig. 14.8).

14.3.3 Impact of Global Prices on Domestic Prices

In 2006–2007, as mentioned before, India imported about 6 MMTs of wheat after a long time. When the global prices of rice and wheat increased drastically in 2007–2008, banning the rice and wheat exports seemed to be a logical response in the country's efforts to insulate its poor from global prices spikes getting transmitted to the domestic markets. As a result, India was actually able to contain its domestic cereal inflation to about 6 % in 2007–2008, which helped restrict the overall food inflation at the time and thus *protect* India's poor from the price volatility. Similarly, India managed to avoid the more severe price spikes of 2010–2011, when

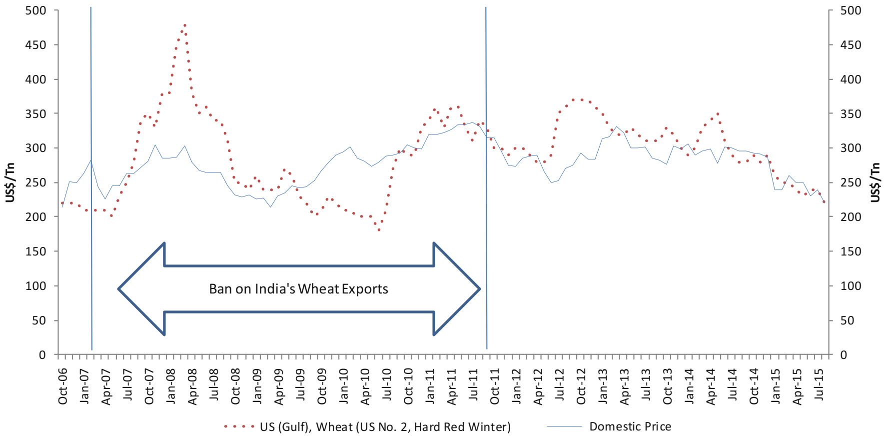

Fig. 14.8 Trend in India's domestic and international wheat prices. *Source*: International price (USA, Gulf, No. 2 Hard Red Winter): GIEWS Food price data and analysis tool. Domestic price (avg monthly data of HYV wheat—wholesale prices in Lucknow, UP and Amritsar, Punjab): DoE

in February 2011 the global food price index even exceeded the peak reached in 2008. However, what happened in the long run is an interesting departure from expectations.

A closer examination of the food price indices of the country and of the world (Wholesale Price Index (WPI) food and FAO food, respectively) reveals that the *protection* was only effective in the short run as the two price indices appear to have converged over the longer run, thus rejecting the *transmission insulation* theory.

Since the period between 2004 and 2013, the correlation between FAO food and Indian WPI food has been 0.78, indicating strong comovement between the indices. Figure 14.9 shows that India's restrictive stance on trade policy has in fact helped the country to escape the food price spikes of the food crisis of 2007–2008 and 2010–2011. However, in the longer run, the domestic price line appears to be converging with its global counterpart.

Clearly, India managed to avoid price spikes in its domestic market. Interestingly, the country also managed to avoid the troughs in global markets. In other words, it did not allow falling global prices to immediately get transmitted to its domestic prices. For the years 2000–2005 and more recently since 2013, when the global food prices fell, Indian food prices remained somewhat higher. It is possible that the domestic prices will converge over a longer period. The upshot is that Indian trade policy has tried to smoothen out the effects of global price spikes and troughs to prevent volatility transmission to the domestic prices, but in the medium to long term, Indian food prices have broadly followed the global food prices.

The FAO Food Price Index is a measure of the monthly change in international prices of a basket of food commodities. It consists of the average of five commodity group price indices, weighted with the average export shares of each of the groups for 2002–2004. The commodity groups are sugar, dairy, meat, edible oils, and

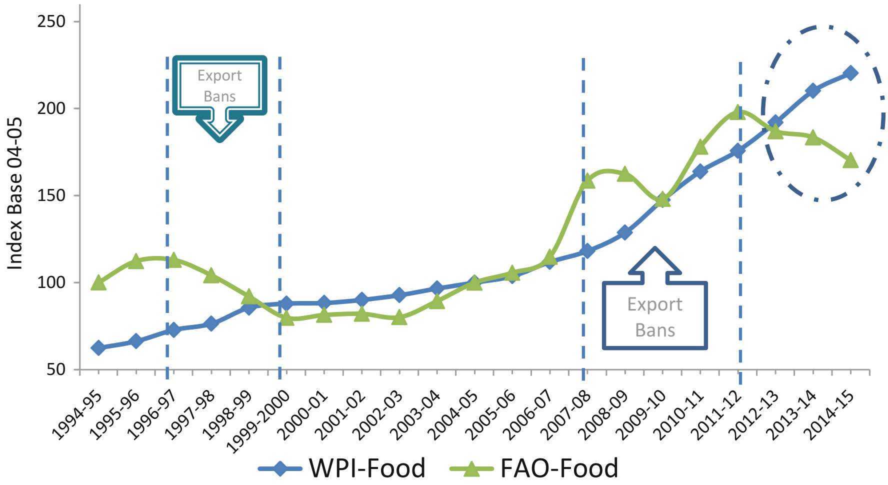

Fig. 14.9 Global price transmission to Indian prices. *Source*: FAO and CSO

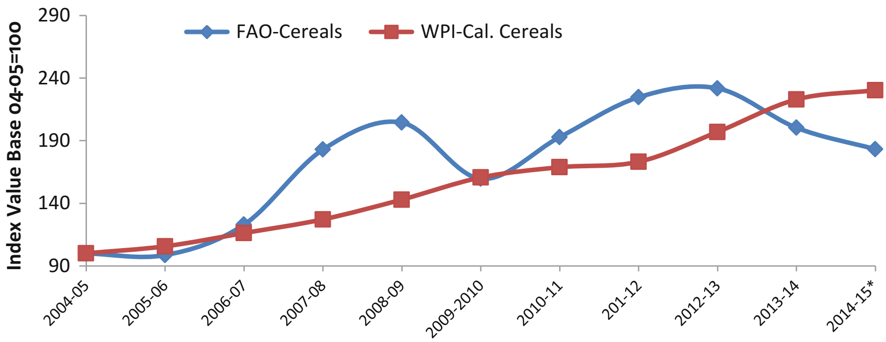

Fig. 14.10 Cereal price comovements. *Source*: FAO and CSO

cereals. Upon bringing the base of all these groups from 2002–2004 to 2004–2005, we analyzed the numbers together with subindices of India's WPI (Figs. 14.10 and 14.11).

Similarly, the domestic prices appear to be catching up with the international long-run trends. The role of restrictive trade policy is evident here.

Several researchers have proven the non-transmission or limited transmission of global volatility to domestic prices (see, e.g., Pinstrup-Andersen 2015; Kalkuhl 2014). Baltzer (2015) wrote:

> Non-fiscal interventions, such as non-tariff trade barriers, parastatal grain traders (China, India, Vietnam, Ethiopia, Malawi, Zambia and Egypt) and price controls (notably Senegal), disrupt the price transmission mechanisms in ways harder to generalize.

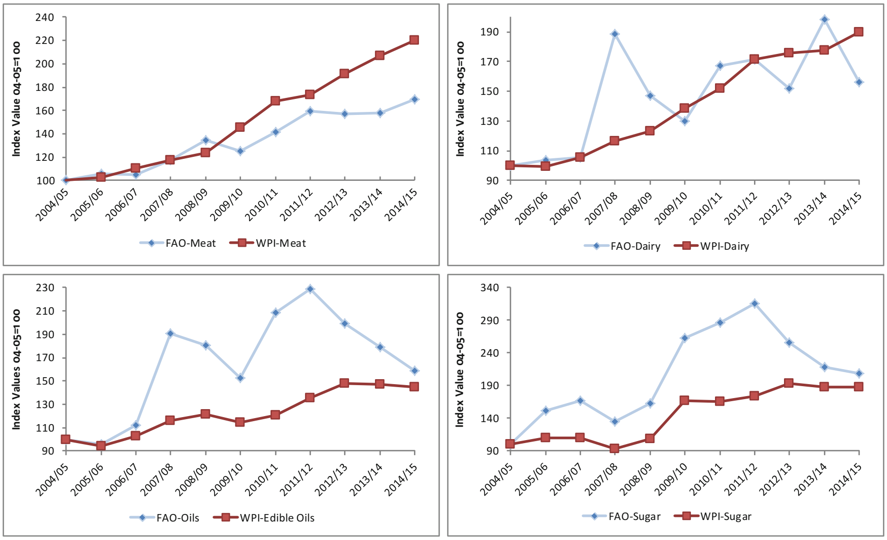

Fig. 14.11 Trends in WPI and FAO price subindices. *Source*: FAO and CSO

India's Economic Survey 2014–2015 attributed the divergence between the global and domestic prices to restrictive domestic food and trade policy. However, the curves shown above highlight the limitations of these opinions—even though these opinions may be true in the short run, but over a longer run, the opinions appear to fall flat with the commoving global and domestic food prices, as evidenced by the converging global and domestic food price curves. More sophisticated, statistical, and econometric tools are needed for a more robust analysis of the phenomenon.

14.3.4 Indian Rice and Wheat Competitiveness

From 2001–2002 to 2007–2008 (Q1), India's domestic wholesale rice prices were generally higher than international prices, but from 2007–2008 (Q2) to 2012–2013 (Q3), they have been continuously lower than the international prices (Fig. 14.12). It may be observed that MSP of paddy converted to rice has been continuously lower than domestic wholesale prices of rice during the same period.

Indian wheat prices, on the other hand, have closely followed the international wheat prices of the US hard red winter (HRW) and the soft red winter (SRW) (*fob*). The 2007 export ban on wheat protected India's domestic wheat prices from the enormous international food price volatility (Fig. 14.13). While the export ban protected consumers from these fluctuations, it also harmed farmer's interests by limiting their exposure to lower domestic prices. Indian wheat prices generally hovered between the *fob* and *cif* wheat prices. With global wheat prices rising in 2007–2009, Indian wheat became highly price competitive. It has regained its price

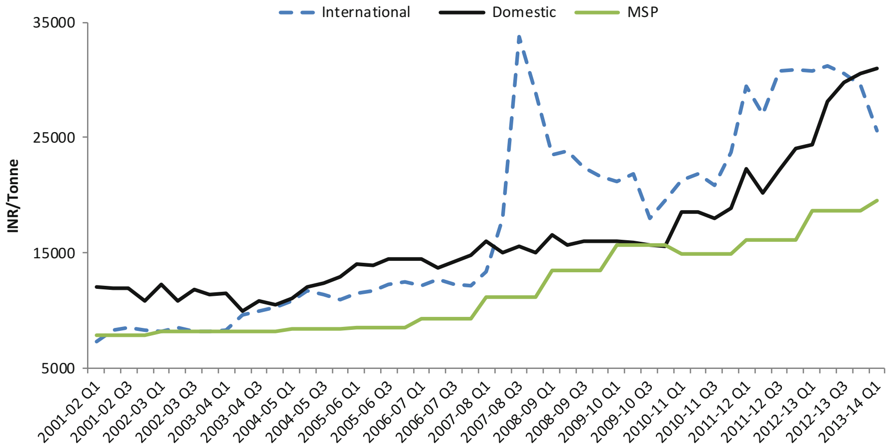

Fig. 14.12 Domestic wholesale prices versus international rice prices. *Source*: World Bank for International prices and DES for Domestic wholesale prices. *Note*: Rice (Thailand), 25 % broken, WR, milled indicative survey price, Government standard, f.o.b. Bangkok. Quarters refer to marketing year (October–September)

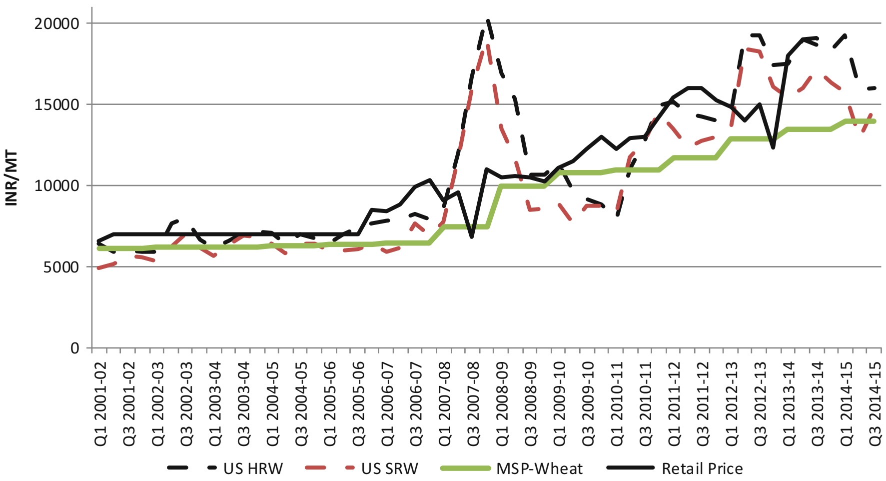

Fig. 14.13 Domestic wholesale prices versus international wheat prices. *Source*: World Bank for International Price and DES for domestic Prices & MSP from CACP Report. *Note*: (1) Wheat (US) No. 1 HRW, export price delivered at US Gulf port for prompt or 30 days Shipment. (2) Wheat (US) No. 2, SRW, export price delivered at US Gulf port for prompt or 30 days Shipment. (3) Domestic prices of wheat are the farm harvest prices in Punjab

competitiveness in 2011, when it opened its wheat exports in September. More than 12 MMTs of wheat were exported in 2012–2013 and 2013–2014.

India's MSP has been fairly lower than most of the other rice and wheat-producing economies (Fig. 14.14). Studies (Gulati et al. 2010) using the nominal

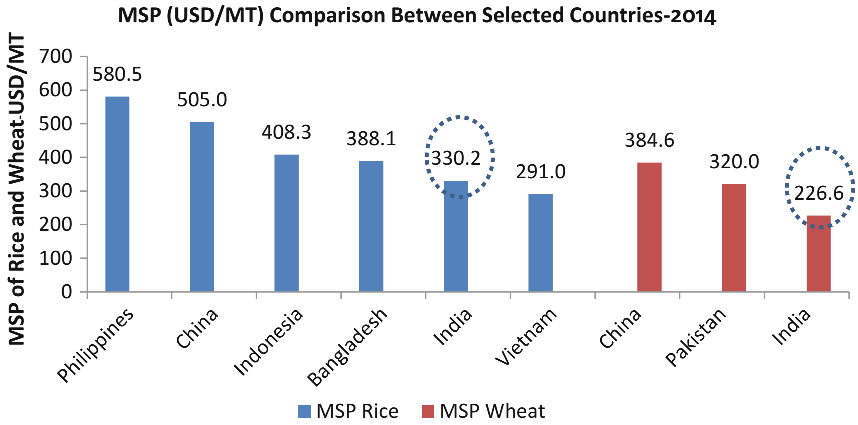

Fig. 14.14 MSP of selected rice- and wheat-exporting countries. *Source*: Links from the respective countries

protection coefficient (NPC) have shown that Indian rice is export competitive, with its domestic prices lower than the global rice prices in most years.

In the next section, we unearth the trends in the domestic production and understand the policy environment governing the rice and wheat farmers and the consumer.

14.3.5 Grain Policy: Domestic

The government intervention in domestic markets of wheat and rice, ranges from providing farmers with price support under MSP, procuring grains from *mandis* (grain wholesale markets) or through millers under compulsory levies on rice, to stocking and distributing the procured grains through the PDS. The reason that government intervention has been heavy in wheat and rice markets is rooted in the country's history of famine and shortage of basic staples. Despite the costs of market intervention, the government is unwilling to withdraw the intervention for fear of risking potential high price volatility, which affects the food security of the vulnerable sections of society. Lately, the new government set up a high-powered committee to look into the functioning of the FCI in this context. The committee made some wide-ranging recommendations, which included abolishing levy on rice, outsourcing grain-stocking operations to private sector, introducing cash transfers in the PDS, and reducing the buffer stocks held by the government. The government has introduced pilot schemes for cash transfers, but many other recommendations are still under consideration.

During the 2007–2008 global price crisis, the Government of India took two major steps: (1) it raised the MSP substantially and (2) it started the NFSM in 2007 to produce additional 20 MMT of grains in the subsequent 5 years.

The MSPs were raised aggressively in the years 2007–2008 and 2008–2009. MSP increases were also necessitated by the country's need to become self-sufficient in cereals' production, which suffered a setback in 2006–2007, when it had to import wheat because FCI grain stocks fell below the norm. The MSP increases formed a pivotal step in the direction of attaining maximum self-sufficiency domestically.

14.3.6 National Food Security Mission 2007–2008

As a response to this forced wheat import in 2006–2007, India launched the NFSM in 2007–2008. The objective of this mission was to increase the country's food grain production by at least 20 MMT in the 5 years after that—rice production by 10 MMT, wheat by 8 MMT, and pulses by 2 MMT. A two-pronged strategy was adopted to boost grain production: (1) introducing better technology (seeds) to the districts/states which were identified as priority, and (2) MSP for wheat and rice were raised by almost 40 % over the next 2 years, thereby encouraging farmers to grow more of food grains. Farmers responded positively to the combination of technology and incentives, and grain production increased by 42 MMT between 2006–2007 and 2011–2012, even though the target was just 20 MMT. This increase in production coincided with a period of export bans on rice and wheat. The unexpected production boom resulted in massive accumulation of grain stocks. The stocks with FCI, for example, reached unprecedented levels of 80.5 MMT on 1 July 2012 (Fig. 14.15).

Increasing MSPs guaranteed the further strengthening of the grain production. Eventually the policymakers opened the exports of wheat and common rice in 2011. Since then India has become the largest rice exporter in the world, regularly

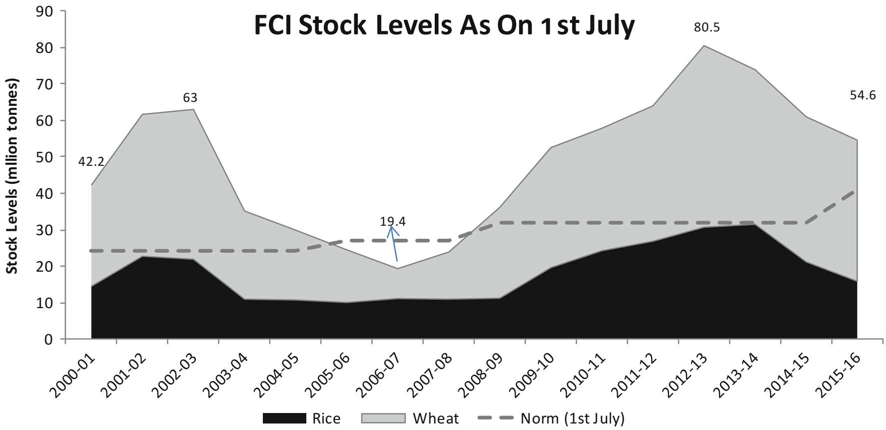

Fig. 14.15 FCI grain (rice and wheat mainly) as of 1st July every FY. *Source*: FCI

exporting more than 10 MMT of rice each year until 2014–2015, when rice exports reached 12 MMT.

Rising grain stocks also encouraged the government to introduce a bill in the parliament in 2011 and then enact the National Food Security Act (NFSA) in 2013.

14.3.7 National Food Security Act, 2013

By ensuring ample food stocks with a robust and expanding production base, the country appeared to have attained food security at the national level. However, as highlighted before, the situation at the microlevel was bleak, with widespread malnutrition and stunting among the population. Backed by the growing food grains stocks, the government enacted the NFSA in 2013.

The PDS is the tool through which the government of India improves food security at the microlevel. The FCI is the nodal agency which procures, stores, and distributes grains (mainly rice and wheat) to states, which in turn distribute it to the identified beneficiaries under the various food-based welfare schemes run by the central government of the country. Appendix (Fig. 14.16) summarizes the evolution of the PDS. The depth, scope, and coverage of the PDS expanded under the NFSA 2013. The Act aims to solve the problem of food and nutritional security of the Indian population. It combines and expands some existing *food-based* welfare schemes and a *conditional cash transfer* scheme. The Act is likely to be the biggest program of its kind so far and aims at reaching more than 800 million people (67 % of India's population), with an annual, legally enforceable distribution commitment of 61.4 MMT of grains sold at highly subsidized prices (with almost 90 % subsidy).

A legal commitment of such quantum of grains is likely to put greater pressure on the government's procurement machinery which would need the farmer to continue (and possibly increase) his production of the two crops. Price incentives are important drivers of farmer behavior (Gulati et al. 2013), and future MSP increases thus form an inevitable tool under NFSA. If the Act, in its present form, is to deliver on its set objective of alleviating poverty and malnutrition, commensurate price incentives have to be put in place. Supplying the committed 61.4 MMTs of grains necessitated the government to revisit its quarterly buffer-stocking norms. The government has already approved a newly revised, quarterly buffer stock norm (with higher norms for three quarters).

The Act is currently unfolding in the country and faces several challenges ranging from large leakages in the PDS and distortions in production basket to ballooning food subsidy bill (Saini and Gulati 2015). There are apprehensions about the capacity and the ability of the act to deliver on its set objectives. The problem is caused by the inefficiency of the existing PDS machinery, which forms the base of implementing the Act. The machinery is marred with inefficiencies and redundancies. (Saini and Kozicka 2014) There are talks of substituting the systems with a dynamic platform of direct cash/benefit transfer (DBT), whereby instead of physical grains an equivalent amount of cash will be transferred into the account of the beneficiary. Four Indian union territories (UTs)—Chandigarh, Puducherry, Daman and Diu, and Dadra and Nagar Haveli—have agreed to introduce the DBT scheme in September 2015. Out of 36 Indian states/UTs, 13 have started implementing the provisions under the Act.

Falling yields in the traditional rice-growing states and the lowering water tables is one of the big challenges faced by the country today. Feeding the growing grain needs of the country necessitates the urgency to create alternative supply stations in the country. Therefore, the resource-rich Eastern states of Bihar, UP, Jharkhand, and Assam need to evolve into becoming the future supplier of rice in particular. The Second Green Revolution is likely to begin in Eastern India this time.

14.3.8 Second Green Revolution

Eastern India, with 2–3 times more rainfall compared to the Northwest states, has underused its high-quality groundwater aquifers. Vast social capital resource gives Eastern India a relative advantage in terms of sustainable rice production. The Eastern states account for 56 % of the total rice planting area in India but produce only 48 % of the total rice production. The productivity levels in the Eastern states, except Uttar Pradesh and West Bengal, are among the lowest in India. Out of the 26.6 million ha rice planting area in Eastern India (UP, Bihar, Jharkhand, West Bengal, Assam, Orissa, and Chhattisgarh), approximately 14.3 million ha is rainfed and thus prone to different abiotic stresses like flooding, drought, and soil salinity/sodicity. These abiotic stresses are the single most important yield-limiting factor for rice production in Eastern India. The rice productivity of Eastern India, except UP and West Bengal, is not only low (1.7–2.5 tns/ha) but also fragile.

The central government has been allocating money under *Rashtriya Krishi Vikas Yojana* from 2010 to 2011 for extending the Green Revolution to the eastern regions of the country comprising of Bihar, Jharkhand, Eastern UP, Chhattisgarh, Orissa, and West Bengal. The objective is to increase the productivity of crops, mainly rice, wheat, maize, pulses, by intensive cultivation through the promotion of recommended agriculture technologies, package of practices and high-yielding stress-tolerant hybrid rice varieties.

14.4 Lessons Learned and the Way Forward

Overall, the experience of 2007–2008 did play a significant role in India's agriculture sector. Country's intrinsic aversion to volatile food prices coupled with a disinclination to importing food to feed its population led the policymakers to act the way they did during the food crisis of 2007–2008.

However, the country learned three key lessons from the food crisis. First, price incentives are important for Indian farmers, whose encouraging response to raising the MSP under the NFSM brought the country to new heights in the global trade. Second, India is not insulated from global events, and putting export bans offers only a temporary respite to the domestic food prices, which in the longer run converged with their global counterpart. Third, agriculture could be a large source of foreign exchange (net exports) for the country. As evident in the trade flows and demonstrated using a Balassa Index,[1] India has a higher relative trade advantage in agriculture than manufacturing. Yet the country has not been able to tap the full potential of the sector because of its restrictive agricultural trade policies.

Therefore, to harness the full potential of the agricultural sector, there is a need to ensure that agricultural trade policies are consistent, stable, predictable, and conceived for the long term. Concerted efforts, however, should be made for aligning domestic and international prices while guarding against sharp price spikes and troughs through constant monitoring and applying calibrated tariffs rather than outright bans.

Food security has been and will continue to be one of the primary concerns of the country's agriculture and food sector. The NFSA 2013 is seen as a vital step in alleviating the issue of widespread poverty and malnutrition. Apprehensions about the inability of the Act to deliver on the set objectives are widespread. There are even talks about substituting the entire system of subsidized physical grain distribution (price policy) with direct cash transfers (income policy), but a complete substitution is still unlikely in the short run. Given the slow pace of policy changes, it may take 3–5 years to transition from physical transfers to cash transfers once the government decides to implement the changes. Therefore, the country would remain dependent on and sensitive to any factors affecting food crops like rice and wheat, particularly with regard to their production and price levels.

However, the country's policymakers should dilute the intrinsic bias of the policy and the policy incentives toward food grains (mainly rice and wheat), which have resulted in inefficient resource allocation and usage. The country needs to reorient its agriculture sector and policies by calibrating them with two things: the changing consumption patterns of the Indian population and the relative comparative advantage that the country's agricultural sector has globally. While the former would bridge the increasing gap between the "plough" and the "plate," the latter would help the country reap benefits from trade in terms of efficiency.

Apart from crops, the country's policymakers have an inherent bias toward certain regions. The Second Green Revolution, which is envisaged to be a game changer for the Eastern states, is a step in the right direction, with the focus shifting away from the traditional northern and southern agricultural states. This evolution should be accompanied by a reorientation of the roles of the many stakeholders, with the public sector playing a much smaller role in the food market in the future.

[1]Balassa Index for revealed comparative advantage: It is an index used in international economics for calculating the relative advantage or disadvantage of a certain country in a certain class of goods or services as evidenced by trade flows. It is based on the Ricardian comparative advantage concept. For year 2013–2014, value of the index for agriculture is 1.37 and that of manufacturing is 0.8, thus indicating India's relative advantage in agri trade than manufacturing.

India is an important economy in the global food space and is naturally interdependent with the world. By having a stable long-run trade policy, creating institutions and infrastructures to facilitate trade, and focusing on promoting resource allocation in line with its inherent competitive advantage, the country will not only tap the full potential of its agricultural sector but will also benefit the world immensely.

Acknowledgments We acknowledge financial support from the Center for Development Research, University of Bonn, within the research project "Volatility in Commodity Markets, Trade Policy and the Poor" financed by the German Ministry of Economic Cooperation and Development (BMZ). We also acknowledge the funding of Infosys Chair for Agriculture at ICRIER that facilitated work on this study.

Appendix

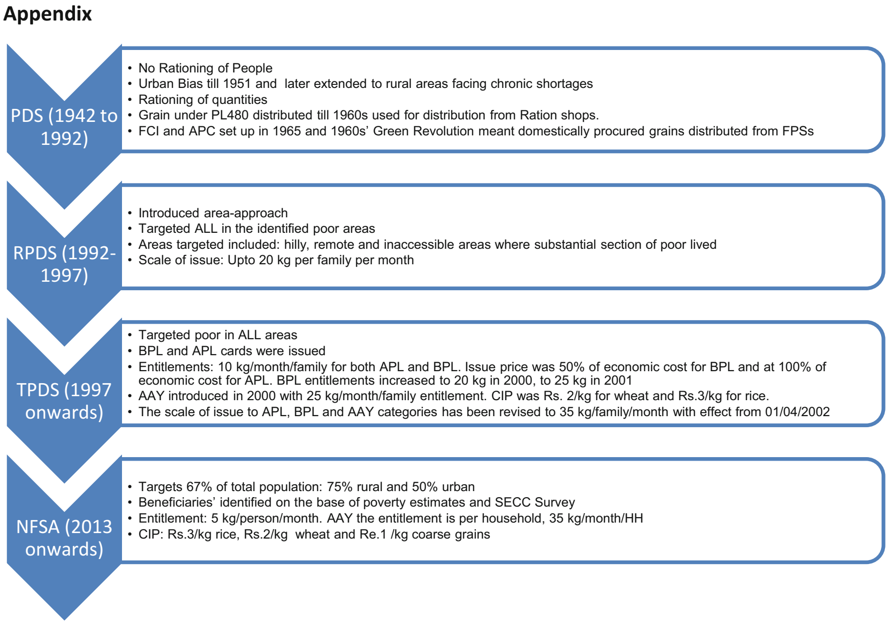

Fig. 14.16 Brief about the evolving system of PDS in India. *Source*: Saini and Kozicka (2014)

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15 The Costs and Benefits of Regional Cooperation on Grain Reserves: The Case of ECOWAS

Lukas Kornher and Matthias Kalkuhl

15.1 Introduction

Despite widespread skepticism towards public intervention in food markets, many governments in sub-Saharan Africa and elsewhere in the world responded to the 2007/2008 global food crisis by implementing or enhancing public stockholding. These interventions are criticized due to their distortive effects on private trading and their high operating costs (Newbery and Stiglitz 1981; Miranda and Helmberger 1988; Tschirley and Jayne 2010). On the other hand, the crisis also showed that international trade is incapable of dampening supply and price shocks when exporters insulate their domestic markets from the international price development (Martin and Anderson 2012; Porteous 2012).

Child mortality and general food insecurity in West Africa are among the highest in the world (FAO et al. 2013; von Grebmer et al. 2013). The region is a major rice importer and is dependent on these imports to meet food consumption targets. International food aid has been an important factor in offsetting fluctuations in national production but has been decreasing rapidly since the middle of the last decade (FAOSTAT 2014). For these reasons, the Economic Community of West African States (ECOWAS) community decided to make plans for a regional emergency reserve.[1]

[1]For a detailed description of the current proposal, see ECOWAS Commission et al. (2012).

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Regional food reserves are viable and comparably cheap means, as an alternative to national reserves (FAO et al. 2011; Wright and Cafiero 2011). This is not a new idea. International risk sharing and multinational insurance schemes were heavily discussed in the 1970s (Johnson 1976; Reutlinger et al. 1976; Konandreas et al. 1978). As with the concept of any insurance, pooling national supplies stabilizes regional food availability due to the imperfect correlation of national production shocks (Koester 1986). However, potential benefits of cooperation can only be realized when countries agree on common rules under which the reserve operates. In other words, how much each country contributes and under which circumstances releases from the reserve are authorized. This requires that all countries benefit from cooperation vis-à-vis without cooperation.

Academic literature on regional storage cooperation is scant. Existing studies underline the potential of risk sharing without explicitly conceptualizing the link to storage. This study aims at closing the gap by providing a methodology to evaluate potential benefits of regional storage cooperation. The main objective is to examine whether storage cooperation could enhance food security in West Africa. Specifically, various possible storage policies are tested, and an efficient load distribution among participating countries is discussed. Generally, the methodology is applicable to any group of countries and not limited to West Africa.

The remainder of the chapter is structured as follows. First, Sect. 15.2 discusses food security and storage as well as trade as means to increase food availability and introduces the concept of regional cooperation. Then, Sect. 15.3 and Sect. 15.4 outline the framework for assessing the benefits of cooperation and then define optimal levels of storage in the presence of stochastic supply with the goal of stabilizing national consumption. The results of this study, including sensitivity analysis, are presented in Sect. 15.5. Section 15.6 concludes this chapter and discusses policy implications.

15.2 Food Reserves, Trade, and Benefits of Regional Cooperation

Annual production is subject to great fluctuation and consequently may be insufficient to meet stable consumption needs in non-exporting economies. Food imports and stocks can offset these fluctuations. The empirical literature emphasizes the interchangeability of trade and storage to offset unstable production (Williams and Wright 1991; Makki et al. 1996, 2001). There are good reasons to believe that free market stock levels in many developing countries are not sufficiently high or optimal (Newbery and Stiglitz 1981; Gilbert 2011). Similarly, the potential gains from regional trade are not exhausted in many developing countries (Badiane et al. 2014). Gilbert (2011) suggests considering a country's specific characteristics to determine the right policy. So, exporters can easily regulate domestic food availability by flexible export quantities. Trade is also advantageous if supply shocks between countries are independent or negatively correlated (Koester 1984; Badiane et al. 2014). In contrast, importers and countries that switch between net importer and net exporter can successfully insure themselves against high international prices by keeping security stocks. Furthermore, high transportation costs (e.g., for landlocked countries) and/or long periods of shipment make public reserves favorable to trade. Trade can also transmit market instability from partner countries into national markets (Makki et al. 2001). Moreover, relying on imports to manage food availability can be problematic when partner countries are noncooperative and restrict exports at times (Gouel and Jean 2015). This was a frequently observed practice during the price surges in 2007/2008 (Martin and Anderson 2012; Porteous 2012). For these reasons, food reserves have a structural advantage over trade integration, at least from a government's perspective.[2]

Food reserves can be divided into two broad categories: emergency or strategic reserves and buffer stocks. The purpose of the former is to overcome food supply shortfalls caused by weather-related shocks (such as droughts or floods), pests, and political instability (Lynton-Evans 1997). During a crisis, additional food is brought into the system via targeted food subsidies (e.g., food stamps, food for work, school feeding programs, etc.). In contrast, buffer stocks are used to generally stabilize commodity prices at both ends of the distribution. In doing so, public institutions buy and sell commodities in order to increase market supply or demand. The objective of the buffer stock is to keep prices within a price band, between a predetermined floor and ceiling price (Newbery and Stiglitz 1981). Purchases and sales can be realized not only in the open market but also through contract farming and subsidized sales to public and private entities. The main danger lies in having to operate buffer stocks permanently, which implies permanent market intervention. Notably, intervention levels of existing national reserves and buffer stocks vary significantly across countries.[3]

The gains from cooperation rest on the concept of risk pooling. Risk pooling, or diversification, originates from the insurance and finance literature and is the central business concept of every insurance company. Pooling uncertain outcomes of multiple individuals reduces the volatility of their joint outcome. Expected losses remain the same, but insurance companies can reduce their accrued liabilities if (and only if) losses of policyholders are not perfectly correlated. On the same account, a group of countries can reduce the stocking norm of their food reserves by sharing the risk of supply shocks. Statistically, the covariance and correlation of individual risks is the key determinant for gains from cooperation. If shocks are idiosyncratic, then risk sharing is feasible. On the contrary, if shocks are highly correlated, the benefits of cooperation will be small (Townsend 1995). From this, it is possible to conclude

[2]On the one hand, deepening trade relationships require trading partners to be equally willing to cooperate; on the other hand, trade integration usually takes time to establish business relations and trust between actors.

[3]Agricultural markets in India, Zambia, and Indonesia are dominated by state-owned enterprises that buy, stock, and sell a very large share of marketed grains. In contrast, several countries maintain public stockholding that is unlikely to affect market prices due to its small size. In an ideal world, buffer stocks should be large enough to influence prices but small enough not to crowd out private investment and distort markets.

that supply instability in one region (a group of countries) is lower if national supply quantities are independent or negatively correlated. The potential of regional risk sharing with respect to supply shocks of major food crops in Africa is well acknowledged in existing studies (Koester 1986; Badiane et al. 2014). Since supply variability is the main reason to establish food reserves, lower supply variability implies that a reserve requires lower stock levels.

Wright and Cafiero (2011) also discuss the role of regional reserves in increasing a country's commitment to refrain from imposing export regulations in times of a food crisis. These commitments seem unfeasible under the common WTO discipline. At the same time, governments dispose of ways to impede exportation through the over-bureaucratization of legal processes. Hence, it is conceivable to combine storage and trade cooperation. In doing so, participating countries provide a share of their national supply for exporting (if harvests are sufficiently high) and in return receive the entitlement to release stocks during a crisis.

A multinational reserve involving a buffer stock scheme, with market purchase and release, seems very challenging to realize. If the regional reserve operates separately at national levels, trade between countries would undermine the principles of operation and could lead to complete inefficacy. On the contrary, if the region is considered as a single market, intervention prices are extremely difficult to determine since price levels naturally differ among member countries, especially without a common currency. Therefore, strategic humanitarian reserves should be preferred.

15.3 Assessment of the Costs and Benefits of Cooperation

In order to assess the costs and benefits of regional cooperation, we compare consumption variability and reserve levels under regional cooperation vis-à-vis without cooperation. In other words, optimal stocking norms are defined for each individual country and for specific groups of countries. If a country's welfare is given by:

$$U = H\ \left[\mathrm{VAR}\left(C\left(\alpha\right)\right)\right] - G\left(\alpha\right), \tag{15.1}$$

where H is a function decreasing with consumption variability Var(C) and G, the costs of interventions that increase with the stock-to-use ratio α; $\alpha \in (0,\ 1)$ reduces consumption variability and thus increases H in the following manner: $H'(\alpha) > 0$ and $H''(\alpha) < 0$.

Then welfare increases with consumption stability and decreases with higher reserve stock levels. A government chooses the optimal policy by opting for a stock-to-use ratio (α) that maximizes social welfare. Accordingly, there is a trade-off when increasing the stock level of the reserve. Higher stock levels guarantee greater consumption stability but are associated with higher operational costs.

The optimal α maximizes social welfare without cooperation. On the contrary, in the case of regional storage cooperation, the level of consumption variability, and thus the optimal stock-to-use ratio, is no longer determined by an individual country through welfare optimization but by a common decision among all member countries. Heterogeneity among regional partners could explain why they may disagree about common regional policies. For instance, countries with high supply instability may be satisfied with a relatively moderate level of consumption stability, whereas countries with stable national supply need regional consumption stability to be sufficiently high to benefit from an intervention. In regional integration, states voluntarily hand their decision-making power over to supernational entities and create a political power that overrules national policies (Heinonen 2006). Taking a game-theoretic approach, the median voter will decide on the level of consumption stability in such a setting (Alesina et al. 2005). As a consequence, countries with similar economic structures lose less in comparison with countries with divergent economic structures.

Thus, the benefits of regional risk sharing are evaluated against the costs of a potentially suboptimal choice of stock-to-use ratio. Following the framework mentioned above, the net benefits (X_i) of cooperation for each country i are given by the difference in social welfare before and after joining the regional agreement:

$$N_i = H_i\left[\mathrm{VAR}\left(\widehat{C}_i\right)\right] - H_i\left[\mathrm{VAR}\left(C_i^*\right)\right] + G_i\left(\alpha_i^*\right) - G_i\left(\widehat{\alpha}_i\right) \tag{15.2}$$

where $\mathrm{VAR}\left(C_i^*\right)$ is the consumption variability resulting from the optimal α_i^* for an individual country without cooperation or the optimal level of target consumption chosen by the country. Analogously, $\mathrm{VAR}\left(\widehat{C}_i\right)$ is the consumption variability under cooperation determined by $\widehat{\alpha}$, which is jointly selected by the member countries.

However, without specifying the functions H_i and G_i, welfare impacts are not unambiguously appraisable. Definite predictions are possible when benefits increase and costs decrease and vice versa. Yet in the remaining cases, a specific functional form of H_i and G_i is required for a clear assessment.

The framework introduced requires the definition of optimal stocking rules or stock-to-use ratios that are applied by each country. This implies stocks need to be sufficiently high to permit stock releases that achieve the desired level of consumption (stability). At the same, the policy governing the release of stocks from the reserve must be strictly defined. Within regional storage cooperation, the member countries must contribute to the endowment of the regional reserve. These contributions could be proportionally equal. In this case, all countries would have identical stock-to-use ratios. Alternatively, Koester (1986) proposes that a country should contribute according to its individual stock needs. In doing so, countries with greater supply instability would be asked to contribute more than countries with greater supply stability. In this way, all countries would benefit from the cooperation in the same manner. Again, the releases from the reserve must make sure that the desired consumption (stability) is given for each member country. This means that whenever a country's supply falls short of its target level (specified in the rules of the reserve), the country would receive stocks from the regional reserve to guarantee national consumption. As opposed to this, if a country's domestic supply is sufficient in satisfying domestic demand in a particular year, then the country does not receive anything from the regional reserve.

15.4 Optimal Stocks and Stocking Rule

In this analysis, two possible types of reserve are considered: an emergency reserve, which releases stocks whenever supply falls short of a predetermined level, and a buffer stock regime, which stabilizes supply in both directions.

15.4.1 Emergency Reserve

In line with the existing literature, the optimal reserve level should be able to absorb historical production and supply shocks by a predetermined probability or margin (Johnson 1976; Konandreas et al. 1978; Koester 1986). Let the market identity be given by:

$$C_t = Q_t + \mathrm{IM}_t - \mathrm{EX}_t = X_t \qquad (15.3)$$

where total consumption (C_t) equals production (Q_t) plus imports (IM_t) minus exports (EX_t). Imports and exports are assumed to be from international markets only. National production and imports constitute total national supply (X_t).

In case production falls short of the desired level, minimum consumption of a country can be satisfied through additional imports. However, food availability has generally (not only in the case of West Africa) seen drastic variations from year to year despite food imports. Furthermore, international food prices fluctuate and therefore make the food import bill unpredictable (Sarris et al. 2011). In such a situation, the emergency reserve would step in to lift consumption to the desired minimum level. Following Konandreas et al. (1978), the desired minimum level is referred to as target consumption level c^* (e.g., 95 % of long-term trend). Then, consumption in a given year is given by:

$$C_t = \max\left[X_t, c^* E\left[C_t\right]\right] \qquad (15.4)$$

where X_t, is the actual supply in at t, and $c^* E\left[C_t\right]$ is the target consumption based on expected supply that is calculated from historical values. By definition $c^* \in [0, 1]$.

In words, when national supply is higher than the target level, consumption just equals total supply. But whenever supply is lower than the target level, the reserve releases the necessary amount to close the gap to satisfy at least $c^* \times 100\%$ of the expected consumption. Consumption is expected to always equal supply. In order to satisfy Eq. (15.4), stocks need to compensate for supply shortfalls of more than $(1 - c) \times 100\,\%$. Subsequently, the ratio of consumption to be stored (α) is defined as the ratio between stocks and expected consumption:

$$S_t^* = \max_t \left[0,\ c^* E\left[X_t\right] - (X_t)\right] \text{ for } t = t_1, \ldots, t_n \tag{15.5}$$

$$\alpha_t^* = \frac{S_t^*}{E\left[C_t\right]} \tag{15.6}$$

where $\max_t \left[c^* E\left[X_t\right] - (X_t)\right]$ is the largest historical supply shortfall over the period t_1–t_n. If supply never falls below $c^* E\left[X_t\right]$, no stocks shall be carried. S_t^* are optimal stocks, and α_t^* is the optimal stock-to-use ratio at present time.

In regional cooperation, the reserve must carry sufficiently large stocks to satisfy the sum of supply shortfalls in all member countries, so that regional consumption is given by

$$C^R{}_t = \sum_i C_{it} \tag{15.7}$$

where $C^R{}_t$ is the regional consumption, which is the sum of the consumption in each member country given by Eq. 15.4.

Accordingly, the individual national reserves carry total regional stocks which are the sum of national stocks:

$$S_t^R = \sum_i S_{it}^* = \sum_i \max_t \left[0,\ c^*{}_i E\left[X_{it}\right] - (X_{it})\right] \text{ for } t = t_1, \ldots, t_n \tag{15.8}$$

where S^R is the amount of regional stocks and all other parameters are described as above.

If national supply shortfalls are not perfectly correlated, then the common regional reserve must carry only enough stocks to balance the sum of the shortfalls that occur in a particular year.

$$\widehat{S}_t^R = \max_t \left[0,\ \sum_i \widehat{c}\, E\left[X_{it}\right] - (X_{it})\ \right] \text{ for } t = t_1, \ldots, t_n \tag{15.9}$$

where $\max_t \left[0,\ \sum_i \widehat{c}\, E\left[X_{it}\right] - (X_{it})\ \right]$ is the largest historical regional supply shortfall over the period t_1–t_n.and $\widehat{c}$ is the consumption target in a regional cooperation which does not vary between member countries i. If supply never falls below $\widehat{c}\ E\left[X_t\right]$, no stocks shall be carried.

The regional reserve shall be endowed with stocks by contributions from its member countries. In this instance, national stocking norms change to:

$$\widehat{S_{it}} = s_i\, \widehat{S}_t^R = \widehat{\alpha_t} E\left[X_{it}\right] \tag{15.10}$$

$$\text{with } \widehat{\alpha}_t = \frac{S_t^R}{E\left[C^R{}_t\right]} \tag{15.11}$$

$$\widetilde{S}_{it} = \frac{S_{it}}{\sum_{i=1}^{n} S_{it}} S_t^R \tag{15.12}$$

where s_i is a country's share of the total regional consumption; $\widehat{S}_{it}$ and $\widetilde{S}_{it}$ are a country's contributions to the regional reserve under equal and relative contributions. Under equal contributions, all countries have the same stock-to-use ratio $\widehat{\alpha}$ in t. Under relative contributions, $\widehat{\alpha}_i$ varies among countries by the extent to which national stocks vary across countries without regional cooperation.

However, regional storage cooperation and intra-regional trade cooperation can work hand in hand. For instance, it is conceivable to assume that supply surpluses are exported to the region. Hence, supply shortfalls in neighboring countries can be first alleviated through trade before releasing stocks from the regional reserve. Storage cooperation could also increase the commitment to such arrangements (Wright and Cafiero 2011).

A reasonable assumption may be that a country's excess surpluses $\text{ES}_{it} = X_{it} - E\left[X_{it}\right]$ are approved for export. Thus, intra-regional trade and regional stocks are given by:

$$T^R{}_t = \sum_i \max\left[0,\ X_{it} - E\left[X_{it}\right]\right] \tag{15.13}$$

$$S_t^R = \max_t \left[0,\ \left[\sum_i \widehat{c}E\left[X_{it}\right] - \left(X_{it}\right)\right] - T^R{}_t\right] \text{ for } t = t_1, \ldots, t_n \tag{15.14}$$

where $T^R{}_t$ is the total quantity traded within the region in a particular year, which is computed as the sum of excess surpluses across all member countries. Regional trade reduces the amount of regional stocks, which are necessary to alleviate supply shocks. Therefore, historical shortfalls, which have to be balanced, diminish with growing amount of intra-regional trade. Contributions of member countries and stock-to-use ratios can be computed in a way analogous to the case without intra-regional trade.

15.4.2 Stabilization Reserve

As opposed to the emergency reserve described in the previous section, the concept of the stabilization reserve is derived from the classical storage literature (Gustafson 1958). Stocks are regarded as part of national supply and demand. Each year, a constant portion (γ) of the total available supply is kept as stock in a reserve; this is a linear approximation of the stocking rule pioneered by Gustafson. In this way, stock levels change over time. After years with good harvests, stock levels will be become higher (and will correspondingly become lower after bad harvests). In this case, the market identity from Eq. (15.3) above changes to:

$$C_t = X_t - \Delta S_t \tag{15.15}$$

$$\Delta S_t = S_{t+1} - S_t \tag{15.16}$$

$$S_{t+1} = \gamma \left(S_t + X_t \right) \tag{15.17}$$

where all parameters are defined the same as above. S_t is opening stocks available for consumption in t, and S_{t+1} are the stocks carried to the next period. ΔS_t is the change in ending stocks from $t - 1$ to t. γ is the constant portion of total available supply that is carried over to the next period.

Inserting Eq. (15.15) in Eq. (15.14), consumption can be written as[4]:

$$C_t = (1 - \gamma) (X_t) + (1 - \gamma) S_t \tag{15.18}$$

Since supply naturally fluctuates, we want to know the expected level of stocks. This can be easily derived since $E[S_t] = E[S_{t+1}]$. Thus,

$$S_t^* = \frac{\gamma E[X_t]}{(1 - \gamma)} \tag{15.19}$$

$$\alpha^* = \frac{\gamma}{1 - \gamma} \tag{15.20}$$

where S_t^* is the optimal stock level and α^* the corresponding optimal stock-to-use ratio.

The objective of the stabilization reserve is to stabilize consumption. Hence, it is of interest is to investigate how consumption variability depends on the stocking parameter (γ). Taking the variance of Eq. (15.18) yields:

$$\text{VAR}(C) = \frac{1 - \gamma}{1 + \gamma} \text{VAR}(X) \tag{15.21}$$

$$\text{CV}(C) = \sqrt{\frac{1 - \gamma}{1 + \gamma}} \text{CV}(X), \tag{15.22}$$

[4]For the complete analytical derivation, see Kornher (2015).

where VAR (C) and VAR (X) are variance of consumption and supply, respectively, and CV (C) and CV (X) are the respective coefficients of variation.

Consequently, consumption variability is a function of supply variability and the stocking parameter (γ). The larger the supply variability, the larger the consumption variability. On the other hand, increasing γ stabilizes consumption. It is important to note that the stabilization reserve in the case of regional storage cooperation works only if markets are fully integrated and if demand and supply adjust perfectly between countries. In this case, regional supply and consumption variability are equal to national supply and consumption variability for each individual member country.

15.5 Results

15.5.1 Supply Patterns in West Africa

Table 15.1 provides economic and agricultural statistics on West African countries involved in this analysis. Heterogeneity between countries exists with respect to income level and food security status. While Ghana and Cape Verde have relatively low prevalence of hunger and malnutrition, 12 % of the total ECOWAS population is still undernourished, with alarmingly high figures in the Sahel zone. With the exception of Mali and to some extent Burkina Faso, all countries depend on imports to guarantee sufficient supply of grain. In general, it is observed that coastal countries have larger import-to-production ratios, with Cape Verde, Cote d'Ivoire, Liberia, Senegal, and Mauritania having ratios above one. Overall, Nigeria's prominent role in the region is to be noted. Due to the country's population, more than 40 % of regional production originates from Nigeria, and thus the country would likely assume a leading role in any regional cooperation agreement.

The subsequent analysis is based on fluctuations in national food production and supply. Supply is calculated as production plus imports. In this way, extreme fluctuations in the production of many import-dependent countries are extenuated. Therefore, the analysis of supply shocks is considered to be more instructive. All imports are considered to be from international markets. In the analysis which considers intra-regional trade, these international imports are considered to be part of the national supply.

Since production increases with agricultural productivity and population growth, unadjusted measures of variability as variance and coefficient of variation become inappropriate measures of variability (Cuddy and Della Valle 1978). One possibility is to correct coefficient of variation and variance by the fitness of a trend function (Koester 1984). Alternatively, variability can be measured after detrending the time series. Thus, variability in supply is given as the variation around a trend. A linear

Table 15.1 Key statistics: ECOWAS

	Population (in 100,000)	GDP per capita PPP	% of under-nourished	Total production (in 1000 mt)	Import/ production (in %)
Benin	10,323	1791	8.1	1667	21
Burkina Faso	16,934	1634	25.9	4949	9
Cape Verde	498	6412	–	7	2.86
Cote d'Ivoire	20,316	3012	21.4	1276	116
Gambia, The	1849	1666	14.4	214	58
Ghana	25,904	3974	3.4	2645	44
Guinea	11,745	1255	17.3	2292	21
Guinea-Bissau	1704	1242	8.7	175	74
Liberia	4294	878	31.4	150	227
Mali	15,301	1641	7.9	5032	3
Niger	17,831	913	12.6	4308	13
Nigeria	173,615	5863	8.5	22,042	32
Senegal	14,133	2269	20.5	1182	150
Sierra Leone	6092	1927	28.8	897	28
Togo	6816	1390	16.5	1142	23
Total ECOWAS	327,355	4123	12	47,978	30
Cameroon	22,253	2711	15.7	3047	37
Chad	12,825	2081	33.4	1647	18
Mauritania	3889	3042	9.3	222	207

Source: AFDB (2014), von Grebmer et al. (2013), USDA (2014). *Note*: Mauritania withdrew from ECOWAS in 2000; CFA countries are Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea-Bissau, Mali, Mauritania, Niger, and Senegal; all other countries use their own free floating currency

trend clearly does not fit the supply data of several countries in the region. Therefore, the data is detrended by using the Hodrick-Prescott filter (HP-filter).[5]

An example is given in Fig. 15.1, which shows the national supply in Ghana. Actual supply quantities are depicted by the black line, and the dashed gray line indicates the HP-filter trend values for a smoothing parameter of 6.25. The deviation of actual supply from trend supply becomes stationary, and variability can be computed by:

$$CV = \sqrt{{}^{1}\!/_{n} \sum \left(\mu - X_t/\overline{S_t}\right)^2} / \mu, \tag{15.23}$$

[5]The HP-filter is widely used to detrend macroeconomic time series data that exhibits cyclical fluctuations. The estimated trend value is given by the minimization of quadratic deviations in due consideration of a smooth trend. As recommended for annual data, the smoothing parameter is chosen to be 6.25 (Gabler Wirtschaftslexikon 2014).

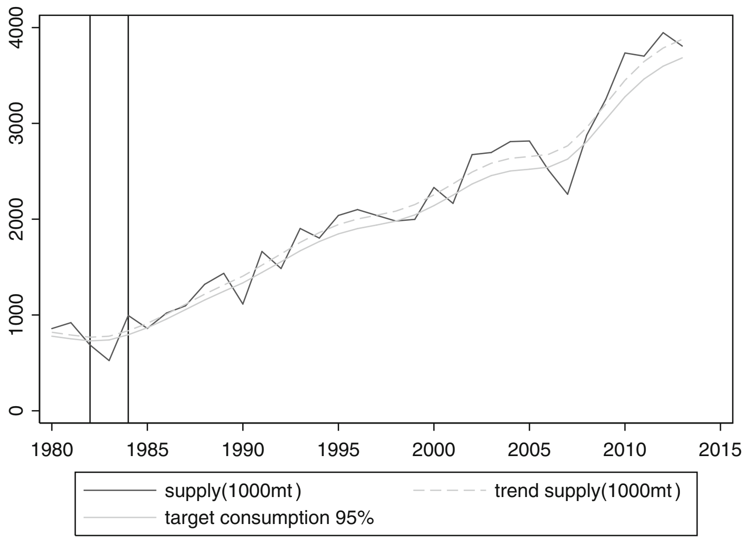

Fig. 15.1 Grain supply in Ghana 1980–2014. *Source*: Author's illustration based on USDA (2014)

where X_t is the total supply in t and $\overline{X_t}$ the trend value of supply determined by the HP-filter. By definition, μ equals 1.

Table 15.2 shows each country's contribution to the total regional grain supply in 2014 as well as the coefficient of variation in production and supply over the period from 1980 to 2014. In brief, there are two general observations. First, supply variability is substantially lower than production variability, in particular for countries with high import-production ratio. Second, no country exhibits production and supply variability that is lower than the figure for the region as a whole. Therefore, the basic requirements for the West African region to benefit from cooperation are fulfilled.

In more detail, production variability is highest for Cape Verde, Mauritania, Senegal, the Gambia, and Chad. All these countries largely depend on import. However, for all of these countries, supply variability is significantly lower. This implies that imports were successfully utilized to stabilize domestic consumption, but the import levels are still higher than in countries with greater self-sufficiency. In general, coastal countries show higher production and supply stability; this can be explained by more favorable climatic conditions in the humid and semi-humid tropical zone compared to the Sahel zone (HarvestChoice 2014). Interestingly, these findings with regard to instability are quite similar to those of Koester (1984), who looks at the period from 1960 to 1980. According to his analysis of the UEMOA countries, Burkina Faso, Cote d'Ivoire, and Mali had more stable production than Senegal, Mauritania, and Niger. The observed pattern seems to persist over time.

Table 15.2 Production and supply instability in West Africa

	Share in regional production	CV production	Share in regional supply	CV supply
Benin	2.9	7.6	2.7	7.6
Burkina Faso	8.9	10.3	7.5	9.1
Cameroon	5.7	7.2	6.0	6.0
Cape Verde	0.0	43.8	0.0	30.3
Chad	3.4	15.7	3.0	13.3
Cote d'Ivoire	2.4	5.5	4.0	5.7
Gambia, The	0.4	16.1	0.5	14.4
Ghana	5.0	14.0	5.6	10.2
Guinea	4.2	5.5	3.9	5.6
Guinea-Bissau	0.4	9.8	0.4	10.3
Liberia	5.0	16.1	0.7	14.8
Mali	10.4	9.7	8.1	9.4
Mauritania	0.4	27.6	1.0	9.6
Niger	8.7	13.5	7.4	12.0
Nigeria	40.6	5.8	41.2	5.4
Senegal	2.4	18.0	4.3	8.3
Sierra Leone	1.5	13.8	1.6	11.1
Togo	2.1	10.2	2.0	8.1
Region	100.0	4.5	100.0	3.4

Source: Author's computation based on USDA (2014)

15.5.2 Emergency Reserve

This subsection discusses the optimal stocking norms for an emergency reserve as defined earlier. The target consumption level is the critical parameter to be chosen. A target consumption level of $j\,\%$ can be represented by $j\,\%$ of annual production (dashed line in Fig. 15.1).[6] The lighter solid line in Fig. 15.1 illustrates this for a target consumption level of 95 %. Then, the deviation of actual supply from target consumption is computed, and the maximum historical shortfall is identified. In the instance of Ghana, the largest shortfall happened in 1983. The size of the shortfall depends on the target consumption chosen. Target consumption levels of individual countries are hypothetical and cannot be observed. A possible way to determine target consumption levels is to assume that each country uses the reserve to mitigate x- % of the largest supply or production shock. From the standard deviation of these shocks of each country, the target consumption level with respect to any quantile can be computed. Normalized standard deviations are equal to the coefficient of variation shown in Table 15.2. Figure 15.2 shows the target consumption levels

[6]Recall that production/supply = consumption.

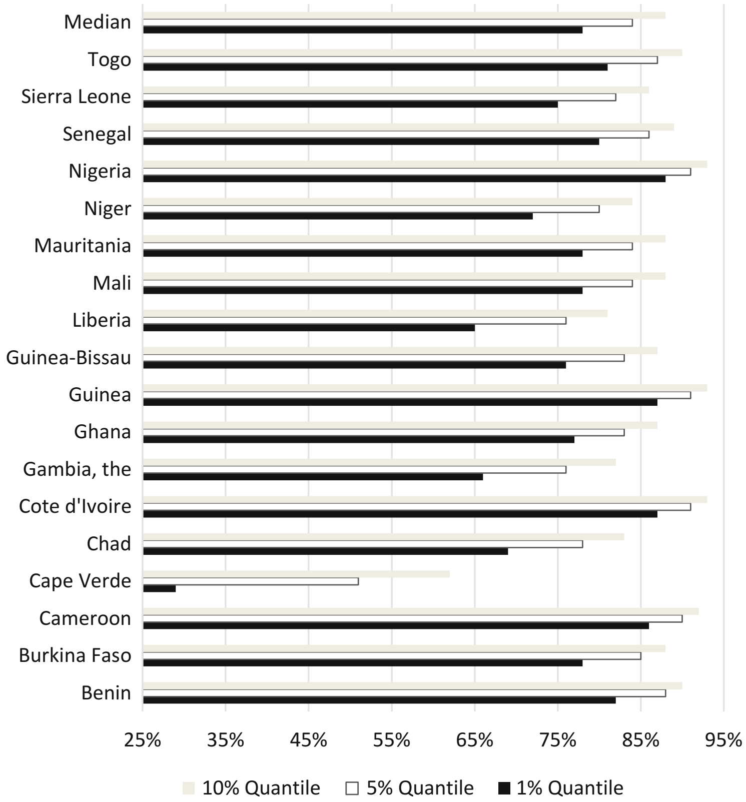

Fig. 15.2 Possible target consumption levels by country. *Source*: Author's illustration

across countries for the 1 %, 5 %, and 10 % quantiles when assuming a normal distribution of supply shocks.[7]

Figure 15.2 contains important information. Intuitively, the larger the tail of the distribution (the greater the quintile), the lower target consumption will be. First, as elaborated above, higher target consumption levels also require larger stocking norms. Second, target consumption levels would vary significantly among the countries: Nigeria, Cote d'Ivoire, and Guinea would have the highest target consumption levels, and Cape Verde would have the lowest. Third, the lower the national supply variability, the higher the target consumption levels in a particular quintile. This is also intuitive because when national supply is more stable, higher target consumption is required to alleviate a relatively moderate supply shock. In

[7] 1 %, 5 %, and 10 % quantiles reflect the frequency of interventions of the national reserve. Thus, absorbing the 10 % largest supply shocks demands the highest frequency of supply shocks.

the following, the median values will serve as possible target consumption levels for the region.

15.5.2.1 Emergency Reserve Without Intra-regional Trade

The stocking norm is defined as the largest historical shortfall between actual and target consumption over the past 35 years. Table 15.3 summarizes the respective stocking norms for all countries and various levels of target consumption. Apart from the median target consumption levels, the target consumption levels of 99 %, 97 %, 95 %, and 90 % are also considered.

Large countries have the highest optimal stocking norms. The corresponding stock-to-use ratios show the relative level of the stocking norms. All countries that are characterized by high supply variability also have the largest optimal stocking norms within an emergency reserve. The total regional stocks according to the maximum historical shortfall rule are between 231,137 tons and 6.2 million tons. The values for the target consumption levels of 95 % and above are well in the range of the actual stock levels according to USDA and FAO CBS. However, one would choose optimal emergency reserve stocks that are smaller than actual stocks since total stocks also include speculative and working stocks of private market participants. In this respect, lower levels of target consumption seem to be more reasonable.

On the other hand, several countries with low supply variability hardly stock anything at target consumption levels below 95 %, as shown in Table 15.3. For instance, Nigeria and Guinea would not store anything at target consumption levels of 88 % and below and thus would not benefit from regional storage with all stocking norms selected using the median values (shown in Fig. 15.2). At the target consumption level of 84 %, Cote d'Ivoire and Senegal would likely also cease to participate in a regional reserve, followed by Benin, Burkina Faso, Cameroon, Guinea-Bissau, Mali, and Togo for 78 % target consumption. Hence, target consumption levels need to be sufficiently high in order that all West African countries benefit from cooperation. For this reason, only simulation results for target consumption levels of 90 % and above are subsequently presented in the main text. The detailed simulation results for the target consumption level of 95 % are tabulated in the main text in Table 15.4; the detailed results for 90 %, 97 %, and 99 % are presented in the Appendix (Tables 15.6, 15.7, and 15.8).

Under storage cooperation, optimal stocking norms can be significantly lower if shortfalls between actual and target consumption levels are independent or not perfectly positively correlated. The potential for the ECOWAS region to benefit from these independencies of production and supply shocks is underlined by the analysis conducted by Badiane et al. (2014).

Table 15.4 shows the results of having a regional reserve. For both production and supply, the remaining columns contain the optimal stocking norm under the following three scenarios: (1) no storage cooperation under autarky, (2) equal contributions from the countries to the regional reserve, and (3) relative contributions to the regional reserve required under autarky. The first column reveals the probability

Table 15.3 Optimal stocking norms vs. actual stocks in 2014

	Optimal reserve levels: supply														Actual stocks	
	99 %		97 %		95 %		90 %		88 %		84 %		78 %		USDA	FAO CBS
	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	S_i^*
Benin	152,677	8 %	127,936	7 %	103,195	5 %	42,379	2 %	32,037	2 %	11,354	1 %	–	–	107,000	162,000
Burkina Faso	593,667	11 %	500,825	9 %	407,983	8 %	203,667	4 %	140,506	3 %	55,756	1 %	–	–	364,000	495,000
Cameroon	203,148	5 %	170,363	4 %	148,788	4 %	94,852	2 %	73,277	2 %	30,128	1 %	–	–	148,000	866,000
Cape Verde	15,455	57 %	14,800	54 %	14,144	52 %	12,505	46 %	11,849	44 %	10,538	39 %	8571	32 %	–	7000
Chad	357,082	17 %	317,808	15 %	278,533	13 %	180,347	9 %	141,073	7 %	80,930	4 %	34,576	2 %	106,000	564,000
Cote d'Ivoire	181,273	6 %	139,631	5 %	99,615	4 %	35,635	1 %	10,043	0 %	–	–	–	–	301,000	467,000
Gambia, The	48,382	14 %	41,486	12 %	34,589	10 %	22,209	6 %	19,160	6 %	13,061	4 %	3914	1 %	29,000	48,000
Ghana	477,451	12 %	422,149	11 %	366,847	9 %	228,592	6 %	173,290	4 %	129,889	3 %	83,183	2 %	476,000	325,000
Guinea	124,296	4 %	87,947	3 %	51,597	2 %	10,864	0 %	–	–	–	–	–	–	201,000	511,000
Guinea-Bissau	26,092	8 %	23,423	7 %	20,755	7 %	14,084	4 %	11,415	4 %	6078	2 %	–	–	24,000	69,500
Liberia	53,601	10 %	48,902	9 %	44,203	8 %	32,455	6 %	27,756	5 %	20,446	4 %	12,343	2 %	53,000	56,000
Mali	417,047	7 %	303,936	5 %	223,631	4 %	78,210	1 %	49,735	1 %	2156	0 %	–	–	764,000	855,000
Mauritania	111,038	15 %	101,159	14 %	91,279	12 %	66,580	9 %	56,701	8 %	36,942	5 %	7303	1 %	59,000	95,500
Niger	681,052	13 %	585,455	11 %	503,972	10 %	345,241	7 %	289,035	6 %	176,625	3 %	72,619	1 %	225,000	522,000
Nigeria	2,167,705	7 %	1,572,822	5 %	977,939	3 %	128,646	0 %	–	–	–	–	–	–	1,539,000	850,000
Senegal	308,029	10 %	258,230	8 %	208,432	7 %	83,935	3 %	34,137	1 %	–	–	–	–	197,000	492,000
Sierra Leone	149,723	13 %	134,597	12 %	119,471	11 %	81,657	7 %	66,531	6 %	36,280	3 %	8628	1 %	0	87,000
Togo	117,762	8 %	105,888	7 %	94,014	7 %	64,329	5 %	52,455	4 %	28,707	2 %	–	–	95,000	171,000
Total	6,185,480	9 %	4,957,354	7 %	3,788,989	5 %	1,726,187	2 %	1,189,001	2 %	638,891	1 %	231,137	0 %	4,688,000	6,643,000

Source: Author's computation based on USDA (2014) and FAO CBS (2014). *Note*: Stock level in mt; the difference in stock levels between USDA and FAO CBS is explained by the issues with regard to USDA data and small countries as well as less-traded crops as sorghum and millet that comprise a significant share of total grain consumption in the region

Table 15.4 Optimal stock levels in 2014 for target consumption of 95 %

	Production				Supply			
	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	26 %	98,832	68,249	58,004	29 %	103,195	66,181	66,804
Burkina Faso	26 %	461,771	209,158	271,009	29 %	407,983	182,765	264,111
Cameroon	11 %	163,986	134,570	96,242	14 %	148,788	146,499	96,319
Cape Verde	43 %	7572	298	4444	40 %	14,144	885	9156
Chad	37 %	301,534	79,510	176,968	31 %	278,533	73,389	180,311
Cote d'Ivoire	14 %	84,520	55,554	49,604	20 %	99,615	97,416	64,487
Gambia, The	34 %	70,230	9566	41,217	43 %	34,589	12,069	22,391
Ghana	17 %	287,853	118,080	168,939	26 %	366,847	136,789	237,481
Guinea	17 %	57,988	99,377	34,033	14 %	51,597	96,782	33,402
Guinea-Bissau	29 %	21,528	7566	12,635	31 %	20,755	10,768	13,436
Liberia	31 %	20,306	7941	11,918	31 %	44,203	18,083	28,615
Mali	37 %	216,774	243,921	127,223	31 %	223,631	199,491	144,770
Mauritania	46 %	49,666	9552	29,149	29 %	91,279	25,604	59,090
Niger	29 %	607,626	204,524	356,610	31 %	503,972	182,173	326,251
Nigeria	17 %	928,445	951,527	544,897	14 %	977,939	1,010,583	633,077
Senegal	40 %	429,613	56,908	252,136	26 %	208,432	106,131	134,930
Sierra Leone	31 %	105,992	35,788	62,206	31 %	119,471	38,301	77,341
Togo	23 %	75,671	49,553	44,411	20 %	94,014	48,925	60,861
Total	97 %	3,989,905	2,342,642	2,342,642	97 %	3,788,989	2,452,834	2,452,834

Source: Author's computation based on USDA (2014). *Note*: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). $S_i{}^*$, $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

of a shortfall in production and supply.[8,9] The last row contains the total stock level of the whole region if the countries operate individual reserves and if they cooperate. Without regional storage cooperation, the total regional stocks amount to 3,989,905 metric tons for production only and 3,788,989 metric tons for supply. In contrast, with cooperation, regional stocks only need to be 2,342,642 and 2,452,834 metric tons. Comparing the two scenarios reveals a 41 % and 35 % reduction in the total storage level for production and supply, respectively. Since relative contributions among the countries imply that all countries benefit equally from the cooperation, the percentage reduction in storage levels applies to all countries alike. The positive effect of a regional storage cooperation holds regardless of the rule of contributions (equal or relative), but two countries, namely, Guinea and Nigeria, are disadvantaged in the case of proportionally equal contributions. Figure 15.3 shows the difference between the effects of both types of contributions on each country. It becomes evident that countries with relatively low levels of supply variability would prefer

[8]Equal contributions imply, proportionally equal to a country's share in regional consumption.

[9]The probability of shortfall is computed from historical shortfalls.

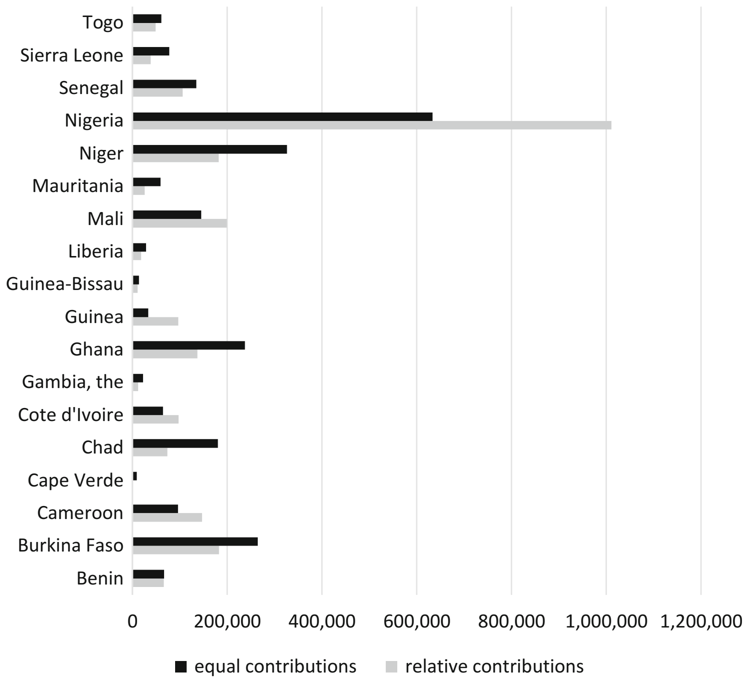

Fig. 15.3 Contributions to a regional reserve with 95 % target consumption by country (based on supply). *Source*: Author's illustration based on USDA (2014). *Note*: Equal contributions to the reserve imply an identical stock-to-use ratio across countries, while relative contributions demand higher stock-to-use ratios in countries with higher variability in supply

relative contributions to the regional reserve. Nigeria, the single largest contributor, could save more than 300,000 metric tons of food when making relative as opposed to equal contribution. Similarly, Guinea, Cote d'Ivoire, Mali, and Cameroon would be able to reduce their contributions under the relative contribution scheme. In fact, the average stock-to-use ratio in the region (5 % for 95 % target consumption) represents a threshold. Without regional cooperation, all countries that have a stock-to-use ratio above the regional average are better off by adopting equal instead of relative contributions, while all countries with a stock-to-use ratio below regional average would prefer relative contributions.

For clarity, the tabulated results for the other target consumption levels are only presented in the appendix. However, their effect on total regional stocks is illustrated in Fig. 15.4. The benefits of cooperation are lower at higher levels of target consumption. At 99 % and 97 % target consumption, regional stocks were, respectively, around 25 % and 30 % lower with cooperation than without cooperation, whereas the benefits of cooperation are greater at the target consumption of 90 %. Accordingly, regional stocks could be 62 % lower with regional cooperation in contrast with without cooperation.

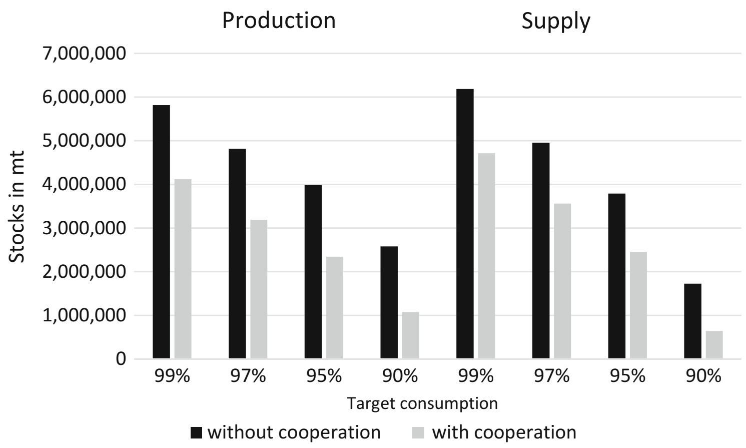

Fig. 15.4 Regional stocks with and without storage cooperation (without intra-regional trade). *Source*: Author's illustration based on USDA (2014)

It is noteworthy that a regional reserve without integration of markets or transfers between countries is required to act significantly more often than a national reserve as the probability of shortfalls increases. Hence, the total quantity needed to compensate for production and supply shortfalls is equal with or without storage cooperation. The benefits of cooperation are apparent only when lower stock levels are kept at any one time. However, these benefits are substantial as countries are also required to renew their reserve stocks on a regular basis, even if the reserve stocks are not used to offset supply shocks.

Lastly, what are the welfare implications that can be derived from the simulation results above? First and foremost, with reasonably high levels of target consumption, optimal stocking norms can be defined so that all countries would benefit from the decision. However, preferences are not homogeneous, and low levels of target consumption put countries with low supply variability at a disadvantage. Since the preferences of countries cannot be observed, only under two circumstances can net benefits be identified when preferences are heterogeneous. First, target consumption chosen by the region is lower than that of a country without cooperation, while stocking norms are lower with cooperation; in this case, a country benefits from cooperation. Second, the net benefits of cooperation are unambiguously negative if target consumption with cooperation is higher than with regional cooperation and if stocking norms are higher than without cooperation. Indeed, the latter can be excluded by choosing target consumption levels above 90 %. Intuitively, countries with large supply variability would likely prefer equal contribution to the regional reserve. Therefore, it is important to offer incentives for all countries to participate in the reserve in order to realize the full benefits of cooperation.

15.5.3 Emergency Reserve with Intra-Regional Trade

When intra-regional trade is allowed, the analysis is analogous to the scenario without trade. Therefore, the largest historical shortfalls and the associated stocking norms in autarky remain unchanged. The only difference is that supply shortfalls in neighboring countries are first alleviated through trade before releasing stocks from the reserve. Participating countries are committed to export only when actual supply exceeds estimated supply as computed by the HP-filter.

Figure 15.5 shows a comparison of the required stocks with and without intra-regional trade. Trade appears to hardly reduce the level of required stocks. The most notable gains are seen when stocks are based on a consumption shortfall of 10 %.

The results of the simulation can be explained by the choice of the criterion used to determine reserve levels according to historical consumption shortfalls. The historically largest shortfall occurred in 2007, and only very few countries were able to export in that year. The exports from these very few countries are not high enough to offset the supply shortfalls of other countries. Small differences in the reserve level notwithstanding, regional trade would reduce the frequency of stock-outs significantly. The probability of a shortfall occurring is at most 43 %, compared to between 89 % and 100 % across all levels of target consumption for the emergency reserve without intra-regional trade. When 5 % shortfall in consumption is allowed, with intra-regional trade, the probability of a shortfall is only between 20 % and 26 % for supply and production, respectively.

These benefits are founded on intra-regional exports. Figure 15.6 shows the average annual exports, based on production and supply figures, over the period

Fig. 15.5 Regional stocks for an emergency reserve with intra-regional trade. *Source*: Author's illustration based on USDA (2014)

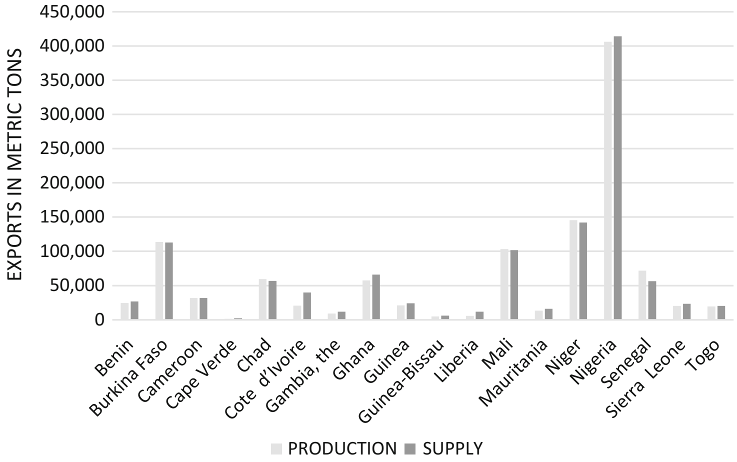

Fig. 15.6 Average annual exports by country 1980–2014. *Source*: Author's illustration based on USDA (2014)

from 1980 to 2014. The total annual exports amounted to 1.13 million tons based on production and 1.16 million tons based on supply data. As calculated using the expected supply for 2014, the total annual exports range between 0.7 % and 0.9 % of total supply in 2014 for Guinea and Cameroon and between 4.59 % and 7.9 % for Cape Verde. By the definition used to determine exports, countries with higher production and supply fluctuations automatically export more than countries with lower fluctuations. This is because these countries exhibit greater positive and negative deviations from the trend. Generally, exports are at a realistic level. Net welfare benefits can be computed in a way similar to the case without intra-regional trade.

15.5.4 Stabilization Reserve

The optimal stocking rule under national stockholding can be estimated using actual stock data. Since the USDA only has poor quality of data on stocks for small countries, the FAO CBS stock data is preferred and utilized in this analysis. The stocking parameter is obtained by estimating the following equation with OLS:

$$S_t = \gamma \ (S_{t-1} + Q_{t-1} + \mathrm{IM}_{t-1} - \mathrm{EX}_{t-1}) + \varepsilon_t \qquad (15.24)$$

where all variables are as described in the previous sections and ε_t is the normally distributed error term.

It should be noted that the constant is omitted in this estimation. First, storage is a nonnegative value, and negative stocks values are also impossible. Second, stocks

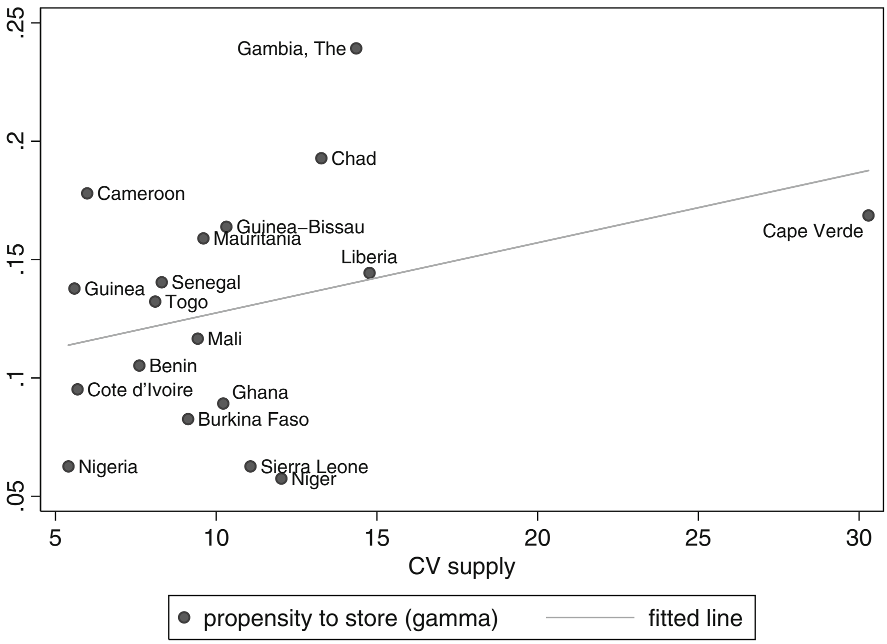

Fig. 15.7 Stocking parameter and supply variability across study countries. *Source*: Author's illustration based on USDA (2014) and FAO CBS (2014)

need to increase with supply starting from zero if supply is zero.[10] The results are presented in Fig. 15.7, which depicts the stocking parameter γ conditional on the level of supply variability estimated by the coefficient of variation around a trend as described in the previous sections.

The solid line represents the overall positive correlation between supply variability and the stocking rule. A slope parameter of 0.30 implies that the stocking parameter increases by 3 percentage points on average when supply variability is 10 percentage points higher.[11] However, there are notable exceptions to this relationship.[12] Niger, Sierra Leone, and Nigeria store only 6 % of its total available supply, although their supply variability is relatively high. In contrast, the Gambia and Chad experience supply variability similar to Niger, but they store 24 % and 19 %, respectively. All other countries in the region store roughly between 8 and

[10]The estimation is associated with several problems (non-stationarity, number of observations), and results have to be interpreted with caution. However, the objective is not to establish causality or to compute confidence intervals but rather to obtain a country's preferences without storage cooperation.

[11]When Cape Verde, an outlier, is excluded, the slope parameter only changes marginally.

[12]It should be noted that an increase of 0.1 is quite substantial because γ ranges between 0 and 1.

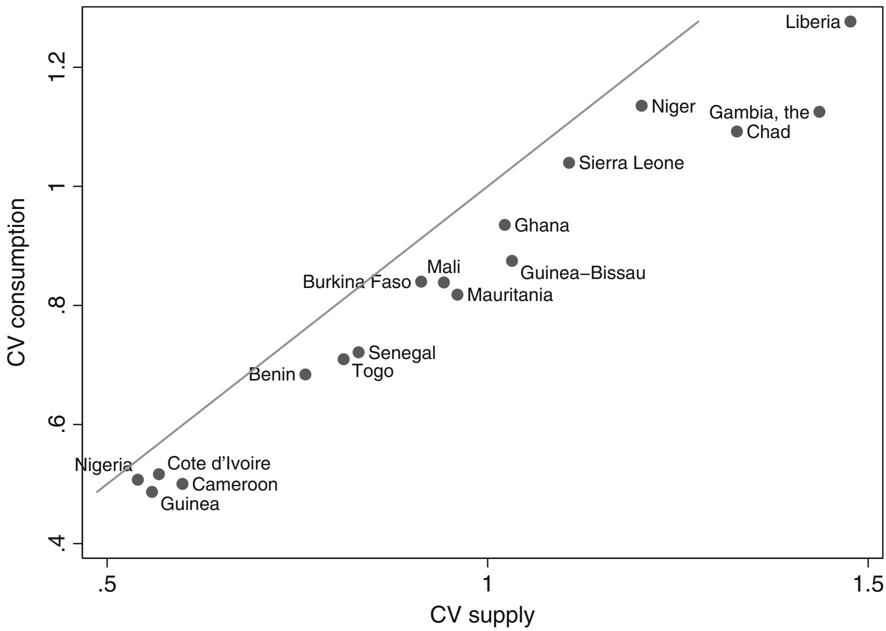

Fig. 15.8 Consumption and supply variability of study countries. *Source*: Author's illustration based on USDA (2014) and FAO CBS (2014)

17 %. Taking the sum of individual stocks as the optimal choice for the region, 9 % of the region's annual supply should be stored due to the low value of Nigeria.

Using the policy parameter and the information on each country's supply variability, it is possible to compute the consumption variability as chosen by each country (see Eq. 15.22). Figure 15.8 shows the relative position of each country with regard to their consumption and supply. The solid line represents the parity between consumption and supply variability; countries without storage would lie on this line. With additional storage, countries move further to the right, away from the solid line. Hence, the larger a country's stocking parameter γ is, the farther away from the parity line countries are. Moreover, for countries with lower supply variability, it is less efficient to decrease consumption variability by one unit by increasing storage. For example, Cameroon needs to store 18 % of its total available supply to reduce consumption variability by 1 %. In contrast, Ghana is able to reduce consumption instability by 0.8 % by storing only 9 % of its available supply.

The costs of stabilization are already described by the stocking parameter γ. The full dimension of the costs become more visible when looking at the amount of stocks required to reach a desired level of consumption stability. Table 15.5 presents the optimal stock levels and stock-to-use ratio for γ calculated using country-level stock data and compares them to actual levels. The resulting stock-to-use ratio is $\alpha = \frac{\gamma}{1-\gamma}$, which has a positive exponential relationship with γ. When $\gamma > 0.5$, stocks already amount to expected consumption levels with a stock-to-use ratio

Table 15.5 Actual and optimal stock levels under a linear stocking rule

	γ^*	CV_c	S^*	S_{2013}	α^*	$\frac{S_{2013}}{C}$
Benin	0.105	6.8	220,802	162,000	11.8	12.8
Burkina Faso	0.083	8.4	466,615	495,000	9.0	8.5
Cameroon	0.178	5.0	899,228	866,000	21.7	16.0
Cape Verde	0.169	25.5	5089	7000	20.3	20.3
Chad	0.193	10.9	496,928	564,000	23.9	22.3
Cote d'Ivoire	0.095	5.2	290,463	467,000	10.5	9.3
Gambia, The	0.239	11.2	107,609	48,000	31.5	30.4
Ghana	0.089	9.4	379,520	325,000	9.8	9.2
Guinea	0.138	4.9	438,248	511,000	16.0	14.3
Guinea-Bissau	0.164	8.7	59,828	69,500	19.6	17.3
Liberia	0.144	12.8	86,482	56,000	16.9	14.7
Mali	0.117	8.4	746,375	855,000	13.2	10.1
Mauritania	0.159	8.2	137,177	95,500	18.9	20.7
Niger	0.057	11.4	314,910	522,000	6.1	5.4
Nigeria	0.063	5.1	1,915,352	850,000	6.7	7.0
Senegal	0.140	7.2	491,235	492,000	16.3	16.2
Sierra Leone	0.063	10.4	72,532	87,000	6.7	5.3
Togo	0.132	7.1	211,342	171,000	15.2	14.9
Region	–	3.1	7,063,305	6,643,000	–	10.3

Source: Author's computation based on USDA (2014) and FAO CBS (2014). *Note*: Country level γ is obtained by the regression (15.24); CV consumption is computed as $CV_c = \sqrt{\frac{1-\gamma}{1+\gamma}}\, CV(X)$ (see Eq. 15.22); the optimal regional γ *i*s unknown

greater than one. Notably, the linear stocking rule predicts actual stocks and stock-to-use ratios quite precisely.

The last row in Table 15.5 provides stock figures for the region as a whole. Given the current stock level of around 7 million tons, the regional stocking rule would imply that 9 % of the total supply needs to be stocked up. This is associated with a consumption variability of 3.4 %, as compared to 3.1 % without storage. It is also possible to describe the initial optimization problem of governments directly as a trade-off between costs and benefits, more specifically, the trade-off between consumption stability and operational costs. Figure 15.9 shows the trade-off for the region as a whole. The dotted black line indicates the status quo – roughly 7 million tons of stocks associated with a coefficient of variation of consumption of 3.1 %. The dashed black line represents a stock level of 11.1 million tons resulting from a stocking parameter of 0.135, which is the median parameter across all member countries.

The required amount of stocks increases overproportionally with a reduction in consumption instability. In order to reach consumption stability of up to only 2.7 %, the region would require roughly 20 million tons of stocks. When no stocks are required however, consumption variability through market integration or transfers between countries is only 3.4 %; this figure is 2 % less for Nigeria, which has

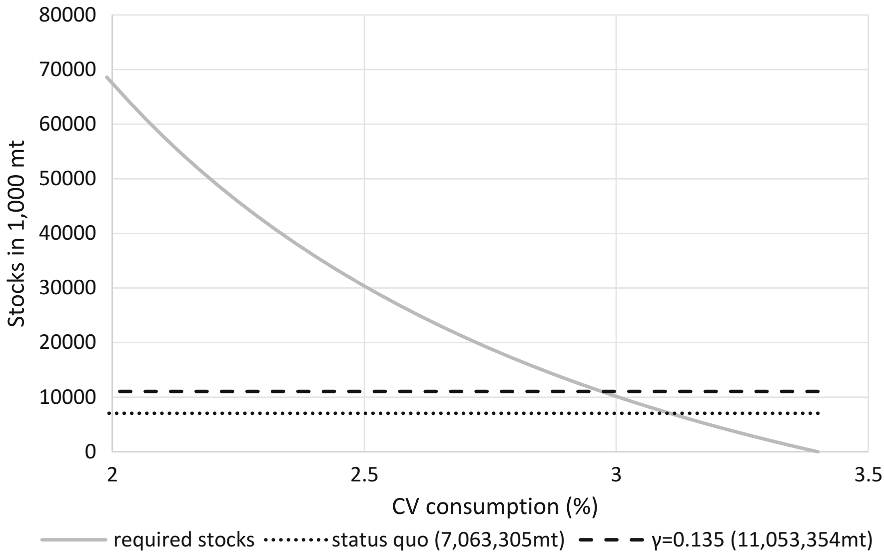

Fig. 15.9 Regional consumption variability at different stock levels. *Source*: Author's illustration based on USDA (2014) and FAO CBS (2014)

the lowest supply variability. This implies that most of the gains originate from trade integration and not from storage cooperation. In other words, consumption stability is largely enhanced by regional trade integration, but increasing stocks have only very little impact on the level of consumption variability. The benefits of regional trade cooperation are significant. Individual countries would need an unrealistically large amount of stocks in their stabilization reserve to achieve a consumption variability of 3.4 %. The costs and benefits of cooperation can be evaluated for a particular level of consumption variability which the region desires. We assume the observed stocking parameter is chosen as the optimal stocking rule by each country. Since trade integration is associated with huge benefits in the form of a reduction of consumption instability, a country in autarky may be worse off only if the regional stocking parameter exceeds the one chosen by the country. Hence, net benefits are strictly positive for all countries up to a stock-to-use ratio of 6.1 % for Niger, 6.7 % for Nigeria and Sierra Leone, 9.0 % for Burkina Faso, and 9.8 % for Ghana; in the same manner, the values for other countries are determined according to α_i^*, as shown in Table 15.5.

Lastly, it is possible to test how a linear stocking rule would have performed over the course of the last 35 years. Figure 15.10 illustrates the performance in relation to the associated target consumption levels. Despite regional trade integration, the simulated regional consumption undershot target consumption levels of 99 %, 97 %,

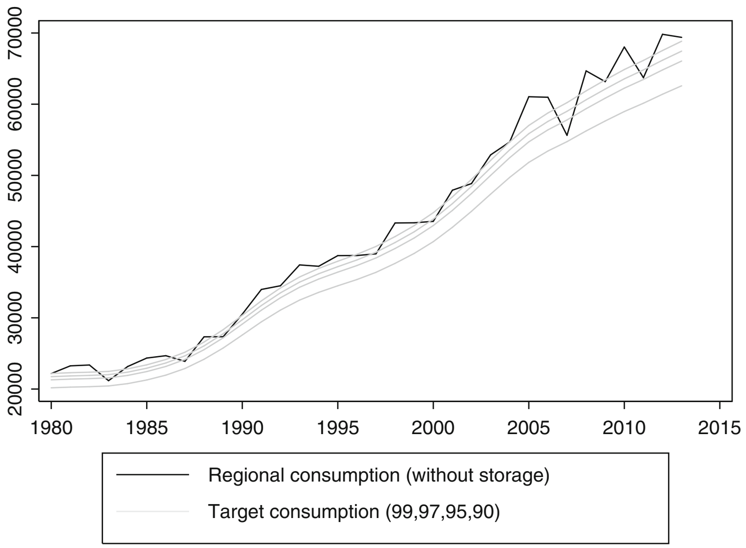

Fig. 15.10 Regional consumption under trade integration without storage. *Source*: Author's illustration based on USDA (2014) and FAO CBS (2014)

and 95 % multiple times.[13] Thus, regional trade integration reduces consumption variability significantly, but it is unable to combat severe supply shortfalls. Conversely, a linear stocking rule which guarantees that all countries achieve net benefits by cooperating ($\alpha = 6.1$ %) would have a guaranteed target consumption of 97 % over the whole period. Clearly, a linear stocking rule is effective in buffering positive and negative supply shock. However, the effects are rather small compared with the benefits of trade integration within the whole region. This may change if the number of participating countries reduces.

15.6 Conclusion

In this study, a methodology for assessing the costs and benefits of regional storage cooperation is outlined and applied to the West African region. Building on the influential works of Johnson (1976) and Koester (1986), the methodology establishes a link between supply and consumption variability, and it accounts for the potential benefits of cooperation through the imperfect correlation of production and supply shocks among neighboring countries. In doing so, the work complements previous studies by conceptualizing the link to storage.

[13]To be exact, the number of shortfalls are (accordingly to target consumption) 99 %, 11 times; 97 %, 7 times; 95 %, 3 times; and 90 %, never.

The principles of risk pooling allow for reducing carry-over stocks by 35–41 % within West Africa without welfare transfers or trade between countries so as to guarantee at least 95 % of the expected trend consumption. For other minimum consumption levels, the benefits are between 25 % and 60 %. National contributions to the reserve can be organized in such a manner that all countries benefit significantly from the cooperation. However, in this way, releases from the reserve would occur frequently, and stocks would need to be refilled on a regular basis. If limited intra-regional trade takes place between areas with surplus and deficiency, the optimal regional stocks under cooperation hardly change. However, the need for stock release intervention reduces significantly. Therefore, trade is very effective in smoothing consumption when supply fluctuations are moderate. In contrast, reserves are required to dampen large supply shortfalls. These benefits are large enough to justify additional costs that may arise from storage cooperation. Lastly, complete market integration in West Africa would greatly benefit countries with high supply variability. Without undertaking any storage, regional supply variability is at 3.4 %, which is higher than that of each country included in the analysis. Storage cooperation beyond full market integration would reduce consumption variability only marginally. Furthermore, trade integration without storage, unlike an emergency reserve, is incapable of dampening severe supply shortfalls.

It is also important to consider offering incentives to countries to encourage them to participate in a regional reserve. When the level of target consumption is relatively low in an emergency reserve, countries with low supply variability do not benefit. Yet these countries are of particular importance to realize the full benefits of regional cooperation. The advantages of cooperation diminish rapidly when countries with limited supply variability or countercyclical shock patterns refuse to participate in the alliance. However, it should be noted that a regional emergency reserve guaranteeing relative high levels of target consumption needs to carry large amounts of stocks, which are associated with high operational costs.

These findings are of great relevance to the ongoing debate on public food storage, trade integration, and regional reserves. Trade liberalization is widely considered as an effective instrument to balance supply variability and production shortfalls. In contrast, public storage is associated with substantial market distortions and comes at high fiscal costs. Nevertheless, a number of developing countries responded to the global food crisis in 2007/2008 by implementing and enhancing public storage to increase food security. This is also driven by the unpredictability of food availability at international markets as exporters attempt to insulate domestic markets. Regional storage cooperation was brought up for discussion as viable and comparably cheap means of addressing a food crisis and as an alternative to national reserves. Moreover, storage cooperation could enhance commitment of exporters to regional trade agreements (Wright and Cafiero 2011).

West Africa has taken a pioneering role by showing the intention to implement a region-wide emergency reserve. Political and economic integration in West Africa is among the most advanced in Africa. However, at present, intra-regional trade is limited partly because of bad infrastructure and bureaucratic hindrances at national boundaries. The results from this study should be understood as an encouragement to regional storage cooperation in the region. Three messages can be taken away from this study. First, production and supply patterns in the region are able to facilitate cooperation which may yield massive benefits. Second, trade integration is more effective than storage in smoothing supply, but storage is required to dampen extreme supply shortfalls. Last, there is great potential for storage cooperation with regard to an emergency reserve and less with regard to a stabilization reserve. Nevertheless, clear rules about individual country's contributions and releases, and, if needed, regional trade management, are essential to organize regional storage with mutual benefits. Administrative complexity is likely to be a smaller problem with a limited number of partner countries. Therefore, future research should attempt to evaluate the costs and benefits for subsets of countries in an attempt to identify the countries which could possibly form a coalition. Moreover, the potential benefit of intra-regional trade integration should be analyzed more rigorously.

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Appendix

Table 15.6 Optimal stock levels in 2014 for target consumption of 99 %

	Production				Supply			
	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	40 %	141,604	120,137	100,356	37 %	152,677	127,265	116,424
Burkina Faso	40 %	631,234	368,174	447,361	40 %	593,667	351,453	452,700
Cameroon	49 %	214,049	236,879	151,698	26 %	203,148	281,713	154,911
Cape Verde	49 %	8101	524	5741	52 %	15,455	1701	11,785
Chad	49 %	368,209	139,960	260,953	46 %	357,082	141,125	272,293
Cote d'Ivoire	37 %	127,531	97,789	90,382	43 %	181,273	187,327	138,229
Gambia, The	43 %	79,208	16,839	56,135	55 %	48,382	23,208	36,894
Ghana	43 %	357,196	207,853	253,148	43 %	477,451	263,042	364,079
Guinea	43 %	90,030	174,930	63,805	46 %	124,296	186,109	94,782
Guinea-Bissau	43 %	26,771	13,318	18,973	46 %	26,092	20,706	19,896
Liberia	40 %	27,477	13,978	19,473	49 %	53,601	34,774	40,873
Mali	58 %	419,760	429,367	297,487	55 %	417,047	383,615	318,019

(continued)

Table 15.6 (continued)

	Production				Supply			
	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$
Mauritania	49 %	56,683	16,814	40,172	46 %	111,038	49,237	84,672
Niger	37 %	779,525	360,017	552,456	37 %	681,052	350,313	519,335
Nigeria	43 %	1,786,527	1,674,944	1,266,127	43 %	2,167,705	1,943,323	1,652,981
Senegal	49 %	477,554	100,173	338,447	52 %	308,029	204,087	234,887
Sierra Leone	37 %	128,728	62,996	91,231	46 %	149,723	73,652	114,171
Togo	43 %	95,910	87,226	67,972	40 %	117,762	94,081	89,800
Region	100 %	5,816,099	4,122,000	4,122,000	100 %	6,185,480	4,716,730	4,716,730

Source: Author's computation based on USDA (2014). *Note*: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). $S_i{}^*$, $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

Table 15.7 Optimal stock levels in 2014 for target consumption of 97 %

	Production				Supply			
	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	34 %	120,218	93,057	79,668	37 %	127,936	96,089	91,907
Burkina Faso	34 %	546,502	285,182	362,163	37 %	500,825	265,358	359,785
Cameroon	29 %	189,018	183,483	125,260	17 %	170,363	212,702	122,386
Cape Verde	49 %	7836	406	5193	40 %	14,800	1285	10,632
Chad	43 %	334,871	108,411	221,916	40 %	317,808	106,554	228,308
Cote d'Ivoire	23 %	106,025	75,746	70,262	31 %	139,631	141,438	100,309
Gambia, The	37 %	74,719	13,043	49,515	54 %	41,486	17,523	29,803
Ghana	37 %	317,677	161,000	210,522	34 %	422,149	198,605	303,265
Guinea	34 %	74,009	135,498	49,045	31 %	87,947	140,519	63,179
Guinea-Bissau	34 %	24,150	10,316	16,004	40 %	23,423	15,634	16,827
Liberia	40 %	23,892	10,827	15,833	37 %	48,902	26,255	35,130
Mali	46 %	309,623	332,581	205,185	49 %	303,936	289,642	218,342
Mauritania	49 %	53,175	13,024	35,238	37 %	101,159	37,175	72,671
Niger	34 %	693,576	278,864	459,627	34 %	585,455	264,498	420,581
Nigeria	34 %	1,285,869	1,297,387	852,134	34 %	1,572,822	1,467,271	1,129,890
Senegal	43 %	453,584	77,593	300,586	43 %	258,230	154,092	185,508
Sierra Leone	34 %	117,360	48,796	77,773	40 %	134,597	55,609	96,692
Togo	31 %	85,791	67,564	56,853	29 %	105,888	71,035	76,069
Region	100 %	4,817,894	3,193,000	3,193,000	97 %	4,957,355	3,561,283	3,561,283

Source: Author's computation based on USDA (2014). *Note*: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). $S_i{}^*$, $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

Table 15.8 Optimal stock levels in 2014 for target consumption of 90 %

	Production				Supply			
	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	$S_i{}^*$	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	11 %	49,479	31,300	20,578	11 %	42,379	17,315	15,755
Burkina Faso	23 %	271,876	95,923	113,071	20 %	203,667	47,818	75,717
Cameroon	9 %	101,408	61,716	42,175	9 %	94,852	38,329	35,263
Cape Verde	34 %	6910	137	2874	34 %	12,505	231	4649
Chad	23 %	218,190	36,465	90,743	23 %	180,347	19,201	67,048
Cote d'Ivoire	6 %	30,755	25,478	12,791	3 %	35,635	25,487	13,248
Gambia, The	29 %	59,007	4387	24,540	31 %	22,209	3158	8257
Ghana	14 %	257,176	54,153	106,957	11 %	228,592	35,789	84,984
Guinea	6 %	17,936	45,576	7460	6 %	10,864	25,322	4039
Guinea-Bissau	17 %	14,974	3470	6227	14 %	14,084	2817	5236
Liberia	26 %	15,564	3642	6473	23 %	32,455	4731	12,066
Mali	11 %	110,280	111,866	45,864	14 %	78,210	52,194	29,076
Mauritania	37 %	40,894	4381	17,007	17 %	66,580	6699	24,753
Niger	20 %	392,751	93,798	163,341	20 %	345,241	47,663	128,351
Nigeria	3 %	497,369	436,384	206,851	9 %	128,646	264,404	47,827
Senegal	29 %	369,686	26,099	153,749	9 %	83,935	27,768	31,205
Sierra Leone	23 %	77,571	16,413	32,261	20 %	81,657	10,021	30,358
Togo	14 %	50,373	22,726	20,950	11 %	64,329	12,800	23,916
Region	89 %	2,582,200	1,074,000	1,074,000	89 %	1,726,187	641,747	641,747

Source: Author's computation based on USDA (2014). *Note*: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). $S_i{}^*$, $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

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Regional Trade and Volatility in Staple Food Markets in Africa

16

Ousmane Badiane and Sunday Odjo

16.1 Introduction

Recent studies have indicated that Africa as a whole and a number of individual countries have exhibited relatively strong trade performance in the global market (Bouët et al. 2014) as well as in continental and major regional markets (Badiane et al. 2014). The increased competitiveness has generally translated into higher shares of regional markets in total exports by the different groupings. Faster growth in demand in continental and regional markets compared to the global market has also boosted the export performance of African countries. For instance, during the second half of the last decade, Africa's share of the global export market has risen sharply, in relative terms, for all goods and agricultural products in value terms, from 0.05 to 0.21 % and from 0.15 to 0.34 %, respectively. This is in line with the stronger competitive position of African exporters mentioned earlier.

By promoting competition and specialization in production, regional trade–similar to global trade–can contribute to food security through its impact on long-term output and productivity growth. At the same time, it can positively affect employment and incomes. Where these effects are positive, trade increases the availability of food and improves the accessibility of food to affected segments of the population. Trade also helps reduce the unit cost of supplying food to local markets, thereby lowering food prices or reducing the pace of food price increase, which in turn improves the affordability of food. Finally, trade can also help stabilize supplies in domestic food markets and reduce the associated risks to vulnerable groups.

All of the above-mentioned benefits can be obtained, perhaps to a larger extent, through trading with the rest of the world. For instance, one could question why a

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given country should pursue an expansion of regional trade as opposed to global trade in general for stabilizing domestic food supplies, given that world production can be expected to be more stable than regional production. Several factors, such as transport costs, foreign exchange availability, responsiveness of the import sector, and dietary preferences, may provide valid economic justification for a country's efforts to boost regional trade as part of a wider supply stabilization strategy that would also include increased trade with extra-regional markets. Regional and global trade should therefore be seen as complementary rather than as substitutes.

The increase in intra-African and intra-regional trade, and the rising role of continental and regional markets as major destinations of agricultural exports by African countries suggest that cross-border trade flows will exert greater influence on the level and stability of domestic food supplies. The more countries find ways to accelerate the pace of intra-trade growth, the larger that influence is expected to be in the future. The current chapter examines the future outlook for intra-regional trade expansion and the implications for volatility of regional food markets. The chapter starts with an analysis of the potential of regional trade to contribute to stabilizing food markets, followed by an assessment of the scope for cross-border trade expansion. A regional trade simulation model is then developed and used to simulate alternative scenarios to boost trade and reduce volatility in regional markets.

16.2 Regional Potential for the Stabilization of Domestic Food Markets Through Trade

Variability of domestic production is a major contributor to local food price instability in low income countries. The causes of production variability are such that an entire region is less likely to be affected than individual countries. Moreover, fluctuations in national production tend to partially offset each other, so that such fluctuations are less than perfectly correlated. Food production can be expected to be more stable at regional level than at country level. In this case, expanding cross-border trade and allowing greater integration of domestic food markets would reduce supply volatility and price instability in these markets. Integrating regional markets through increased trade raises the capacity of domestic markets to absorb local price risks by: (1) enlarging the area of production and consumption and thus increasing the volume of demand and supply that can be adjusted to respond to and dampen the effects of shocks; (2) providing incentives to invest in marketing services and expand capacities and activities in the marketing sector, which raises the capacity of the private sector to respond to future shocks; and (3) lowering the size of needed carryover stocks, thereby reducing the cost of supplying markets during periods of shortage and hence decreasing the likely amplitude of price variation.

A simple comparison of the cereal production variability in individual countries against the regional average is carried out to illustrate the potential for local market stabilization through greater market integration (Badiane 1988). For that purpose, a trend-corrected coefficient of variation is used as a measure of production variability at both country and regional levels. We then use a normalization procedure whereby the value of the coefficient for each country is divided by the value of the coefficient for the corresponding region. Calculations are carried out for each of the three regional economic groupings (as mentioned above), and the results are presented in Table 16.6 in the annex and plotted in Fig. 16.1a–c below. The bars in the figures represent the normalized coefficients of variation, which indicate how much more (when normalized coefficient are greater than 1) or less (when normalized coefficient are less than 1) volatile a country's production is when compared with production at the level of their respective region.

Of the three regions, SADC has the highest level of aggregate volatility with a coefficient of variation of 18.58 or more than two and three times that of ECOWAS and COMESA, respectively. For the vast majority of countries, national production volatility is considerably larger than regional level volatility. The only exceptions are the Democratic Republic of Congo (DRC) in SADC and to a lesser extent Côte d'Ivoire in ECOWAS. None of the COMESA countries has a more stable production than the regional aggregate. The COMESA countries can be divided into two subgroups: (1) a relatively low volatility subgroup with normalized coefficients of less than twice the regional average, including Burundi, Comoros, DRC, Egypt, and Uganda and (2) a high volatility regional subgroup with volatility levels that are at least five times higher than the regional level, comprising Malawi, Mauritius,[1] Rwanda, Sudan, Swaziland, Zambia, and Zimbabwe. Kenya and Madagascar both have moderate levels of volatility and fall between the two groups. Most countries in SADC and ECOWAS are in the moderate regional category, with only Botswana and Mauritius (in SADC), and Gambia, Liberia, Mali, and Senegal (in ECOWAS) showing volatility levels more than three times higher than the respective regional levels. The countries in the moderate- and high-volatility subgroups would benefit the most from increased regional trade in terms of greater stability of domestic supplies.

The likelihood that a given country would benefit from the trade stabilization potential, as suggested by the difference between its volatility level and the regional average, will be greater if its production fluctuates more and is weakly correlated with that of the other countries in the region. Figure 16.2 presents the distribution of correlation coefficients between individual country's production levels for each regional group. For each country, the lower segment of the bar shows the percentage of correlation coefficients that are 0.65 or less or the share of countries with production fluctuations that are defined as relatively weakly correlated with the country's own production movements. The top segment represents the share of countries with highly correlated production fluctuations, with coefficients that are higher than 0.75. The middle segment is the share of moderately correlated country productions, with coefficients that are between 0.65 and 0.75.

[1]Mauritius has a coefficient that is more than 18 times the regional average and is not shown in the figure for clarity.

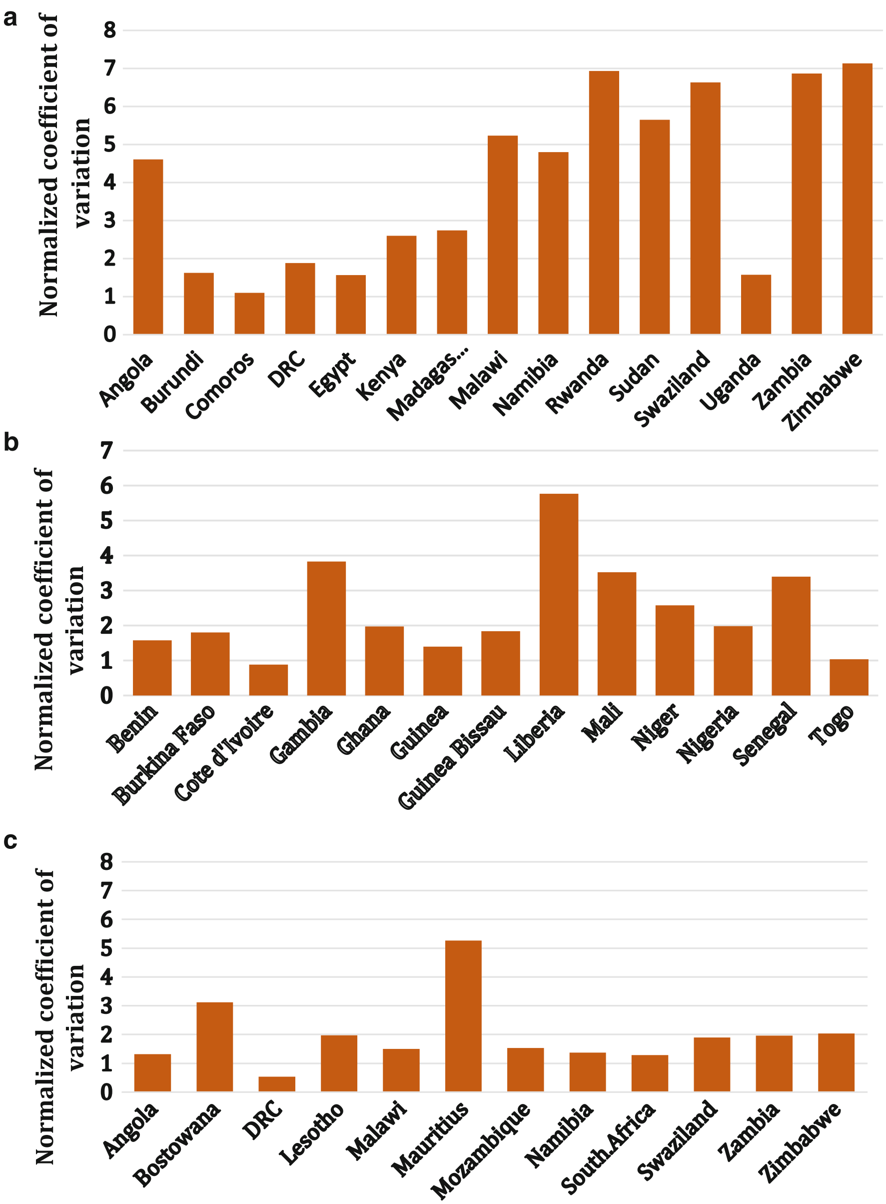

Fig. 16.1 (**a**) COMESA cereal production instability, 1980–2010. (**b**) ECOWAS cereal production instability. (**c**) SADC cereal production instability. *Source*: Authors' calculation. All graphs based on FAOSTAT 2014 data from 1980 to 2010

Using the above criteria, countries in the most volatile region, SADC, have the highest concentration of weakly correlated country production levels. As shown

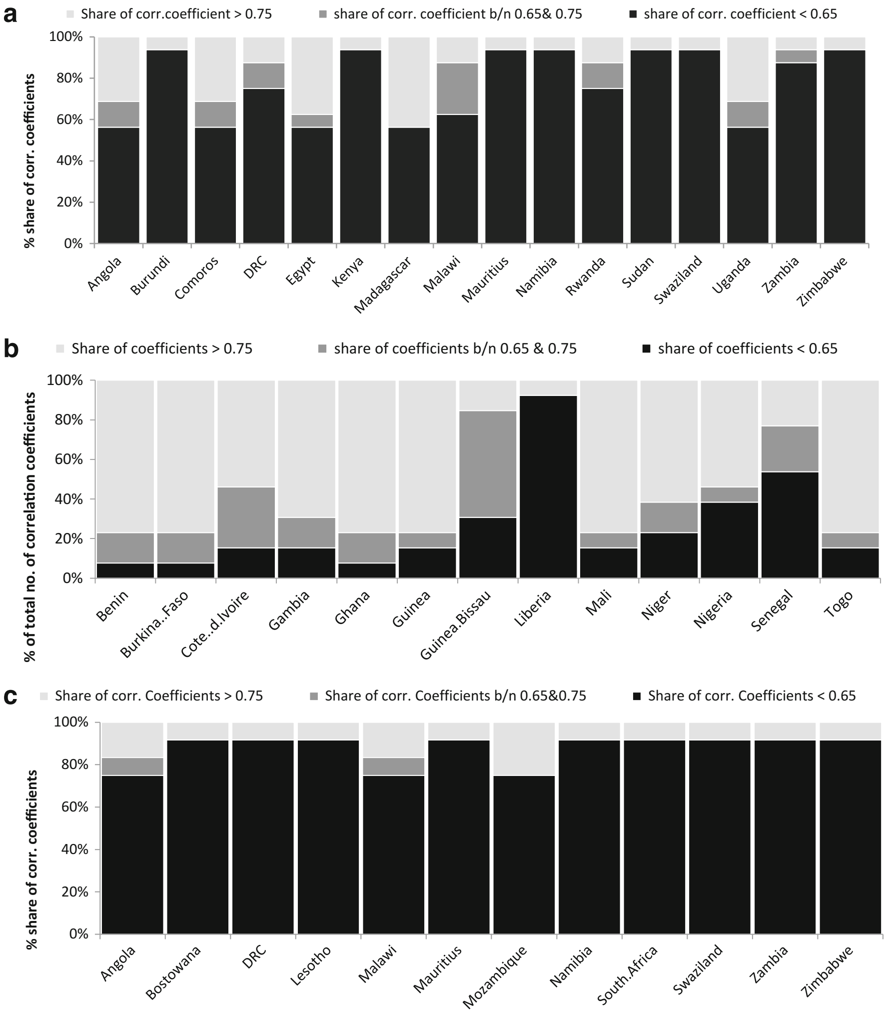

Fig. 16.2 (**a**) Distribution of correlation coefficients, COMESA. (**b**) Distribution of correlation coefficients, ECOWAS. (**c**) Distribution of correlation coefficients, SADC. *Source*: Authors' calculation. All graphs based on FAOSTAT 2014 data from 1980 to 2010

in Fig. 16.2c, only three countries have less than an 80 % share of correlation coefficients below 0.65. The combination of high volatility and weak correlation suggests that countries in this region would benefit the most from increased regional trade in terms of domestic market stabilization. They are followed by COMESA countries, where 60 % of the correlation coefficients for any given country are below 0.65. In contrast, country-level production levels in the ECOWAS region tend to fluctuate more together than the other two regions, as shown by the high share of coefficients above 0.75. The division of the region into two nearly uniform subregions, Sahelian and coastal, may be an explanation. In general, however, the patterns and distribution of production fluctuations among countries in all the three regions are such that increased trade could be expected to have a stabilizing effect on domestic agricultural and food markets. But that is only one condition; the other is that there is actual potential to increase cross-border trade, a question that will be examined in the next section.

16.3 The Scope for Specialization and Regional Trade Expansion in Agriculture

Despite the recent upward trends, the level of intra-African and intra-regional trade is still very low compared with other regions. Intra-African markets accounted only for an average 34 % of the total agricultural exports from African countries between 2007 and 2011 (Badiane et al. 2014). Among the three RECs, SADC had the highest share of intra-regional trade (42 %), and ECOWAS the lowest (6 %). COMESA's share of intra-regional trade was 20 %. Although SADC is doing much better than the other two RECs, its member countries still account for far less than half of the value of agricultural trade within the region (Badiane et al. 2014).

There may be a host of factors behind the low levels of intra-regional trade. These factors may not only make trading with extra-regional partners more attractive, but they may also raise the cost of supplying regional markets from intra-regional sources. The exploitation of the regional stabilization potential, as pointed out above, would require measures to lower the barriers to and the bias against transborder trade such as to stimulate the expansion of regional supply capacities and of trade flows across borders. This supposes that there is sufficient scope for specialization in production and trade within the subregions. Often, it is assumed that neighboring developing countries would exhibit similar production and trading patterns because of the similarities in their resource bases, leaving little room for future specialization. There are, however, several factors that may lead to different specialization patterns among such countries. These factors include (1) differences in historical technological investments and thus the level and structure of accumulated production capacities and skills; (2) the economic distance to, and opportunity to trade with, distant markets; and (3) differences in dietary patterns as well as consumer preferences that affect the structure of local production. The different patterns of specialization in Senegal compared with the rest of Sahelian West Africa and in Kenya compared with other Eastern African countries well illustrate the influence of these factors.

Consequently, we use a series of indicators to assess the actual degree of specialization in agricultural production and trade, and whether there is real scope for transborder trade expansion as a strategy to exploit the less-than-perfect correlation between national productions to reduce the vulnerability of domestic food markets to shocks. The first two indicators are the production and export similarity indices, which measure and rank the relative importance of the production and trading of individual agricultural products in every country. The level of importance or position of each product is then compared for all relevant pairs of countries within each subregion.[2] The indices have a maximum value of 100; an index value of 100 implies that the production or trade patterns between the considered pair of countries are completely similar. The closer the index value is to zero, the greater the degree of specialization between the two countries. Index values of around 50 and below are interpreted as indicating patterns of specialization that are compatible with higher degrees of trade expansion. The estimated indicator values for the three regional groupings, covering 150 products in total, are presented in Fig. 16.3a, b. Each bar represents the number of country pairs that falls within the corresponding range

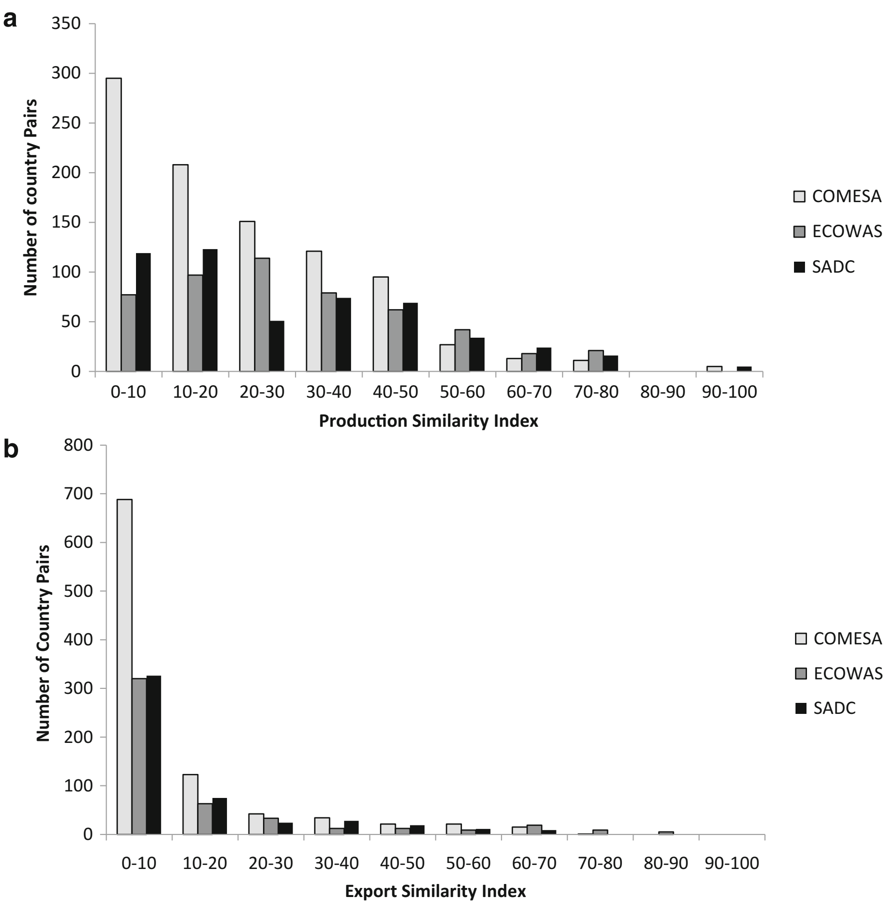

Fig. 16.3 (**a**) Similarity of production patterns, 2007–2011. *Source*: Authors' calculations based on data from FAOSTAT 2014. (**b**) Similarity of trading patterns, 2007–2011. *Source*: Authors' calculations based on data from FAOSTAT 2014

[2]See Koester (1986).

of index values. The vast majority of country pairs fall within the 0–50 range. A value of less than 60 is conventionally interpreted as compatible with higher trade exchange between the considered pair of countries. The estimated index values therefore suggest that there exists sufficient dissimilarity in the current production and trading patterns between countries and hence a scope for transborder trade expansion in all three subregions.

The third indicator, the revealed comparative advantage (RCA) index, is computed to further assess the degree of trade specialization among countries within the three regions. The RCA index compares the share of a given product in a given country's export basket with that of the same product in total world exports. A value greater than 1 indicates that the considered country is performing better than the world average; the higher the value is, the stronger the country's performance in exporting the considered product. Of the nearly 600 RCA indicators estimated for various products exported by different COMESA countries, 70 % have an index value higher than 1. ECOWAS and SADC each have a total of about 450 indicators. The share of indicators higher than 1 is about the same as in the case of COMESA: 68 % for SADC and 73 % for ECOWAS. For each regional grouping, the 20 products with the highest normalized RCA index value are presented in Table 16.1. The normalized RCA is positive for RCA indicators that are greater than 1 and negative otherwise.[3] For very high RCA indicators, the normalized value tends toward 1.

All the products listed in the table have normalized RCA values above 0.98. The rankings reflect the degree of cross-country specialization within each REC. In ECOWAS, for instance, a total of 12 products, spread across 8 out of 15 member countries, account for the highest 20 indicators for the region. There are 13 products in that category in the case of COMESA, and these products come from 9 out of 19 countries. SADC has the highest number of products in that category, a total of 14, but they come from only 5 out of 15 countries. The table also illustrates the difference in degree of specialization between the three major regions. Only two of the top ranking products (carded and combed cotton, and cashew nuts in shell) are common to the ECOWAS and SADC regions. Even between COMESA and SADC, only six of the top ranking products are common to the two regions, while there are no common top ranking products between COMESA and ECOWAS. A fuller appreciation of the degree of specialization across all countries in the three regions is best obtained by looking at the RCA values for the entire set of products and countries. For instance, if countries have similar patterns of specialization, the same products would tend to rank equally high and the values of the RCA indicator for the same product would not vary significantly across countries. Similarly, if countries have similar patterns of specialization, exports would be concentrated around a few products, with substantial variation of the indicator value across products. An analysis of the variance of the RCA index is, therefore, carried out to test for either of the above-mentioned possibilities. The results of the analysis, presented in Table 16.2, show that for the entire sample of African countries, nearly two-thirds

[3]The formula for the normalized RCA is $(RCA - 1)/(RCA + 1)$.

Table 16.1 Revealed comparative advantage indices by region, average 2007–2011

COMESA		ECOWAS		SADC	
Commodity	Country	Commodity	Country	Commodity	Country
Cloves	Comoros	Cashew nuts, with shell	Guinea Bissau	Vanilla	Madagascar
Vanilla	Comoros	Cake of groundnuts	Gambia	Cloves	Madagascar
Vanilla	Madagascar	Groundnut oil	Gambia	Coffee husks and skins	Tanzania
Coffee husks and skins	Uganda	Cashew nuts, with shell	Benin	Tobacco, unmanufactured	Malawi
Cloves	Madagascar	Groundnuts shelled	Gambia	Cotton carded, combed	Malawi
Oil essential nes	Comoros	Cashew nuts, with shell	Gambia	Cashew nuts, with shell	Tanzania
Coffee husks and skins	Burundi	Groundnut oil	Senegal	Cake of cottonseed	Zimbabwe
Sesame seed	Ethiopia	Copra	Gambia	Cake of cottonseed	Tanzania
Skins dry slt sheep	Ethiopia	Cake of groundnuts	Senegal	Cotton carded, combed	Tanzania
Coffee subst. cont. coffee	Rwanda	Cake of cottonseed	Benin	Cloves	Tanzania
Coffee husks and skins	Kenya	Rubber nat dry	Liberia	Coffee subst. cont. coffee	Malawi
Goat meat	Ethiopia	Cottonseed oil	Togo	Sesame oil	Tanzania
Cotton carded, combed	Uganda	Cottonseed oil	Benin	Cashew nuts, with shell	Mozambique
Sesame seed	Eriteria	Sugar beet	Gambia	Hides nes	Zimbabwe
Tobacco, unmanufactured	Malawi	Cashew nuts, with shell	Cote D'Ivoire	Cotton linter	Zimbabwe
Oilseeds, nes	Ethiopia	Cotton linter	Benin	Tobacco, unmanufactured	Zimbabwe
Broad beans, horse beans, dry	Ethiopia	Cocoa beans	Cote D'Ivoire	Cotton linter	Malawi
Cotton carded, combed	Burundi	Cake of Groundnuts	Togo	Tea	Malawi
Skinsdry sltsheep	Rwanda	Cocoa paste	Cote D'Ivoire	Cotton waste	Malawi
Tea	Rwanda	Cocoa beans	Ghana	Peas, green	Zimbabwe

Source: Authors' calculations based on FAOSTAT 2014

Table 16.2 Estimation of RCA variability across countries and products

Source of variance	Sequential sum of square	Mean squared	*F*	*P*-value	Share of variation explained
Model	1489.66	6.03	46.63	0.00	72.86 %
Country	936.94	23.42	181.09	0.00	45.82 %
Commodity	552.44	2.68	20.73	0.00	27.02 %
Year	0.28	0.28	2.19	0.14	0.01 %
Residual	555.03	0.129			27.14 %
Total	2044.69	0.45			
Number of obs.	4539	R^2 0.73	R^2 adj 0.71		

Note: The mean square (partial sum of squares/degrees of freedom) is used to compute the *F*-statistic and determine the significant amounts of variation. This ANOVA is without interaction terms due to the missing values from the unbalanced nature of the data. The time factor is included

(63 %) of the total variation of the RCA index among countries and commodities is accounted for by country-to-country variation. The balance of variation is explained by variation across products. The RCA index, like the previous two indicators, thus confirms the existence of dissimilar patterns of trade specialization in agricultural products.

So far, the analysis has established the existence of dissimilar patterns of specialization in production and trade of agricultural products among countries within and across the three major regions. Two final indicators, the Trade Overlap Indicator (TOI) and the Trade Expansion Indicator (TEI), are calculated to examine the potential to expand trade within the three blocks of countries based on current trade patterns.

The indicators measure how much of the same product a given country or region exports and imports at the same time. The TOI measures the overall degree of overlapping trade flows for a country or region as a whole, while the TEI measures the overlapping trade flows at the individual product level for a country or region. The results are presented in Fig. 16.4 and Table 16.3. The results indicate that there is a considerable degree of overlapping trade flows: 25 % for Africa as a whole and as much as 40 % for the SADC region. Normalized TOI values, obtained by dividing country TOI values by the TOI value, for the respective regions can be found in Badiane et al. (2014). In the vast majority of cases, they are significantly less than 1. The overlapping regional trade must therefore be taking place between different importing and exporting countries. In other words, some countries are exporting (importing) the same products that are being imported (exported) by other member countries in their respective grouping, but in both cases to and from countries outside the region. By redirecting such flows, countries should be able to expand transborder trade within their groupings.

The TEI indicates which products have the highest potential for increased transborder trade based on the degree of overlapping trade flows. Table 16.3 lists the 20 products with the highest TEI value for each of the three regions. The lowest TEI value for any of the products across the three regions is 0.41. RCA values

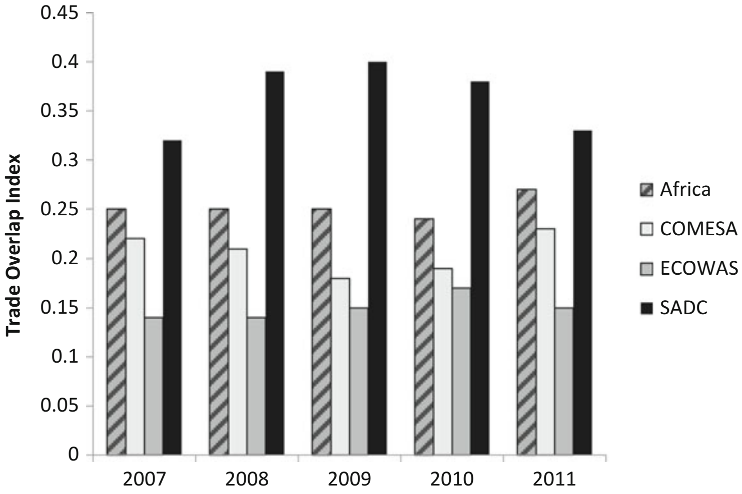

Fig. 16.4 Trade overlap indicators, average 2007–2011. *Source*: Authors' calculations based on FAOSTAT 2014

for the same products presented in Badiane et al. (2014) are all greater than 1, except for only three products: fresh fruits in ECOWAS, bananas in COMESA, and chocolate products in SADC. The fact that products with high TEI also have high RCA indicator values point to a real scope for transborder trade expansion in all three subregions.

The findings above indicate a real potential to expand intra-trade in all three regions beyond the levels shown in Table 16.1, even with current production and trade patterns. The remainder of the chapter therefore analyzes the outlook for intra-trade expansion and the expected impact of volatility of regional food markets over the next 15 years. This is done by simulating alternative policy scenarios to boost intra-regional trade and by comparing the resulting effect on the level and volatility of trade flows up to 2025 with outcomes simulated under a baseline scenario that assumes continuation of historical trends.

Table 16.3 Trade expansion indicators, average 2007–2011

COMESA		ECOWAS		SADC	
Commodity	TEI value	Commodity	TEI value	Commodity	TEI value
Beans, dry	0.825	Tobacco products	0.926	Pepper (piper spp.)	0.919
Sugar confectionery	0.821	Fatty acids	0.763	Cake, cottonseed	0.856
Vegetables, preserved	0.819	Groundnuts, shelled	0.744	Cottonseed	0.849
Juice, fruit	0.819	Hides, cattle, wet salted	0.681	Cigarettes	0.815
Cigarettes	0.782	Coffee, extracts	0.676	Hair, fine	0.811
Spices	0.716	*Fruit, fresh*	0.620	Bran, wheat	0.797
Sugar raw centrifugal	0.716	Fruit, tropical fresh	0.592	Waters, ice, etc.	0.783
Fruit, prepared	0.703	Cigarettes	0.573	Bran, maize	0.782
Groundnuts, shelled	0.700	Tea, mate extracts	0.535	Fruit, dried	0.776
Cake, cottonseed	0.680	Oilseeds	0.524	Sugar	0.774
Pineapples	0.677	Onions, dry	0.513	Cider, etc.	0.762
Cereal preparations	0.665	Oil, cottonseed	0.510	Molasses	0.759
Anise, badian, fennel, coriander	0.655	Pepper (piper spp.)	0.479	*Juice, fruit*	0.749
Waters, ice, etc.	0.655	Margarine short	0.456	Onions, dry	0.743
Cheese, whole cow milk	0.604	Roots and tubers	0.454	Flour, cereals	0.730
Bananas	0.592	Cereal preparations	0.439	*Chocolate products*	0.723
Bran, wheat	0.586	Chickpeas	0.415	Meat, pig, preparations	0.715
Tobacco products	0.586	Vegetables fresh or dried products	0.412	Cauliflowers and broccoli	0.712
Pepper (piper spp.)	0.578	*Fruit, prepared*	0.412	Coconut(copra) oil	0.705
Orange juice, single strength	0.566	Pineapple, canned	0.406	Vegetables frozen	0.697

Source: Authors' calculations based on FAOSTAT 2014. *Note*: Italics denote products with RCA < 1; products with high TEI but which are not being produced in the regions are included as they relate to re-export trade. There were two in the case of COMESA and SADC and six in the case of ECOWAS

16.4 The Outlook for Regional Cross-Border Trade and Market Volatility Under Alternative Scenarios

The preceding analysis presents evidence that African countries could use increased regional trade to enhance the resilience of domestic markets to supply shocks. The high cost of moving goods across domestic and transborder markets and outwardly biased trading infrastructure are major determinants of the level and direction of trade among African countries. A strategy to exploit the regional stabilization potential therefore has to include measures to lower the general cost of trading and remove additional barriers to cross-border trade. This section simulates the impact of such changes on regional trade flows, using IFPRI's regional Economy-wide Multimarket Model (EMM) described below.[4]

16.4.1 The Regional Trade Simulation Model

In this study, the original EMM was modified to differentiate between intra- and extra-regional trade sources and destinations and between informal and formal trade costs in intra-regional trade transactions. In its original version, the EMM solves for optimal levels of supply $QX_{r\,c}$, demand $QD_{r\,c}$ and net trade (either import $QM_{r\,c}$ or export $QE_{r\,c}$) of different commodities c for individual member countries r of the modeled region.

Supply and demand balance at the national level determines domestic output prices $PX_{r\,c}$ as stated by Eq. (16.1), while Eq. (16.2) connects domestic market prices $PD_{r\,c}$ to domestic output prices, taking into account an exogenous domestic marketing margin $margD_{r\,c}$. The net trade of a commodity in a country is determined through mixed complementarity relationships between producer prices and potential export quantities and between consumer prices and potential import quantities. Accordingly, Eq. (16.3) ensures that a country will not export a commodity ($QE_{r,c} = 0$) as long as the producer price of that commodity is higher than its export parity price, where $pwe_{r\,c}$ is the country's FOB price and $margW_{r\,c}$ is an exogenous trade margin accounting for the cost of moving the commodity to and from the border. If the domestic market balance constraint in Eq. (16.1) requires that the country exports some excess supply of a commodity ($QE_{r,c} > 0$), then the producer price will be equal to the export parity price of that commodity. Additionally, Eq. (16.4) governs any country's possibility to import a commodity, where $pwm_{r\,c}$ is its CIF price. There will be no import ($QM_{r,c} = 0$) as long as the import parity price of a commodity is higher than its domestic consumer price. The domestic market balance constraint requires that, if a country has to import a commodity to meet a given excess demand ($QM_{r,c} > 0$), then the domestic consumer price will be equal to the import parity price of that commodity.

[4] See Diao et al. (2007) and Nin-Pratt et al. (2011).

$$\mathrm{QX}_{r\,c} + \mathrm{QM}_{r\,c} - \mathrm{QE}_{r\,c} = \mathrm{QD}_{r\,c} \tag{16.1}$$

$$\mathrm{PX}_{r\,c} \cdot (1 + \mathrm{marg}D_{r\,c}) = \mathrm{PD}_{r\,c} \tag{16.2}$$

$$\mathrm{PX}_{r\,c} \geq \mathrm{pwe}_{r\,c} \cdot (1 - \mathrm{marg}W_{r\,c}) \quad \perp \quad \mathrm{QE}_{r,c} \geq 0 \tag{16.3}$$

$$\mathrm{pwm}_{r\,c} \cdot (1 + \mathrm{marg}W_{r\,c}) \geq \mathrm{PD}_{r\,c} \quad \perp \quad \mathrm{QM}_{r,c} \geq 0 \tag{16.4}$$

In the version of the EMM used in this study, the net export of any commodity is modeled as an aggregate of two output varieties differentiated by their market outlets (regional and extra-regional) while assuming an imperfect transformability between the two export varieties. Similarly, the net import of any commodity is modeled as a composite of two varieties differentiated by their origins (regional and extra-regional) while assuming an imperfect substitutability between the two import varieties.

In order to implement export differentiation by destination, the mixed complementarity relationship in Eq. (16.3) is replaced with two new equations which specify the price conditions for export to be possible to both destinations. Equation (16.5) indicates that for export to extra-regional market outlets to take place ($\mathrm{QEZ}_{r\,c} > 0$), suppliers should be willing to accept a price $\mathrm{PEZ}_{r\,c}$ that is not greater than the export parity price when exporting to that destination. Similarly, Eq. (16.6) ensures that exporting to within-region market outlets is possible ($\mathrm{QER}_{r\,c} > 0$) only if suppliers are willing to receive a price $\mathrm{PER}_{r\,c}$ that is not more than the regional market clearing price $\mathrm{PR_c}$ adjusted downward to account for exogenous regional trade margins $\mathrm{marg}R_{r\,c}$ incurred in moving the commodity from the farm gate to regional market (see Eq. (16.17) below for the determination of $\mathrm{PR_c}$).

$$\mathrm{PEZ}_{r\,c} \geq \mathrm{pwe}_{r\,c} \cdot (1 - \mathrm{marg}W_{r\,c}) \quad \perp \quad \mathrm{QEZ}_{r\,c} \geq 0 \tag{16.5}$$

$$\mathrm{PER}_{r\,c} \geq \mathrm{PR_c} \cdot (1 - \mathrm{marg}R_{r\,c}) \quad \perp \quad \mathrm{QER}_{r\,c} \geq 0 \tag{16.6}$$

Subject to these price conditions, Eqs. (16.7)–(16.10) determine the aggregate export quantity and its optimal allocation to alternative destinations. Equation (16.7) indicates that the aggregate export of a commodity by individual countries $\mathrm{QE}_{r\,c}$ is obtained through a constant elasticity of transformation (CET) function of the quantity $\mathrm{QEZ}_{r\,c}$ exported to extra-regional market outlets and the quantity $\mathrm{QER}_{r\,c}$ exported to intra-regional market outlets, where $\rho^e_{r\,c}$, $\delta^e_{r\,c}$, and $\alpha^e_{r\,c}$ are the CET function exponent, share parameter, and shift parameter, respectively. Equation (16.8) is the first-order condition of an aggregate export revenue maximization problem, given the prices that suppliers can receive for the different export destinations and subject to the CET export aggregation function. The equation indicates that an increase in the ratio of intra-regional to extra-regional prices will increase the ratio of intra-regional to extra-regional export quantities (i.e., exports shift toward destinations which offer higher returns). Equation (16.9) helps identify the optimal quantities supplied to each destination; it states that aggregate export revenue at producer price of export $\mathrm{PE}_{r\,c}$ is the sum of export sales revenues from both intra-regional and extra-regional market outlets at supplier prices, while Eq. (16.10) sets the producer price of export to be the same as the domestic output price $\mathrm{PX}_{r\,c}$, which is determined by the supply and demand balance equation (Eq. 16.1) as earlier explained.

$$\mathrm{QE}_{r\,c} = \alpha^{e}_{r\,c} \cdot \left(\delta^{e}_{r\,c} \cdot \mathrm{QER}_{r\,c}^{\rho^{e}_{r\,c}} + \left(1 - \delta^{e}_{r\,c}\right) \cdot \mathrm{QEZ}_{r\,c}^{\rho^{e}_{r\,c}}\right)^{\frac{1}{\rho^{e}_{r\,c}}} \tag{16.7}$$

$$\frac{\mathrm{QER}_{r\,c}}{\mathrm{QEZ}_{r\,c}} = \left(\frac{\mathrm{PER}_{r\,c}}{\mathrm{PEZ}_{r\,c}} \cdot \frac{1 - \delta^{e}_{r\,c}}{\delta^{e}_{r\,c}}\right)^{\frac{1}{\rho^{e}_{r\,c} - 1}} \tag{16.8}$$

$$\mathrm{PE}_{r\,c} \cdot \mathrm{QE}_{r\,c} = \mathrm{PER}_{r\,c} \cdot \mathrm{QER}_{r\,c} + \mathrm{PEZ}_{r\,c} \cdot \mathrm{QEZ}_{r\,c} \tag{16.9}$$

$$\mathrm{PE}_{r\,c} = \mathrm{PX}_{r\,c} \tag{16.10}$$

Import differentiation by origin is implemented by following the same procedure for export differentiation by destination, as described above. Equation (16.4) is replaced by Eqs. (16.11) and (16.12). Accordingly, import from extra-regional origins will happen ($\mathrm{QMZ}_{r,c} > 0$) only if domestic consumers are willing to pay a price $\mathrm{PMZ}_{r\,c}$ that is not smaller than the import parity price for the extra-regional variety. Furthermore, import from intra-regional origins is possible ($\mathrm{QMR}_{r,c} > 0$) only if domestic consumers are willing to pay at a price $\mathrm{PMR}_{r\,c}$ that is not smaller than the regional market clearing price PR_{c} adjusted upward to account for exogenous regional trade margins $\mathrm{marg}R_{r\,c}$ incurred in moving the commodity from the regional market to consumers.

$$\mathrm{pwm}_{r\,c} \cdot (1 + \mathrm{marg}W_{r\,c}) \geq \mathrm{PMZ}_{r\,c} \quad \perp \quad \mathrm{QMZ}_{r,c} \geq 0 \tag{16.11}$$

$$\mathrm{PR}_{r} \cdot (1 + \mathrm{marg}R_{r\,c}) \geq \mathrm{PMR}_{r\,c} \quad \perp \quad \mathrm{QMR}_{r\,c} \geq 0 \tag{16.12}$$

Under these price conditions, Eq. (16.13) represents aggregate import quantity $\mathrm{QM}_{r\,c}$ as a composite of intra- and extra-regional import variety quantities $\mathrm{QMR}_{r\,c}$ and $\mathrm{QMZ}_{r\,c}$, respectively, using a constant elasticity of substitution (CES) function; in the equation, the terms $\rho^{m}_{r\,c}$, $\delta^{m}_{r\,c}$, and $\alpha^{m}_{r\,c}$ stand for the CES function exponent, share parameter, and shift parameter, respectively. The optimal mix of the two varieties is defined by Eq. (16.14), which is the first-order condition of an aggregate import cost minimization problem, subject to the CES aggregation (Eq. 16.13) and given import prices from both origins. An increase in the ratio of extra-regional to intra-regional import prices will increase the ratio of intra-regional to extra-regional import quantities (i.e., imports shift away from more expensive sources). Equation (16.15) identifies the specific quantities imported from each origin. It defines the total import cost at consumer price of import $\mathrm{PM}_{r\,c}$ as the sum of intra-regional and extra-regional import costs, while Eq. (16.16) sets the consumer price of import to be the same as the domestic market price $PD_{r\,c}$, which is determined by Eqs. (16.1) and (16.2), as earlier explained

$$QM_{r\,c} = \alpha^m_{r\,c} \cdot \left(\delta^m_{r\,c} \cdot QMR_{r\,c}^{-\rho^m_{r\,c}} + \left(1 - \delta^m_{r\,c}\right) \cdot QMZ_{r\,c}^{-\rho^m_{r\,c}}\right)^{-\frac{1}{\rho^m_{r\,c}}} \tag{16.13}$$

$$\frac{QMR_{r\,c}}{QMZ_{r\,c}} = \left(\frac{PMZ_{r\,c}}{PMR_{r\,c}} \cdot \frac{\delta^m_{r\,c}}{1 - \delta^m_{r\,c}}\right)^{\frac{1}{1+\rho^m_{r\,c}}} \tag{16.14}$$

$$PM_{r\,c} \cdot QM_{r\,c} = PMR_{r\,c} \cdot QMR_{r\,c} + PMZ_{r\,c} \cdot QMZ_{r\,c} \tag{16.15}$$

$$PM_{r\,c} = PD_{r\,c} \tag{16.16}$$

After determining export quantities and prices by destination, and import quantities and prices by origin, the regional market clearing price PR_c can now be solved. Equation (16.17) imposes the regional market balance constraint by equating the sum of intra-regional export supplies to the sum of intra-regional import demands, with $qdstk_c$ standing for discrepancies existing in observed aggregate intra-regional export and import quantity data in the model's base year. Thus, PR_c is the price that ensures regional market balance.

$$\sum\nolimits_r QER_{r\,c} = \sum\nolimits_r QMR_{r\,c} + qdstk_c \tag{16.17}$$

The model is calibrated separately for each of the three RECs. Calibration is performed such that for every member country within each REC, the same production, consumption, and net trade data are replicated as observed for different agricultural subsectors and two nonagricultural subsectors in 2007–2008. Baseline trend scenarios are then constructed such that until 2025, changes in crop yields, cultivated areas, outputs, and GDP reflect the same observed changes. Table 16.6 in the annex compares the calibrated agricultural and economy-wide GDP growth rates under the baseline scenario with the observed rates in the recent years. Although the model is calibrated to the state of national economies 7 years earlier, it closely reproduces the countries' current growth performances.

Four different scenarios are simulated using the EMM. The first is the baseline scenario described above, which assumes a continuation of current trends up to 2025. It is used later as a reference to evaluate the impact of the changes under the remaining three scenarios. The latter scenarios introduce the following three different sets of changes to examine their impacts on regional trade levels: a reduction of 10 % in the overall cost of trading in every country; removal of all cross-border trade barriers–that is, a reduction of their tariff equivalent to zero; and a 10 % yield increase across the board. These changes are modeled to take place between 2008 (the base year) and 2025. The change in cross-border exports is used as an indicator of the impact on intra-regional trade. In the original data, there are large discrepancies between recorded regional exports and import levels, the value of the latter often being multiples of the former. The more conservative export figures are therefore the preferred indicator of intra-regional trade.

16.4.2 Intra-trade Simulation Results

The results for the different regions are presented in Figs. 16.5 and 16.6. Figure 16.5 presents the results of the baseline scenarios for the three regions from 2008 to 2025. Assuming the current trends to continue, intra-regional trade in both ECOWAS and SADC is expected to expand rapidly but with marked differences between crops. The aggregate volume of intra-regional trade in staples would approach 3 million tons in the case of ECOWAS and about half of that amount in the case of SADC if the growth rates in yields, cultivated areas, and nonagricultural income sustained at their current level until 2025. Cereals would see the smallest gains, while trade in roots and tubers as well as other food crops would experience much faster growth in the case of ECOWAS. This is in line with the current structure of and trends in commodity demand and trade. While the increase in demand for roots and tubers is being met almost exclusively using local sources, the fast growing demand for cereals is heavily tilted toward rice, which is supplied from outside the region. The two leading cereals that are traded regionally, maize and millet, therefore benefit less from the expansion of regional demand and have historically seen slower growth in trade than roots and tubers. In the case of SADC, the rise of Angola as a main exporter of roots and tubers starting in 2013 is a main factor in explaining the strong boost in regional trade of that commodity. Zimbabwe had been the sole exporter of roots and tubers before 2013 and exported only very modest quantities. Hence, the high rates of growth of overall regional exports can be attributed to the developments in Angola.

The story is a bit different in the case of COMESA. As was already made apparent by the market share analysis earlier, the COMESA regional market has been the least dynamic of the three regional markets and the only one associated with a negative market effect. COMESA is the only region where the member countries have experienced a decline in competitiveness as a whole. The underwhelming performance is reflected in the baseline scenario. If current trends were to continue, the levels of intra-regional trade would continue to stagnate, except in the case of cereals. And even for this group of products, the decline in trade volumes would be reversed, but the reversal would not be enough to bring the trade volumes back to their initial levels. The projected evolution of the trade in cereals reflects different country dynamics and a shift in the sources of regional exports. The fall in regional trade levels at the beginning of the period is a result of a continual decline in exports from the two main traditional suppliers Egypt and Malawi. At the same time, the faster growth in several other countries, particularly Tanzania and Ethiopia, results in rising exports from these countries, starting from 2011 for Tanzania and from 2019 for Ethiopia. The result is a U-shaped pattern in COMESA cereals exports: the declining exports in some countries are eventually offset by the increasing imports in other countries. The graphs in Fig. 16.6 show the cumulated changes in intra-

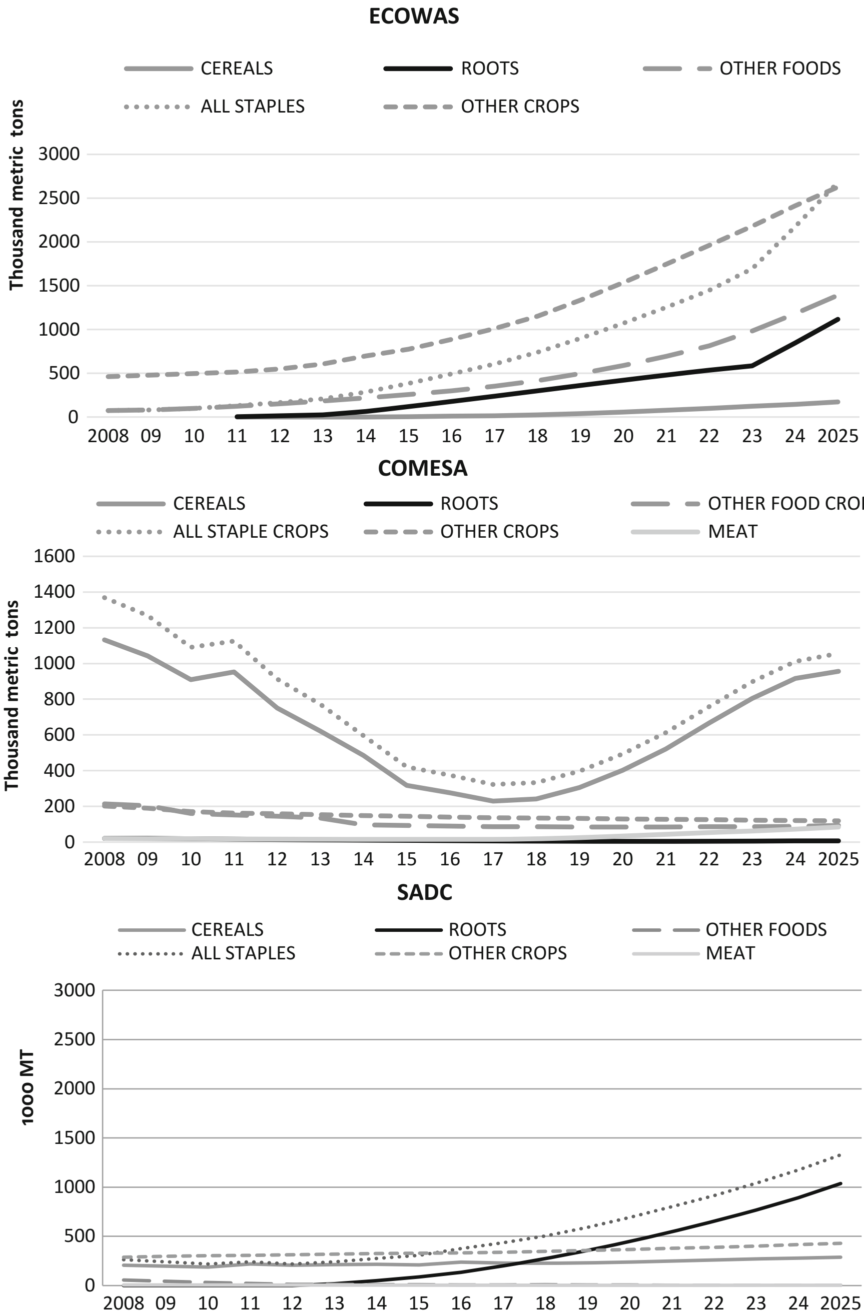

Fig. 16.5 Regional exports outlook, baseline. *Source*: Authors' calculation

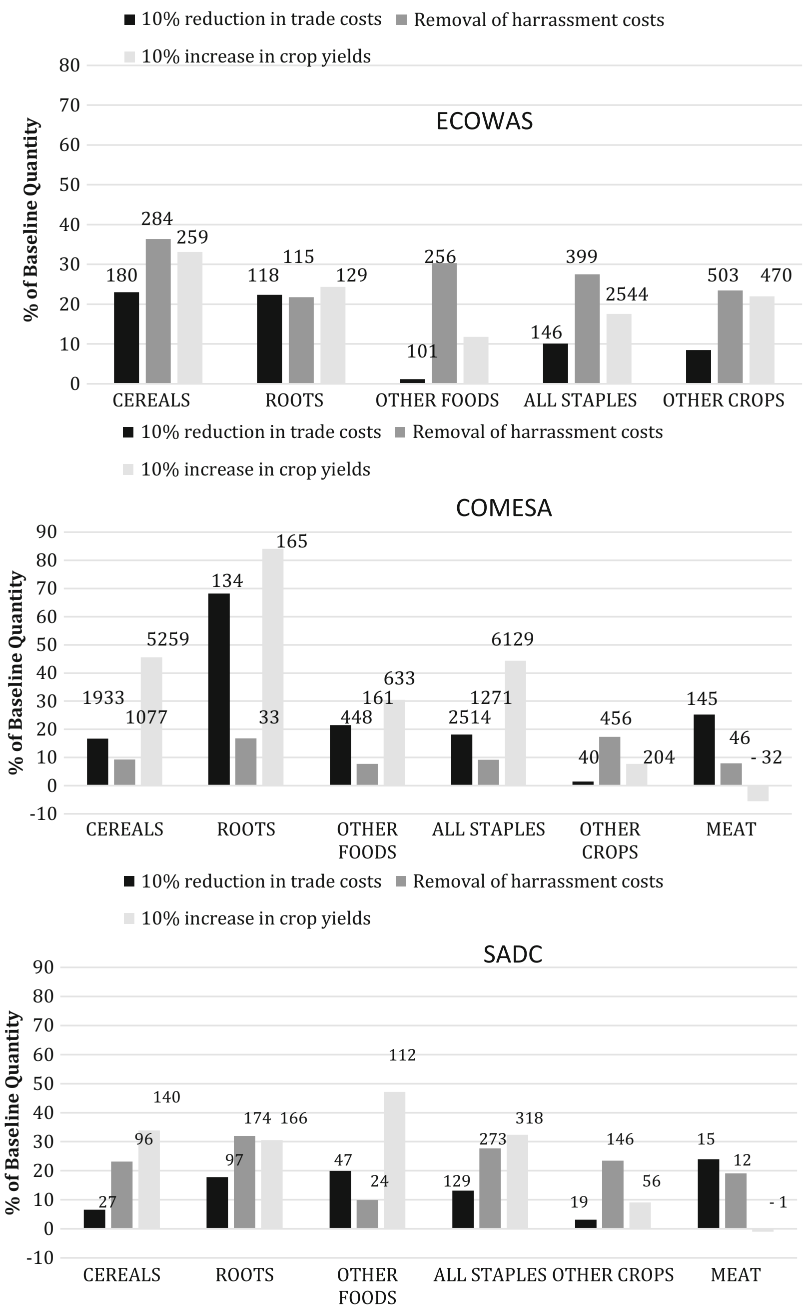

Fig. 16.6 Changes in cost, yields, and exports. *Source*: Authors' calculation. *Note*: Figures above the *bars* indicate cumulative increases in regional export supply in 1000 mt. Other crops include all or subset of the following crops: fruits and vegetables, cotton, sugar, cocoa, coffee, tea, tobacco, spices, and nuts

regional export levels by 2025 compared with the baseline results; the changes are the result of a reduction in total trading cost, removal of transborder trade barriers, and a yield increase. The bars represent the percentage changes, and the numbers above the bars indicate the corresponding absolute changes in 1000 metric tons. The results show that intra-regional trade invariably increases by a considerable margin for cereals and roots and tubers (the main food crops) in response to changes in trading costs and yields. Intra-community trade levels in ECOWAS climb by between 10 and 35 % for most products over the entire period. By 2025, when compared to baseline trends, the volume of cereal trade increases by a cumulative total of between 200,000 and 300,000 mt for individual products and the volume of overall staple trade by between 1.5 and 4.0 million tons. Cereals seem to respond better than other products in general. It also appears that removing transborder trade barriers would have the strongest impact of trade flows across the board.

The COMESA region shows similar increases in overall trade in staples. Cereals trade tends to be proportionally less responsive but because of its initial higher levels, the cumulative additional volume of regional trade is much higher, ranging from 0.7 million to more than 3.0 million tons above the baseline. Also, in contrast to ECOWAS, intra-regional trade in COMESA seems to be more responsive to changes in overall trading costs and yields than to changes in cross-border barriers. This may be explained by the fact that equivalent tariffs constitute a smaller fraction of producer prices, and hence changes in barriers result in smaller changes in incentives. Trade in the SADC region also seems to respond more to changes in transborder trade barriers and yields, as in the case of ECOWAS. A 10 % increase in yields would raise trade in staples by a cumulative volume of slightly more than 3.0 million tons by 2025 compared to the baseline scenario.

16.4.3 Regional Market Volatility Under Alternative Policy Scenarios

Under each scenario, the model-simulated quantities of intra-regional exports $\mathrm{QER}_{r\,c}$ are used to estimate an index of future export volatility at country and regional level as follows: First, a trend-corrected coefficient of variation TCV is calculated for each country, using the following formula as in Cuddy and Della Valle (1978):

$$\mathrm{TCV} = \mathrm{CV} \cdot \sqrt{\left(1 - \overline{R^2}\right)} \tag{16.18}$$

where CV is the coefficient of variation and $\overline{R^2}$ is the adjusted coefficient of determination of the linear trend regression obtained using the time series of aggregate quantities of intraregional exports of all staple food crops from 2008 to 2025.

Second, an index of regional volatility TCV_{REC} is derived for each REC as a weighted average of trend-corrected coefficients of variation of its member countries with the formula

$$TCV_{REC}^2 = \sum_i^n s_i^2 \cdot TCV_i^2 + 2\sum_i^n \sum_j^n s_i \cdot s_j \cdot v_{ij} \cdot TCV_i \cdot TCV_j \qquad (16.19)$$

where TCV_i and TCV_j are the trend-corrected coefficients of variation in aggregate exports of staple food crops in countries i and j, n is the number of member countries in the REC, s_i and s_j are the shares of countries i and j in the region's overall intra-regional exports of staple food crops, and v_{ij} is the coefficient of correlation between aggregate exports of countries i and j. Finally, the coefficients of variation at country level are normalized by dividing them by the respective regional coefficients.

The historical and simulated levels of cross-border trade volatility of food staples in the various regions are reported in Table 16.4. The volatility levels simulated under historical trends are calculated based on the TradeMaps database.[5] Table 16.5 shows the comparison of the simulated volatility levels under the various alternative scenarios with historical volatility levels, with the difference expressed in absolute point changes. The figures in the two tables show that volatility levels are lower under nearly all scenarios than under historical trends. The only exception is in the case of ECOWAS, where regional cross-border trade volatility decreases with a reduction of overall trading costs, but it rises when cross-border trade barriers

Table 16.4 Regional cross-border trade volatility under various scenarios

	Historical trend (1996–2012)	Baseline trend (2008–2025)	10 % reduction in trade costs (2008–2025)	Removal of cross-border trade barriers (2008–2025)	10 % increase in crop yields (2008–2025)
ECOWAS	0.345	0.33	0.323	0.354	0.378
COMESA	0.682	0.55	0.505	0.551	0.449
SADC	0.73	0.126	0.131	0.173	0.151

Source: Authors calculations from TradeMaps database and EMM model simulation results

[5]In the SADC case, baseline and historical trends of the trade volatility deviate a lot. The main explanation is that, unlike traditional CGE models where countries are exporters or importers from the beginning and remain as such for the length of the simulation period, our model allows countries to enter or exit the regional export market based on relative prices. Therefore, we have used historical production as opposed to trade data to calibrate the model, given that not all countries have historical trade data. The baseline volatility of trade flows is therefore not a result of calibration but rather derives from the calibrated baseline production and its induced trade flows. The SADC region, unlike other regions, has undergone a major structural change in terms of the composition and source of production and thus trade of agricultural products, with Angola, a new player, emerging as the most important trading partner and roots and tubers as the single most important traded agricultural commodity. The projected overwhelming dominance of the more stable Angola in regional production and trade under continuation of current trends is the main explanation of the drop in baseline export volatility.

Table 16.5 Change in regional trade volatility under alternative scenarios (2008–2025)

	Baseline trend	10 % reduction in trade costs	Removal of cross-border trade barriers	10 % increase in crop yields
Absolute point change compared to historical trend				
ECOWAS	−0.015	−0.022	0.009	0.033
COMESA	−0.132	−0.178	−0.132	−0.234
SADC	−0.604	−0.600	−0.557	−0.579

Source: Authors calculations from TradeMaps database and EMM model simulation results

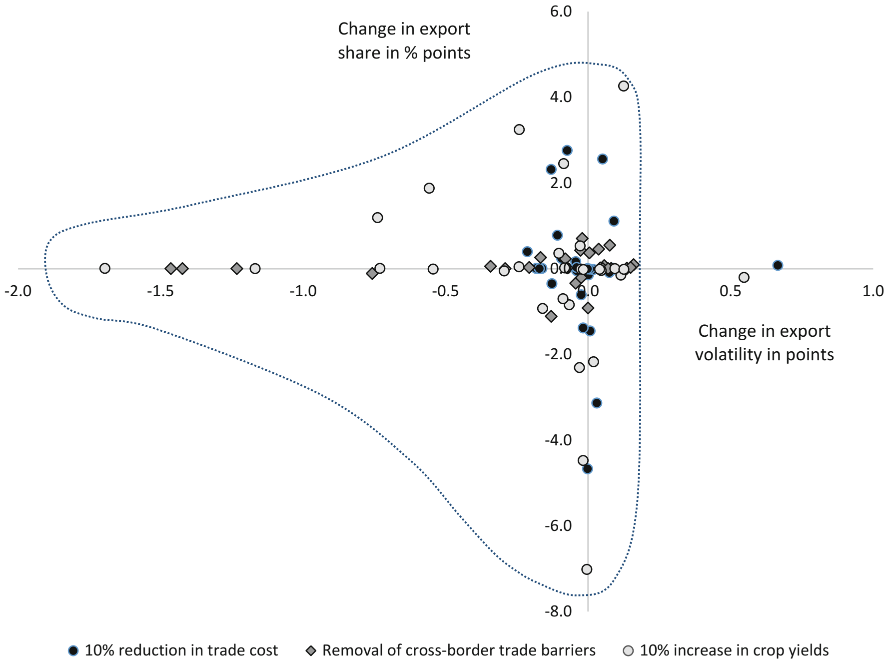

Fig. 16.7 Changes in country export shares and volatility compared to baseline trends

are removed or when yields are increased. The magnitude of changes are, however, rather small across all three scenarios. The figures also show that when the current trend of rising volumes of intra-regional trade continues, volatility levels in all three regions are expected to decline compared to historical trends. A better comparison is therefore to contrast changes that take place under the two trade policy scenarios and the productivity (meaning increasing yields) scenario with the expected volatility levels under the baseline scenario. Furthermore, the direction and magnitude of changes in the level of intra-regional trade volatility are determined by the combined effect of changes in the level of volatility as well as changes in the share of cross-border exports in individual countries. Figure 16.7 above shows changes in volatility levels (x-axis) and shares of exports (y-axis) by individual countries under each of the scenarios when compared with the baseline. The different dots indicate the position of different countries under the three scenarios. The tilted distribution of country positions to the left of the x-axis indicates that most countries' exports would experience a lower level of volatility.

The combined changes in export share and volatility for individual countries under each of the scenarios are reported in Table 16.7 and presented in Figs. 16.8, 16.9, 16.10 in the Annex. Only countries that have historically exported are considered. Changes in a country's production patterns resulting from the simulated policy actions lead to changes in both the volatility and the level of exports,and hence the shares in regional trade of each country. The magnitude and direction of these changes determine the contribution of individual countries to changes in the volatility level in regional food markets.

16.5 Conclusions

The current chapter has examined the potential to use increased intra-regional trade among Africa's main regional economic communities as a means to raise the resilience of domestic food markets to shocks across their member countries. The distribution and correlation of production volatility as well as the current patterns of specialization in the production and trade of agricultural products among African countries suggest that it is indeed possible to raise cross-border trade to reduce the level of instability of local food markets. The results of the baseline scenario indicate that continuation of recent trends would sustain the expansion of intra-regional trade flows in all three regions, particularly in the ECOWAS region. The findings also reveal that it is possible to significantly boost the pace of regional trade expansion, which in turn would contribute to creating more resilient domestic food markets through modest reduction in the overall cost of trading, a similarly modest increase in crop yields, or the removal of barriers to transborder trade. More importantly, the simulation results also suggest that such policy actions to promote transborder trade would reduce volatility in regional markets and help lower the vulnerability of domestic food markets to shocks.

Appendix

Table 16.6 GDP and agricultural growth rates under baseline and recent trends

	agrGDP		GDP			agrGDP		GDP	
	Baseline	Trends	Baseline	Trends	Baseline	Trends	Baseline	Trends	
Benin	5.23	4.85	4.84	5.13	Burundi	2.50	2.51	6.12	6.70
Burkina Faso	5.36	5.48	5.67	5.50	Comoros	2.75	2.75	3.26	2.60
Cape Verde	2.37	2.03	6.89	7.50	D. R. Congo	1.25	1.25	2.43	2.20
Chad	1.83	1.33	5.61	8.00	Djibouti	2.31	3.24	9.04	3.00
Cote d'Ivoire	2.74	2.21	3.95	3.69	Egypt	3.33	3.39	6.25	5.20
Gambia	4.53	3.96	7.00	7.19	Eritrea	5.26	5.36	5.60	2.90
Ghana	3.56	3.48	6.44	7.06	Ethiopia	6.51	6.52	9.08	8.20
Guinea	5.17	5.00	4.25	4.33	Kenya	2.42	2.17	2.03	3.40
Guinea Bissau	4.02	3.97	3.86	4.30	Libya	1.39	1.43	3.05	2.20
Liberia	2.55	2.00	4.02	5.09	Madagascar	1.99	1.98	3.18	3.90
Mali	3.70	3.26	5.24	6.26	Malawi	1.57	1.57	1.90	2.70
Mauritania	2.54	2.46	4.49	3.22	Mauritius	3.31	3.31	4.58	5.00
Niger	3.25	3.19	2.61	2.84	Rwanda	5.28	5.30	9.39	7.60
Nigeria	5.04	5.00	5.62	4.79	Seychelles	1.48	1.47	−1.89	2.30
Senegal	2.75	2.30	3.52	3.44	Sudan	2.50	2.45	6.40	7.20
Sierra Leone	4.94	4.83	6.08	5.67	Swaziland	1.03	1.11	2.85	2.60
Togo	2.31	1.63	4.54	6.66	Tanzania	4.64	4.65	7.60	6.00
					Uganda	3.01	3.01	6.51	8.10
					Zambia	1.06	0.95	3.49	6.30
					Zimbabwe	−0.51	−0.68	−0.85	1.00

Source: Authors' calculations

Table 16.7 Change in volatility and share of staple exports under alternative scenarios, 2008–2025

	Change in volatility compared to baseline (points)			Change in share compared to baseline (% points)		
	10 % reduction in trade cost	Removal of cross-border trade barriers	10 % increase in crop yields	10 % reduction in trade cost	Removal of cross-border trade barriers	10 % increase in crop yields
Benin	−0.073	−0.043	−0.085	2.756	−0.338	2.448
Burkina Faso	−0.213	0.077	−0.027	0.398	0.545	0.530
Ivory Coast	−0.126	−0.026	−0.066	−0.351	0.428	−0.843
Gambia	−0.039	−0.206	−0.294	−0.047	0.026	−0.052
Ghana	−0.023	−0.079	−0.088	−0.609	0.227	−0.704
Guinea	0.002	0.160	0.116	−0.144	0.095	−0.151
Guinea-Bissau	0.086	0.055	−0.082	0.009	0.005	0.016

(continued)

Table 16.7 (continued)

	Change in volatility compared to baseline (points)			Change in share compared to baseline (% points)		
	10 % reduction in trade cost	Removal of cross-border trade barriers	10 % increase in crop yields	10 % reduction in trade cost	Removal of cross-border trade barriers	10 % increase in crop yields
Liberia	−0.001	0.136	0.094	−0.002	0.003	−0.002
Mali	0.031	0.057	−0.017	−3.137	0.069	−4.475
Niger	0.091	−0.129	−0.241	1.111	−1.115	3.247
Senegal	0.019	0.137	0.126	−0.020	0.014	−0.016
Sierra Leone	0.666	−0.073	−0.242	0.075	0.016	0.045
Togo	0.083	0.150	0.046	−0.038	0.026	−0.042
Egypt	−0.129	−0.020	−0.102	2.315	0.701	0.360
Eritrea	0.075	0.043	0.547	−0.091	0.014	−0.203
Ethiopia	0.052	0.005	0.125	2.557	0.368	4.261
Kenya	0.006	0.081	0.041	−0.009	0.004	−0.016
Libya	−0.001	0.001	−0.004	−4.669	−0.918	−7.018
Sudan	0.007	0.037	0.020	−1.456	0.453	−2.175
Angola	−0.043	−0.024	−0.030	0.165	−0.210	−2.306
Botswana	−0.002	0.052	−0.025	−0.003	0.001	−0.008
Congo, Dem. Rep	−0.182	−1.232	−0.730	0.004	0.000	0.006
Madagascar	−0.162	−1.423	−1.695	0.007	0.001	0.005
Malawi	−0.107	−0.757	−0.557	0.781	−0.114	1.876
Mozambique	−0.130	−1.288	6.099	0.165	0.007	0.194
South Africa	−0.017	−0.166	−0.159	−1.382	0.258	−0.927
Swaziland	−0.002	0.071	−0.016	−0.007	0.001	−0.022
Tanzania	−0.093	−0.342	−0.739	0.237	0.052	1.189
Zambia	−0.170	−1.464	−1.168	0.002	0.001	0.000
Zimbabwe	−0.039	−0.290	−0.543	0.030	0.003	−0.008

Source: Based on simulation results using Economy-wide Multimarket Models of ECOWAS, COMESA, and SADC regions

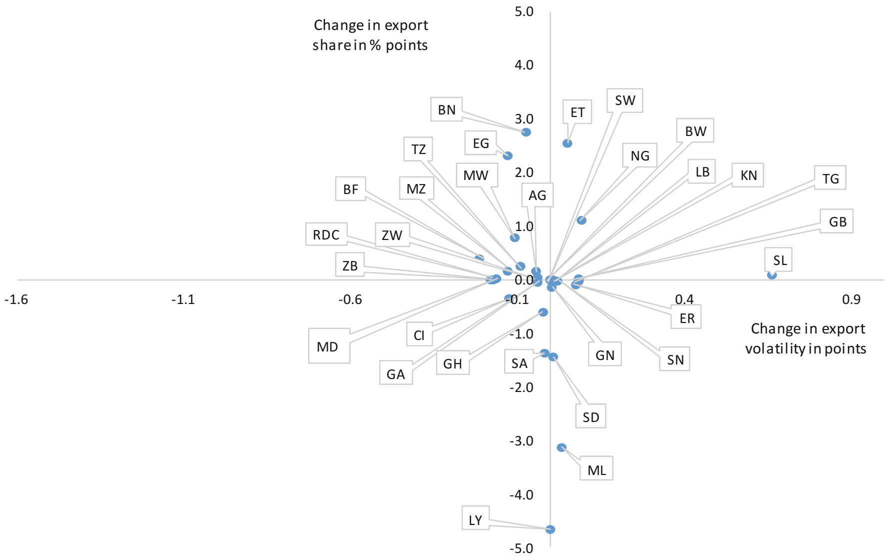

Fig. 16.8 Changes in country export share and volatility under 10 % reduction in trade costs compared to baseline. *Source*: Based on Table 16.7

Fig. 16.9 Changes in country export share and volatility under a removal of cross-border trade barriers compared to baseline. *Source*: Based on Table 16.7 above

Fig. 16.10 Changes in country export share and volatility under 10 % increase in crop yields compared to baseline. *Source*: Based on Table 16.7. *Note*: For the sake of clarity, values for Madagascar and Mozambique, which are too large compared to the rest, are not plotted in the figure

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ASEAN Food Reserve and Trade: Review and Prospect

17

Irfan Mujahid and Lukas Kornher

17.1 Introduction

High uncertainty and volatility of food prices in the recent years have renewed the interests of many countries in considering food reserves as an important instrument in managing food price instability. These reserves come back into the focus of policy agenda as a result of the huge doubts on the reliability of international trade to guarantee food supply. The 2008 crisis, in particular, highlighted that low levels of food stocks make countries vulnerable to excessive price volatility even only with low levels of supply or demand shocks (Wright 2009).

Countries in Southeast Asia have been using storage-based price stabilization for decades (Rashid et al. 2007). Grain price stabilization in the Philippines started in 1960s, carried out by Rice and Corn Administration (RCA) and Rice and Corn Board (RICOB). In Indonesia, price stabilization is managed by *Badan Urusan Logistik* (BULOG), a national food reserve agency created in 1967. At the regional level, the cooperation on food reserves has been ongoing since the late 1970s, when the original members of the Association of Southeast Asian Nations (ASEAN) established the Agreement on Food Security Reserve (AFSR). The ASEAN Emergency Rice Reserve (AERR) was created in 1979 with the initial earmarks of 50,000 tons of rice to serve as the subset of national stocks in addressing

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food emergencies in the region. However, due to small size of the stocks and its complex release mechanism, the AERR had never really been activated during the entire operational period of more than a quarter of a century (Dano 2006).

The recent food price crisis affecting almost all countries in the world led to a new phase of the regional reserve cooperation in Southeast Asia. The ten member countries of ASEAN, in partnership with China, Japan, and Korea, agreed on the ASEAN Plus Three Emergency Rice Reserve (APTERR), which entered into force in July 2012. The APTERR is a permanent reserve scheme which replaces the pilot project East Asia Emergency Rice Reserve (EAERR), which itself was presented as a metamorphosis of the AERR. The initial earmark of APTERR is 787,000 tons of rice, roughly twice the size of von Braun and Torero's (2008) proposal for a modest emergency grain reserve of 300,000–500,000 metric tons for the whole world. However, the APTERR has hardly been tested in practice. Since entering into force, only 200 tons of rice have been released at the end of 2012 for poverty alleviation and the malnutrition eradication program in Indonesia, and another 800 tons of rice in early 2014 for typhoon Haiyan victims in the Philippines. Several other small releases have been made during its pilot phase from 2004 to 2010.[1]

This study aims to review the storage-based price-stabilization policy in Southeast Asia, both at the national and regional level, and to discuss the prospect of the policy in the current era of price instability. The remainder of the article is organized as follows: Sect. 17.2 provides information on ASEAN market structure, which will discuss the food trade and development of trade cooperation in the region. Sections 17.3 and 17.4 describe food reserves at the national and regional level in ASEAN, including a discussion on their cost and benefit. The discussion about food reserves at the national level will use several countries in ASEAN as examples, while at the regional level, the discussion will mainly focus on the ASEAN+3.[2] Section 17.5 analyzes the WTO rules on public stockholding, and the last section provides the concluding remarks.

17.2 ASEAN Food Market Structure

The recent waves of global food price crisis have affected almost all countries in the world. ASEAN countries are among those that are hit by the price crisis. Since 2007, the food price index increases have been higher than the consumer price index increases in the region (Fig. 17.1).

ASEAN countries accounted for 29 % of the total global rice output in 2013, while maize production in this region accounted only for 4 % of the total global output. Countries in this region are not traditional producers of wheat and other

[1] www.apterr.org, accessed on 17 September 2014.

[2] Association of Southeast Asian Nations (ASEAN) members are: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam; Plus Three Countries (+3) are China, Japan, Rep. Korea.

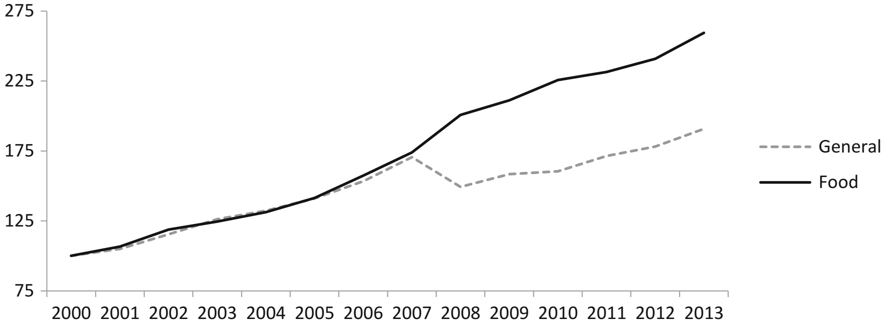

Fig. 17.1 General and food price index in Southeast Asia (2000 = 100). *Source*: FAOSTAT

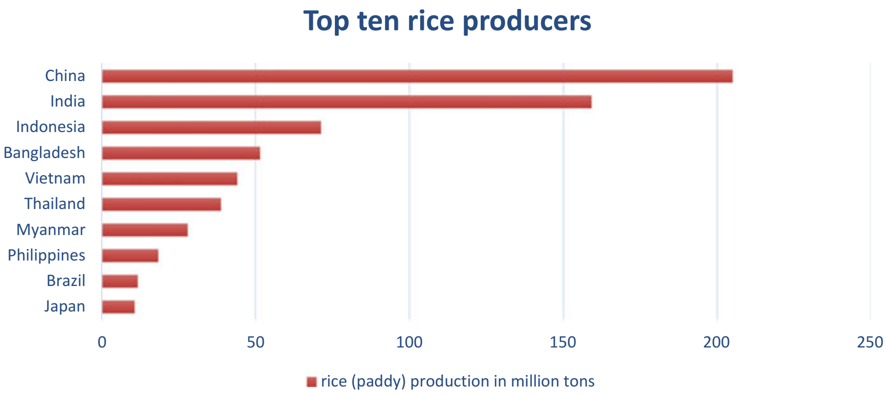

Fig. 17.2 World's rice production in 2013. *Source*: FAOSTAT

cereals. The countries rely heavily on import for their supply of these commodities. Most Southeast Asians eat rice as their main staple food. Rice constitutes more than half of the population's total calorie intake from cereal. In Thailand and Vietnam, rice accounts even for more than two-third of their total calorie intake from cereal.[3]

ASEAN provides a mix of cases. It is home to some of the world's biggest producers, consumers, exporters, and importers of rice at the same time. Thailand and Vietnam are among the biggest rice exporters, whereas Indonesia, Malaysia, and the Philippines are among the biggest rice importers in the world. However, Indonesia and the Philippines, with their goals to achieve self-sufficiency, view trade as the last source of supply, making them occasional rice importers depending on their production level. Other countries such as Singapore and Brunei are considered as traditional purchasers of rice (Fig. 17.2).

[3]Own calculation based on FAOSTAT data. The shares are among cereals, in 2012.

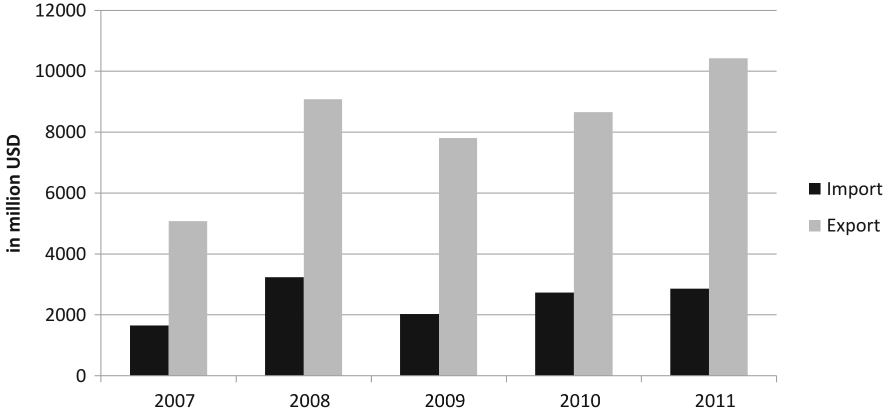

Fig. 17.3 ASEAN rice trade 2007–2011. *Source*: FAOSTAT

Table 17.1 ASEAN rice trade balance 2011 (million USD)

Country	Import	Export	Net import
Brunei	39.6	2.0	37.6
Myanmar	1.6	98.5	−96.9
Indonesia	1513.2	0.8	1512.3
Cambodia	4.9	107.9	−103.1
Lao PDR	9.8	NA	NA
Malaysia	606.1	0.4	605.7
Philippines	383.2	1.7	381.5
Singapore	284.3	52.6	231.6
Thailand	8.9	6507.5	−6498.6
Vietnam	1.3	3656.8	−3655.5

Source: FAOSTAT

The international rice market has been historically thin and unstable (Dawe and Timmer 2012). The geographic concentration of rice production and the thinness of international rice trade with high transactions costs are among the factors contributing to its instability. Only about 5 % of the total global rice production enters the international market, which is mostly concentrated in Asia. Southeast Asia as a region is a net rice exporter (Fig. 17.3), but the bulk of the countries are rice importers (Table 17.1).

ASEAN countries' imports are mainly sourced from within the region. The countries in this region absorb roughly one-third of the total regional exports and send the excess rice supply to the rest of the world (Fig. 17.4).

The average rice tariff rates of ASEAN countries are relatively high compared with other commodities. In 2012, the tariff for rice was 15.94 % on average among ASEAN countries, which was much higher than the total average tariff rates for all commodities (Table 17.2).

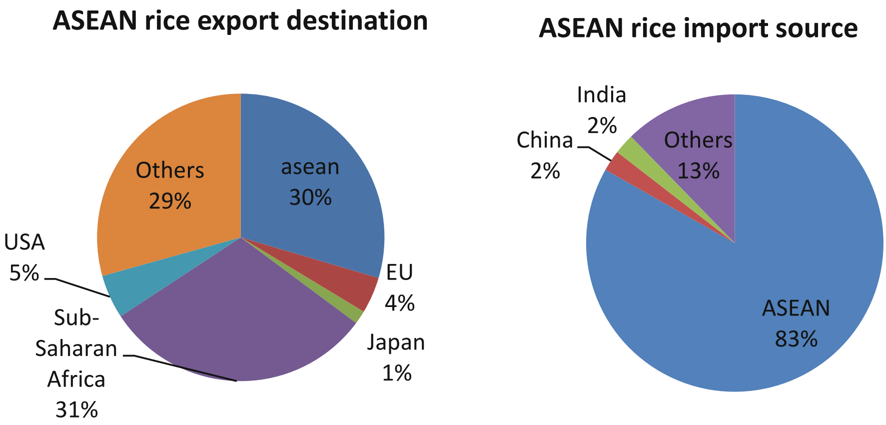

Fig. 17.4 ASEAN rice trade flow 2011. *Source*: UN COMTRADE

Table 17.2 Average tariff rates of ASEAN countries' in 2012 (%)

Sector	Tariff rates
All commodities	5.42
Food commodities	7.01
Rice	15.94

Source: TRAINS database accessed via WITS
Note: Average tariff rates not weighted, classification based on standard product in SITC

Southeast Asian countries liberalize their markets through regional and multilateral trade agreements. The cooperation through ASEAN started in 1967, and all ASEAN members are currently also members of the World Trade Organization (WTO). Through the ASEAN Trade in Goods Agreement (ATIGA), which supersedes the Common Effective Preferential Tariff (CEPT) scheme implemented in 1992, international trade within the region is almost without tariffs except for certain sensitive commodities. In addition to bilateral cooperation between ASEAN members and many other countries, the members also build cooperation with neighboring countries while maintaining ASEAN centrality (Fig. 17.5). There are AK-FTA (with Rep. Korea), AC-FTA (with China), AANZFTA (with Australia and New Zealand), and AI-FTA (with India). Although the agreement of ASEAN and Japan has not yet entered into force, many ASEAN members have already established bilateral agreement with Japan. Furthermore, Regional Comprehensive Economic Partnership (RCEP), which will combine ASEAN and their six partners, is currently under negotiation.[4] ASEAN itself is entering a new phase of stronger cooperation through the ASEAN Economic Community (AEC) in 2015.

[4]RCEP participating countries are ASEAN countries (Brunei, Burma, Cambodia, Indonesia, Laos, Malaysia, Singapore, Thailand, Philippines, Vietnam) plus their six partners (Australia, China, India, Japan, New Zealand, and South Korea), launched in November 2012.

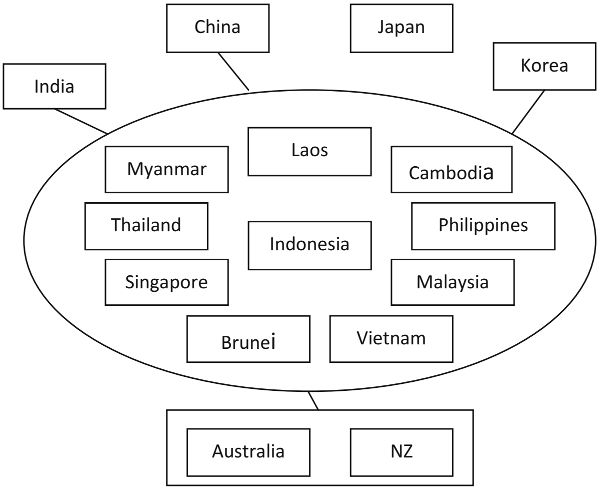

Fig. 17.5 ASEAN free trade agreement. *Source*: WTO

Table 17.3 Tariff of selected agricultural product of different trade agreement regimes 2012 (%)

Commodity	MFN applied	ATIGA	AKFTA	ACFTA	AANZFTA	AIFTA
Animals & product	4.6	0.0	0.1	0.0	0.8	2.2
Dairy products	5.4	0.0	0.0	0.0	0.8	2.2
Fruit, vegetables, & plants	5.3	0.0	0.1	0.0	1.2	3.8
Coffee & tea	6.4	0.0	0.0	0.0	0.4	4.3
Cereals	11.8	7.1	7.3	7.3	7.7	10.1
Oil seeds, fats, & oils	4.3	0.0	0.0	0.0	0.1	2.3
Sugar	12.8	8.1	8.1	8.1	8.1	10.4
Cotton	4.0	0.0	0.0	0.0	0.0	1.6
Other agriculture products	4.1	0.0	0.0	0.0	0.1	2.4

Source: WTO. *Note*: *MFN* most favoured nations, *ATIGA* ASEAN Trade in Goods Agreement, *AK FTA* ASEAN Korea FTA, *AC FTA* ASEAN China FTA, *AANZFTA* ASEAN Australia New Zealand FTA, *AI FTA* ASEAN India FTA

However, despite having significantly reduced their tariffs on many commodities through trade agreements among ASEAN members (and plus countries), considerably high cereals tariffs are still in place (Table 17.3). Cereal products, especially rice, are considered highly sensitive commodities in ASEAN, and thus ASEAN countries still make exceptions by not reducing the tariff on these commodities.

17.3 National Food Reserves in Southeast Asia

The fact that the international rice market has been historically thin and unstable forced countries in this region to prevent the transmission of world price fluctuations to domestic markets (Dawe and Timmer 2012; Rashid et al. 2007). Storage-based public intervention policies have been part of their development agenda for many years to control food availability in the market.

Food price stabilization in the Philippines is managed by the National Food Authority (NFA), which acts as a regulator as well as a corporation engaged in grain trading. The history of the NFA started in the 1960s, when the RICOB and the RCA were still active. In 1972, the National Grains Authority (NGA) replaced these two agencies to promote the integrated growth and development of the grain industry in the country. In 1981, the NGA was transformed to the NFA, and the new organization has two primary mandates: ensuring food security and stabilizing the supply and price of rice. This highlighted the importance of rice in the society. The NFA aimed to fulfill its mandates through procurement, distribution, importation, and buffer stock activities. For the buffer stock activities, the NFA is required to maintain rice stocks which are equivalent to 15 days of consumption for the entire country in its warehouses (Aquino et al. 2013).

In Indonesia, price stabilization was managed by BULOG, a national food reserve agency created in 1967 with the special objective to protect Indonesian domestic markets from sharp price fluctuations on world markets. BULOG buys excess rice production that is not absorbed by the market during harvest seasons from farmers, keeps the rice in its warehouses throughout the country, and distributes the rice at low prices during planting seasons, drought, or other conditions that may cause sharp increases in market rice prices. BULOG maintains a ceiling price policy to ensure the affordability of rice for low-income consumers, especially those living in urban areas. Like the NFA in the Philippines, BULOG also monopolizes rice imports in Indonesia.

As rice importers, Indonesia and the Philippines mainly control rice imports. Other countries, such as Vietnam, which is an exporter country, also use public reserve policies to control rice exports. VINAFOOD in Vietnam is responsible for managing rice availability and rice prices in the market.

17.3.1 Benefits and Costs of National Reserves

Although it is difficult to separate the contributions of policies, we have provided some reviews and discussions on the costs and benefits of national food reserve using qualitative approaches. Rashid et al. (2007) argued that storage-based price-stabilization policies benefit countries through price stability and better agricultural performance. Southeast Asian countries were among those that successfully

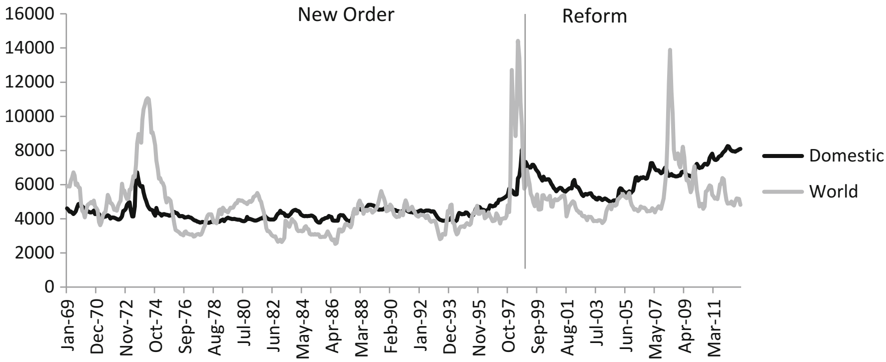

Fig. 17.6 Rice prices in Indonesia during "New Order" and "Reform." *Source*: Dawe (2008) and GIEWS

managed their domestic food prices for years. Under the "New Order,"[5] Indonesia was one of the success stories of food price stabilization, especially for rice. From 1969 to 1997, domestic rice prices were substantially less volatile than in the "reform"[6] period after 1998, when BULOG has less power to intervene in the market[7] (see Fig. 17.6). In Vietnam, agricultural policies introduced in the early phase of the unification of North and South Vietnam have transformed the country with disappointing agricultural production to one of the biggest rice exporters in the world.

Price stability benefits consumers and producers at the same time (Timmer 1989). Poor consumers in Southeast Asia, like many others in developing countries, spend more than half of their income on food (von Braun and Tadesse 2012). Excessive price volatility and spikes can cause food and nutrition insecurity for those consumers who cannot maintain consumption stability. Reducing food and nutrition intake, even only temporarily, can have short- and long-term effects (Block et al. 2004). Price-stabilization policy serves as a preventive program instead of a response program for emergency cases. This kind of policy can help consumers better manage their expectations on food prices and thus better manage their food and nutritional intake. Price stability also helps producers maintain consumption stability because most farmers in Southeast Asia are also categorized as poor citizen living in rural areas.

Furthermore, price stability allows farmers to better manage price expectations on food crops, which can enhance efficiency in the farming sector through better management of planting systems. Moreover, price stability contributes to social and

[5]"New Order" refers to the government lead by President Soeharto, in power from 1967 to 1998.

[6]"Reform" refers to democratization era in Indonesia after the lost power of Soeharto regime in 1998.

[7]Empirical test using standard deviations of log of prices in difference (SSD) shows 0.05 for the periods before 1998 and 0.1 for the periods after 1998.

political stability. Arezki and Brückner (2014) showed that price movements can induce political instability, which is manifested in political riots and civil conflicts. Sociopolitical instability can in turn make it difficult for governments to promote growth and development.

Food price stability is in fact associated with the rapid economic growth during the early development phase in Southeast Asia (Dawe and Timmer 2012; Cummings et al. 2006). However, the downside of stabilization policies are that the fiscal costs of public reserves are often high, while the benefits may not be as high as expected. In the Philippines, for instance, the government spending on the NFA surpassed its spending on agrarian reform, research and development, and extension services during the period of 2003–2008 (Aquino et al. 2013). In Indonesia, a financial audit report by Arthur Anderson covering the period from April 1993 to March 1998 suggested that total inefficiency of BULOG was about US$400 million per year (Arifin 2008). Likewise, the economic costs of distorting market and crowding out private storage and trade can also be very high.

Over decades, there have been several shifts in the price-stabilization policies in Southeast Asia. In the 1980s and 1990s, public reserves fell out of favor particularly because of the changing interest of many countries, which wanted to improve market efficiency. Fiscal difficulties caused by the Asian crisis in the late 1990s triggered countries in the region to intervene less in the market. Indonesia loosened its monopolistic structure and created competition within the domestic market. BULOG lost its domestic power to monopolize the sugar and rice trade because Indonesia was required to comply with the International Monetary Foundation (IMF) Letter of Intent by liberalizing its market.

17.4 Regional Food Reserve Cooperation

Following the global food price crisis in 2008, ASEAN countries agreed on the ASEAN Integrated Food Security (AIFS) framework, which aimed to address four major components of the food security challenges: food security arrangements and emergency short-term relief, sustainable food trade development, integrated food security information system, and agricultural innovation. The AIFS framework provides the foundation for the establishment of the APTERR, an ASEAN regional reserve cooperation together with its three partners.[8] The APTERR was finally agreed upon in October 2011 and entered into force in July 2012.

The history of the APTERR dates back to 1979, when the original members of ASEAN[9] agreed on the ASEAN Emergency Rice Reserve (AERR). The objective was to build up physical rice reserves that would serve the needs of member countries when the demand in any member country cannot be fulfilled from own

[8] China, Japan, and Rep. Korea.

[9] Five original members are: Indonesia, Malaysia, Philippines, Singapore, and Thailand; current ASEAN members also include Brunei, Cambodia, Laos, and Vietnam.

production or through purchases in international market. The main reason for the cooperation was that the ASEAN countries identified food instability as a common threat and as the consequence of the high vulnerability of the region's food production. The AERR was created with the initial earmarks of 50,000 tons of rice as a subset of national stocks. Releases from the AERR were to be arranged through bilateral negotiation between a country in a state of emergency and a country offering its earmarked reserve. The system, however, was never used, and the amount of rice in the reserve was too undersized to cope with an actual emergency.

The efforts of building up stocks in the region continued. In 2001, ASEAN countries, in partnership with China, Japan, and Korea, initiated a consultation and cooperation process in establishing an emergency rice reserve at the regional level. A pilot project of the East Asia Emergency Rice Reserve (EAERR) was created at the end of 2003 with the political support of the ASEAN Plus Three countries. The purpose of the EAERR is twofold: maintaining food security in case of emergency and contributing toward price stability in the region (APTERR 2014). The food price crisis in 2008 led the ASEAN Plus Three governments to strengthen the financial and stockpiling abilities of the EAERR and move beyond the project beyond its pilot phase. The APTERR was finally agreed upon as a permanent scheme in October 2011 and entered into force in July 2012.

The initial earmarked stock of the APTERR is 787,000 tons of rice, which were voluntarily contributed by the member countries (Table 17.4). The stocks remain owned and controlled by the respective governments for meeting the needs of any other member countries in case of emergency. The governments are also responsible for the management cost of their earmarked stocks to ensure the stocks remain in

Table 17.4 Earmarked stock of APTERR

Country	Earmarked stocks (tons)
ASEAN countries	
Brunei Darussalam	3000
Cambodia	3000
Indonesia	12,000
Lao PDR	3000
Malaysia	6000
Myanmar	14,000
Philippines	12,000
Singapore	5000
Thailand	15,000
Vietnam	14,000
Plus Three countries	
China	300,000
Japan	250,000
Korea	150,000
Total	787,000

Source: APTERR

good quality. Another type of APTERR stock is a stockpiled emergency rice reserve, which could be in form of cash or rice, but is owned collectively by APTERR member countries and managed by the APTERR secretariat under the supervision of the APTERR council.[10]

The APTERR is designed to mainly address emergency situations anywhere in the region. Emergency is defined as "the state or condition having suffered extreme and unexpected natural or man-induced calamity, which is unable to cope with such state or condition through its national reserve and is unable to procure the need through normal trade."[11] In principle, given the definition of emergency, extreme price volatility is not a reason for releasing rice from the APTERR.

The APTERR presents itself as a subset of national reserves. Rice release from the APTERR is only possible when a national reserve is unable to cope with extreme shocks. The release of APTERR stock is based on the request of the member country which encounters an emergency rice shortage. The requesting country is also responsible for the transportation and operational costs incurred during the stock release.

The APTERR heavily relies on the commitment and political will of every member country, without any sanction mechanism in place. Nevertheless, APTERR member countries appoint a Management Team to ensure rice releases take place in case of emergency.

17.4.1 The Benefits and Costs of Regional Reserves

There have been extensive debates on storage-based price-stabilization policies (Galtier 2013). On the one hand, countries with public reserve policies can benefit from price stability and better agriculture performances, which are associated with economic success. On the other hand, the policies are often criticized for their high fiscal and economic costs.

National public food reserves in Southeast Asia are largely managed as buffer stocks to address price instability. The size of national public food reserves is usually large, and their stocks are frequently rotated to maintain the quality of the stocks. Consequently, the fiscal costs of storing food/grains are high, and the potential of creating market distortion is high as a result of the high degree of intervention. On the other hand, an emergency public reserve usually holds a low amount of stocks and is only intended for addressing humanitarian needs rather than for price stabilization.

In the competitive storage model, the central idea behind storing food today for tomorrow's consumption is based on the assumption that an equilibrium price can be reached when today's price (p_t) equals the expected price tomorrow (p_{t+1}) plus the costs of storage. Stocks are held in anticipation of profit, which implies that the

[10]The APTERR council is composed of one representative from each APTERR member country.

[11]ASEAN Integrated Food Security Framework.

marginal gain of holding stocks should exceed the marginal cost. However, under this condition, the optimal stock level is not necessarily optimal from the social welfare perspective.

Using this assumption, public involvement in stockholding is needed to address the economy-wide consequences of demand or supply shocks. Difficulties arise when determining the optimal stock level (Gardner 1979) as it depends on the criterion of desirability. For instance, public rice stocks maintained by the NFA in the Philippines are equivalent to 15-day consumption needs of the entire country (Aquino et al. 2013). This stock level is determined based on the assumption that the national stock level (public and private) should be equivalent to the 90-day consumption needs, which covers the lean season, when usually no harvests from domestic production prevail.

Notwithstanding the difficulties in determining the optimal stock level, we provided an illustration on how regional cooperation can significantly reduce the required stocks.[12] Following Kornher and Kalkuhl (2014), we estimated the required stocks as the difference between the largest historic supply shortfall and the percentage of threshold:

$$S = \max\left[\left(1 - \frac{x}{100}\right) E\left(Q_t\right) - Q_t\right] \qquad (17.1)$$

where x is the level of allowed supply shortfall. For instance, if we want to maintain 97 % consumption stability, then the allowed supply shortfall is 3 %. $E(Q_t)$ is the expected supply level at time t. Since supply for consumption increases with population growth, we measured shortfall around a trend.

Supply shortfalls of countries individually were compared with the total supply shortfalls of the entire region using the coefficient of variation of supply, which can be written as:

$$\mathrm{CV}^2\left(\sum_1^n Q_i\right) = \sum_1^n s_i^2\,\mathrm{CV}\ \left(Q_i\right) + 2\sum_1^n\sum_{i+1}^n s_i s_i + 1\ r_{i,\,i+1}\,\mathrm{CV}\left(Q_i\right)\mathrm{CV}\left(Q_{i+1}\right) \qquad (17.2)$$

where $\mathrm{CV}^2\left(\sum_1^n Q_i\right)$ is the coefficient of variation of the regional supply, and Q_i is the supply of each country. s_i and $r_{i,\,i+1}$ are a country's share and coefficient of correlation, respectively. This condition assumes that there is free flow of food between the countries within the region. Production shortfall can be compensated by imports, which means that the supply shortfall in one country can be compensated by supply surpluses in other countries.

[12]Further discussion on optimal stock level can be found in Kornher and Kalkuhl (2014).

Table 17.5 Stocks required for allowed supply shortfall of 3 % (tons)

	w/o cooperation		With cooperation		Actual APTERR stock	
	Required stock	Stock-to-use ratio	Required stock	Stock-to-use ratio	Earmarked stock	Stock-to-use ratio
ASEAN						
Brunei	1227	23.22	688	13.02	3000	56.76
Cambodia	47,768	12.95	26,799	7.27	3000	0.81
Indonesia	57,413	1.05	32,210	0.59	12,000	0.22
Lao PDR	18,912	10.73	10,610	6.02	3000	1.7
Malaysia	17,947	5.59	10,069	3.14	6000	1.87
Myanmar	34,552	2.37	19,385	1.33	14,000	0.96
Philippines	78,355	5.41	43,960	3.04	12,000	0.83
Singapore	10,420	23.28	5846	13.06	5000	11.17
Thailand	130,132	8.60	73,008	4.82	15,000	0.99
Vietnam	136,657	5.42	76,669	3.04	14,000	0.55
Plus Three						
China	678,268	3.2	380,533	1.8	300,000	1.42
Japan	132,280	8.7	74,214	4.88	250,000	16.45
Korea	59,788	6.93	33,543	3.90	150,000	17.40
Total	1,403,717	3.81	787,535	2.14	787,000	2.14

Source: Own elaboration based on USDA PSD. *Note*: required stocks w/o cooperation and with cooperation are calculated for 2 months consumption

Considering that not all of ASEAN countries are rice producers, supply data (production + imports) was used instead of production data only. Rice supply in Singapore, for instance, relies heavily on imports. Using the actual rice supply data of ASEAN+3 countries from the USDA PSD for the period of 1980–2014, we estimated the required stocks for the 2-month consumption stability at 97 % (allowed supply shortfall of 3 %). Countries' stocks were determined from the regional stocks using their consumption shares. The results of the estimations are presented in Table 17.5.[13]

The simulations showed that regional cooperation can significantly reduce the required rice stock by roughly 44 %, from 1,403,717 to 787,535 tons. This implies that the fiscal costs associated with holding stocks can be reduced through cooperation and risks sharing. The simulations also showed that all countries can reduce the required contributions of stocks through regional risk sharing.

In the APTERR system, stocks remain owned and controlled by the respective governments for the purpose of meeting the needs of any other APTERR member countries when they experience an emergency. However, transportation costs arise when transferring rice from a donor country to a country in need. This transportation costs should also be taken into consideration when calculating the cost reduction

[13]Correlation matrix of supply shortfall, maximum shortfall, average annual supply, and consumption shares that were used for the estimations are available in Appendix.

Table 17.6 Storage and transportation cost (million USD)

	Storage cost		Transportation cost		Total cost	
	Low	High	Low	High	Low	High
w/o cooperation	35	49	–	–	35	49
With cooperation	20	28	0.7	1.1	20.7	29.1
Cost savings					14.3	19.9

Source: own elaboration. *Note*: Storage cost is estimated in the range of US$25 (low) to US$35 (high) per ton. Transportation cost within ASEAN+3 countries is estimated in the range of US$10 (low) to 15 (high) per ton

resulting from cooperation. Since transportation costs arise only when a country within the region experiences a shortfall, we calculated the transportation costs from the expected trade volume[14] in times of shortfall, which was estimated to be equal to the required stocks for 2 months consumption. The results are available in Table 17.6.[15]

The total cost saving through food reserve cooperation was estimated to be about US$14.3–19.9 million when storing enough food to satisfy consumption for 2 months. The saving is roughly 40 % of the estimated cost without cooperation.

The current APTERR stock is roughly equal to the total stocks needed by the region to maintain consumption stability at 97 % for 2 months. However, the voluntary contribution of each member country of the APTERR is not the same as the required stock for each country with cooperation through risks sharing. For instance, Japan and Korea contribute more than what they need, but Cambodia and Lao PDR contribute less than their required stocks. Richer countries of the APTERR are more likely to provide food assistance to their poorer neighboring countries. This can be seen also from the voluntary contributions of APTERR member countries: each of the “Plus Three” countries contributes more than the total contribution from all ASEAN countries. There is a strong indication that the large contribution from the “Plus Three” countries has brought APTERR into practice. Its predecessor, the AERR, which consisted only of ASEAN members with small size of stock, had never released its stock during its entire operational period.

We also conducted a simulation to determine the required stock for ensuring consumption stability of 97 % in different cooperation regimes in order to analyze whether countries benefit from larger cooperation (Table 17.7). Through our simulation of three scenarios—ASEAN, ASEAN+3, and ASEAN+3 plus India—we found that the benefits of cooperation decreased when more countries joined the cooperation. This is possible because the correlation of shortfall risks increases with the increasing number of member countries. However, although the benefits of cooperation were decreasing, the required stock was still significantly reduced.

[14]The expected trade volume in times of shortfall is based on the mean value of the historical regional shortfalls.

[15]Numbers of supply shortfall for each country are available in Appendix.

Table 17.7 Stocks required for allowed supply shortfall of 3 % in different (tons)

Regional cooperation (simulation)	Required stocks without cooperation	Required stocks with cooperation	Reduced by (%)
ASEAN	533,382	178,885	66
ASEAN+3	1,403,717	787,535	44
ASEAN+3+India	2,362,418	1,637,777	31

Source: Own elaboration based on USDA PSD

For instance, if India also joined the ASEAN+3 cooperation, the required stock would be reduced by 31 %. Moreover, larger cooperation means larger coordination between countries, which can potentially prevent collective action failures.

17.5 WTO Rules on Public Reserve

The central issue in a WTO-compatible framework for developing countries, including those in Southeast Asia, is whether these countries are able to stockpile their staple food (i.e., rice) to ensure stable incomes for their farmers while ensuring that their low-income citizens are able to access the basic food at an affordable price. This issue, however, affects or has the potential to affect other countries. The potential spillovers of public reserves are high in different member countries due to different conditions of countries in ensuring food security for the citizens. The increasing demand for food for stockholding purposes increases prices and potentially reduces supply for immediate consumption in other countries. When food stocks are finally released for consumption, international trade can be distorted, affecting market competition.

The present WTO rules allow member countries to maintain or introduce domestic support measures without any limitations or reduction commitments. To qualify for this, domestic support to food reserves must meet "the fundamental requirement that they have no, or at most minimal, trade distorting effect or effects on production."[16] Countries, however, may argue the definition of minimal trade distorting effects.

A public reserve is not only economically complex but also politically encumbered. The Bali Package, which has been mentioned as the first-ever agreement reached in the history of the WTO, still makes an exception for public stockholding. In the 9th ministerial meeting held in Bali, Indonesia, at the end of 2013, the WTO member countries adopted an interim solution and agreed to negotiate a permanent solution that would specifically address public reserve by the 11th

[16]WTO Agreement on Agriculture.

ministerial conference in 2017. Furthermore, in the Post-Bali work, countries also agreed to continue with the interim solution if the permanent solution cannot be agreed upon by 2017. This means that no agreement has been reached for a public reserve. Nevertheless, the interim solution, which should prevent countries from challenging other countries through dispute settlement mechanism until a permanent solution is found, can be a starting point for a new institutional arrangement to prevent collective action failures of uncoordinated national public reserves, which can further destabilize prices at the international level.

17.6 Conclusion and Policy Implication

Public food reserve policies have been used by many countries for decades. Although in the 1980s and 1990s, public reserves fell out of favor with many countries particularly against the backdrop of changing interest, with the countries turning their attention to improving market efficiency, the policy has always been part of the development agenda of many countries. Storage-based stabilization policy through public food reserve is receiving much more attention today in the era of increasing food price volatility. Food security concerns in the recent years have led many countries to reconsider using public food reserve as the main policy to deal with such uncertainty and price instability.

ASEAN countries have provided an interesting case with their long experience in implementing storage-price-based stabilization policies. Despite the difficulties in measuring the impact of different policies, price stabilization has been an integral part of the development agenda of ASEAN countries for decades and has contributed to price stability, which is associated with the economic successes in this region. ASEAN also has shown that cooperation at the regional level is possible. The APTERR presents itself as a regional effort to face the common challenges of ensuring food security.

One of the main concerns regarding public reserve is that the fiscal cost of storing food is relatively high. The cost, however, can be reduced with cooperation. The simulations have shown that regional cooperation significantly reduces the required stocks, which in turn reduces the costs of holding them. Even when transportation cost arising because of decentralized storage in the different countries is taken into account, the total cost for food reserve with cooperation is still lower than without cooperation. This definitely will be beneficial for all participating countries. Admittedly, determining the optimal stock level is difficult. It always depends on the criterion of desirability. The current earmarked stock of the APTERR is designed mainly to address emergency situation rather than for price stability. However, it may have a calming effect on the market and thereby prevent the rapid increase in food prices.

ASEAN and their partner countries can also consider expanding their cooperation to include other neighboring countries. The simulation which considered India as the "fourth" country showed that such cooperation would still significantly reduce the required stocks that will be beneficial for all member countries involved. India was emphasized in the simulation because of its important role in the region. The fact that the country is home to around 200 million undernourished people[17] has brought serious concerns to the policymakers in the country. With the world's largest food programs covering public procurement, storage, and distribution of wheat and rice, India has successfully stabilized its food prices for many years. However, the policies give rise to very high fiscal cost. In 2013, the cost is estimated to be around 1.2 % of the country's GDP (Kozicka et al. 2015).

While India is not part of ASEAN Plus Three countries food reserve cooperation, ASEAN and India have already signed an FTA, which has been in force since January 2010. The countries involved could also consider including food reserve as part of their cooperation which will likely be beneficial to all the participating countries. In addition to reducing the overall fiscal costs, larger cooperation and coordination also mean that collective action failures are diminished.

Learning from ASEAN case, public food reserve is an ancient idea that is still relevant today. The way forward is to build institutional arrangements that facilitate coordination and cooperation among countries through various channels, including the multilateral trading system of the WTO. Each of the ASEAN trade agreements with six countries[18] which could be deepened under the RCEP framework, which combines all ASEAN "plus" agreements together, and this could be a starting point for a stronger and larger cooperation in various areas, including public reserves.

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Appendix

[17]Estimated from 17 % of population as stated in the Global Hunger Index, IFPRI et al. (2014).

[18]The six countries are Australia, China, India, Japan, Korea, and New Zealand.

Table 17.8 Correlation of supply shortfalls from target consumption of 97 %

	BRN	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	CHN	JPN	KOR
BRN	1												
KHM	−0.0124	1											
IDN	−0.1529	0.0534	1										
LAO	−0.0805	−0.0614	0.3666*	1									
MYS	0.1322	0.1505	0.0084	0.15	1								
MMR	−0.2106	0.0689	0.1542	0.1115	0.6032*	1							
PHL	0.0871	−0.0514	−0.0697	0.0825	0.0027	−0.1111	1						
SGP	−0.1477	0.3081	−0.1211	−0.1792	−0.1117	−0.1291	0.0638	1					
THA	−0.1184	−0.1699	0.0066	0.0013	−0.0322	−0.0356	0.4060*	0.3721*	1				
VNM	−0.1455	−0.1263	−0.0643	−0.1139	−0.0923	−0.1028	−0.0728	0.0142	0.0815	1			
CHN	0.4617*	−0.0895	−0.0635	−0.1097	0.2073	−0.0577	−0.072	0.0488	0.1212	−0.0664	1		
JPN	0.0248	−0.0494	0.224	0.5026*	−0.0518	−0.1373	−0.0028	−0.1397	−0.0782	−0.0897	0.2056	1	
KOR	0.2939	0.0595	−0.0642	−0.0528	0.5680*	0.109	−0.0374	−0.194	−0.1071	−0.1088	0.5560*	0.0391	1

Source: Own calculation based on USDA PSD. *Note*: *BRN* Brunei Darussalam, *KHM* Cambodia, *IDN* Indonesia, *LAO* Lao PDR, *MYS* Malaysia, *MMR* Myanmar, *PHL* Philippines, *SGP* Singapore, *THA* Thailand, *VNM* Vietnam, *CHN* China, *JPN* Japan, *KOR* Rep. Korea

* represents significance level at 95 %

Table 17.9 Rice supply, consumption, and shortfall 1980–2014

	Supply		Consumption		Shortfall		
	Annual average (000 tons)	Regional share (%)	Annual average (000 tons)	Regional share (%)	Number of shortfall	Maximum shortfall (000 tons)	Mean of shortfall (000 tons)
ASEAN							
Brunei	31.7	0.01	31.71	0.01	14	7.36	1.27
Cambodia	2494.63	0.80	2213.09	1.00	9	286.61	36.52
Indonesia	37, 250.69	11.94	32, 765.20	14.84	3	344.48	15.57
Lao PDR	1089.40	0.35	1057.20	0.48	9	113.47	11.35
Malaysia	2327.60	0.75	1926.37	0.87	7	107.68	6.92
Myanmar	10, 019.80	3.21	8751.66	3.96	7	207.31	19.50
Philippines	10, 958.83	3.51	8685.11	3.93	6	470.13	23.72
Singapore	271.86	0.09	268.60	0.12	11	62.52	7.09
Thailand	18, 737.71	6.01	9079.97	4.11	6	780.79	66.28
Vietnam	19, 028.09	6.10	15, 135.54	6.85	3	819	39.41
Plus Three							
China	191, 979.50	61.56	126, 655.20	57.35	4	4069.61	180.69
Japan	11, 315.51	3.63	9118.14	4.13	7	793.68	50.65
Rep. Korea	6352.40	2.04	5171.37	2.34	6	358.73	41.60
Total	311, 857.73	100	220, 859.17	100	92	8422.30	500.57
Regional	311, 857.73	100	220, 859.17	100	31	4725.21	506.43

Source: Own calculation based on USDA PSD. *Note*: Regional refers to ASEAN Plus Three countries as a region

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18 When Do Prices Matter Most? Rice, Wheat, and Corn Supply Response in China

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18.1 Introduction

Unexpected high and volatile food prices during the 2007–2008 world food crisis and thereafter have reemphasized the question of how countries can protect themselves from supply shortages. In view of the various trade restrictions imposed by some major exporting countries, governments tend once again to focus more on self-sufficiency and food storage. Additionally, emerging economies like China aim at increasing their yields. This is because the possibilities of expanding agricultural land are limited, while population, total grain demand, and meat consumption are rising.

The primary purposes of analyzing the supply response are threefold in this chapter. First, this work aims to identify the different factors that can affect production, such as market prices, biophysical conditions, and infrastructure. The second objective is to analyze the differences in the effects of these factors on the different crops. The third aim is to evaluate how the predictive power of prices evolves over time and therefore to understand when farmers react most strongly to prices. Hence, a clear understanding of the farmers' planting and production behavior is needed.

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In the context of empirical estimations, farmers' decision-making is generally modeled as a two-step process (Colman 1983): First, farmers choose the crop type based on past weather conditions and decide their cropping area based on the prices they expect to receive several months later. Second, after planting, they change their farmland management measures according to market prices and weather condition to achieve a high yield. We focus on the production response of winter wheat, indica rice, and corn as these crops are the main staple foods in China. China is the biggest producer of rice and wheat and one of the biggest producers of corn. The results of the research can also be used as the basis for a short-term forecasting tool for monitoring Chinese food security or as part of a worldwide food availability monitoring tool. However, forecasting would require timely availability of data, which usually is not possible for data from the Chinese Agricultural Yearbooks.

In China, early works in this field have focused on the roles of price and marketing reforms in agricultural production (e.g. Lin 1991). Empirical studies have found a positive impact of price changes on output during the first years of reform (Lin 1992; Huang and Rozelle 1996). Lin (1992) found that 15 % of output growth in 1978–1984 came from the rise in relative prices. Huang and Rozelle (1996) showed about 10 % of rice output growth between 1978 and 1984 was caused by price effects. The gains have also resulted from increased allocative efficiency through market liberalization since the early 1990s. For example, de Brauw et al. (2004) showed that increasing marketization had a positive effect on crop allocation and productivity. The recent works have paid more attention to the impacts of subsidizing agriculture after China shifted its agricultural policy from taxing farming households to providing them with subsidies in 2004. While these subsidies are given to all producers and are very high, even higher than in the USA and the EU on a per unit area basis in 2012, they are quite low on a per household or per farm basis as farms in China are mostly of small scale (Huang et al. 2013). Except for subsidies for machinery, which influenced the purchase of machineries, most other subsidies for grain, input, and seed were found not to influence farmers' area allocation decisions (Huang et al. 2011). This finding provides the rationale behind not explicitly including subsidies in this study. Increased grain outputs in the later years were partly attributed to land reallocation to grain production (Yu and Jensen 2010). With the help of a dynamic panel approach, acreage and yield responses to output prices were analyzed in a case study for Henan (Yu et al. 2011). Both area and yield were found to be price-responsive. However, evidence from other provinces is missing, and the effects of high temperatures have not been addressed. This chapter focuses on both of these issues. Furthermore, the role of prices at different points in time is at the heart of this analysis. At the global level, price volatility and therefore price risks were found to reduce the supply response (Haile et al. 2016). However, as prices are comparably stable in China, price volatility was not considered as an important factor in this study.

In the face of global warming, interest in its impacts on agriculture is increasing. The impacts of climate change are expected to be huge and have already been partly documented. The general findings include an expected decline of crop yields in China, as in other developing countries (Tao et al. 2006). By employing farm-level data and the Ricardian method, the average impact of higher temperatures was found to be negative, whereas the average impact of more rainfall was found to be positive (Wang et al. 2009). Overall, weather conditions, market prices, and infrastructures can be seen as the three most important conditions for agriculture production. This study makes an important contribution to evaluating how such weather-related variables, especially high temperatures, affect the production of the considered crops at the province level. Furthermore, to our knowledge, this is the first study which addresses the production response to prices at different periods in time in order to analyze the farmers' price expectation formation process.

The next four sections present the data, methods, results, and conclusions, respectively.

18.2 Data Description and Usage

Data on acreage, production, output market prices, procurement prices, fertilizer prices, rainfall, consumer price index (CPI), irrigated area, temperatures, sunshine, effective irrigated area, and prices of competing crops were collected from the Chinese agricultural and statistical yearbooks from 1996 to 2012. Province-level data was used whenever possible, but whenever such data was scarce, national-level data was used instead. Own crop prices were deflated by the CPI; other prices were deflated by the own crop price, resulting in relative prices to take into account any possible correlation. Table 18.1 provides an overview of the aggregation level, frequency, and transformations of the data. The summary statistics of the variables are presented in Table 18.2 for the individual crops.

A panel data set was created for each crop, whereby the province-wise production of a crop was used as the dependent variable to be explained by the other variables. The provincial production data, collected from the National Bureau of Statistics of China, was collected from 1995 to 2012 and includes information on 20 provinces planting winter wheat, 29 provinces planting corn, 13 provinces planting early and late indica rice, and 15 provinces planting middle indica rice. For indica rice, data from the early, middle, and (double) late seasons were pooled together to get more observations and hence ensuring that the number of observations did not fall below 249. However, this came at the cost of not being able to detect any heterogeneity in the response which cannot be captured by the fixed effects.

The planting season and complementing and substituting crops may differ slightly among the different provinces. For winter wheat, the planting season is from September to October, and its harvesting takes place in the late April or May of the following year. The main substitute is rapeseed, followed by cotton, while corn is a complementing crop. Corn is mainly planted from April to June and harvested between August and October. The main substitutes are soybean and cotton, and the main complementing crops are wheat and rapeseed. Based on the farmers' production behavior, we focused on input and output prices, weather conditions, and infrastructure. For crop prices, monthly wholesale prices were used. This is because wholesale prices were more easily available than farm gate prices and also

Table 18.1 Overview of the data used for the regression analysis

Data	China ... yearbook	Scale	Frequency	Transformation
Production	Rural statistic	Province	Yearly	Logged
CPI	Statistical	Province	Monthly	Continuous CPI build from yearly changes
Total farm crop area	Rural statistic	Province	Yearly	–
Irrigated area	Water conservancy	Province	Yearly	Divided by total farm crop area and logged
Nonirrigated area	–	Province	Yearly	log(1-irrigated area/total farm crop area)
Wholesale prices	Grain	National	Monthly	Divided by continuous CPI and logged (for competing crop prices: divided by own crop price)
Fertilizer prices	Price	National	Monthly	Divided by wholesale price and logged
Rainfall	Water conservancy	Province	Monthly	Logged
Hours of sunshine	1	Province	Monthly	Logged
Lowest temperature	1	Province	Monthly	–
Average temperature	1	Province	Monthly	–
Highest temperature	1	Province	Monthly	–
Area affected by drought	Water conservancy	Province	Yearly	Divided by total farm crop area and logged

Note: The second column shows the source, i.e., from which of China's yearbooks the data is taken. 1 means that it is not taken from any yearbook but from the National Meteorological Information Center of China

because of the high transmission from wholesale to farm gate prices, as reported in the literature (Liu et al. 2012).

As land and labor are limited, planting behavior can be affected by the price of competing crops. Fertilizer prices were chosen as the main input market price. Wages, obtained from Bloomberg, were also included, but their time series is short and as a result so is the number of observations. Due to this and the fact that they turned out to be insignificant, they were not reported in this chapter but are available upon request. The agricultural production system is sensitive to weather effects, and there are very few measures available to farmers to compensate for weather effects. Therefore, weather conditions, collected from the National Meteorological Information Center of China, were a very important independent variable in this analysis. The percentage share of cultivated area under irrigation can also be seen as a measure of infrastructure and technology. Missing values for this variable, but not for any other variables, were imputed. Irrigation also allows farmers to compensate for insufficient rainfall and partly even droughts. As irrigation is typically used in combination with the application of chemical fertilizers, it represents a higher standard of agricultural infrastructure. However, irrigation relates to the cultivated land area under irrigation and hence is not crop specific. As a result, only very

Table 18.2 Summary statistics of the data from all provinces

	Obs	Mean	SD	Min	Max
Corn					
Production (1000 tons)	552	458.7	549.5	0.9	2675.8
June WSP (CNY/kg)	463	1.4	0.4	0.9	2.3
Irrigation (1000 ha)	552	1813.9	1385.8	144.2	5205.6
Rainfall @ growing (cm)	534	14.1	6.8	1.5	40.4
Average temp @ growing (°C)	534	24.9	3.3	13.2	30.7
Drought area (1000 ha)	495	448.1	544.2	1.0	3133.0
Fertilizer price (CNY/kg)	492	1916.4	672.6	1186.0	3140.0
Winter wheat					
Production (1000 tons)	360	464.3	686.8	0.2	3177.4
March WSP (CNY/kg)	301	1.5	0.4	1.0	2.2
April's sunshine hours	360	5.6	1.8	1.7	9.4
Irrigation (1000 ha)	360	2041.9	1466.8	173.6	5205.6
Rainfall @ growing (cm)	360	6.0	4.8	0.2	22.4
High temp @ flowering (°C)	360	26.0	4.1	16.6	37.3
Rainfall @ planting (cm)	360	2.9	1.6	0.1	11.7
Drought area (1000 ha)	321	399.5	482.9	1.0	2573.0
Fertilizer price (CNY/kg)	320	1897.8	665.3	1184.0	3000.0
Indica rice					
Production (1000 tons)	707	406.1	433.0	0.0	2161.1
WSP @ planting (CNY/kg)	594	1.5	0.4	0.9	2.5
Sunshine hours @ planting	707	5.4	1.4	2.1	10.4
Irrigation (1000 ha)	707	1751.3	985.5	169.9	3929.7
Rainfall @ growing (cm)	707	11.4	4.3	2.6	26.2
Rainfall @ planting (cm)	707	3.8	2.6	0.1	19.5
High temp @ growing (°C)	707	33.7	2.0	27.2	39.7
Drought area (1000 ha)	639	292.9	361.0	1.0	2250.0
Fertilizer price (CNY/kg)	632	1867.1	668.0	1126.0	3340.0

Note: Data which is only available on a national basis has been copied for all provinces and therefore is shown to have more observations than it actually has on the national level. Data is only reported if the value for production for that crop, year, and province is available. Unless the month is indicated, the @ is used to specify time periods

limited conclusions can be drawn about how irrigation affects production. This is discussed further in Sect. 18.4 and also applies to the drought area, which is also not crop specific.

As some of the weather data has a high level of autocorrelation, it is not possible to consider every month in the econometric analysis. Therefore, only the most important month is included, except for rainfall, in which case the sum of the most important months is calculated. The hypotheses to test in this chapter are as follows: (1) A positive response to own output prices, and a negative response to competing crop prices as well as fertilizer prices, at least if the crop has a higher fertilizer requirement than competing crops; (2) own output prices matter most in the time period from shortly before to a few month after planting, during which farmers make their decisions on areas and yields; (3) droughts and insufficient rainfall have a negative effect on production; (4) irrigation has a positive impact and can reduce the negative impact of insufficient rainfall or high temperatures.

This approach has some limitations. The biggest limitation might be the aggregation level of data. Some price data were only available at a national level, but as price transmission within China is high (Huang and Rozelle 2006), this might not be a concern. For the biophysical variables, even though they were available at the provincial level, this aggregation might be more problematic as rainfall, hours of sunshine, and temperatures may vary in different parts of the same province. Therefore, the influence of these biophysical variables is likely to be underestimated due to this high level of aggregation. Furthermore, important variables may not be considered which could be an issue if they fluctuate a lot in the short term. If they mostly consist of a long-term trend instead, then they will be captured by orthogonal deviations and lagged production and, as a result, will not cause any problems.

18.3 Methodology

Strictly speaking, a farmer's decision-making process consist of two steps: the area decision and the yield decision (Colman 1983). The considered determinants are mostly the same but may differ slightly as, for example, competing crop prices are not that important after the area decision was made. However, they still may be important because they may affect how farmers allocate their inputs such as fertilizers, pesticides, and water and other variables. On the other hand, not all variables which influence yields also matter when allocating the area. Unexpected rainfall shocks (or price shocks) after planting cannot be anticipated and therefore cannot affect the area decision. However, these shocks may affect a farmer's fertilizer application and therefore yield. Therefore, modeling production is a combination of the area and yield processes and can only be investigated by considering the sum of both effects. Nevertheless, it is important to see the combined effects as we are interested in the total production volume and want to know which variables have an influence and how the variables influence. Another reason to look at the combined effect on production is that statistical issues arise when looking at area and yield separately. This is because area and yield influence one another, and therefore this additional endogeneity has to be dealt with. For example, area allocation decisions may affect yields in two different ways: High prices could cause farmers to favor large planting areas, which should increase the expected yields, whereas planting area expansion may negatively influence yields if the additional crop areas are located on less-productive lands.

The Arellano–Bond difference GMM and system GMM estimators (Holtz-Eakin et al. 1988; Arellano and Bond 1991; Arellano and Bover 1995; Blundell and Bond 1998) were used for a number of reasons. First, the time period was rather short, usually around 14 years, while the number of observations per time period was comparatively large: 20 for wheat, over 29 for corn, and around 40 for rice. The difference GMM and system GMM estimators control for such dynamic panel bias. Second, the production response is a dynamic process, i.e., current realizations depend on past ones. Third, fixed effects allow for heterogeneity across groups, namely provinces. Last, idiosyncratic disturbances may have individual-specific patterns of heteroskedasticity.

For all three crops, four different specifications are shown in the tables in Sect. 18.4, with the first three presenting different control variables for the difference GMM estimator and the fourth illustrating the results for the last specification using the system GMM estimator for comparison and robustness checks. While including more variables allowed more factors to be controlled for, it also decreased the degrees of freedom, the significance of variables which are correlated and most importantly the number of observations (because many variables could only be obtained for a limited number of years). Comparing the different specifications and comparing the difference and system GMM results provide a further consistency check. In general, we think that the difference GMM estimator is more appropriate as it cannot be ruled out that the first differences of the instrument variables are uncorrelated with the group fixed effects. Our findings support this hypothesis, as will be shown in the next chapter. The Windmeijer finite-sample correction for standard errors was used (Windmeijer 2005). We used the xtabond2 command in Stata, which was written by David Roodman, and followed the application guidelines in his accompanying paper (Roodman 2009). Instead of first differencing, forward orthogonal deviations were used (Arellano and Bover 1995; Roodman 2009), i.e., the average of all available future observations was subtracted. This procedure removes fixed effects, just like differencing, but because lagged observations are not used, these remain orthogonal to the transformed errors. This way, the number of observations will not be reduced by gaps in the dataset. As suggested, time dummies for all years were included in all model specifications (ibid).

For proper usage of the GMM techniques, a number of tests need to be run to check the consistency of the estimations (ibid.; Efendic et al. 2009). The joint significance of the variables was evaluated with an F-test, the p-value of which we expected to be clearly below 0.1 (ibid.). While the first lagged residuals are expected to be correlated, the twice lagged residuals must not (Arellano and Bond 1991). Considering the null hypotheses, this means the p-value of the AR1 test in the result tables was expected to be smaller than 0.1, while the p-value for the AR2 test should be higher than 0.1 (for significance at the 10 %-level). Furthermore, the Hansen-J test allows checking if the model specification and all over-identifying restrictions are correct (Baum 2006). It is suggested that the p-value should be above 0.25 but at the same time should not perfectly match 1 for this test (Roodman 2009). The difference-in-Hansen test was used to investigate the exogeneity of instruments. The null hypothesis is that they are exogenous. Hence, the respective p-values have to be above 0.1 in order to not reject the null hypothesis. The number of instruments was chosen to provide robust test statistics. There are no clear rules about the appropriate number of instruments. However, the number of instruments should always clearly be lower than the number of observations, which is the case for all our specifications.

Furthermore, the coefficient of the lagged endogenous variable (production in our case) should be less than one to obtain a steady state behavior (Roodman 2009), which is the case in all of the presented models. Finally, the validity of the estimates can be verified by examining if the coefficient of the lagged dependent variable is larger than the one obtained by a fixed effects model and smaller than one obtained by using OLS (Bond 2002). This was the case for all specifications and the FE and OLS estimates of the lagged dependent variables are reported in the tables.

All the test statistics were fulfilled in all specifications except for two instances: (1) the first specification for winter wheat, which failed to reject the second order autocorrelation at the 10 % level but nevertheless did so at the 5 % level; and (2) the first specification for indica rice, which failed to reject the Hansen-*J* test and the difference-in-Hansen test.

Apart from evaluating the production response using the price at a predetermined point in time, this work aims at analyzing how production responds to prices at different points in time. Therefore, the regressions were conducted with prices at different months before and after planting, from 20 months before up to 20 months after planting, and how this changes the results is graphically illustrated. For this analysis, the second specification is used for all crops as this specification provides the maximum number of observations while fulfilling all test criteria and while including the most important variables. This procedure allowed us to analyze how farmers build their price expectations, in particular whether they used previous year's prices around planting or harvesting time or if they used the latest prices which, under the assumption of efficient markets, incorporate all available information about supply and demand.

For indica rice, data for the three different seasons were pooled together. Hence, there is no fixed planting month, but the appropriate planting month was chosen depending on the season instead. All the other variables were similarly chosen relative to the month of planting for that season. This means, for example, that the planting time price is April for early indica, May for middle indica, and July for late indica rice. Similarly, rainfall during the growing season refers to April and May for early indica, May and June for middle indica, and July and August for late indica rice.

All variables were logged, and therefore the effects can be interpreted as elasticities. The only exception are temperatures, which also exhibited negative values and are more intuitive to interpret in their non-logged form.

18.4 Results

18.4.1 Basic Regression Results

The results for the production of corn are shown in Table 18.3, for winter wheat in Table 18.4, and for indica rice in Table 18.5. The first row always shows the lagged production. Wholesale prices are denoted by WSP followed by the month or relative time period. The latter are always denoted by the @ symbol and refer to

Table 18.3 Results for corn production response

	(1)	(2)	(3)	(4)
L. Production	.807***	.772***	.902***	.956***
	(.166)	(.143)	(.139)	(.034)
WSP June	.296***	.291***	.226***	.177***
	(.077)	(.055)	(.065)	(.05)
Irrigated	−.115	20.1**	16.8**	1.61
	(.131)	(8.12)	(8.07)	(6.65)
Rain @ growing	−.059	−.013	−.076	−7.4e−03
	(.063)	(.06)	(.08)	(.033)
A-Temp @ growing	−.029*	−.095***	−.058*	−.014
	(.015)	(.026)	(.029)	(.024)
Drought area	−.032***	−.033***	−.035***	−.014
	(8.6e−03)	(9.1e−03)	(.01)	(.013)
Nonirrigated X rain @ growing		.077*	.071*	.066***
		(.045)	(.037)	(.021)
Irrigated X A-temp @ growing		−.067**	−.052*	−5.3e−04
		(.027)	(.027)	(.023)
Fertilizer @ planting			−.203**	−.231***
			(.074)	(.065)
Irrigated X fertilizer @ planting			−.182**	−.191***
			(.068)	(.058)
Substitute @ planting			.018	6.3e−03
			(.027)	(.017)
Constant				6.29
				(6.9)
Estimator	Difference	Difference	Difference	System
Groups	29	29	29	29
Instruments	27	29	28	30
p:F-test	1.7e−19	1.3e−23	1.1e−27	4.0e−37
p:AR1	1.5e−03	1.1e−03	9.9e−04	3.2e−04
p:AR2	.919	.685	.949	.581
p:Hansen-J	.291	.326	.286	.535
p:Diff-Hansen	.812	.9	.436	1
OLS	.988	.991	.985	.985
FE	.741	.683	.747	.747
Observations	384	384	296	325

Note: Standard errors in parentheses. WSP: wholesale price; X indicates interaction terms; A-temp: average temperature; specifications with different explanatory variables for the difference GMM estimator (1–3); for comparison and robustness checks, the results of the last specification are also shown for the system GMM estimator (4)

$p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 18.4 Results for winter wheat production response

	(1)	(2)	(3)	(4)
L. Production	.951*** (.104)	.951*** (.11)	.96*** (.087)	.964*** (.063)
WSP March		.338*** (.116)	.292** (.132)	.255* (.143)
H-temp @ flowering	−.043*** (9.6e−03)	−.044** (.019)	.061 (.123)	−.037 (.122)
Sun @ flowering	.156 (.092)	.081 (.205)	.124 (.207)	.196 (.293)
Rain @ planting	.054** (.021)	.045 (.026)	.04 (.042)	.047 (.037)
Rain @ growing	3.5e−04 (.032)	−.045 (.037)	−.143 (.099)	−.133 (.091)
Irrigated	−.055 (.483)	−.344 (.478)	−31.9 (37.2)	−.093 (26.4)
Drought area	−.037** (.014)	−.026 (.016)	−.034 (.02)	−.026* (.014)
Nonirrigated X rain @ growing			−.137 (.135)	−.177 (.165)
Irrigated X H-temp @ flowering			.105 (.125)	−1.1e−03 (.089)
Constant				10.3 (36)
Estimator	Difference	Difference	Difference	System
Groups	20	20	20	20
Instruments	26	25	27	29
p:*F*-test	1.4e−13	2.0e−12	2.0e−14	1.8e−22
p:AR1	8.8e−03	.019	.012	.016
p:AR2	.053	.185	.173	.241
p:Hansen-*J*	.595	.463	.805	.744
p:Diff-Hansen	.949	.847	1	1
OLS	1.01	1.02	1.02	1.02
FE	.865	.855	.863	.863
Observations	280	249	249	269

Note: Standard errors in parentheses. WSP: wholesale price; X indicates interaction terms; H-temp: high temperature; specifications with different explanatory variables for the difference GMM estimator (1–3); for comparison and robustness checks, the results of the last specification are also shown for the system GMM estimator (4)

$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

Table 18.5 Results for indica rice production response

	(1)	(2)	(3)	(4)
L. Production	.913***	.914***	.778***	.911***
	(.07)	(.055)	(.112)	(.081)
WSP @ planting	.196***	.181***	.163**	.241**
	(.067)	(.054)	(.061)	(.094)
Rain @ growing	.053*	.152	.115	.425
	(.027)	(.139)	(.178)	(.284)
Sun @ growing	.174***	.167***	.142*	.023
	(.061)	(.05)	(.074)	(.117)
H-temp @ growing	−.024**	−.026***	−.039***	.019
	(.01)	(8.5e−03)	(.013)	(.03)
Irrigated		.356	.323	1.06
		(.521)	(.674)	(.731)
Nonirrigated X rain @ growing		.294	.262	.691
		(.287)	(.346)	(.495)
Drought area		−4.9e−03	−1.4e−03	4.6e−03
		(8.8e−03)	(8.0e−03)	(.012)
Fertilizer @ planting			.032	−.048
			(.078)	(.058)
Substitute @ planting			.018	.04
			(.032)	(.048)
Constant				−4.51
				(9.08)
Estimator	Difference	Difference	Difference	System
Groups	41	39	39	39
Instruments	20	23	22	24
p:*F*-test	2.8e−16	3.2e−20	1.2e−15	1.0e−22
p:AR1	.073	.098	.118	.096
p:AR2	.174	.171	.142	.138
p:Hansen-*J*	.153	.341	.409	.24
p:Diff-Hansen	.088	.102	.227	.569
OLS	.997	.998	.994	.994
FE	.727	.722	.551	.551
Observations	548	503	394	433

Note: Standard errors in parentheses. WSP: wholesale price; X indicates interaction terms; H-temp: high temperature; specifications with different explanatory variables for the difference GMM estimator (1–3); for comparison and robustness checks, the results of the last specification are also shown for the system GMM estimator (4)

$p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

the planting, growing, flowering, or harvesting season of the crop. Average and high temperatures are written as A-temp and H-temp, respectively. Interaction terms are indicated by an X, while the prices of competing crops are presented as substitute. The bottom part of the tables shows which estimator was used; the test statistics; and the number of groups, instruments, and observations.

The results for corn, illustrated in Table 18.3, show that all specifications seem to be valid based on the provided test statistics. A significant amount of variation in production can be explained by the previous year's production (which also takes into account unobserved variables). The coefficient ranges from 0.772 to 0.956 and is significant at the 1 % level in all specifications. The wholesale price in June turned out to be also always highly significant and had a major contribution, as evident in its elasticity of around 0.2. This implies that a 1 % increase in prices will lead to a 0.2 % increase in production, which seems reasonable and is comparable to the results obtained by similar studies. The fraction of irrigated area is only significant in two specifications but has a huge impact in both. However, it is only significant for the difference GMM specifications that included the interaction terms, which could possibly be attributed to collinearity in these variables (their correlation coefficient is −0.79 for corn, −0.17 for wheat, and −0.46 for rice). In addition, the total effect of irrigation is the elasticity of irrigation plus the interaction term of irrigation with the average temperature. The interaction term takes the value of −20.69 at the sample mean for the second specification, resulting in a combined marginal effect of −0.59. Despite corn needing rainfall during the growing season, the rainfall variable did not seem to have any significant effect on the corn production. However, corn needs little water compared to other staples and in particular vegetables. As mentioned in Sect. 18.2, the irrigation variable measures the total cultivated area under irrigation. This may not be a good proxy for the actual irrigated crop areas; in particular, it is not a measure of crop-specific irrigation. Furthermore, the quality of irrigation is not reflected in this variable. Moreover, considering rainfall variability and water availability, the quality of irrigation may change drastically over time. Therefore, the influence of irrigation can only be approximated, and thus it is unsurprising that no effect was found in many of the specifications (when compared with wheat and rice).

High average temperatures during the growing season, which is in mid-summer, have a small but significant negative impact. When interacted with the nonirrigated area (i.e., the fraction of the agricultural area which is not irrigated), we found that rainfall during the growing season became significant. As expected, rainfall had a positive influence on production, albeit a small one. When interacted with irrigation, high average temperatures are negative and significant for the difference GMM specification. This differs from our expectations but might be explained by the imprecise approximation of irrigation or by high temperatures offsetting the benefits of irrigation. As expected, the drought area had a significant and negative influence in all but the system GMM specifications. High fertilizer prices at planting time reduced the total production; again, this effect seems to be more pronounced in provinces with a high share of irrigated area. This may be attributed to the fact that levels of fertilizer application are usually much higher on irrigated areas, which may therefore be over-proportionally affected. Prices of competing crops turned out to be insignificant, despite testing various ways of including them in the analysis, such as using the province-specific main competing crop only or a weighted average of competing crops.

For winter wheat, presented in Table 18.4, the previous year's production was again the most important driver and consistently significant at the 1 % level. Wholesale prices in March had a similar positive and significant effect, as for corn. The elasticity is around 0.29, even slightly higher than for corn. The first specification did not include any prices to ascertain if there are any changes when more observations are included. This is because the number of observations for winter wheat is relatively low compared with corn and rice. The amount of sunshine at flowering (around two months before harvesting) is insignificant. From the literature, wheat is expected to require much sunshine during this period (FAO 2015). Furthermore, much rain is needed during and shortly after planting as well as during flowering and yield formation (ibid.). The positive influence of rainfall during and after planting can be observed in the first specification only. Rainfall during the growing season and its interaction term with the nonirrigated area are always insignificant. This might be a result of data aggregation, as explained above. The irrigated area seems to have no effect, but this may be attributed to the poor approximation of irrigation, as explained above. The drought area has a significant negative impact in two specifications, again albeit with a very small effect. The expected negative effect of overly high temperatures during flowering time vanished once the interaction term with irrigation is included. Then, both terms became insignificant. Fertilizer prices and prices of competing crops had no significant effect but reduced the number of observations significantly. Therefore, they are not shown separately but are available upon request.

Similar to corn and wheat, lagged production was the most important driver of indica rice production, as illustrated in Table 18.5. The effect of the wholesale price is similar to the case of corn; it was always significant and had an effect size of around 0.2. Rain during the growing season, a large amount of which is required to flood rice paddy fields, was positive but only significant at the 10 % level in one specification. But as explained before, this might be a result of aggregating rainfall data across the provincial level. The results did not change when we included squared rainfall. Even when interacted with the nonirrigated area, the rainfall stayed insignificant. The irrigated area itself is insignificant, which, as detailed before, might be attributed to the poor proxy used for irrigation. For sunshine, we found that a 1 % increase in the number of hours of sunlight increased the production by around 0.16 % in all the difference GMM specifications. Similarly, the damaging effect of overly high temperatures during the growing season can be observed in all difference GMM specifications. The drought area, fertilizer prices, and the prices of competing crops all turned out to be insignificant. The underlying reasons might be that the costs of switching crops from rice are relatively high and that rice needs a comparatively small amount of fertilizer per unit of output.

Overall, our results were mostly comparable to other similar studies. In a non-crop specific analysis, Ghatak and Seale (2001) found that price elasticity was between 0.174 and 0.394, which is similar to ours. Looking only at the national level, own price elasticities of 0.23 for rice, 0.052 for wheat, and 0.164 for corn have been reported (Haile et al. 2015). Our results for rice and corn were comparable, whereas we found a higher price response for wheat. For Henan, Yu et al. (2011) found no significant response for wheat but a surprisingly high elasticity of 0.737 for corn. However, according to the study, the elasticities of competing crop prices were also high and significant. They also reported that rainfall increased winter wheat production when considering the total effect on area and yield. For corn, they found that rainfall had no effect, which is consistent with our results if only the non-interacted rainfall is considered, as in the study by Yu et al.

18.4.2 Impact of Prices on Production During the Marketing Year

As explained in Sect. 18.3, one of the aims of this chapter is to analyze how production reacts to prices at different points in time. Therefore, the regressions with same specifications were run for prices at different months before and after the planting time. For all other variables, the values used remain the same as before. The results are depicted in Fig. 18.1 for corn, in Fig. 18.2 for winter wheat, and in

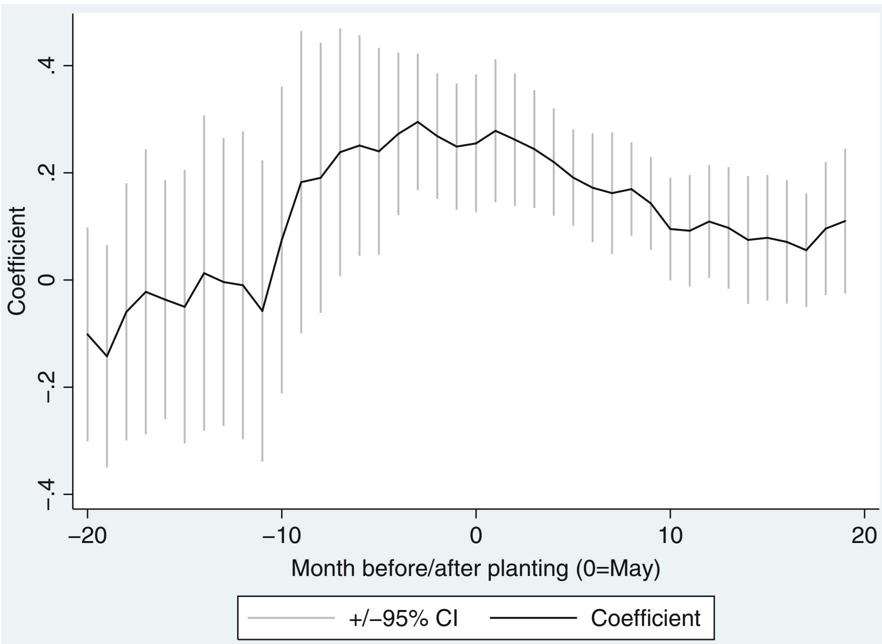

Fig. 18.1 Explanatory power of the wholesale prices over time for corn production

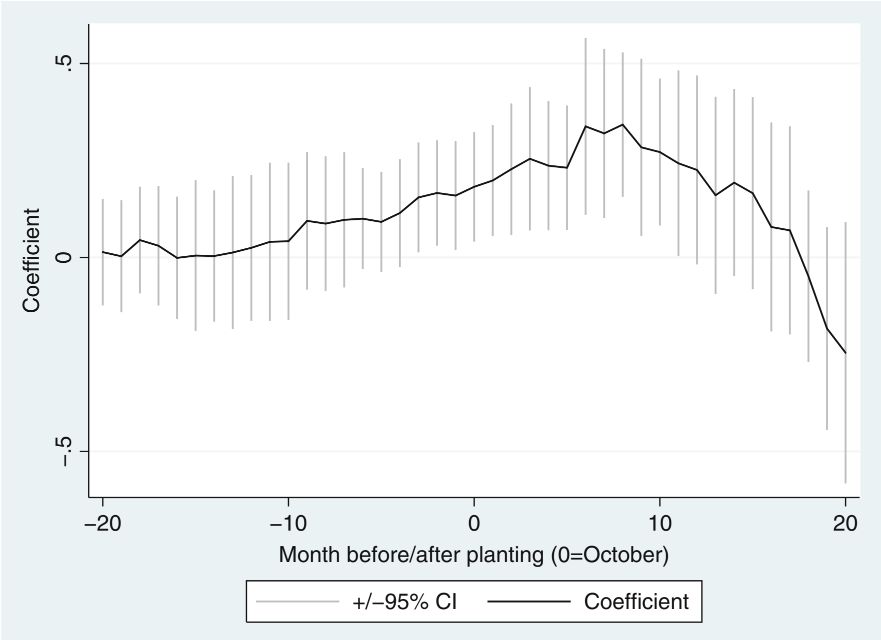

Fig. 18.2 Explanatory power of the wholesale prices over time for winter wheat production

Fig. 18.3 for indica rice. The figures show the coefficients and the 95 % confidence intervals; the statistical significance of the response can be inferred from the figures. The further the distance between the bars and the $y = 0$ line, the higher the level of significance. If the $y = 0$ line is included in the bars, the coefficient is not statistically significant at the 5 % level. The months before or after planting are depicted on the x-axis of the graphs.

Prices far before or after planting did not have much explanatory power for all crops; hence they do not influence production strongly. However, prices around planting time are usually highly significant and, at least for corn and rice, also have the highest coefficient. For rice, prices are significant in a few months far before planting, which may be attributed to the high level of autocorrelation. Nevertheless, both the level of significance and the coefficient increased and reached their highest level around planting time. Both rice and corn have a relatively short growing time—about 2–6 months—compared to wheat. This explains why prices during planting period were very important as farmers chose their area and had only little time afterwards to influence yields. Particularly for rice, the beginning of the growing season is highly important and a lack of water cannot be compensated for at a later stage. The finding of a decreased level of significance and lower coefficients a few months after planting is therefore consistent with our expectations. For wheat, the graph looks different: the level of significance as well as the size of the coefficient increased even after planting and reached their highest levels around 6–8 months

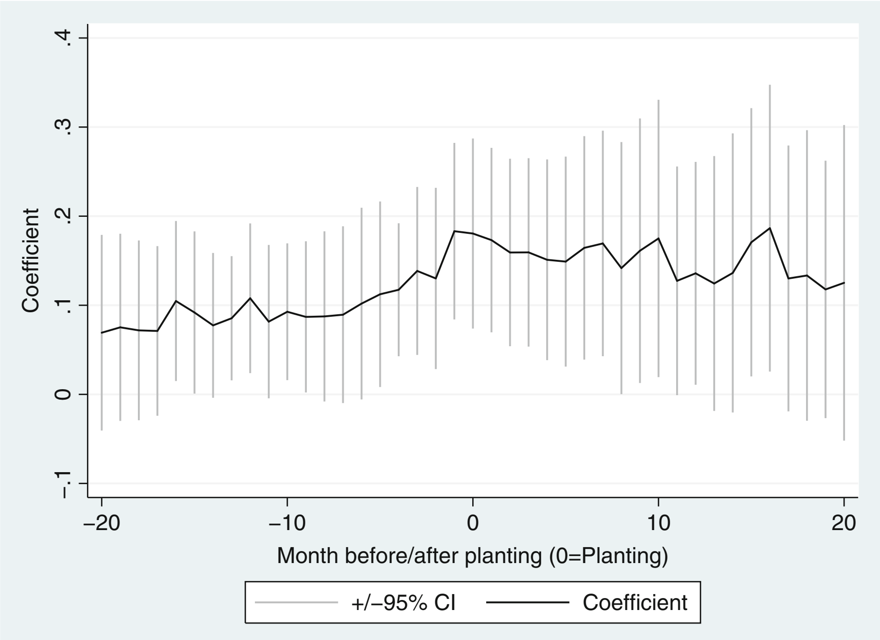

Fig. 18.3 Explanatory power of the wholesale prices over time for indica rice production

after planting. This can be explained by the different growing patterns, i.e., wheat grows for about 7–9 months after it is planted. Furthermore, the most sensitive phase of the crop is the flowering and yield formation period, whereby the wheat plant is very sensitive to water and temperatures (FAO 2015). This period is around 65–15 days before the harvest. As a result, it is crucial how farmers take care of their crops during this time period, while the establishment, tillering, and winter dormancy periods are of minor relevance (ibid.). Considering this, it matches our expectations that prices around 6 months after planting are very important for yield. For area however, prices at planting time should be the crucial factor. Although without making a distinction between area and yield, it is not possible to draw further conclusions about this.

Comparing the different crops, we found that farmers seem to react earlier to corn prices than the prices of winter wheat and indica rice. Rice showed the lowest response to prices, which might be a result of relatively high costs of area reallocation. For all crops, prices remained highly significant for a while after planting. This indicates that not only area but also yield respond to prices, regardless of whether it is due to fertilizer or pesticide application, irrigation, or other factors. For prices at harvesting time and thereafter, this method suffers from endogeneity problems as it is no longer clear if prices drive production or vice versa. Therefore, this method is only robust for the time before harvesting.

A clear result of this analysis is that farmers, at least on average, do not mainly take into account previous year's planting or harvesting prices but rather consider current prices around planting time to be the more important. This is at odds with naïve and Nerlovian price expectation models, which use lagged harvest prices for estimating production decisions. Economically, it makes sense to use current prices as they include more information about the demand and supply situation than last year's prices.

Additional graphs which show the significance (p-values) of the supply response over time for all crops and both estimators are shown in the appendix (Figs. 18.4 and 18.5). For these and the subsequent graphs, model specification two was used for all crops, and only the prices were varied over time while all other explanatory variables were kept the same. As expected, these graphs show a U-shaped curve with more or less distortions depending on the crop and estimator. Figures 18.6 and 18.7 show the same results for corn while also illustrating the results for other variables: Fig. 18.6 for the difference GMM estimator and Fig. 18.7 for the system GMM estimator. These graphs again support our hypothesis that the difference GMM estimator performs better than the system GMM estimator. The fluctuations of the system GMM results were much higher, particularly for winter wheat and indica rice as shown in Fig. 18.5. Furthermore, the fluctuations of the non-price variables were also much higher, as indicated in Fig. 18.7. In general, the period up to which prices are significant extended further after planting for the difference GMM, while in the case of winter wheat the period also started before planting.

This method of investigating prices at different points in time may also be used for general model specification tests. For a robust model, we expect the significance of the tested variables to consist of low-frequency components, which implies that there are only slow and smooth changes. The occurrence of big fluctuations in a specification, in particular if some variables constantly alternate between being insignificant and significant, suggest that the specification is not robust. Figure 18.5 and in particular Fig. 18.7 accordingly indicate that the system GMM specification is less consistent than the difference GMM specification. However, the system GMM fluctuations may still be acceptable; for problematic specifications, much higher fluctuations can easily be observed. Interestingly, prices around 2–5 months before planting time seem to have such a high explanatory power in the case of the system GMM that all other variables apart from the lagged production became insignificant (Fig. 18.7). This is an indication that prices before planting might be the most important factor influencing final production. Examining the area and yield response separately could shed more light on this issue. Overall, the price response and the response to other variables were consistent with our expectations, even though many variables turned out to be insignificant.

18.5 Conclusion

The corn, winter wheat, and indica production response for the main agricultural provinces in China was analyzed using the difference GMM estimator and, for comparison, the system GMM estimator. The major findings include the following: (1) All crops strongly responded to prices at planting time. (2) The price response of corn and wheat was higher than rice. (3) While prices shortly before and after planting period had very high explanatory power, prices further away from planting period had lower coefficients and were mostly insignificant. (4) Wheat was an exception in the sense that its prices were highly significant long after planting and showed large coefficients, which could be attributed to wheat's long growing period and the crop's sensitivity 1–2 months before harvest. (5) High temperatures negatively influenced production for all crops, which may become problematic in the future due to climate change impacts. (6) Irrigation was measured poorly and therefore may have limited the significance of the results; nevertheless the results indicated that irrigation may partly help to mitigate a shortfall in rainfall but cannot (fully) compensate for the negative effects of high temperatures. (7) Fertilizer prices had a negative impact on corn production only.

In general, the difference GMM estimator seems to perform better than the system GMM estimator. The presented method to analyze the importance of prices at different points in time may also be used for general model specification tests if data on explanatory variables is available at a sufficiently high frequency.

The mixed evidence regarding the role of weather events and irrigation in affecting production could be due to the use of province-level data, which might be too aggregated to study spatially differentiated weather impacts. On the other hand, the panel data contained observations obtained over time, which is an important advantage over cross-sectional farm-level data, in particular when studying the role of determinants with little spatial dispersion (such as prices). The analysis of prices for production, one of the main contributions of this chapter, could only be undertaken with the help of a panel data set over multiple years. Not only do the findings indicate that farmers use up-to-date price information when making their production decisions, but the month-specific price elasticities also highlight when the Chinese agricultural sector can best respond to price spikes and scarcities. As the price elasticities ranged from 16 % (rice) to 34 % (wheat), increasing domestic demand can be met to a substantial extent by supply expansion – provided that prices are suitable signals about supply and demand conditions.

Acknowledgments The authors are grateful for the financial support of the Federal Ministry of Economic Cooperation and Development of Germany (BMZ) within the research project "Volatility in Commodity Markets, Trade Policy, and the Poor." The authors are also thankful for the financial support from the European Commission within the FoodSecure project and National Natural Science Foundation within research project "National Food Security Projection, Early Warning and Development Strategy" (71333013). Furthermore, the authors thank Tobias Heimann, Mahsa Shahbandeh, and Ling Zhu for collecting valuable data and providing research assistance and Mekbib Haile for very fruitful discussions on the modeling approach.

Appendix

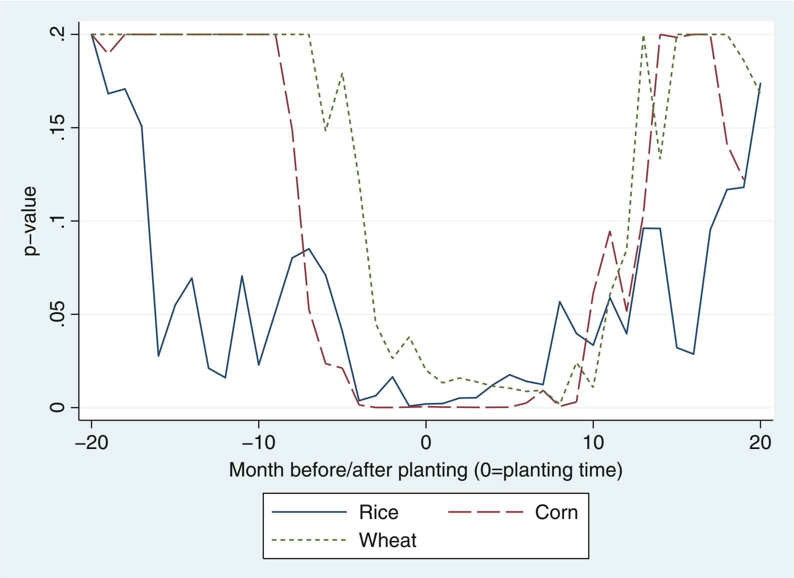

Fig. 18.4 Significance (*p*-value) of the wholesale prices over time for the difference GMM estimator

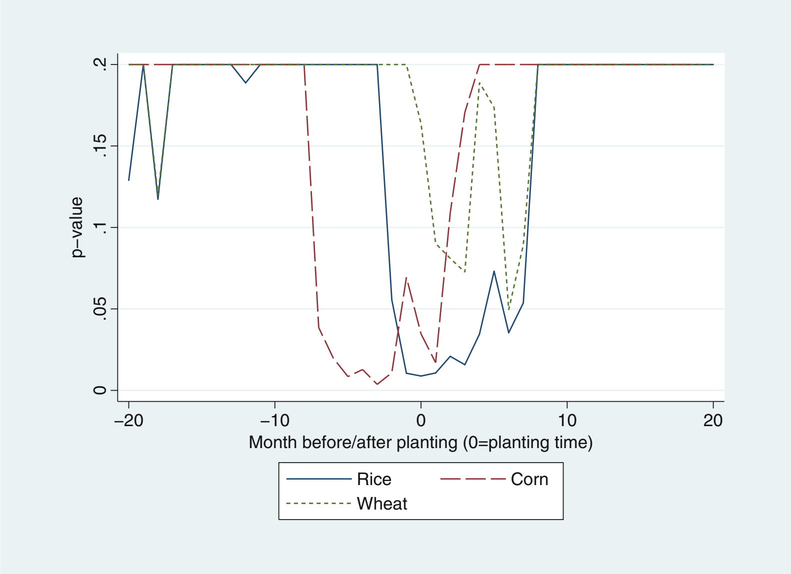

Fig. 18.5 Significance (*p*-value) of the wholesale prices over time for the system GMM estimator

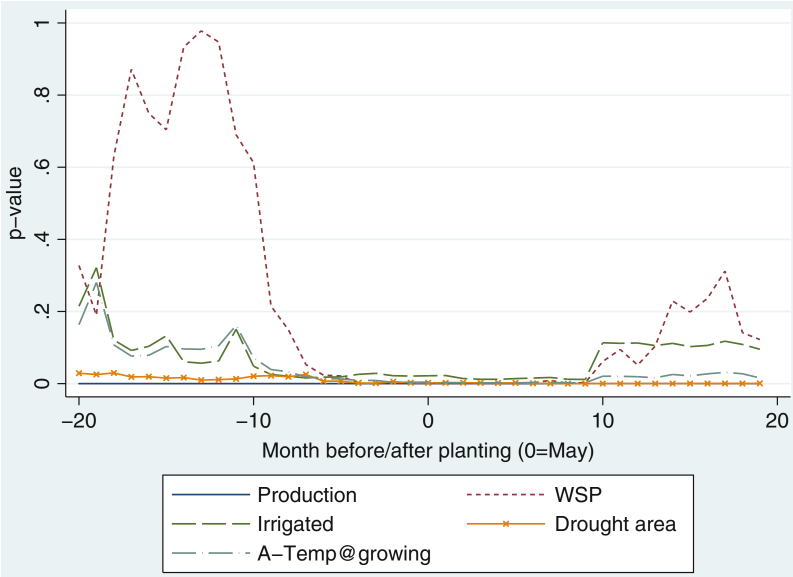

Fig. 18.6 Significance (*p*-value) of the explanatory variables over time for the second corn regression using the difference GMM estimator. Not all explanatory variables are shown to maintain recognizability, and the prices are the only variables which were varied over time

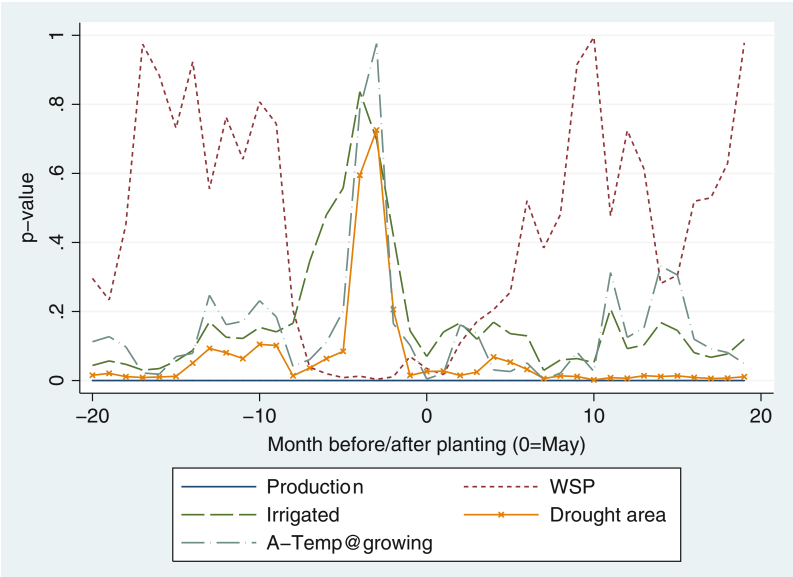

Fig. 18.7 Significance (*p*-value) of the explanatory variables over time for the second corn regression using the system GMM estimator. Not all explanatory variables are shown to maintain recognizability, and the prices are the only variables which were varied over time

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19 Consistency Between Theory and Practice in Policy Recommendations by International Organizations for Extreme Price and Extreme Volatility Situations

Maximo Torero

19.1 Introduction

Food prices have increased significantly in the past few years, with particularly sharp spikes seen during the 2007/08 season (see Fig. 19.1). There is some agreement on the causes of such price increases: (a) weather shocks that negatively affected agricultural production; (b) soaring energy and fertilizer costs; (c) rapidly growing income in developing countries, especially in China and India; (d) the devaluation of the dollar against most major currencies; (e) increasing demand for biofuels; and (f) changes in land use patterns. While there is no consensus on the relative importance of each of these culprits, it is widely agreed that most of these factors will further increase food prices in the medium and long run. Prices may become more volatile as well, as evidenced by the subsequent food crisis in 2010. Climate change will induce more weather variability, leading to erratic production patterns. Moreover, the volatile nature of the market is likely to induce possible speculation and exacerbating price spikes. Additionally, in an effort to shield themselves from price fluctuations, different countries may implement isolating policies, further exacerbating volatility.

Looking at the volatility at global level is important because, although the food price spikes of 2008 and 2011 did not reach the heights of the 1970s in real terms as shown in Fig. 19.2, price volatility—the amplitude of price movements over a particular period of time—has been at its highest level in the past 15 years.

High and volatile food prices are two different phenomena with distinct implications for consumers and producers as detailed in Torero (2012). Finally, increased price volatility over time can also generate larger profits for investors, drawing new players into the market for agricultural commodities. Increased price volatility

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Fig. 19.1 FAO food price index. *Source*: FAO

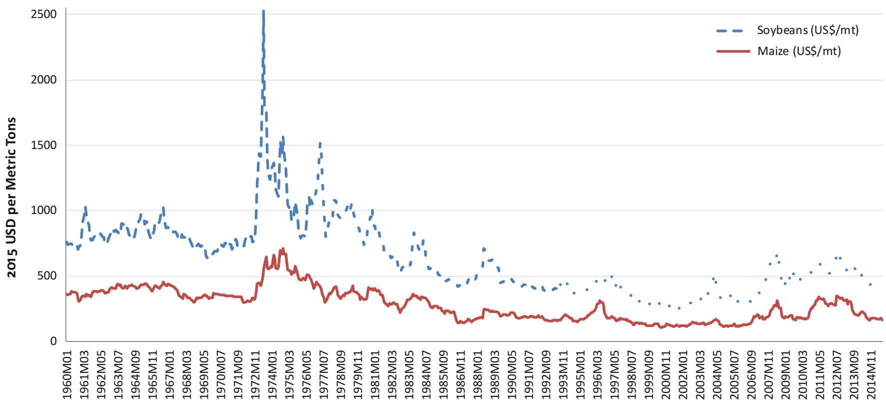

Fig. 19.2 Real price evolution. Index = 100 in 2015. *Source*: World Bank

may thus lead to increased—and potentially speculative—trading that in turn can exacerbate price swings further.

This situation imposes several challenges. In the short run, the global food supply is relatively inelastic, leading to shortages and amplifying the impact of any shock. The poorest populations are the ones hit the hardest.[1] As a large share of their

[1]There is a general concern that increasing food prices has especially adverse effects on the poor. However, until recently, there was no rigorous evidence of this. On the one hand, there would most probably be negative effects on poor urban consumers who spend a considerable portion of their budget on food. But on the other, there are gains to farmers who benefit from increased prices for their output. In general, this impact depends on whether the gains to net agricultural producers are larger than the losses to consumers. Directly dealing with this issue, Ivanic and Martin (2008)

income is already being devoted to food, the poor will likely be forced to reduce their (already low) consumption. Infants and children may suffer lifelong consequences if they experience serious nutritional deficits during their early years. Thus, the short-term priority should be to provide temporary relief for vulnerable groups.

In the long run, the goal should be to achieve food security.[2] The drivers that have increased food demand in the last few years are likely to persist (and even expand). Thus, there will be escalating pressure to meet these demand requirements. Unfortunately, increases in agricultural productivity have been relatively meager in recent years. In this line, "the average annual rate of growth of cereal yields in developing countries fell steadily from 3 % in the late 1970s to less than 1 % currently, a rate less than that of population growth and much less than the rise of the use of cereals for other things besides direct use of food" (Delgado et al. 2010, p 2).

There is a wide array of options to achieve these short- and long-term objectives, and there are no one-size-fits-all policies. Most policies come with significant trade-offs, and each government must carefully weigh the benefits and costs they would face. For example, governments might try to make food more readily available by reducing food prices through price interventions. While this policy might achieve its short-term goal, it can potentially entail fiscal deficits and discourage domestic farmers' production. Other policies not only have domestic consequences but can entail side effects for other countries. In their efforts to insulate themselves from international price fluctuations, some countries might impose trade restrictions; if a country is a large food exporter, the government might impose export taxes, quantitative restrictions, or even export bans. Albeit increasing domestic supply and lowering national prices, these policies would reduce the exported excess supply, induce even higher international prices, and hurt other nations. In addition, the "right" policies depend on the particular institutional development of a country. Middle-income countries might already have safety networks for vulnerable populations which can trigger prompt aid to those most in need in times of crisis. However, countries with lower incomes do not have such mechanisms readily available. Finally, the effectiveness of different policies will vary depending on the market characteristics of the commodity in which the government is intervening (i.e., the market structure for wheat is very different from that of rice, which is different from that of soybeans, etc.).

In this regard, this chapter describes some of the most important policies of the International Organizations like the World Bank, IFAD, AFD, and the IADB have prescribed to different countries during the food crisis of 2007/08. The

and Ivanic et al. (2011) find that the food crisis has led to significant increases in poverty rates in developing countries.

[2]Food security is a situation in which "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs, and food preferences for an active and healthy life" (World Food Summit 1996). Even when increases in food production are not a sufficient condition for food security, they are indeed a necessary condition thereof (von Braun et al 1992).

understanding of such policies is important for at least three reasons. First, food crises are very sensitive episodes that affect the basic needs of entire populations, especially those of the world's poorest countries. As such, they require timely and sensible measures. Second, increasing food prices and price volatility are likely to remain an important challenge in the medium and long run. Third, food policies are usually complex; they need to be assessed to consider their domestic impact, the trade-offs that they entail with respect to other objectives, their consequences for other countries, and their feasibility in particular contexts.

This chapter is divided into five sections (excluding the introduction). The second section analyzes a series of policies recommended by international organizations during the 2007/08 crisis and the policies recommended at the G8 Meeting of Finance Ministers in Osaka, June 13–14, 2008. The third section analyzes the policy recommendations which came out after the 2007/08 crisis and which were the result of research work done by the same international organizations. First, some short-term policies are analyzed in which two mechanisms are emphasized: support for the poor and price stabilization (with an emphasis on trade restrictions and food reserves). Second, medium- and long-term policies to increase agricultural productivity, through productivity gains and elimination of postharvest losses, are discussed. The fourth section describes specific loans and policies prescribed for selected countries during the 2007/08 food crisis. It analyzes their consistency and cohesiveness when contrasted with the general policies that some International Organizations formally recommended as well as with those policies that were recommended after 2008. The final section summarizes and presents some concluding remarks.

19.2 Proposed Policies and the G8 Summit

In this section, a detailed description of the policies officially proposed and the G8's document prepared for the Ministers of Finance Meeting in 2008 (Table 19.1 presents a summary of all these policies) are presented. These policies can be classified either as short-term policies or as medium- and long-term policies. Specifically, within the short-term policies, we identify two groups of policies: (a) short-term support for the poorest and (b) price stabilization policies.

19.2.1 Short-Term Policies (Social Protection and Trade Policies)

19.2.1.1 Short-Term Support for the Poorest

Governments' short-term objective is to increase access to food, especially for the most vulnerable shares of their population. In this sense, policies should provide targeted short-term subsidies to those in the most distress. Countries that already have Targeted Cash Transfer (TCT) and Conditional Cash Transfer (CCT) programs in place can scale them up and increase the subsidies they provide (World Bank 2008). TCTs provide additional income to poor households with children or disabled or elderly members. CCTs provide the same benefits but are contingent on some

Table 19.1 Policies proposed by International Organizations and G8 Summit

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Trade policy		
Tariff and VAT reductions	– "At first glance, reducing tariffs and other taxes on key staples is both effective and desirable. In times of sharply increasing prices, reductions in tariffs and taxes can provide some relief to consumers, albeit at a fiscal cost . . . Yet longer term, such unilateral changes in one tariff but not others may alter the structure of relative incentives and could end up channeling private resources to second-best uses in terms of growth and welfare, which illustrates the need to consider separately short and longer term responses" (pgph. 13)	– Recommended for all countries with significant taxes and tariffs on food grains: – Can significantly lower domestic prices in countries where share of tariffs in retail prices is high but scope limited in low tariff settings – Easy to implement – Domestic food grain producers face more competition – Fiscal losses depend on composition of domestic revenues
Export bans and restrictions	– "The least desirable trade-related policy interventions to manage food prices are export restrictions or bans on key staples . . . This type of measure has a limited impact on domestic price levels and a significant negative effect on the earnings of domestic producers and exporters. Besides leading to sharp price fluctuations and supply uncertainty in countries that depend on imports, these measures often have the greatest negative impact on the country imposing the restriction as domestic production and foreign exchange earnings fall and traditional commercial relationships are severed" (pgph. 14)	– Bad policy option in all countries due to negative externalities on others and disincentives for future production – Can help stabilize domestic grain prices in the short run but undermines long-term supply response – Creates disincentives for domestic producers particularly those dependent on export markets – Serious beggar-thy-neighbor effects due to price volatility and shortages particularly when they are applied by major exporters
Promotion of bilateral or regional trade	– "Finance technical assistance and investments for regional trade and transport facilitation. It could also finance activities that would accelerate on-going trade facilitation actions that would specifically improve the functioning of regional staple food and input markets. Assessments of technical, policy, logistical and other constraints to regional and cross-border trade in staple foods and agricultural inputs will be supported" (pgph. 100, B6)	

(continued)

Table 19.1 (continued)

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Food reserves		
Use of strategic grain reserves (buffer stocks) to lower prices	– "Many countries maintain physical grain reserves in lesser or greater volumes. These reserves are maintained in order to service emergency relief operations, support public distribution of food to chronically food insecure populations, and reduce volatility in consumer and/or producer prices. International experience in the management and use of so-called strategic grain reserves[b] is mixed, with frequent concerns about operational inefficiencies, financial cost, and disincentives for private traders to perform normal arbitrage functions. Some of the problems with grain reserves can be overcome by establishing clear and open rules for market interventions, including the private sector in the tendering for supplies for the reserves, combining grain and financial reserves to reduce costs, and utilizing very professional management, supported by good information systems and analytical capacity" (Annex 5, pgph. 27)– GFRP provides technical assistance for grain stock risk management (Annex 5, pgph. 28)	– Second best option used in low-/middle-income countries which have the capacity to manage food stocks and need to respond quickly to food availability issues (they insure against delays and price volatility in international markets) – Can be used to provide targeted consumer subsidies – Excess stocks can undermine private markets and reduce capacity to respond during shocks – Professional management of stocks with good management information systems and clear criteria for market intervention required
Use of strategic grain reserves for humanitarian purposes	– "About one-fifth of developing countries sampled have begun adding to grain buffer stocks, creating, re-creating, or adding to 'strategic reserves'. These are often used to provide subsidized food rations for the poor. Recent price spikes in international markets, and the current difficulty in obtaining supplies, particularly in the rice market, suggests that more countries will try to increase domestic stockholdings despite the high costs of management and risks of leakage. If so, this is likely to perpetuate the price spike as participants go into global markets with higher orders than normal despite the much higher prices. An alternative approach using financial instruments rather than physical grain stores is for governments to enter into contingency purchasing contracts with domestic and/or international suppliers" (pgph. 15)	

Social protection		
Cash transfers (means-based and CCTs)	– "Direct transfers in cash or in kind, are the simplest and most straightforward way to get additional resources to the most vulnerable households to mitigate the effects of a food crisis. Targeted Cash Transfers (TCTs) are preferable to in-kind transfers, as they avoid incurring the costs of food transport and distribution. They often target households with children, elderly or disabled individuals. These programs have relatively low administrative costs and do not distort prices. Benefits can be differentiated by level of need, household size or composition. Similarly, existing Conditional Cash Transfer Programs (CCTs) (which link the benefit to requirements such as school attendance or health service take-up) are an option for channeling support rapidly—but the complexity of such programs means it will not normally be feasible to establish new ones as vehicles for an emergency response" (pgph. 110) – "Cash programs are preferred to in-kind programs, as they have lower administrative costs. However, when local food markets do not function and food is not available, in-kind programs are preferred" (Annex 5, pgph. 47)	– Best suited to countries with sufficient institutional capacity to appropriately target and disburse cash to large numbers of people (middle income and selected low income) – Typically cash transfers have lower overhead costs relative to food programs – Can be linked to use of health and education services (conditional cash transfers). Where access to health and education services is limited, the condition may rule out the neediest families. Moreover, monitoring the compliance with conditions involves an extra administrative system. Where programs are well established, their benefit can be raised or their coverage expanded, but setting up new programs has a long lead time. Unconditional needs based cash transfers more broadly applicable during crises – Transfer amounts need to be adjusted to keep pace with inflation

(continued)

Table 19.1 (continued)

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Near cash transfers (food stamps, vouchers, etc.)	– "Food stamps are an intermediate step between cash transfers and food distribution. GFRP may support the subsidy value of food stamps and the associated logistics (e.g., printing physical food stamps or supplying smart cards). It will fund the analysis of needs and targeting criteria; program monitoring; the development of necessary infrastructure; and financing for new programs/scaling up existing food stamp and food ration programs, including means for stamp redemption and for smart cards to reduce leakage" (pgph. 111)	– Most often used when countries are transitioning from in-kind to cash transfers – Lower overheads than food transfers, slightly higher than for cash transfers – Requires retail chain and effective distribution system
Public work programs	– "Labor intensive public works programs are an option to generate incomes in targeted communities while also delivering services, rehabilitation or construction of infrastructure. These programs are particularly useful in the absence of good household targeting systems as they self-select unemployed beneficiaries by requiring them to work. So long as wages are set below market levels they are not likely to displace people from existing jobs" (pgph. 114)	– Recommended for low-income countries where targeting cash transfers via means or proxy means testing is difficult – Potential for effective self-targeting, though often scale of program is small enough that additional targeting criteria are needed – Local infrastructure can be created but quality control important – Effective implementation of the work programs is administratively demanding – Substantial nonlabor costs (usually 40–60 % of total) – Administrative costs of handling food higher than comparable cash for work programs

Feeding programs (school-based and maternal/child feeding)	– "In countries where no large cash transfer system is in place, they (school feeding) may offer the best option for delivering additional resources quickly and on a large scale, to offset the impact on household budgets of the food crisis. Like CCTs, they have the additional benefit that they act as an incentive to send children to school and thus, they lower the probability that children will be taken out of school in response to the negative income effect of food price rises (e.g., to send them to work). As well as food consumed at school, take-home rations could be distributed for consumption by younger siblings. Geographical targeting could be used to focus on the poorest areas of the country" (pgph. 113) – "GFRP will provide short-term support to strengthen the coverage and delivery of existing nutrition and primary health programs. Priority areas for support will include (a) Nutrition education and growth promotion to improve nutritional practices by changing behaviors with respect to breastfeeding and complementary infant feeding, dietary quality, hygiene, and child care. (b) Provision of targeted food supplements and micronutrients, including (i) food supplements for vulnerable pregnant and lactating women and children under 2 years, for recuperation of severely malnourished children, and for HIV/AIDS patients under treatment with antiretroviral drugs, (ii) micronutrients such as iron and folic acid supplements, Vitamin A, and interventions to address iodine and zinc deficiencies for high-risk population, (c) Other primary health interventions which reduce the risk of malnutrition (such as immunizations, oral re-hydration therapies and protection against malaria) could also be supported" (pgph. 116)	– Recommended for countries in parallel with above options as the primary focus of these programs is on protecting the most vulnerable—e.g., children and mothers – Maternal feeding can encourage accessing other health/nutrition education services – School feeding can be combined with other interventions such as deworming – Food needs to be low cost yet nutritious and feeding timed to minimize teaching disruptions—take-home rations are an alternative to on-site feeding – While school feeding can effectively target children, it misses infants whose feeding needs are highest – Nutritional supplementation programs may need to be scaled up, especially for infants

(continued)

Table 19.1 (continued)

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Strengthening social protection programs	– "GRFP will finance capacity building and related investments needed to develop new programs and to improve program effectiveness of existing programs. This may include activities to (a) recommend and implement appropriate developments of the social protection system to provide a basis for more effective mitigation to future crises; (b) improve the capacity of existing transfer programs in selection of beneficiaries (targeting and needs analysis); beneficiary registers; payment systems for cash transfer programs and delivery systems for in-kind programs; procurement systems; program governance; oversight mechanisms aimed to reduce the amount of funds lost to error, fraud or corruption; Management Information Systems (MIS), monitoring and evaluation; communication campaigns; (c) strengthen linkages between the transfer programs and the health and education sectors, for example, ways to verify compliance with conditionality; (d) to strengthen communication on health and nutrition and (e) the monitoring and evaluation of social protection, health and nutrition programs" (pgph.118)	
Food subsidies	– "Food subsidies via untargeted open market sales, subsidies on imports, ration shop sales and other measures to lower the market price for consumers can entail a substantial fiscal cost. Subsidy costs can be reduced by taking into consideration (i) type of food commodity to be subsidized, (ii) mechanisms to reduce leakages, and (iii) exit strategies" (Annex 5, pgph. 26)	– Second best option in countries where targeted safety net programs cannot be scaled up sufficiently during crises – May not distort domestic markets much if consumer subsidy is financed by the budget and not by limiting producer prices; is rationed; and is applied to products consumed mainly by the poor (e.g., coarse rice) – Institutional ability to operate "low price markets/shops" with adequate food rations is required – There is some risk of the rich hiring the poor to procure subsidized items

Price controls on strategic staples or on trader margins		– Bad policy option in all countries – Lowers prices to all consumers regardless of need – Discourages domestic production, processing, and trade – Creates black markets and rationing which often benefit more affluent people – Danger of aggravating rapid migration to cities over time
Other price stabilization policies	– "To avoid major fiscal deficits that could threaten macro-stability or cuts in public expenditures that could threaten development, governments may request funding under this facility to finance short-term price stabilization programs, including market intervention policies such as open-market sales of stocks or imports" (Annex 5, pgph. 15)	
Supply policies		
Higher levels of public and private investment in agricultural support services	– GFRP "provides technical and financial assistance to support governments in their immediate and medium-term response to the crisis resulting from shortfalls in domestic food availability in combination with rising international food prices" (pgph. 71) – "Longer-term lending to support investments in infrastructure will continue using regular Bank mechanisms, and support under GFRP would not displace longer-term agriculture-related lending such as investments in irrigation infrastructure, rural roads or agriculture research" (Executive Summary, pgph. 7) – GFRP does support the following policies: • Rehabilitation of existing small-scale irrigation • Strengthening farmer access to critical information (dissemination of technology, advisory services, linking farmers to markets, ICT applications, etc.).	– Necessary investment in all regions – Significant scope for increasing yields in all regions through greater use of existing technology and water and soil management – Agricultural research as share of agricultural output lags behind in LDCs relative to MICs—essential for continued productivity increase – Revamped extension with product marketing services required—investments in data, capacity, and community-based extension important – Public investments need to ensure sufficient provision for operations and maintenance (e.g., large irrigation projects) – Agricultural strategies need to differentiate between needs of commercial farmers and those of smallholders

(continued)

Table 19.1 (continued)

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Reduction of postharvest losses	– "Support could take various forms, including: (i) training and demonstration of low cost on-farm storage technologies; (ii) technical assistance, training and investment support for community-level 'food banks'; (iii) training and facilitation of investment by grain traders and millers in drying, sorting, and fumigation equipment and upgrades in existing storage facilities; (iv) rehabilitation of rural roads and bridges where deficiencies in such transport infrastructure are shown to substantially contribute to staple food product/quality losses; and (v) training, technical assistance, and supplemental equipment to strengthen existing food grain quality control inspectorate services and food safety surveillance systems" (pgph. 123)	– Necessary investment in all regions – Reduction of postharvest losses (estimated up to 25 % of output) is key to greater intensification of production
Investment in rural and trade-related infrastructure	– GFRP does not provide support for rural roads. Roads would be financed through regular Bank mechanisms	– Priority in countries with poor trade and transport infrastructure, in rural areas – Improvements in rural accessibility can lead to lower prices of all products as well as stimulate surplus production – Investments in improving customs, logistics management, and marketing infrastructure will strengthen producer incentives
Input subsidies	– "Provide finance and technical assistance: (i) to reform laws and regulations which inhibit the development of agricultural input markets; (ii) to develop or scale up voucher and supplier credit schemes, based on 'smart subsidy' and other principles; (iii) for investments and training to strengthen existing systems for seed and fertilizer quality control; (iv) for investments to upgrade/rehabilitate seed multiplication and distribution facilities, and (v) for fertilizer imports through revolving fund or other financially sound mechanisms" (pgph. 72)	– Appropriate for low-income countries where access by farmers to credit, farming inputs, and risk management instruments is limited – Fiscal costs can be high – Subsidies need to be transparent and well targeted – Exit strategy needs to be built-in and communicated publicly – Risks crowding out private input supply

Strengthening access to finance and risk management tools	– "Support: (i) credit lines and capacity-building for formal financial institutions to increase agricultural lending; (ii) the development of legal/regulatory frameworks and provision of credit lines and technical assistance to extend the use of supply chain finance; (iii) the scaling up of community-based financial institutions; (iv) feasibility studies and training to enable farmer organizations, market intermediaries, and financial institutions to utilize selected physical or financial strategies to manage commodity price risks; and (v) feasibility studies, training, and advisory services to facilitate further applications of commercial agricultural (and weather) insurance" (pgph. 125)	– Appropriate for all countries particularly those susceptible to large fluctuations in agricultural output – Support required for innovative financing mechanisms for supply chain management and managing commodity price volatility – Financial products which transfer weather-related risks to international insurance/derivative markets are complex and required capacity building and possibly government cost-sharing
Other policies		
Price risk management	– "Provide support to governments and major private sector entities to identify if/how market-based hedging products can be incorporated in national policies and commercial strategies, and, where feasible, to implement price hedging transactions" (Annex 5, pgph. 29)	– (Forward contracts for international grain procurement are) Appropriate for countries with data/capacity required to make decisions on forward contracts – Government role is to facilitate implementation in the public interest by private sector entities rather than function as direct market actors

(continued)

Table 19.1 (continued)

	Proposed policies under the Global Food Crisis Response Program (GFRP)	G8's "Addressing the food crisis"[a]
Early warning and weather risk management for food crop production	– "The following activities are included: (i) investment in automatic weather station infrastructure and data reporting systems; (ii) capacity building in agro-meteorology, crop surveillance, and crop estimation systems; (iii) assessment of the technical, operational, and commercial feasibility of applying weather-indexed insurance or derivative products as part of disaster risk management strategies; (iv) technical assistance in insurance product design, (v) intermediation services for weather risk management transactions between client governments and the international market; (vi) partial financing of premiums on weather insurance/derivative transactions and (vii) technical support to help governments develop plans for utilizing funds that accrue from insurance payouts, for example, in designing safety net programs that scale up on the basis of payments" (pgph. 100, B5)	

[a]Taken from World Bank (2008) Addressing the food crisis: the need for rapid and coordinated action. Group of Eight, Meeting of Finance Ministers. Osaka, June 13–14, 2008. Annex 4

[b]Throughout the GRFP Framework document, the definition of "Strategic Reserves" is unclear. In some sections, they seem to refer to humanitarian reserves (whose purpose is food distribution among the poorest), while in others they seem to reflect (generalized) price stabilization objectives

conditionality (which usually encompasses an educational, nutritional, or health requirement). These approaches of cash transfer constitute first-best responses for several reasons: (a) they prioritize assistance for targeted groups, (b) they do not entail additional costs of food storage and transportation, (c) they do not distort food markets, and (d) in the case of CCTs, they explicitly prevent human capital deterioration. However, there is an important shortcoming to these approaches: countries with weaker administrative capacity—which are usually those most affected by food crises—are less likely to have implemented any TCTs or CCTs.[3] In this line, Delgado et al. (2010) argue that "it is essential that during noncrisis years, countries invest in strengthening existing programs—and piloting new ones—to address chronic poverty, achieve food security and human development goals, and be ready to respond to shocks."

When TCTs and CCTs are not available, governments may implement other types of assistance programs. First, school feeding (SF) programs might be useful to relieve child malnourishment. However, they are usually ineffective to combat infant malnutrition (when adequate nutrition is most needed), unless food consumed at school can be complemented with take-home rations for younger siblings. Additionally, SF relies on geographic rather than household-specific targeting and entails food storage and distributions costs. Food for Work (FfW) programs are a second option. These are easier to implement and are (in principle) self-targeted: they provide low wages so only poor people should be interested in participating. However, in very poor regions, the vast amount of unemployed and underemployed may lead to considerable leakages and distortions in the labor market (Wodon and Zaman 2008). Also, only a portion of the funds allocated to these programs directly cuts poverty. Beneficiaries leave other jobs to participate in them; thus, the benefits of FfW are not the whole wages they provide, but only the differential income (with respect to the previous job). These programs might create distortions in the labor market. Finally, governments can also provide direct food aid. However, there is no guarantee that this aid can be effectively targeted toward the most vulnerable populations. Furthermore, food aid may become an entitlement and might result in long-term fiscal problems.

19.2.1.2 Price Stabilization Policies

Support programs for the poorest might not be easily implemented during food emergencies because they take time to be put into action. At the very least, they require a distribution network and plenty of logistical coordination. This forces governments to implement other policies to shield their population from food emergencies. Moreover, even when technically sound schemes such as CCTs are readily available during a crisis, some countries might still try to pursue more widespread

[3]For example, these policies might be more suitable for medium-income countries, such as in Latin America. World Bank—LAC (2008, Table 8) documents 17 countries with CCTs and 18 countries with Targeted Nutritional or Social Assistance Programs.

measures for political reasons.[4] Constituencies (and, in general, populations) are very sensitive to food prices, and governments may fear opposition, turmoil, or even being ousted. For example, Burkina Faso suspended import taxes on four commodities after the country experienced riots over food prices in February 2008. Other countries that experienced riots during the 2007/08 crisis were Bangladesh, Cambodia, Cameroon, Côte d'Ivoire, Egypt, Indonesia, Mauritania, Senegal, and Yemen (Demeke et al. 2008).

In this light, many countries try to stabilize prices through trade policies and management of food reserves. The specific trade-offs imposed by these mechanisms will be discussed subsequently. In general, they are not first-best options: countries use scarce resources to reduce general prices, effectively subsidizing both the poor and the nonpoor[5] and creating potentially pervasive market distortions. However, countries with no other means or with politically unstable regimes may have few other options to cope with food emergencies.

19.2.2 Medium- and Long-Term Policies

Short-term responses mainly deal with demand problems as consumers—and especially the poor—are hard-hit. However, short-term policies that help consumers might be detrimental for producers and for market development in the long run. For example, export taxes on wheat in Argentina help decrease consumer prices, but also disincentive production. As suggested by a newspaper article, "with scant incentive to produce, farmers have slashed the land sown with wheat to a 111-year low, and cereal exports from the rolling pampas of what should be a breadbasket country have virtually halved over the past 5 years. Wheat farmers in Argentina have turned to other crops, such as soybean, while some international investors, who are critical to the flow of money into capital-intensive agriculture, have left the country and turned to Uruguay, Paraguay, and Brazil".[6] While acknowledging the importance of short-term responses to food crises, these responses should be chosen to minimize any long-term adverse effects on agricultural supply.

[4] As suggested by HDN and PREM (2008), "effective nutritional and social protection interventions can protect the most vulnerable from the devastating consequences of nutritional deprivation, asset depletion and reductions in education and health spending. Policy responses need to balance political economy considerations that call for measures to help a broad swath of the affected population, with the urgency of protecting the very poor."

[5] Wodon and Zaman (2008) posit the following argument: "Consider the share of rice consumption in the bottom 40% of the population. This share varies from 11% in Mali to 32% in Sierra Leone. This means that if one considers the bottom 40% as the poor, out of every dollar spent by a government for reducing indirect taxes on rice, and assuming that the indirect tax cuts result in a proportionate reduction in consumer prices, only about 20 cents will benefit the poor on average."

[6] "Argentina's farmers unable to fill the wheat gap," Financial Times, August 10th, 2007. Link: http://www.ft.com/intl/cms/s/0/910f25ac-a4a8-11df-8c9f-00144feabdc0.html#axzz1vXMMOjP5

Long-term policies that expand food availability are becoming increasingly important.[7] Agricultural demand has experienced large expansions in recent years—even above that regularly imposed by population growth—due to rapidly growing incomes in developing countries (such as China and India) and rising demand of food for biofuel production in developed countries.[8] As these patterns are likely to persist, there is a need to increase agricultural supply in order to keep up with the additional demand.[9]

There are two main policies targeted toward increasing food production. The rate of growth of the yields of major crops has been declining steadily since the 1970s. Thus, on the one hand, there is the need to enhance the productivity and resilience of major crops. Yet many challenges will make this a daunting task. Availability of fertile land will be limited by increasing urbanization, salinization, erosion, and degradation. Water will also become scarcer. Additionally, climate change will most certainly have an adverse effect on agricultural production through erratic rainfall, pest proliferation, and crop failure. Thus, any policy to increase agricultural productivity should address these complex obstacles.

On the other hand, supply can also be expanded through the enhancement of postharvest practices. Between harvest and consumers' access to food, agricultural production goes through many stages: product processing, storage, handling, transportation, and distribution. In each of these phases, there are production losses. For example, grains molder with improper storage technologies and facilities, as well as poor roads, preventing food from reaching markets. Albeit complementary, even in the absence of productivity gains, better postharvest practices can have a significant impact on food availability.

19.3 Policies Recommended After 2008

19.3.1 Short-Term Policies

19.3.1.1 Trade Policies

When faced with increasing food prices, net food exporters can impose export taxes or bans. While lower prices hurt local producers, these policies do benefit

[7]Examples of other policies in the long run are: production and price insurance for farmers; provision of other public goods for rural areas (such as education and health services); policies for water basin management; technology improvements for rainfed land (water capture infrastructure, practices for water retention in soil, etc.); strengthening of producer organizations; etc. Certainly, these are also important policies. However, for the sake of brevity, they are not mentioned here.

[8]Mitchell (2008) estimates that about 70–75 % of food price increases were due to rising food demand for biofuel production.

[9]As suggested by the World Bank's South Asia Region report (2010), "the food crisis is by no means over... There is growing agreement that a two-track approach is required, combining investments in safety nets with measures to stimulate broad-based agricultural productivity growth, with major emphasis on major food staples."

domestic consumers and boost the revenue of governments enacting them. Thus, it is not surprising that many food-producing countries enacted some form of export restriction during the 2007/08 food crisis. Demeke et al. (2008) surveyed different government policies in 81 developing countries and found that 25 of them either banned exports completely or increased export taxes.

Analogously, net food importers can decrease their tariffs (or even subsidize imports) to buffer the impact of rising international food prices. At least in the short run, these policies are able to temporarily reduce internal prices; however, they also have domestic side effects (see Table 19.1). Some argue that tariff reductions might not have been effective in shielding importing countries from the 2007/08 food crisis. FAO et al. (2011) argue that "the scale of price increases was such that for many countries reducing import tariffs had relatively modest impact because the initial tariffs were low or the scale of the price increases was so large. In any event, this instrument was quickly exhausted as tariffs were reduced to zero" (p. 14). Additionally, tariff reductions diminish governments' revenue, leaving them with fewer resources with which to palliate the impact of food price increases. The situation might be especially serious when there are few alternative sources of revenue (e.g., weak tax collection, large informal sector, etc.). Eventually, this could lead to serious fiscal deficits.

These strategies should not entail any consequences for international markets if only small countries implement them. These countries' food exports or imports are not substantial relative to international trade, and they are mostly price takers on the world markets. However, trade policies of large food exporters or importers do effectively affect international supply or demand of a commodity. When large exporters impose export restrictions during a food emergency, they tighten the already short supply abroad and further increase international prices. In a similar fashion, as large food importers reduce their tariffs, they increase internal consumption, fueling global demand and generating further escalations of food prices in external markets. If exporting and importing countries both follow these strategies, their efforts to insulate themselves might cancel out each other's efforts.

Martin and Anderson (2011) describe this phenomenon on the international market for a certain commodity. Initially, there is excess supply from world's exporters and excess demand from importers. The authors then consider an exogenous shock that reduces production in some exporting countries. In the absence of any trade policy, this shock changes the balance between supply and demand. If a large exporting country tries to avoid an increase in domestic prices and imposes a tax on exports, this further reduces the excess supply and leads to higher international prices. If a large importing country retaliates and reduces its tariffs to exactly offset the trade policy imposed by the large exporter, this would increase global excess demand. The final outcome in this scenario is that the traded quantity and price in both countries would be the same as before either policy was enacted. However, other countries around the world would be worse off, as the final price on the international market would soar. This can eventually give other countries the incentive to impose similar policies, leading to a trade war of import tariffs and export taxes. As Martin and Anderson (2011) suggest, "insulation generates a classic collective-action problem akin to when a crowd stands up in a stadium: no one gets a better view by standing, but any that remain seated gets a worse view."

So to what extent should countries implement such policies and impose beggar-thy-neighbor consequences upon others? There is no consensus in this respect. On one hand, Timmer (2010) analyzes the implications of trade restrictions on rice markets during the 2007/08 food crisis and finds that stabilizing domestic prices using domestic border intervention could be an effective strategy to handle food crises. Timmer argues that unstable demand and supply needs to be accommodated somehow, and that passing this responsibility to the international market may be the most fair and successful way to do so.

On the other hand, Anderson and Nelgen (2012) advise against any trade restrictions, using a model of supply and demand for the market of a particular commodity. Their results are presented in Tables 19.2 and 19.3. Table 19.2, not surprisingly, shows that trade restrictions did boost international food price increases between 2006 and 2008.[10] Yet the results also suggest that everyone should take part of the blame for this: the policies of both exporting and importing countries, and both developing and high-income countries, fueled the price increases. Table 19.3 compares the changes in international prices that would have taken place without trade interventions with effective domestic prices. All in all, their estimates show that these policies had a very heterogeneous impact for different countries and commodities. On average for all countries, domestic wheat prices increased more than adjusted international prices. These policies were somewhat more effective for other crops, but overall their effect was not large: 2 % for maize and 12 % for rice.

Anderson and Nelgen (2012) advise governments to refrain from imposing insulating trade policies because they amplify price increases and, moreover, are not always effective. Theoretically, small countries cannot affect international markets individually by changing their trade policies. However, Anderson and Nelgen (2012) claim that if many small countries do so simultaneously, it can have an aggregate

Table 19.2 Contributions of high-income and developing countries, and of importing and exporting countries, to the proportion of the international price change that is due to policy-induced trade barrier changes, 2006–08[a]

	Total proportional contribution	High-income countries' contribution	Developing countries' contribution	Importing countries' contribution	Exporting countries' contribution
Rice	0.40	0.02	0.38	0.18	0.22
Wheat	0.19	0.09	0.10	0.07	0.12
Maize	0.10	0.05	0.05	0.03	0.07

[a]Taken from Anderson and Nelgen (2012), Table 7

[10]Their findings are qualitatively consistent with those of Bouët and Laborde (2010). Their calculations are based on a multicountry general equilibrium model for wheat. They show how price increases are amplified by both tariffs and export taxes.

Table 19.3 Comparison of the domestic price with the rise in international grain prices net of the contribution of changed trade restrictions; rice, wheat, and maize, 2006–2008 (% unweighted averages)[a]

	International price rise		Domestic price rise		
	Incl. contribution of changed trade restrictions	Net of contribution of changed trade restrictions	All countries	Developing countries	High-income countries
Rice	113	68	56	48	74
Wheat	70	56	77	65	81
Maize	83	75	73	62	82

[a]Taken from Anderson and Nelgen (2012), Table 8

sizeable impact. In this line, they argue that trade restrictions and reduction of import tariffs should be discouraged across the board.

To analyze this last point, Table 19.4 shows the shares of imports and exports for soybean, rice, wheat, and maize by region (following the World Bank classification)[11] in 2004, before the food crisis. We posit that Anderson and Nelgen's results (in Tables 19.2 and 19.3) seem to hide very large disparities within their "exporting," "importing," "developing," and "high-income" labels. For example, estimates in Table 19.2 show the impact of trade restrictions on the increase of the international price of rice to be around 40 %; 38 % is from developing (with the remaining 2 % from high-income countries) and 18 % is from importing countries (and the remaining 22 % from exporting countries). From the export side, Thailand, India, and Vietnam—which account for 65 % of all rice exports—imposed trade restrictions. From the import side, important importers such as the Philippines and other Asian countries were concerned about a potential shortage and reduced their tariffs. Policies enacted by these large players exemplify how trade restrictions can lead to significant price spikes. However, from the evidence presented in Tables 19.2 and 19.3, it is unclear if trade restrictions by smaller countries would entail serious consequences for international markets. For example, Sub-Saharan Africa accounts for 0.1 % of rice exports worldwide. Excluding Nigeria, South Africa, Côte d'Ivoire, and Ghana, the share of all other Sub-Saharan African countries was only 10.7 % of worldwide rice imports. It is reasonable to believe that, even if all nations in this region changed their trade policies, there would not be a sizable impact on the international rice market.

While economists tend to be more critical of the use of import barriers as creating instability in world markets, they frequently applaud import barrier reductions undertaken in the same context. There may be some basis for this support if the reduction is believed to be permanent once undertaken. If, however, it is undertaken purely on a temporary basis as a way to reduce the instability of domestic prices, the effects on the instability of world prices are clearly quite symmetric. From a policy

[11]See http://data.worldbank.org/about/country-classifications/country-and-lending-groups

Table 19.4 Share of exports and imports by region and selected countries for soybeans, maize, wheat, and rice (2004)

1.A: Soybean exports, 2004		
	Exports (US$, thousands)	Share (%)
High income	7,563,204	48.5
United States of America	6,692,040	42.9
All others	871,164	5.6
East Asia & Pacific	161,858	1.0
Europe & Central Asia	17,518	0.1
Latin America & Caribbean	7,827,815	50.2
Brazil	5,394,910	34.6
Argentina	1,740,110	11.2
All others	692,795	4.4
Middle East & North Africa	315	0.0
South Asia	897	0.0
Sub-Saharan Africa	7144	0.0
Others	5101	0.0
Total	15,583,852	100.0
1.B: Soybean imports, 2004		
	Imports (US$, thousands)	Share (%)
High income	8,035,760	41.0
Japan	1,774,620	9.1
Netherlands	1,504,200	7.7
Germany	1,129,570	5.8
All others	3,627,370	18.5
East Asia & Pacific	8,935,462	45.6
China	7,680,418	39.2
All others	1,255,044	6.4
Europe & Central Asia	252,591	1.3
Latin America & Caribbean	1,693,014	8.6
Mexico	1,107,990	5.7
All others	585,024	3.0
Middle East & North Africa	605,239	3.1
South Asia	36,913	0.2
Sub-Saharan Africa	10,572	0.1
Others	14,763	0.1
Total	19,584,314	100.0

(continued)

Table 19.4 (continued)

2.A: Rice (milled) exports, 2004		
	Exports (US$, thousands)	Share (%)
High income	1,324,307	18.0
East Asia & Pacific	3,534,287	47.9
Thailand	2,368,150	32.1
Vietnam	950,315	12.9
All others	215,822	2.9
Europe & Central Asia	18,692	0.3
Latin America & Caribbean	174,862	2.4
Middle East & North Africa	227,739	3.1
South Asia	2,076,696	28.2
India	1,448,460	19.6
Pakistan	627,240	8.5
All others	996	0.0
Sub-Saharan Africa	9500	0.1
Others	5479	0.1
Total	7,371,562	100.0
2.B: Rice (milled) imports, 2004		
	Imports (US$, thousands)	Share (%)
High income	2,341,903	35.1
Saudi Arabia	534,327	8.0
United Arab Emirates	327,843	4.9
United States of America	257,666	3.9
All others	1,222,067	18.3
East Asia & Pacific	1,045,859	15.7
Philippines	274,585	4.1
China	268,003	4.0
All others	503,271	7.5
Europe & Central Asia	187,705	2.8
Latin America & Caribbean	408,097	6.1
Middle East & North Africa	713,678	10.7
Iran	294,853	4.4
Iraq	173,481	2.6
All others	245,344	3.7
South Asia	320,804	4.8
Sub-Saharan Africa	1,488,627	22.3
Nigeria	297,000	4.4
South Africa	202,605	3.0
Côte d'Ivoire	166,656	2.5
Ghana	108,412	1.6
All others	713,954	10.7
Others	170,998	2.6
Total	6,677,671	100.0

(continued)

Table 19.4 (continued)

3.A: Wheat exports, 2004		
	Exports (US$, thousands)	Share (%)
High income	15,522,857	80.4
United States	5,180,990	26.8
Australia	3,089,040	16.0
Canada	2,688,820	13.9
France	2,553,110	13.2
All others	2,010,897	10.4
East Asia & Pacific	116,505	0.6
Europe & Central Asia	1,463,350	7.6
Russian Federation	535,975	2.8
Kazakhstan	389,550	2.0
Ukraine	288,900	1.5
All others	248,925	1.3
Latin America & Caribbean	1,663,311	8.6
Argentina	1,365,480	7.1
All others	297,831	1.5
Middle East & North Africa	161,885	0.8
South Asia	328,790	1.7
Sub-Saharan Africa	49,506	0.3
Others	30	0.0
Total	19,306,234	100.0
3.B: Wheat imports, 2004		
	Imports (US$, thousands)	Share (%)
High income	7,160,391	33.0
East Asia & Pacific	3,905,051	18.0
China	1,873,488	8.6
Indonesia	841,000	3.9
Rest	1,190,563	5.5
Europe & Central Asia	1,437,367	6.6
Latin America & Caribbean	2,864,681	13.2
Brazil	838,770	3.9
Mexico	617,765	2.8
Rest	1,408,146	6.5
Middle East & North Africa	3,644,814	16.8
South Asia	553,803	2.6
Sub-Saharan Africa	2,081,078	9.6
Nigeria	475,983	2.2
Sudan	209,055	1.0
Rest	1,396,040	6.4
Others	32,260	0.1
Total	21,679,445	100.0

(continued)

Table 19.4 (continued)

4.A: Maize exports, 2004		
	Exports (US$, thousands)	Share (%)
High income	8,568,195	73.3
United States	6,137,510	52.5
France	1,456,650	12.5
All others	974,035	8.3
East Asia & Pacific	522,558	4.5
Europe & Central Asia	311,766	2.7
Latin America & Caribbean	1,926,278	16.5
Argentina	1,193,810	10.2
Brazil	597,336	5.1
All others	135,132	1.2
Middle East & North Africa	13,878	0.1
South Asia	155,724	1.3
Sub-Saharan Africa	191,276	1.6
Others	774	0.0
Total	11,690,449	100.0
4.B: Maize imports, 2004		
	Imports (US$, thousands)	Share (%)
High income	8,296,019	58.7
Japan	2,931,850	20.7
Korea	1,431,560	10.1
All others	3,932,609	27.8
East Asia & Pacific	1,433,257	10.1
China	818,609	5.8
Malaysia	330,943	2.3
All others	283,705	2.0
Europe & Central Asia	500,491	3.5
Latin America & Caribbean	2,138,720	15.1
Mexico	745,120	5.3
Colombia	332,085	2.3
All others	1,061,515	7.5
Middle East & North Africa	1,666,104	11.8
Egypt	364,819	2.6
Iran	335,092	2.4
Algeria	298,350	2.1
All others	667,843	4.7
South Asia	76,319	0.5
Sub-Saharan Africa	516,643	3.7
Others	26,016	0.2
Total	14,136,926	100.0

Source: FAOSTAT (http://faostat.fao.org/)

viewpoint, this remains an important distinction because the multilateral trading system has quite different rules in the two cases (see Bouët and Laborde 2010).

In addition, any of these policies may have important beggar-thy-neighbor consequences and may fuel price increases of important commodities. Insulating trade policies imposed by importers and exporters (as well as high-income and developing countries) were indeed responsible for a considerable share of price spikes seen during the 2007/08 food crisis. However, most of the turmoil was likely caused by large exporters and importers. In this sense, policy recommendations should distinguish between larger and smaller countries.

Finally, there is a key asymmetry between net exporters and net importers of an agricultural commodity during a food crisis. Net exporters can benefit from increases in world prices, but net importers are hurt and have no capacity to retaliate efficiently. If large exporting and importing countries cooperate, then it is possible for smaller countries to implement policies to reduce import tariffs and, in the short term, reduce national prices. Clearly, however, any non-cooperation by large importing countries implementing similar policies will neutralize this effect.

19.3.1.2 Food Reserves

Food reserves can be maintained in order to service emergency relief operations, support public distribution of food to chronically food insecure shares of a country's population, and reduce volatility in consumer and/or producer prices, thus stabilizing prices. The basic idea is simple: accumulate food stocks when prices are low (to prevent very low prices that would harm producers) and release them when supply becomes tighter (to reduce very high prices that harm consumers). However, international experience in the management and use of reserves is not clear and is open to significant variation in policies under the Global Food Crises Response Program (GFRP) operations because the so-called strategic grain reserves were not clearly defined.

Timmer (2010) advises governments to hold rice buffer stocks to reduce volatility in the domestic market. Rather than requiring governments to cope with the consequences of food crises, reserves would ensure price stability and prevent acute crises from taking place. However, Timmer's recommendations should be taken with caution, as his analysis is very specific to the rice market, which is much more speculative than other markets.

Gouel and Jean (2012) argue that buffer stocks do not provide relief when there are sharp increases in international food prices. Using a theoretical model for a small open economy, the authors find that buffer stocks might help producers by keeping prices from reaching low levels. However, such stocks do not protect consumers from price spikes without further trade restrictions; this is because small economies are price takers, so domestic prices will follow the international markets (adjusted by transport costs). When prices are high on the international market and there are no export restrictions in place, at least part of the reserves accumulated in buffer stocks will be exported, given that there is no need for local distribution, and will maximize the returns to the commodities being held, which need to rotate to minimize operation costs. While these policies may increase governments' revenues (exporting their stocks when international prices are high), they do not protect consumers from high commodity prices.

Domestic buffer stocks posit other problems. First, as they aim to control general prices, they are less effectively targeted toward the neediest shares of a country's population (Wright 2009). Second, storage can be expensive, and the poorest countries (which are most vulnerable to food crises) are the ones least likely to be able to afford expensive storage costs (Torero 2011). Third, poor management renders buffer stocks ineffective in many cases. When controlled by parastatals and other government agencies without strong accountability systems, they are potentially subject to political use and mismanagement. Finally, buffer stocks create market distortions; as perishable reserves have to be rotated, their cyclical interventions in the market can send wrong signals to producers and consumers.

For most of these authors, national emergency reserves seem to be a better option than domestic buffer stocks for price stabilization. While buffer stocks for price intervention require considerable stockpiling and subsidize both the poor and the nonpoor, emergency food reserves can more effectively provide aid to the most vulnerable shares of a country's population and entail smaller costs because they require smaller reserves (see Wright 2009). Also, reserves are less likely to create market distortions and disrupt private sector activities (FAO et al. 2011). These mechanisms might prove especially useful for isolated or landlocked countries where, in case of distress, sluggish transportation of food assistance can pose serious threats to vulnerable shares of the population.

The extreme volatility observed during the 2007/08 food crisis suggests that some mechanism of food reserves for price stabilization is necessary to ease the effect of shocks during periods of commodity price spikes and high volatility. (For further discussion of such mechanisms, see Chap. 6 of this book.) There seems to be some consensus around this idea, but policymakers disagree about which specific mechanisms to use to implement such food reserves. As in the case of trade interventions, the most appropriate choices are likely to depend on the characteristics of the specific market under intervention, each country's capacity to cope with crises, and the possibility of establishing international coordination mechanisms. While it likely does not make sense to establish national buffer stocks in most grain markets, Timmer's (2010) support for them may be more valid in a few cases. For example, rice markets might be more speculative than others; thus, price stabilization through buffer stocks makes somewhat more sense in this case. On the other hand, buffer stocks usually entail high costs and market distortions and are prone to corruption. Thus, most countries—especially those with weak institutions and scarce resources—should probably refrain from using stocks and should instead establish emergency reserves for humanitarian reasons.

19.3.2 Medium- and Long-Term Policies

In this section, we summarize the major medium- and long-term policies proposed.

19.3.2.1 Policies to Increase Agricultural Productivity and Resilience

There is a wide array of policies aimed at increasing agricultural productivity and resilience; some of the most widely discussed include:

Input Subsidies

The World Bank (2008) argues that "while development of efficient agricultural input market is a long-term process, this subcomponent (improving smallholder access to seed and fertilizer) would provide rapid support to clients facing immediate and near-term constraints related to seed and fertilizer availability, distribution, affordability and utilization" (p. 90). The plan envisages the implementation of a *market-smart* approach, characterized by: (a) targeting poor farmers; (b) not displacing existing commercial sales; (c) utilizing vouchers, matching grants, or other instruments to strengthen private distribution systems; and (d) being introduced for limited periods of time only.

While they provide a sensible rationale, it is unclear how these principles would be implemented in practice. Poorer countries—which likely have the least developed input markets—may find it difficult to target only those farmers in need. Additionally, subsidy programs that would strengthen, rather than displace, the private sector are likely to require complex mechanisms; institutional weaknesses in poor countries may render these programs unfeasible.

Moreover, these programs usually entail significant fiscal costs. Zaman et al. (2008) estimate that Malawi's input subsidy program costs approximately 3 % of GDP. Importantly, in recent years, rising fuel prices have considerably increased fertilizer costs. If this trend continues in the future, the budget implications of these policies would become even larger.

Finally, more evidence is required to assess the effectiveness of these policies. Dorward et al. (2010) evaluate the 2005/06–2008/09 fertilizer subsidy program in Malawi; their estimates of the benefit–cost ratios of the program range from 0.76 to 1.36, with a (rather small) mid-estimate of 1.06. Arguably, with recent increases in fertilizer prices, a current benefit–cost ratio of the program may be even smaller. Additional potentially adverse impacts of the displacement of private sector operations still require more thorough evaluation and understanding.

Investment in Research and Development

The introduction of high-yield varieties was instrumental for increases in agricultural supply during the 1960s and 1970s. The foreseeable worsening of climatic conditions imposes new challenges, however. Currently, new strands of wheat, maize, rice, and other crops are being developed to have enhanced resistance to droughts, diseases and insects, salinity and other soil problems, extreme temperatures, and floods. In addition, other developments promise enriched varieties with higher nutritional content.

Such policies are highly profitable. Byerlee et al. (2008) find that "many international and national investments in R&D have paid off handsomely, with an average internal rate of return of 43 % in 700 R&D projects evaluated in developing countries in all regions" (p. 11). However, research and development (R&D) is a typical public good and, as such, faces considerable underinvestment, particularly in developing countries. Thus, governments must expand their expenditures in R&D and must complement this budget increase with other policies. For example, the sustainability of these programs requires private–public participation in the seed industry to generate demand and supply coordination. It also requires strengthening regulatory policies in seed markets, including variety release, seed certification, and phytosanitary measures. R&D should also envisage extension services and other mechanisms to facilitate diffusion and technology adoption by farmers.

Irrigation

Investment in irrigation should be a critical component of any strategy to increase agricultural supply. Irrigation more than doubles the yields of rain-fed areas because more crops can be harvested in any given year; it also at least partially promotes resilience, protecting farmers against droughts. Delgado et al. (2010) estimate that expansion of irrigation infrastructure to all land in developing countries "would contribute about half of the total value of needed food supply by 2050."[12]

Irrigation projects appear to exhibit high rates of return. Jones (1995) analyzes 208 World Bank-funded irrigation projects and finds an average rate of return of 15 %. Despite the importance and impact of such projects, the Global Food Crises Response Program (GFRP) has determined that "under this emergency response program, it is not anticipated that investment support would be provided for new irrigation schemes, as this would be supported under the Bank's regular lending program."[13]

19.3.2.2 Policies to Reduce Postharvest Losses

Developing countries face significant postharvest losses due to mishandling. For cereals, these are estimated to be 10–15 % of harvest; when combined with deterioration in storage (in farms and facilities) and milling, this number can reach 25 %. Poor (or nonexistent) roads compound these losses, as agricultural products cannot reach consumer markets, and information failures impede supply from reaching demand (or at least prevent it from reaching the most efficient markets). Some of the policies discussed to reduce postharvest wastage include:

[12]This would require, however, 40 % more withdrawals of water for agriculture. Thus, these policies should be complemented by increased productivity in existing irrigated areas.

[13]GFRP would limit their financing to: (i) support quick turnaround physical investments in rehabilitation of existing irrigation (small-scale) schemes; (ii) finance investments in rehabilitation or development of field drainage and collector drains to reduce problems of water logging and soil salinity; (iii) finance training for water-user groups and others on operation and maintenance of investments; (iv) finance assessments of groundwater or surface water hydrology and sustainable water use; and (v) finance feasibility studies for medium-term irrigation investments.

Improved Handling of Harvests and Storage Practices

Significant portions of agricultural production are lost due to postharvest mishandling. One example comes from improper drying of crops. If crops are stored in high humidity, they can be affected by mycotoxins and become unfit for consumption. In addition to the risk of growing mold, production stored in improper containers can also attract plagues, insects, and rodents, which can spoil the food. This is only one example of postharvest mishandling in a process where any number of small practices can potentially spoil food. Training in proper drying techniques and building adequate infrastructure in this area can considerably reduce wastage and improve food availability.

The implementation of extension services for postharvest losses should include: (1) training and demonstration of low cost-on-farm storage; (2) technical assistance and investment support for community-level food banks; and (3) training and investment support for grain traders and millers in drying and sorting, as well as fumigation equipment and upgrades in existing storage facilities. These should be complemented with strengthening inspections and quality control surveillance to prevent the spread of pests or diseases.

Information Systems

Imperfect information is especially pervasive in agricultural markets at both the domestic and the international levels. In both cases, a lack of adequate and timely information creates a mismatch between supply and demand. In many cases, the consequence is the allocation of production to suboptimal markets, where the demand is lower. In other cases, severe information constraints can result in agricultural production not reaching any market at all and thus being wasted.

At the domestic level, many countries have implemented agricultural information systems that can be accessed through internet portals, SMS on mobile phones, kiosks, radio shows, etc. The challenge ahead is to find cost-effective mechanisms to produce timely information that can be easily and widely accessed by producers and traders.

At the international level, there is scarce reliable data on stocks and availability of grains and oilseeds. Additionally, there is little monitoring of the state of crops and short-term forecasts based on trustworthy technology (remote sensing, meteorological information, etc.). FAO et al. (2011) proposed the creation of the Agricultural Market Information System (AMIS), which involves major agricultural exporters and importers, as well as international organizations with expertise in food policy. It comprises two organisms: the Global Food Market Information Group (to collect and analyze food market information) and the Rapid Response Forum (to promote international coordination). While the specific details of its duties and membership (and the political negotiations surrounding them) still need to be addressed, AMIS is a first step in answering the need for global information and coordination mechanisms.

Rural Roads

Transport infrastructure plays an important role in the reduction of both the level and variability of food prices. Without roads to transport their agricultural production, some farmers cannot reach consumer markets; others have market access, but at a very high cost. Delgado et al. (2010) argue that, in most cases, transport costs represent 50–60 % of total marketing costs. Byerlee et al. (2008) estimate that less than 50 % of the rural African population lives close to an all-season road. Transport infrastructure can also help reduce price variability. Roads are useful means to spread out regional shocks; if a certain region is hit by a shock (weather or other), it can import food from another region. For example, during the food crisis, regions with better infrastructure in Indonesia were not hit as hard as those poorly connected.

19.4 Analysis of Consistency

The question that this section tries to answer is how consistent or inconsistent the operational policy recommendations have been with respect to: (a) Proposals of International Organizations and the G8's document prepared for the Ministers of Finance Meeting in 2008 and (b) the different policy recommendations proposed by key researchers and analyzed in detail in the previous two sections. With this objective in mind, we analyze as an experiment the portfolio of loans of GFRP operations detailed in Table 19.5, covering operations in 13 developing countries. Table 19.6 provides a detailed summary of all these World Bank operations which have as their core objective the mitigation of the impact of the food crisis.

Table 19.5 Documents analyzed for GFRP operations

Country	Project ID	PAD	ICR
Mozambique	107313	✓	✓
Djibouti	112017	✓	✓
Honduras	112023	✓	N/A
Haiti	112133	✓	N/A
Bangladesh	112761	✓	✓
Sierra Leone	113219	✓	✓
Madagascar	113224	✓	✓
Rwanda	113232	✓	N/A
Burundi	113438	✓	✓
Philippines	113492	✓	✓
Guinea	113625	✓	✓
Mali	114269	✓	N/A
Cambodia	117203	✓	✓

Note: PAD is Project Appraisal Document of the World Bank and ICR is the Implementation, Completion and Results Report of the World Bank

Table 19.6 Summary of selected World Bank operations to mitigate the impact of the food crisis

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
Mozambique	– Remove import duties on diesel and kerosene (and also VAT on diesel) – In 2008, these measures (and an additional urban transport subsidy) entailed spending 0.8 % of GDP – This is a large expenditure compared to the "Food Production Action Plan" (0.5 % of GDP)		– Government expanded the Food Subsidy Program (PSA), a direct cash transfer to eligible households – PSA increased beneficiaries by 20 % and benefits by 50 %	– Government approved "The Food Production Action Plan."[a] This plan includes: support for technology adoption, development of agricultural services, provision of high-quality seeds, construction of storage silos, agricultural service delivery (research, finance, etc.), linking smallholders to markets, and stimulating demand for local food – Promote the construction and rehabilitation of agricultural infrastructure and increase access to agricultural technologies and extension information – Improve quality for road infrastructure	– Improve budget process and use of public expenditures, improve revenue collection, public financial management procurement system, (internal and external) audit bodies, human resource management in the public sector, etc.	– In general, "the government intends to allow the pass through of international prices of food and fuel to the domestic economy, notably envisaging no trade distortions or generalized subsidies, while protecting the economic sectors most vulnerable to the increase in energy prices" (PAD, pgph. 80)

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
Bangladesh	– Government removed custom duties for rice and wheat.	– Increase the targeted size of public food stock from 1 million to 1.5 million tons – At least, part of the objective is to use them for price stabilization purposes[b]	– Increase budget of seven existing social protection programs: Open Market Sales (OMS), Test Relief Food, Gratuitous Relief for Food, Food Assistance in CTG-Hill Tracts Area, Food for Works, Vulnerable Group Development, and Vulnerable Group Feeding – However, there seem to be considerable leakages (PAD, Annex 4, pgph. 7–8) – Creation of the 100-Days Employment Guarantee Program	– Bring the fertilizer distribution network closer to farmers (from the *upazilla* to the union level) – Increase government's rice procurement price to stimulate production	– Increase tax collection – Prices of petroleum products, urea fertilizer, and compressed natural gas (CNG) were heavily subsidized by SOEs. Government reduced SOE's deficit through prices increases	– Government aspires to become self-sufficient in rice production: "since the availability of rice trade in international trade can no longer be taken for granted and with Indian rice export restrictions continuing, the talk in Dhaka has moved from imports to complete self-reliance" (source: PAD) – No improvements in targeting mechanisms of social programs (which have considerable leakages)
Philippines	– Government runs the National Food Authority (NFA), which is the sole entity allowed to import rice, regulate rice trading, and determine farm gate support and retail price stabilization	– NFA to release rice buffer stocks in periods of price increases	– Government increased budget for existing social protection programs (see PAD, Annex 5)		– The operation does not include policies to enhance agricultural production. However, other government initiatives do	– The government is striving for rice self-sufficiency which, according to technical analysis, might have actually undermined food security

	– Initially, NFA aggressively sought to increase their stocks with large import tenders, which exacerbated price volatility – Subsequently, NFA decided to suspend rice tenders and established bilateral deals with Japan and Vietnam – In the medium-term, the Philippines is due to lift quantitative trade restrictions on rice by WTO agreements	– The government allocated temporary rice import quotas, rather than solely relying on NFA imports. However, as domestic prices were lower than international prices, the incentive failed – In the medium-term, the government is supposed to transfer rice trade to the private sector (as envisioned in the Medium-Term Philippine Development Plan) – The Philippines is trying to push a regional rice reserve mechanism through ASEAN	– However, the most significant social protection program remains NFA with a budget of $1.2 billion for 2008. NFA is poorly targeted and under-covers the poor[c] – The government launched a CCT (Pantawid Pamilya), conditional on children's school attendance and health checkups – Coverage of the CCT is based on the National Household Targeting System for Poverty Reduction (NHTS-PR). NHTS-PR is a proxy means test for beneficiary selection and the government is adapting other programs' coverage accordingly – The Food for School program is implementing geographic targeting, prioritizing the 20 poorest provinces and the 100 poorest municipalities		– Government launched FIELDS (Fertilizer; Infrastructure and irrigation; Extension and education; Loans; Drying and other postharvest facilities; and Seeds) program. Rather than creating new programs, FIELDS is an acceleration and scaling up of the existing production programs – Government has also subsidized seeds and fertilizer to farmers. However, there appears to be considerable leakage and mismanagement (PAD, pgph. 55–56)	– NHTS-PR would "provide the government with the vehicle to re-direct more inefficient subsidies that are not well-targeted to the poor (such as the NFA rice subsidy) to more targeted programs and possibly cash-based programs in the future" (source: PAD)

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
Djibouti			– There are limited social protection mechanisms in Djibouti. WFP provides emergency food assistance in rural areas, but coverage is small. Government is planning to expand this program in cooperation with UNICEF and local NGOs – Besides this, as the food crisis unraveled, there were no major existing social assistance programs to scale-up. The government's immediate policy was to implement an untargeted policy and eliminate the consumption tax rate on five basic food items (rice, sugar, cooking oil, wheat flour, and powder milk) – However, this policy was mostly ineffective: there was a low pass-through from reduced tax rates to consumer prices.[d]	– The government implemented a fisheries' support program to increase food supply and increase immediate fish output. The program provides training in modern techniques, boats, and microcredit to young fishermen – Government implemented a program for external agricultural production in Ethiopia and Sudan	– Rehabilitate ten community wells in rural areas. These wells will provide support to nomadic pastoralists who have been severely affected by recent droughts	– "The impacts of the measures supported by this program were expected to have a regressive distribution. In particular, the main intervention supported by this operation (tax exoneration of food items) was untargeted and therefore benefitted richer households as much (or relatively more) than poorer households. However, given the large size of the poor population (74 %), the intervention was considered to have an immediate relief on poor households" (ICR, pgph. 59)

			Possible explanations for this outcome are: (a) the high concentration of the food market in Djibouti with few importers and distributors and (b) heightened security risks posed by pirates in international waters – Government has drafted an action plan to suggest ways to improve targeting and direct support for the poor. As part of this, Djibouti completed a population census[e]			
Honduras		– Government to fund the purchase and storage of strategic grain reserves (US$9.5 million)	– Increase PRAF, an already existing CCT program, from 148,000 to 200,000 beneficiaries through an IADB $20 million operation – Government implemented PASAH (Program Supporting Food Security in Honduras), targeted to female-headed households in poor areas. PASAH provides support for productive activities with funds from the European Community	– Enactment of the Emergency Law to Prevent the Shortage of Basic Grains[f] – Loans for medium and smallholders (3.5–35 ha) at favorable terms through BANADESA (National Bank for Development) – Subsistence producers (<3.5 ha) to benefit from a technological package of improved seeds, fertilizer, and technical assistance	– Increase budget allocation for SENASA—National Service of Agricultural and Animal Health (US$1.5)	– Most of these initiatives are part of a more general response to the food crisis by the Honduran government – However, the proposed operation seems to be more oriented to release funds for the government to aid the financial sector – The government is concerned about the effect of increasing food prices on households' real income. This is expected to have an adverse effect on banks' outstanding portfolio of consumer loans

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
				– BANADESA also to finance the expansion of small scale irrigation projects – The government is implementing the "Price Risk Management of Agricultural Commodities in Honduras" project, with funding from the World Bank and IDB – The government is also implementing the Second Road Rehabilitation and Improvement Project, which seeks to rehabilitate secondary roads		– The PAD argues that "The supplemental financing will be an important source of budget financing for the government, providing fiscal space to continue responding to the food crisis, while helping to maintain the macroeconomic stability that led the IMF board to approve a stand-by agreement on April 7, 2008. Timely program support will also assist government efforts to strengthen the financial sector in a period characterized by exogenous shocks that could potentially weaken some banks" (PAD, p. 11)
Haiti			– Rising food prices led to riots and the resignation of the Prime Minister in April 2008. The government announced a temporary subsidy to reduce the price of rice as an emergency measure. Between May and December 2008, the estimated budget for this subsidy was US$30 million	– The third priority area of the "Program of Action against the High Cost of Living" is to scale up agricultural inputs and investments to boost agricultural production		– Since 2004, the World Bank has supported two Economic Reform Governance Operations: ERGO I (US$61 million) and ERGO II (US$23 million)

			– The government, in coordination with donors, drafted the "Program of Action against the High Cost of Living." Two priority (of the three) areas of this plan are: (i) employment generation through labor-intensive works and (ii) expansion of food assistance programs—including feeding programs for schoolchildren, mothers, and infants—for 6 months			– The World Bank's objective appears to be the sustainability of these operations. "The urgent need for public expenditures to respond to the food crisis in the wake of the riots has resulted in higher financing requirements than originally anticipated. This supplemental financing grant will enable the government to continue to make progress on the reform program supported by EGRO II which could otherwise be jeopardized by the unanticipated gap in financing for the 2008 budget" (PAD, pgph. 35)
Cambodia	– Cambodia implemented a ban on rice exports in March 2008, fueling rice price increases in international markets		– Expansion of the Identification of Poor Households Targeting Program.[g] This targeting mechanism is mostly used by Health Equity Funds (HEF) and, to a more limited extent, ADB-supported Emergency Food Assistance Project. However, it will be applied to a broader range of safety net interventions	– Improve access to and transparency of seed and fertilizer markets: These policies include the suspension of VAT for fertilizers; distribution of seed and fertilizer vouchers for farmers with less than 1 ha of land; and a pilot for "smart subsidies"	– Improve the governance and effectiveness of government emergency response and crisis policy actions through quarterly reports, including an independent monitoring component	

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
	– In May 2008, when harvest prospects improved, the ban was lifted – The government has a new focus promoting rice production, improving price incentives through expansion of official rice exports: the "Policy Document on the Promotion of Paddy Rice Production and Export of Milled Rice" sets a target of 1 million tons of milled rice exported by 2015		– Design of a food and cash for work program – Government to provide WFP with 2000 MT per year over 3 years to increase food distribution through school feeding and food for work programs	– Additionally, the government is concerned by high market concentration and quality problems in the fertilizer market. Thus, the government is strengthening its regulation of this market. However, most of fertilizer quality problems can be traced back to production in Vietnam rather than adulteration in Cambodia – Strengthen the role of community-based farmer organizations to access inputs and credit, technical support and market and policy inputs – Boost credits for investments in higher quality milling facilities, "which serve as a key interface between smallholders and markets in terms of quality standards an input supply" (PAD, pgph. 67)		

Mali	– The government introduced a 6-month tariff and VAT exemption for rice. In return of this measure, traders committed to hold their prices (at US$7.2/kg). However, prices rose considerably afterwards	– During the crisis, the government released grain stocks held by the Food Security Commission – Government is revising its guidelines to "establish a more efficient and transparent management system as well as developing countercyclical marketing measures to stabilize cereal prices, e.g., selling cereals during the hunger season in July–September when prices are at their highest level" (PAD, pgph. 12) – "A recent USAID review concluded that Malian authorities have been quite effective in stock management and in their attempts to use the grain stocks to stabilize local food prices" (PAD, pgph. 14)	– "The government's social safety nets, mainly consisting of school feeding and nutrition programs, are small in scale and poorly targeted, with limited impact on the ground" (PAD, pgph. 10). However, the operation does not include any policies to strengthen safety nets	– Government is implementing the Rice Initiative. This includes: "(i) measures to improve crop input distribution by increasing the availability of seed for locally-produced rice varieties; (ii) new/expanded subsidies on crop inputs; (iii) measures to improve marketing channels, with the objective of facilitating the commercial relationship between producer organizations; and (iv) subsidies for equipment, access to water/irrigation, and extension services" (source: PAD)	– The government froze nonessential spending for 6 months to accommodate to budget pressures from the food crisis – This has affected delivery of public services	– Poverty Reduction Support Credit (PRSC) is an important piece of the World Bank's strategy in Mali. Its second phase (PRSC II) was approved by the Board in May 2008 (US$42 million) – This GFRP operation provides supplemental financing for PRSC II – "The urgent policy measures put in place to combat high food prices have put extraordinary pressures on the national budget. The proposed supplemental financing would . . . help the Government of Mali fill in an unanticipated financing gap caused by the food crisis and thus maintain the course of important socioeconomic policy reforms agreed under the PRSC-II and GPRSP" (PAD, pgph. 32)

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
Guinea	– Reduced custom duties for low quality rice from 12.75 to 0 % (original target was 2.5 %) between June 1 and October 31, 2008 – Guinea imposed a ban on agricultural exports applicable for 2007.[h] In 2008, the government issued a ministerial order clarifying that the agricultural export ban was no longer in place, with the exception of rice – The government envisaged to replace the rice export ban with export taxes and committed to a study for its implementation. However, the new de facto government has reinstated the rice ban	– The government plans to build "an emergency food reserve of 25,000 metric tons" (source: PAD). Documentation does not specify whether these reserves would act as humanitarian or buffer stocks	– The government negotiated with rice importers, unions, and civil society to control wholesale and retail profit margins (GNF 1000 and 2000 per 50 kg bag, respectively) – Distribution of take-home rations for children of families of five or more members – Emergency school feeding and nutrition support – Implementation of an "Emergency Urban Labor-Intensive Public Works Program," which includes road maintenance and urban works programs aimed to provide employment and income to affected households	– "Emergency Agricultural Productivity Support Program," which includes: (i) production of 2000 certified seed, (ii) procurement of 2,000 tons of fertilizer, and (iii) distribution of input packages to 70,000 smallholder farmers		– "Since the coup in December 2008, the Bank's engagement and activities in Guinea have been on hold. Management has invoked the provisions of OP/BP7.30, dealing with de facto governments. Contacts with the Guinean regime have been limited to technical correspondence on the fiduciary issues. Currently, Guinea is under suspension of disbursements for non-payment (over 60 days)" (ICR, p. 17)

Burundi	– Temporary exemption of transaction taxes and import duties for 13 staple products (beans, maize, potatoes, etc.) – These temporary measures were applied until July 2009, when an 18 % VAT was introduced and Burundi began to apply the common external tariff of the East African Community		– Scaling-up WFP's School Feeding and Nutrition Program for Primary Schools (SFNP). Originally, the government budgeted US$3 million to serve 120,000 children. However, it only allocated US$2.4 million and benefited 88,164 children – The operation also supported increased budget allocation to aid refugees returning to the country after a ceasefire was enacted		– Though not part of this operation, the government is implementing other policies through different funding sources (AfDB, Belgium, Netherlands, Norway, etc.): exempt diesel from transaction taxes and import duties, subsidies for diesel in pro-poor sectors, distribution of agricultural inputs, rehabilitation of irrigation systems, etc.	
Madagascar			– Expansion of food for work and school feeding Programs. An estimated US$10 million are to be allocated	– The government is implementing a rice intensification campaign to boost production in the short run. The campaign aims to increase productivity in existing rice lands and to start rice production in areas that would not normally grow rice (US$20 million)	– Elimination of a VAT for rice (from an original level of 20 %). It is expected that this measure would translate into reduced consumer prices due to the high degree of competition in the rice market	– The World Bank is implementing a longer-term strategy in Madagascar through a Poverty Reduction Support Credit (PRSC)

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
				– Specifically, this program would "strengthen the supply of farming system development technology packages geared at promoting intensification of rice cultivation. The program will be implemented by service providers who will be contracted through producer associations and through the subsidization of the selected technology package via the intermediation of microfinance institutions" (PAD, Annex 1, pgph. 6)	– Elimination of rice VAT would entail a fiscal loss of US$20 million – The World Bank is preparing two additional financing proposals for two existing credits ("Community Development Fund" and "Rural Development Projects") to strengthen safety nets and boost agricultural productivity in the medium term	– The Bank approved the PRSC-5 (the second component of the second PRSC series) in May 2008. The PRSC-5 aims at "complementing the significant portfolio of ongoing International Development Association investment projects targeting infrastructure, environmental protection, mining, rural development, integrated growth poles, irrigation and watershed management, and regional telecommunications" (PAD, pgph. 13) – In this line, the current operation would "enable the government to continue to make progress on the reform program supported by the PRSC program, which would otherwise be jeopardized by the unanticipated gap in financing for the 2008 and 2009 budgets, including the maintenance of a stable macroeconomic framework" (PAD, pgph. 23)

Sierra Leone	– Temporary reductions in import duties for the following products: • Rice (from 15 to 10 %) • Flour (from 20 to 10 %) • Wheat (from 5 to 2.5 %) • Sugar (from 20 to 10 %) – Additionally, the fixed reference price to value rice imports was established at US$375 per metric ton (well below prevailing world price) – The import duty on petroleum was reduced from 5 % of CIF ad valorem to US$20 per metric ton. Excise taxes on petroleum were also reduced – As the international price of petroleum reduced significantly, its tariffs and excise taxes were restored to precrisis levels – While there have been some reductions in the price of rice, sugar, wheat, and flour, these have not returned to their precrisis levels, and the tariff reductions were maintained		– The government protected the provision of selected basic services from the rising costs of food and fuel – Specifically, the government seeks to protect food aid provided to the following vulnerable groups: • Hospital patients in district hospitals and community health centers • Lactating mothers and children under five in hospitals • Pupils in government boarding schools and handicapped children • Children in remand homes and approved schools who receive food	– Government provided 71,000 bushels of seed to rice farmers	– Government used funds from a strategic petroleum reserve to subsidize petroleum prices for 5 weeks between June and July 2008 – The World Bank approved a separate GFRP grant of US$4 million in August 2008 to support a cash-for-work program. An additional US$4 million GFRP grant was approved in November 2009 to scale-up this program – Other World Bank operations aim to increase agricultural production in the medium and long run: the Rural and Private Sector Development Project (US$30 million) and the Infrastructure Development Project (US$55 million)	– The World Bank supports Sierra Leone's Poverty Reduction Strategy (PRS). The 2005–07 PRS established three action pillars: (i) good governance, security and peace building; (ii) pro-poor sustainable growth for food security; and (iii) human development – At the time of the operation, the government was preparing the 2009–11 PRS – "The proposed grant of US$ 3 million equivalent would support the Government's PRS by providing the authorities with needed fiscal space to partially compensate for the lost revenues resulting from the recently reduced tariffs on food and fuel imports. This support would help mitigate the impact of such price increases and contribute to continued basic service delivery for vulnerable groups" (PAD, pgph. 5.1)

(continued)

Table 19.6 (continued)

	Trade policy	Food reserves	Social protection	Supply policies	Others	Remarks
Rwanda				– Government implemented the Crop Intensification Program (CIP), providing improved seeds and fertilizer – There was a pilot project for fertilizer distribution during the 2008 season: in order to negotiate lower prices, the government engaged in bulk purchases. Subsequently, the government directly distributed fertilizer at subsidized prices through farmer loans – Albeit production increases in CIP, only 4 % of fertilizer loans from the pilot were recovered – Additionally, increases in international prices are likely to create large fiscal deficits for the program – The government will implement reforms regarding the CIP. While it will still buy fertilizer in bulk quantities, it will carry out auctions to private sector operators who bid for it. The government will subsidize successful bids below the cost.	– World Bank is implementing other projects to increase agricultural production in the medium and long run. These include: irrigation infrastructure, and access to rural microfinance	– Funds provided by this operation can only be used to fill in the immediate needs for the food crop intensification program. However, fertilizer for export crops (such as tea and coffee) can be purchased with government resources or funds from alternative donors (e.g., AfDB) – There are inherent risks to this project: sustainability[j], mis-targeting, crop leakage, collusion, rent seeking, poor cost recovery, etc. However, no ICR report is available

				There will be additional subsidies based on a voucher system. Credit for farmers to purchase fertilizers will be provided by the private sector[i]		

[a]See PAD, Box 3

[b]While partially increased for humanitarian purposes ("to ensure that there is enough food in the country to feed the population in a crisis when import channels may be temporarily blocked"), there are also price-strategic purposes ("to ensure that the food stock is large enough to influence, if necessary, the open market price . . . "). See: PAD, pgph. 64

[c]"Evidence shows that this is not well targeted to the poor. Based on the FIES 2006, NFA rice accounted for only 13 % of the total spending on rice by the poorest quintile. Moreover, 40 % of NFA rice is not consumed by the poor. Only 31 % of the total consumption of NFA rice goes to the poorest quintile" (PAD, pgph. 39). Due to these leakages, the government implemented family access cards to poor households in Metro Manila. Some 270 thousand cards have been issued, but admittedly "the method used to identify the poor has been less than optimal."

[d]The ICR suggests that: (a) "the difference between domestic and international prices [*of tax-exempted items*] was higher in all but one case, that of sugar, after the removal of taxes in Djibouti"(ICR, pgph. 38) and (b) "except for sugar, the results reveal that the mark-up on domestic food markets was higher than the one in international markets" (ICR, pgph. 39)

[e]This is considered a major milestone since all previous population statistics were based on a 1991 demographic survey (ICR, pgph. 52)

[f]This includes: (i) support for productive infrastructure, (ii) technological inputs, (iii) financial instruments to mitigate both credit and agricultural risk, (iv) enhanced grain storage facilities, and (v) food security

[g]This is a participatory system: "the identification process is carried out by village representatives, with the support and supervision of the commune council, as well as district-level representatives. Village representatives are responsible for conducting household interviews, assessing household "poverty scores" according to the information gathered through the interviews, and preparing draft lists of poor households. Draft lists are then displayed in public locations, so that villagers are able to view them and possibly complain during or following the village consultation meeting, held before the final list of poor households is submitted to the commune council" (PAD, pgph. 48)

[h]"The clarified policy stance on the export of agricultural produce helped in particular the small agricultural producers which had developed a successful regional trade in a number of agricultural markets. It was estimated by the Guinean association of potato growers that these alone had lost the equivalent of US$ 8,000 a day, when exports were banned" (ICR, p. 13)

[i]"There is currently an information and sensitization campaign underway with the union of popular banks and micro-finance institutions. The aim of the campaign is to inform farmers of the fertilizer program and the potential need for access to finance, and the potential returns. Technical modifications of the Agricultural Guarantee Fund (AGF) have been proposed to reduce the transaction costs for microfinance institutions to access the AGF, thereby providing market-based incentives for participation. It is fully expected that leaving the credit side to financial institutions—which are more equipped than government to make and recover loans—will result in much higher loan recovery rates compared to levels last year" (PAD, pgph. 17)

[j]The PAD claims that "as fertilizer prices normalize, and as farmers become more familiar with the benefits associated with fertilizer application, the need for explicit subsidies will diminish leading to a sustainable system. The global experience of the IFDC has been that during the first few years of the auction, private sector participants become aware of the large profits to be made in the activity. As a result, there is a gradual increase in the average level of bids submitted for the fertilizer lots. This in turn progressively reduces the government's subsidy at the auction level. Secondly, the voucher system is designed to enable the government to gradually withdraw or reduce the level of the subsidy, at any point in time. This would involve a gradual reduction in the discount specified on the printed voucher. As the situation improves, this would eventually lead to a cessation of the distribution of vouchers. Furthermore, in Rwanda, the government has already started actively promoting (among coffee and tea participants) private sector group bulk purchase of fertilizer. The aim here is for government to withdraw from this area, as elaborated in the Fertilizer Strategy" (PAD, pgph. 8). However, the sustainability of this policy seems to rely on a large number of assumptions

Table 19.7 Summary of operations

	Official position of World Bank during 2007/08		Policies recommended by the World Bank after 2008	
	Consistent	Not consistent	Consistent	Not consistent
Mozambique	X		X	
Bangladesh	X			X
Philippines	X		X	X
Djibouti	X		X	X
Honduras	X			X
Haiti	X		X	X
Cambodia	X	X (export ban)	X	X
Mali	X	X	X	X
Guinea	X	X (export ban)	X	X
Burundi	X		X	X
Madagascar	X		X	X
Sierra Leone	X	X	X	X
Rwanda		X		X

Following an assessment of each of the specific operations for the 13 developing countries, benefits are analyzed and summarized in Table 19.7:

(a) **Mozambique**: Overall, consistent with the policy recommendations in 2007/08 and after 2008. The government allowed a pass-through of international prices while protecting vulnerable groups (expanding PSA program). In addition, through the GFRP operation, the World Bank supported the implementation of reforms to increase agricultural productivity through the provision of infrastructure and public goods (technology adoption, construction of silos, agricultural infrastructure, etc.).

(b) **Bangladesh**: Overall, consistent with the policy recommendations on trade in 2007/08 but not consistent with later World Bank research after 2008. Specifically, the GFRP operation was used in accordance with the GFRP framework to support the reduction of import duties for rice and wheat, and there was an increase of public food stocks (at least partially to act as price buffers) from 1 to 1.5 million tons. On the other hand, it is important to mention that the increased public targeting for aid programs was positive in terms of performance of the program in identifying the proper beneficiaries. However, most of it was untargeted and had severe leakages (e.g., large share of budget allocated to open market sales).

(c) **Philippines**: The GFRP operation resulted in a combination of policies which were consistent with the official World Bank policy recommendations in 2007/08 and were both consistent and inconsistent with the post-2008 recommendations. On the consistent side, as a result of the GFRP operation, the government launched the Household Targeting System for Poverty Reduction (NHTS-PR) and introduced a CCT (Pantawid Pamilya). In addition, the NHTS-

PR will become a targeting instrument for other social programs, and the Food for School Program is prioritizing the poorest provinces and municipalities to enhance targeting of the most vulnerable share of the population. Finally, the government pushed for a regional rice reserve mechanism through ASEAN, which is an emergency regional rice reserve to assure food security in the region and which has a very clear trigger mechanism and governance. In addition, the country was engaged in large rice import tenders, exacerbating increases in international food prices, but the GFRP made the government commit, as part of the loan, to change its tendering policy in a way that would reduce prices. The government also agreed to withdraw a big tender that was going to increase price pressure in the international market. Finally, bilateral rice deals were established, reducing pressure on external markets. These policies, although consistent in the short term with the GFRP framework, are inconsistent with later World Bank recommendations. In the medium term, the government is due to lift quantitative trade restrictions by WTO agreements, and there is a medium-term plan to transfer rice trade to the private sector. However, currently the National Food Authority (NFA) has the monopoly over rice imports. NFA still concentrates a significant proportion of its food aid budget, which is poorly targeted. NFA's reserves act as a buffer stock for price stabilization.

(d) **Djibouti**: The GFRP operation resulted in a combination of policies which were consistent in general with the official World Bank policy but which, at the same time, were inconsistent with the policy recommendations after 2008. On the consistent side, when the crisis started, there were few social protection mechanisms; the government was able to expand the WFP-operated food assistance program in rural areas (one of the few existing) with GFRP support. It also completed a population census as a first step to implement direct and targeted protection mechanisms for the poor and provided support for fisheries to boost food production. On the inconsistent side with the post-2008 recommendations but consistent with the GFRP framework and official policy of the World Bank, the government eliminated the consumption tax rates on five basic staples; this policy was not effective in reducing consumer food prices. Low pass-through rates were probably due to high concentration in the food market (few importers and distributors) and security risks posed by pirates in international waters.

(e) **Honduras**: Overall, consistent with the policy recommendations. The proposed operation seems to be more oriented to releasing funds for the government to aid the financial sector, given the government is concerned about the effect of increasing food prices on households' real income; therefore, the government uses the resources as a buffer to mitigate the expected adverse effect on banks' outstanding portfolio of consumer loans. However, the financial sector was not the real target of the operation; it was just the fastest way to transfer cash to the government for more general crisis response policies.

(f) **Haiti**: The GFRP operation resulted in a combination of policies which were both consistent and inconsistent with the policy recommendations. On the consistent side, as a result of the GFRP, a "Program of Action against the

High Cost of Living" (with a focus on employment generation through labor-intensive works and expansion of food assistance programs) was developed. In addition, the government also implemented what they refer to in the GFRP framework as a second best policy, i.e., subsidies to reduce the price of rice between May and December 2008 (US$30 million). However, there are specific circumstances that need to be met for the Bank to accept this type of policy (see GFRP Framework document p.26, para. B2). Moreover, post-2008 these policies were not supported.

(g) **Cambodia**: The GFRP operation resulted in a combination of policies which were consistent with the GFRP framework and official position of the World Bank. Despite the initial ban on rice exports in March 2008, they lifted this ban in May 2008 and are currently seeking to promote rice production. The main policy is to create price incentives by promoting exports (goal of one million tons of milled rice exported by 2015). In addition, they expanded the "Identification of Poor Households Targeting Program" to be applied to safety nets, implemented food for cash and food for work programs, and boosted credit for milling facilities which act as an interface between smallholders and markets. In addition, consistent with the GFRP framework and official World Bank position in 2008, the GFRP operation subsidized fertilizers by the suspension of the VAT and by implementing a pilot for "smart subsidies" using vouchers to be distributed to smallholders. However, this type of policy was not recommended post-2008, given (as it has been shown in the case of Malawi) that it bears the risk of significant fiscal deficit. Finally, the government regulated the fertilizer market in principle to avoid adulteration; however, most of the adulteration appears to happen in Vietnam (from where fertilizer is imported) rather than in Cambodia.

(h) **Mali**: The GFRP operation resulted in policies which were both consistent and inconsistent with the official policy recommendations of the World Bank and with what was recommended after 2008. On the consistent side, the government increased seed availability for locally produced rice varieties and improved marketing channels to facilitate relationships between producer organizations. Finally, a program of subsidies for equipment, access to water/irrigation, and extension services was implemented. On the inconsistent side, the government introduced 6 month VAT and tariff exemptions for rice, implemented a price-stabilizing buffer stock through the Food Security Commission, introduced subsidies on crop inputs which were not "smart subsidies," and finally, despite acknowledgement of weak safety nets, made no efforts to strengthen them.

(i) **Guinea**: The GFRP operation resulted in a combination of policies which were both consistent and inconsistent with the official World Bank policy recommendations and with the post-2008 recommendations. On the consistent side, in both policies recommended in 2008 and after 2008, the government implemented a safety net system to distribute take-home rations for children of families of 5+ members, an emergency school feeding and nutrition support, and an emergency urban labor-intensive public works program. On the inconsistent side, the country imposed a ban on agricultural exports in

2007; although it was lifted in 2008 for most products, it was not lifted for rice. Although the GFRP operation did not support this, the government could have included a conditionality to be able to obtain the loan. In addition, and consistent with the GRFP framework but not the post-2008 recommendations, with support from the GFRP, the country was able to eliminate custom duties for low quality rice between June 1 and October 31, 2008, and initiated plans to build an emergency food reserve of 25,000 metric tons, although it is not clear if this is for humanitarian or price-stabilizing purposes. Finally, the government implemented the "Emergency Agricultural Productivity Support," which includes the distribution of subsidized seed and fertilizer packages to 70,000 smallholder farmers, although these were not the type of smart subsidies proposed by the GRFP framework.

(j) **Burundi**: The GFRP operation resulted in a combination of policies which were both consistent and inconsistent with the official World Bank policy recommendations. On the consistent side, the government scaled up WFP's school feeding and nutrition program. However, funds allocation and the number of beneficiaries fell short of initial goals. In addition, the government supported the return of refugees to the country. Finally, and consistent with the GRFP framework but inconsistent with post-2008 recommendations, the government implemented exemption of transaction taxes and import duties until July 2009.

(k) **Madagascar**: The GFRP operation resulted in a combination of policies which were consistent with the official World Bank policy recommendations. The government expanded the food for work and school feeding programs and introduced a rice intensification campaign through producer associations. This program aims to provide subsidies for selected agricultural technologies through microfinance institutions. Finally, the government eliminated the VAT for rice, which, although consistent with the GFRP framework, was not consistent with post-2008 recommendations.

(l) **Sierra Leone**: The GFRP operation resulted in a combination of policies which were both consistent and inconsistent with the official World Bank policy recommendations. On the consistent side, the government protected selected basic services from increasing costs of food and fuel (those for hospital patients, lactating mothers, government's boarding schools, etc.). In addition, the tariffs for four products were reduced; this reduction is to be maintained until prices return to precrisis levels. On the inconsistent side, the government provided fully subsidized rice seed to farmers (71,000 bushes), which were not targeted as the "smart subsidies" strategy recommended in the GFRP.

(m) **Rwanda**: The GFRP operation resulted in policies which were inconsistent with both the official World Bank policy recommendations and the post-2008 recommendations. Specifically, the government implemented the Crop Intensification Program for food crops which included significant market intervention by the government: (a) purchasing fertilizers in bulk in international markets; (b) auctioning fertilizer to private traders; (c) promoting private microcredit for smallholders; and (d) providing additional targeted subsidies through vouchers.

This program has significant risks: mis-targeting, crop leakage (i.e., cannot be used for export crops), collusion among traders, and an extremely low loan recovery rate (during a pilot in 2008, recovery was only 4 %).

19.5 Final Remarks

The world faces a new food economy that likely involves both higher and more volatile food prices, and evidence of both conditions was clear in 2007/08 and 2011. After the food price crisis of 2007/08, food prices started rising again in June 2010, with international prices of maize and wheat roughly doubling by May 2011. This situation imposes several challenges. In the short run, the global food supply is relatively inelastic, leading to shortages and amplifying the impact of any shock. The poor are hit the hardest. In the long run, the goal should be to achieve food security. The drivers that have increased food demand in the last few years are likely to persist (and even expand). Thus, there is a significant role for the World Bank to play in increasing the countries' capacity to cope with this new world scenario and in promoting appropriate policies that will help to minimize the adverse effects of the increase in prices and price volatility, as well as to avoid exacerbating the crisis.

In this regard, this chapter describes some of the most important official policies that the World Bank prescribed to different countries during the food crisis of 2007/08. In addition, it compares those policies to what was proposed by World Bank research after 2008. The chapter focuses on the proposed short-term, medium, and long-term policies. In terms of short-term policies, two mechanisms are emphasized: support for the poor and price stabilization (with an emphasis on trade restrictions and food reserves). In terms of medium- and long-term policies, we focus on the recommendations linked to increasing agricultural productivity through productivity gains and elimination of postharvest losses.

In support of the poor, Targeted Cash Transfers (TCT) and Conditional Cash Transfer (CCT) programs already in place clearly constitute first-best responses for several reasons: (a) they prioritize assistance for targeted groups, (b) they do not entail additional costs of food storage and transportation, (c) they do not distort food markets, and (d) in the case of CCTs, they explicitly prevent human capital deterioration. When TCTs and CCTs are not available, governments may also implement other types of assistance programs, although this could bring some inefficiency. Therefore, in poor countries where TCTs and CCTs are not yet in place (such as most Sub-Saharan Africa), it is essential that during noncrisis years, countries invest in strengthening existing programs—and piloting new ones—to address chronic poverty, achieve food security and human development goals, and be ready to respond to shocks. Across the different GFRPs, we see these policies implemented by the World Bank, specifically in the Philippines, Djibouti, Haiti, Cambodia, Guinea, Burundi, and Madagascar.

In terms of short-term price stabilization policies through trade policies and management of food reserves, we identify important inconsistencies in what was recommended in the official position by the World Bank, through the GFRP framework document and in the G8's document prepared for the Ministers of Finance Meeting in 2008, and in post-2008 recommendations. Clearly, the official recommendations in 2008 were more flexible, especially in regards to trade policies and physical reserves, and in some cases allowed short-term interventions that could end in pervasive market distortions. As a result, most of the operations under the GFRPs were consistent with the official policy recommendations with the exception of Cambodia, Guinea, Sierra Leone, and Rwanda (see summary in Table 19.7).

On the other hand, if we look at the post-2008 recommendations, all of them will avoid any potentially pervasive market distortions. Even more, regarding trade policies, most of the work of the World Bank will advise against any trade restrictions (on both the import and the export side). In that sense, if we assess ex post the GFRP operations, we find that in many of the countries, the policies implemented as a result of the GFRP created additional trade restrictions other than export bans, which was the only bad policy identified in the GFRP framework document. This was the case for Bangladesh, Philippines, Mali, Guinea, Burundi, and Sierra Leone.

Nevertheless, and as explained in Sect. 19.3, it is important to mention that what the GFRP framework recommended in 2008 relative to what was recommended post-2008 is in a certain way justifiable as a short-term measure given that all in all, trade policies may be an effective instrument for short-term price stabilization purposes in some nations: those facing considerable political unrest, lacking adequate food distribution networks, with no safety nets available, etc. However, they may have important beggar-thy-neighbor consequences and may fuel price increases of important commodities. The 2007/08 food crisis—especially in the case of rice—is quite illustrative in this respect. Insulating trade policies imposed by importers and exporters (as well as high-income and developing countries) were indeed responsible for a considerable share of price spikes. However, even when the aggregate effect of the actions of these broad groups is quite large, most of the turmoil was likely caused by large exporters and importers. In this sense, if the argument is that such policies create further imbalances for others, policy recommendations should distinguish between larger and smaller countries; from all the countries where we see these inconsistencies, the Philippines is the only one falling into the category of a significant importer of rice where the World Bank should be clearly against import tenders and quantitative restrictions, given they clearly helped to exacerbate international prices in the rice market.

With respect to food reserves, the discussion seems to highlight the need for food reserves to ease the effect of shocks during periods of commodity price spikes and volatility. There seems to be some consensus around this idea. The disagreement stems from the specific mechanisms to implement food reserves. As in the case of trade interventions, the most appropriate choices are likely to depend on the characteristics of the specific market under intervention, the country's capacity to cope with crises, and the possibility of establishing international coordination mechanisms. While it likely does not make sense to establish national buffer stocks in most grain markets, it may be more valid in a few cases, such as in the rice market. Again, however, regional reserves with strong governance and clear triggers are preferred. However, it is important to mention that the GFRP framework is not extremely clear on this in difference to what was recommended post-2008. It is in that sense that when analyzing the operational plans of the GFRPs, proposals can be identified that promote country-level reserves as buffer stocks, as in the case of: (a) Bangladesh where the stocks were increased from 1 to 1.5 million MT of rice, (b) the NFAs in Philippines, and (c) the NFAs in Guinea. It could also be argued that these reserves were consistent with the official position of the World Bank through the GFRP framework, although clearly these types of policies are problematic in countries where the necessary conditions for these reserves to work don't exist. Additionally, buffer stocks usually entail high costs and market distortions and are prone to corruption. Thus, most countries—especially those with weak institutions and scarce resources—should probably refrain from using buffer stocks.

Finally, with respect to the medium- and long-term policies, we see significant investment in the GFRPs (e.g., the provision of infrastructure and public goods in Mozambique, increasing seed availability in Mali, and the rice intensification program in Madagascar). In addition, and as recommended in the GFRP framework document, we also see the important presence of input subsidies similar to those that have failed in Malawi with a fiscal cost of around 3 % of the GDP. These plans envisage the implementation of a market-smart approach to input subsidies. Such a strategy is characterized by: (a) targeting poor farmers; (b) not displacing existing commercial sales; (c) utilizing vouchers, matching grants, or other instruments to strengthen private distribution systems; and (d) being introduced for a limited period of time only. Albeit outlining a sensible rationale, it is unclear how these principles would be implemented in practice in poor countries like in the GFRPs in Haiti, Cambodia, Mali, Sierra Leone, and Rwanda. Poorer countries—which likely have the least developed input markets—may find it difficult to target only those farmers in need. Additionally, subsidy programs that would strengthen, rather than displace, the private sector are likely to require complex mechanisms. Institutional weaknesses of poor countries may render them unfeasible, aside from the fiscal costs.

It is important to note that in many countries, input markets are not well developed, as they are hampered by various policy, institutional, and infrastructure constraints that can only be overcome over time, while improvement in access to inputs would provide substantial benefits in the short run, given the crisis circumstances. It is in that sense that the "smart subsidies" proposed under the GFRP framework could be conceptually justifiable even though as a short-term measure they can also create fiscal problems as previously mentioned based on the Malawi experience. Moreover, it is of central importance that any "smart subsidy" policy includes the five key characteristics mentioned in the previous paragraph. Furthermore, a long-time horizon is required to apply the "first-best" policies, namely, the alleviation of constraints (such as infrastructure and missing credit markets) which inhibit the development of efficient input markets.

Therefore, although this "second best measure" in the face of existing constraints as stated in the GFRP framework document could be justifiable in the short term the key is to assure all other needed elements are in place for its success; specifically, it has to be guaranteed that investments to alleviate the key constraints of the input market are also started at the same time. All of these arguments are conceptually valid, although their applicability in any given country cannot be taken for granted; in most cases, applicability was not actually and explicitly verified in the assistance programs funded under GFRP, and the key four characteristics of the proposed "smart subsidies" strategies were not validated in advance.

In summary, when assessing the consistency of the specific loans and policies prescribed officially by the World Bank for selected countries during the 2007/08 food crisis, we identify that (given the significant flexibility of the World Bank official recommendations) most of the loans comply with what was proposed in the GFRP framework. However, when analyzing the consistency of those recommendations to the research results published by the World Bank post-2008, we found significant inconsistencies, especially in short-term policies. As a result, it is extremely important for the World Bank to carefully assess the risks and costs of the implementation of the official, more flexible, recommendations of the GFRP against what is currently being advocated at the Bank and to carefully assess how to avoid these inconsistencies in the future.

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Part V

The Micro-Economics of Price Risk, Volatility and Price Shocks: Households, Firms and Communities

Access to Information and Price Expectation Errors of Smallholder Farmers: Theory and Empirics 20

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20.1 Introduction

Producers use different information when making decisions concerning their economic activities. Past trends, outcomes in related markets, media reports, weather, and published forecasts are some of the information that farmers use in their resource allocation decisions (Just and Rausser 1981). The intrinsic feature of agriculture—the lag between production decision and output realization—makes these types of information indispensable to agricultural producers. Besides, agricultural production is inherently stochastic due to weather shocks, pest infestations, and other shocks, which affect the general market supply condition and therefore prices. Farmers need to form their expectations of market prices and potential yield for the upcoming harvesting season in order to make their production decisions. They invest in accessing and processing price and other market information, which they believe affects prices at harvesting time. This study assesses the information sources relevant to smallholder farmers and how efficiently farmers utilize the available information in their price expectation formations. This is important since modeling price expectations is an integral part of any agricultural supply response study (Moschini and Hennessy 2001).

In this study, we seek to empirically test the impact of access to information on the level of investment in information acquisition. Access to information is used synonymously with low costs of acquiring information to forecast future prices, which is notably a continuous rather than a discrete concept. Whereas ownership of information and communications technologies (ICT) and distance to markets serve as a measure of access to information (or costs of acquiring information), we use farmer realized price forecasting errors as a measure of the outcome

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variable of interest. In particular, we seek to address the research question whether access to information (i.e., access to ICT and grain markets) results in a smaller price forecasting error of smallholder farmers in rural Ethiopia. Analyzing the distribution of smallholders' price expectations relative to realized prices assists policymakers in delivering information on price outlook and price risk management strategies. The main findings indicate that smallholders who have access to ICT and who reside closer to major grain markets are more likely to have smaller price forecasting errors. Public investment in both information and physical infrastructure that reduces the cost of accessing information is therefore vital for improving the precision of farmers' price expectations.

Several approaches have been applied to model expectations of agricultural producers. These include naïve expectation (Ezekiel 1938), whereby expected prices are assumed to be equal to the latest observed prices; adaptive expectation (Nerlove 1958), whereby farmers are assumed to revise their expectations depending on past errors; and rational expectation (Muth 1961), which assumes that expectations are consistent with the underlying market structure and that economic agents make efficient use of all available information. Other research has focused on modeling supply response using a quasi-rational price expectation (Holt and McKenzie 2003), which is consistent with price prediction from a reduced-form dynamic regression equation. Futures prices have also been used as proxies for price expectations (Gardner 1976).

Acquiring information is a common and critical feature of all of these expectation hypotheses. Because searching for and processing information are costly (Stigler 1961), it is unlikely that producers make use of all available information to form their price expectations (Orazem and Miranowski 1986). This is even more so in the context of subsistent smallholder farmers with limited access to credit and capital. Farmers therefore gather and process price and other market information that could potentially improve their price forecasts the most. A rational farmer invests in acquiring market information to the extent that the expected marginal benefit (in terms of more accurate price expectation) is greater or equal to the marginal cost of investing in acquiring the information. Ownership of information assets, such as a radio, a television, and a phone, and proximity to grain markets could potentially reduce the costs of investing in acquiring information. The government could also improve market efficiency by lowering the costs of access to information by providing market information as a public good through organized market information systems.

There is a large body of literature that investigates the effect of market information systems (MIS) or ICTs on the economic performances of farmers, traders, and consumers. Most of the existing empirical work has focused on the impact of MIS or ICTs on price dispersion between markets and sellers (Aker and Fafchamps 2015; Jensen 2007), price asymmetry between traders and farmers (Svensson and Yanagizawa 2009), traders' search behavior (Tack and Aker 2014), farmers bargaining power and selling prices (Mitchell 2011), consumption expenditures (Labonne and Chase 2009), and farmers' marketing choices (Tadesse and Bahiigwa 2015), among others (see Nakasone et al. 2014 for a recent review). The empirical evidence has been mixed regarding the effect of improved market price information on prices at micro level. Yet, there seems to be little evidence arguing against its positive effect on lowering price dispersion and search costs and improving agricultural market performance at a macro-scale (Nakasone et al. 2014). Access to better information through ownership of mobile phones, a radio, or a television could potentially assist farmers in making a more informed price expectation. This, in turn, helps them to make better decisions in terms of their crop choices, the amount to plant, land management efforts, and the amount and type of investment that they undertake in each cropping season. The present study therefore uses primary data from smallholders in Ethiopia to empirically evaluate the impact of access to information on farmers' price expectations.

The remainder of this chapter is organized as follows: The following section presents a theoretical model that studies the importance of market information in improving the price signal for farmers. Section 20.3 outlines the empirical model, the data, and some descriptive statistics. Section 20.4 presents and discusses the econometric results, and the last section concludes this chapter.

20.2 Theoretical Model

We employ a simple theoretical model to understand farmers' decision behaviors on production and information acquisition. The model consists of two stages: a production decision (second stage) and a decision about investment in information acquisition (first stage). The model is solved by backward induction. We therefore start with the second stage.

Consider a farmer who decides on the output level y given a quadratic production cost $c(y) = \alpha y^2$. Crop prices are assumed to be random with mean μ and variance σ^2. Because production costs accrue before harvesting, the farmer maximizes discounted revenue from crop sales. With a discount rate of r (cost of capital), the farmer maximizes expected profits:

$$\max_y E\left[\frac{py}{1+r} - c(y)\right] = \frac{E[p]\,y}{1+r} - c(y). \tag{20.1}$$

The first-order condition is $\frac{E[p]}{1+r} = c'(y) = 2\alpha y$. With rational expectations (i.e., $E[p] = \mu$) the optimal production under uncertainty is given by $y^* = \frac{\mu}{2\alpha(1+r)}$. Substituting y^* into the expected profit function yields:

$$E[\pi_v] = \frac{\mu}{1+r}\left(1 - \frac{1}{2\alpha}\right) + \frac{\mu^2}{(1+r)^2}\frac{1}{4\alpha}, \tag{20.2}$$

where the subscript v on π_v denotes profits under volatile prices. In case of no ex-ante uncertainty about prices, $E[p] = p$, the optimal production is $y^* = \frac{p}{2\alpha(1+r)}$, and thus the expected profit π_{c} conditional on the fact that the farmer knows the random price ex-ante is

$$E\left[\pi_{\mathrm{c}}\right]=E\left[\frac{p}{1+r}\left(1-\frac{1}{2\alpha}\right)+\frac{p^2}{(1+r)^2}\frac{1}{4\alpha}\right]=\frac{\mu}{1+r}\left(1-\frac{1}{2\alpha}\right)+\frac{E\left[p^2\right]}{(1+r)^2}\frac{1}{4\alpha}. \tag{20.3}$$

With $E\left[p^2\right]=\sigma^2+\mu^2$, we obtain

$$E\left[\pi_{\mathrm{c}}\right]=E\left[\pi_{\mathrm{v}}\right]+\frac{\sigma^2}{(1+r)^2}\frac{1}{4\alpha}. \tag{20.4}$$

Thus, farmers with access to perfect information on the harvest price are expected to have on average higher profits than farmers with uncertainty. The discrepancy increases with the magnitude of the uncertainty (variance σ^2).

In the first stage, the farmer chooses their level of investment in information acquisition, which results in acquisition of a perfect price signal regarding harvesting prices with probability ρ or no signal with probability $1-\rho$. With the probability $1-\rho$, the price remains as uncertain as it would be without any investment in information acquisition (i.e., the farmer receives no signal regarding harvesting prices). The cost of investing in information acquisition is given by a twice differentiable function $\beta k(\rho)$, where $k(0)=0,\ k'>0, k''>0, k(1)=\infty$ and β is a scaling factor. Hence, ρ measures the quality of the signal or the level of investment to obtain a perfect signal. The information investment decision involves choosing a $\rho\in[0,1]$ such that the expected profit—which is a weighted sum of the expected profit with certainty $E[\pi_{\mathrm{c}}]$ and the expected profit with uncertainty $E[\pi_{\mathrm{v}}]$—is maximized after the costs of information acquisition are netted out, thus:

$$\max_{\rho\in[0,1]}\ \rho E\left[\pi_{\mathrm{c}}\right]+(1-\rho)\,E\left[\pi_{\mathrm{v}}\right]-\beta k\left(\rho\right). \tag{20.5}$$

Given the profit in the second stage, the farmer chooses the optimal level of investment in information ρ^* to maximize the expected profit in the first stage. After substituting the expected profit from the second stage into Eq. (20.5), the first-order condition is obtained as:

$$\frac{\sigma^2}{(1+r)^2}\frac{1}{4\alpha\beta}=k'\left(\rho^*\right). \tag{20.6}$$

Proposition 1 The optimal investment in information ρ^* increases in σ^2 and decreases in r, a and β. Thus, investment in information acquisition increases with price volatility, whereas it is negatively correlated with discount rates, costs of acquiring information, and production costs.

Proof Calculating the total derivative in each parameter gives: $\frac{d\rho^*}{d\sigma^2} = \frac{1}{(1+r)^2\ 4\alpha\beta\ k''(\rho^*)} > 0$, $\frac{d\rho^*}{d\alpha} = -\frac{\sigma^2}{(1+r)^2\ 4\alpha^2\beta\ k''(\rho^*)} < 0$, $\frac{d\rho^*}{d\beta} = -\frac{\sigma^2}{(1+r)^2\ 4\alpha\beta^2\ k''(\rho^*)} < 0$ and $\frac{d\rho^*}{dr} = -\frac{2\sigma^2}{(1+r)^3\ 4\alpha\beta\ k''(\rho^*)} < 0$.

The magnitude of the forecasting error V of the price expectation formation of the farmer can be measured by the expected squared deviations of the expected prices p^{e} from realized prices p^{r}; thus $V = E\left[(p^{\mathrm{r}} - p^{\mathrm{e}})^2\right]$. The farmer's expected price p^{e}, in turn, depends on the level of information acquisition ρ and is $p^{\mathrm{e}} = \rho p^{\mathrm{r}} + (1-\rho)\,\mu$. It is the weighted sum of the realized price (revealed at probability ρ) and the unconditional mean μ of the random distribution of the price. Substituting p^{e} into V, we obtain $V = E\left[((1-\rho)\,(p^{\mathrm{r}} - \mu))^2\right] = (1-\rho)^2 E\left[(p^{\mathrm{r}} - \mu)^2\right]$, where $E\left[(p^{\mathrm{r}} - \mu)^2\right] = \sigma^2$ is the (unconditional) variance of the price.

Corollary 1 The magnitude of a farmer's forecasting error V (measured as the squared deviation of the farmer's expected price conditional on the information acquired from the realized price) is $V = (1-\rho)^2\sigma^2$. It increases with σ^2 and decreases with ρ.

One particular implication of the corollary is that in case of no information acquisition, that is, $\rho = 0$, the forecasting error is just the unconditional variance of the price series. For full information acquisition, $\rho = 1$, the forecasting error will be zero. As V decreases with ρ, the impact of the structural parameters on the forecasting error in the optimum V^* has a sign opposite to that of the impact of these parameters on ρ^*. The exception is σ^2, which influences both the optimal ρ^* and V^* in opposite directions.[1]

This chapter employs empirical analyses to validate the theoretical model and to determine the sign and magnitude of the impacts of the structural parameters on the accuracy of price expectation formation. Because it is nearly impossible to observe investment in acquiring information per se, we explain the size of the price expectation error (or realized price forecasting error) with empirical data. The structural model parameters are linked to our empirical data as indicated in the last column of Table 20.1.

[1]Formally, $\frac{\partial V^*}{\partial\sigma^2} = (\rho^* - 1)\left[(\rho^* - 1) + \frac{\sigma^2}{2\alpha\beta(1+r)^2 k''(\cdot)}\right]$ after substituting $\frac{d\rho^*}{d\sigma^2}$ from *proposition 1* into the derivative of V with respect to σ^2. As can be easily verified, $\frac{\partial V^*}{\partial\sigma^2} > 0$ for sufficiently small values of σ^2 and $\frac{\partial V^*}{\partial\sigma^2} < 0$ for sufficiently large values of σ^2.

Table 20.1 Impact of structural parameters on the quality of the price signal

Parameter in the theoretical model	Impact in optimum On the quality of the signal ρ	On the forecasting error V	Related explanatory variables in empirical model
Cost of information β	$\rho^*(\beta) < 0$	$V^*(\beta) > 0$	Ownership of ICT, years of schooling, distance to market, distance to extension agents' office
Discount rate r	$\rho^*(r) < 0$	$V^*(r) > 0$	Discount rate, years of schooling
Production costs α	$\rho^*(\alpha) < 0$	$V^*(\alpha) > 0$	Distance to market, distance to extension agents' office, family labor
Volatility σ^2	$\rho^*\left(\sigma^2\right) > 0$	$V^*\left(\sigma^2\right) \gtrless 0$	Crop price volatility, crop and/or village fixed effects

20.3 Methods

20.3.1 Data and Descriptive Statistics

Data for this study were obtained through a household survey. A random sample of 415 rural smallholders were selected from seven villages out of four different districts of Ethiopia, namely Kersa, Shashemene, Ada'a, and Debre Birhan Zuria.[2] Adele Keke is a kebele[3] selected from Kersa district and households in this village trade with the adjacent towns of Dire-Dawa, Harar, and Aweday. Smallholders in this kebele produce staple crops, typically corn and sorghum, and cash crops, like chat[4] and potato. We also interviewed households from four neighboring kebeles at the Debre Birhan Zuria district, which is 120 km northeast of Addis Ababa. The town of Debre Birhan is a nearby market for their grain production, which typically consists of barley, wheat, and horse beans, among others. Sirbana Godeti is a kebele that was selected in the Ada'a district and it is the major supplier of *teff* to the surrounding and Addis Ababa markets. Having relatively fertile soil, smallholders in this area also produce several leguminous crops and vegetables.

[2]The households in our sample were those selected for the widely used Ethiopian Rural Household Survey (EHRS), and detailed information on sampling techniques can be found from Dercon and Hoddinott (2004).

[3]A kebele is the smallest administrative unit in Ethiopia.

[4]Chat is a perennial cash crop and a mild stimulant that is commonly used in the southern and eastern parts of Ethiopia.

Finally, we interviewed households from Turfe Ketchema, which is located about 12 km northeast from the town of Shashemene, where most of their marketing are conducted. The main crops that the smallholders in this survey area produce include potatoes, corn, wheat, barley, and *teff*.

The survey was conducted in April and May 2013, which was immediately before or at the onset of planting for the main "*meher*" season of 2014. This helped us obtain good information on planting time prices. Furthermore, the dataset provided detailed information on household demographics, asset holdings, production and consumption, purchases and sales, seasonal prices, information sources, among others. Data on sowing time prices from the nearby grain markets were obtained from the central statistical agency (CSA) of Ethiopia. Grain prices for the then upcoming harvesting prices, which were not known at the time of our survey, are obtained from three different enumerators who travelled to the respective markets to collect price information.

Following the liberalization of markets in Ethiopia in the early 1990s, prices have not only served as an incentive for farmers to produce more, but they have also become less predictable. Consequently, recent food price volatility has posed additional challenges to farmers in their production decisions. Information regarding input and output price developments, weather conditions, and input availability are hence crucial for the farmer to make a better production decision. Based on the survey data, most of the smallholder households perceive prices as highly unpredictable. About 85 % of the households reported that output prices were likely to increase in the next one year, whereas the other 11 % indicated that prices would have declined. Although most of the farmers (87 %) reported that changes in output prices (in a year) were more likely to range from a decrease by half to an increase by twice of the amount they predicted, the remaining households reported that prices could be outside this range.

Farmers form their price expectations based on information that they have access to. We asked the respondents two similar but subtly different questions regarding their sources of price information. First, we wanted to know the major sources of information for the market prices of their crops. Second, we asked them a more specific question with regard to what information they observe to predict the harvesting time price of the crop they chose to cultivate. Figure 20.1 shows the major responses. There are three main sources of price information for rural households in Ethiopia. Most of the smallholder farmers (54 %) visited close-by markets to sell or buy products and thereby gather price information for the commodities they are interested in, whereas about 45 % of them got price information from their fellow farmers. About two-thirds of the households owned either a radio (57 %) or a mobile phone (66 %), or a television (8 %), and about a quarter of the rural households reported using these ICT tools as their sources of output price information. The

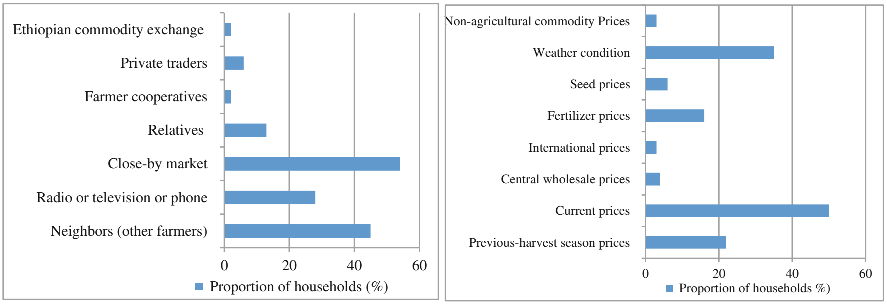

Fig. 20.1 Primary sources of price information (*left*) and relevant information for price expectation formation of smallholders (*right*) *Note*: respondents were allowed to give multiple responses

descriptive statistics also indicated that the Ethiopian Commodity Exchange (ECX) has not done enough to reach out rural smallholder farmers with price information.[5]

An interesting observation is that about half of the smallholders form their harvesting time price expectations based on the currently available price information. About a fifth of the respondents also considered prices from the past harvesting period in forming their price expectation. This may suggest that these households form their price expectations in line with the adaptive or naïve price expectation formation hypothesis. This is consistent with Chavas (2000), which indicated that close to half of the US beef markets were associated with the naïve expectation hypothesis. Nevertheless, other information such as weather, input prices, and central wholesale prices were reported by the smallholder farmers in our sample as relevant information in forming price expectation.

Subject to their access to information and their ability in data processing, farmers make their price predictions for the next harvesting period. The better the access farmers have to relevant price information, the more precise their price predictions are expected to be. This, in turn, results in a more efficient allocation of production resources. Table 20.2 presents the descriptive statistics for the smallholders in our sample, highlighting household characteristics, asset holdings, and other variables that could potentially affect farmers' data gathering and processing abilities that, in turn, influence their price expectation formations.

The summary statistics in Table 20.2 show a lot of similarities among the households from the four survey districts. On average, the household heads were in their mid-50s, and greater than two-third of them were married and male. The average family size (6.1) is slightly greater than the average household size in rural Ethiopia, which is 5.1 according to the household consumption and expenditure survey in 2010/2011 (CSA 2012). Although about 55 % of the overall household

[5]Established in 2008 as a partnership between market actors, members of the exchange, and the government, the ECX is a marketing system that, among other things, aims to disseminate real-time market information to all market players.

Table 20.2 Summary statistics of sampled smallholders by district

District	Debre Birhan		Ada’a		Kersa		Shashemene		Total	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household characteristics										
Age of head	55	15	59	15	52	150	52	18	54	16
Female-headed HH (%)	30	46	31	46	35	48	29	46	31	46
Married HH head (%)	64	48	65	48	69	47	79	41	68	47
Family size	5.41	2.07	5.50	2.13	7.27	3.02	6.54	3.25	6.07	2.69
Years of schooling	1.36	2.56	1.75	2.92	1.24	2.16	3.65	4.43	1.90	3.18
Leadership position (%)	25	44	13	34	15	36	20	40	20	40
Discount rate	0.28	0.46	0.39	0.60	0.73	1.42	0.57	1.12	0.46	0.89
Asset ownership										
Total farm size (ha)	2.39	0.78	1.62	0.84	0.96	0.62	1.18	0.63	1.68	0.94
Per capita farm size (ha)	0.51	0.32	0.32	0.22	0.17	0.16	0.22	0.17	0.34	0.29
Radio ownership (%)	62	49	53	50	48	50	63	49	57	50
TV ownership (%)	1	11	23	42	4	21	12	33	8	28
Mobile ownership (%)	62	49	71	46	73	45	63	49	66	47
ICT ownership (mobile or radio or TV) (%)	80	40	81	40	79	41	80	40	80	40
Oxen ownership (%)	86	35	73	45	16	37	58	50	63	48
Tropical livestock unit (TLU)[a]	9.60	4.83	5.00	3.53	2.35	1.48	2.79	2.20	5.85	4.83

(continued)

Table 20.2 (continued)

District		Debre Birhan		Ada'a		Kersa		Shashemene		Total	
Variable		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household asset (index)[b]		0.70	0.64	0.02	0.79	−0.89	0.82	−0.38	0.94	0.00	2.45
Farm income share (%)		91	13	87	22	95	17	96	1	92	16
Market share (%)		2	80	18	16	1	3	30	22	11	18
Access to market and other services											
Dist. to nearby grain market	km	10.36	3.11	11.45	1.61	6.81	3.33	8.73	3.65	9.46	3.47
	hr	2.05	0.62	2.28	0.49	1.73	0.95	1.64	0.82	1.94	0.76
Dist. to dry weather road	km	2.48	2.25	0.52	0.78	0.58	0.56	0.85	1.18	1.41	1.84
	hr	0.55	0.49	0.13	0.15	0.17	0.19	0.25	0.30	0.33	0.40
Dist. to all weather road	km	3.42	2.63	1.06	1.03	1.39	1.81	2.79	2.07	2.41	2.33
	hr	0.69	0.47	0.25	0.21	0.33	0.25	0.62	0.42	0.51	0.42
Dist. to extension agents	km	4.16	3.13	3.02	1.54	1.77	4.82	12.28	86.92	5.16	40.20
	hr	0.92	0.61	0.70	0.48	0.39	0.32	0.36	0.35	0.65	0.54
N		159		78		89		89		415	

Source: Survey data, 2013

[a]A tropical livestock unit (TLU) is an animal unit used to aggregate different classes of livestock. One TLU typically equals an animal of 250 kg live weight. We use 1 TLU to refer to 1 ox/cow, 0.75 bull/heifer, 0.45 calf, 0.15 goat/sheep, 0.5 donkeys, 1.15 horse/mule, 1.5 camel, and 0.005 for poultry (adapted from Ramakrishna and Demeke 2002)

[b]This is a weighted sum of all household assets except livestock and land computed by a principal component analysis

heads had some literacy skills through formal or informal education, the average family head had completed only the second grade. The smallholders in the sample had relatively large discount rates (46 %), which indicate severe liquidity problems. We measured discount rate using a survey question that elicits the minimum amount of money that a household head would have to be given in 6 months time in order to make them no different relative to a fixed amount given to them today.

The total land owned by the average smallholder was about 1.68 ha: smallholders in Debre Birhan district had, on average, slightly greater than 2 ha of land, whereas those in Kersa had slightly less than a hectare of land. The average per capita farm size was less than half a hectare. Besides, ownership of information assets such as mobile phone, radio, and television are very important in obtaining market, rainfall, and other information that could improve households' production decisions. The data showed that about 80 % of the smallholders owned at least one ICT tool.[6]

Other indicators of access to market and information include distances from basic facilities. For instance, smallholder farmers are located on average 3 km away from an all-weather road and 10 km from a nearby grain market. Thus, the average farmer needs to walk about 1 and 2 h to access these facilities, respectively. As agriculture is the main activity in all districts, it is not surprising that off-farm income contributes less than 10 % of the households' incomes. The degree of commercialization (market share of grains), as measured by the share of output sale from total production, is negligible in Kersa and Debre Birhan districts. This is mainly because *chat* is the main cash crop in Kersa, and sale of livestock is common in the latter.[7]

20.3.2 Empirical Model

We employed an econometric model to test part of the above theoretical model with the described household survey data. More specifically, we empirically assessed factors that determine the quality of the price signal, for example, whether households with better or cheaper access to information have more accurate price expectations. Our presumption was that a better price signal, as explained in the theoretical model, implies a more precise price expectation. To this end, we identified relevant variables that affect the precision of smallholders in their expectation formation. We obtained data on smallholders' expectations of harvesting season prices at planting time. This

[6]In this chapter, ICT ownership is the same as ownership of any of the three ICT assets, namely radio, television, or mobile phone.

[7]We calculated the market shares based on total sale and production of the six crops, namely teff, wheat, corn, sorghum, barley, and horse beans to be consistent with our empirical analysis.

allowed us to compute a deviation of farmers' expected prices (p^e) from realized harvesting period output prices (p^r or p_{t+1}) and use the deviation as a proxy for the quality of the price signal (i.e., as a measure of investment into information acquisition). Suppose PE denotes a measure of the price signal quality (henceforth prediction error), which is related to the variable V in the theoretical model. A simple model to explain prediction error for a typical farmer i can be specified as:

$$\mathrm{PE}_i = \alpha + \gamma \mathrm{ICT}_i + \theta M_i + X'\beta + \omega_i, \tag{20.7}$$

where PE is the deviation of each farmer's expected prices from the realized market prices—the outcome variable of interest; and the cost of information acquisition is captured by the two key variables of interest ICT and M. While ICT refers to ownership of information assets (radio, television, and phone), M refers to distance to markets. Both variables capture costs of acquiring information. X refers to a vector of all other explanatory variables that could potentially affect investment in information acquisition (and thus the level of precision in price expectation), such as household characteristics, discount rate, farm size, household wealth, and years of schooling; ω_i is an error term; and α, γ, β are parameters to be estimated.

As noted in footnote 6, we used ownership of the abovementioned ICT tools as one of the proxies for access to information. In other words, we expect farmers to use their radios, televisions, or phones to access better information on variables that influence harvest-time prices, suggesting beneficial effect on their price forecasting ability. There are at least two concerns with this assumption. First, it is possible that farmers use the ICT tools for purposes other than accessing information (e.g., for luxury purposes). Richer farmers, who tend to have more of these information assets, can have better price forecasts based on other channels. Second, there is a possibility that farmers who do not own these information assets share common intrinsic characteristics, such as poor farming skills and management abilities, which are unlikely to be affected by having better market information.

We have taken a few measures to account for these issues. First, we controlled for covariates, such as the level of education, age, wealth proxy variables, and other farmer characteristics, to take into consideration farming experiences and management abilities. Second, we controlled for a variable that captures access to price information, which is an interaction between ownership of ICT and whether farmers use any of the ICT tools as a source of price information. It is worth noting here that farmers may (and are expected to) use their information assets to access more than just price information. This in turn may affect their price prediction. Therefore, ownership of ICT tools remains our main explanatory variable of interest that serves as a proxy to "access to information." Lastly, we calculated household-specific average crop yield for our sample farmers using data from previous rounds of the Ethiopian rural household survey (ERHS). We specifically computed the average crop yield from the crop seasons of the ERHS data collected in 2004, 2009, and from our survey in 2013. If ownership of a radio, television, or mobile phone is systematically related to farming or management skills and ability, then we would expect farmers without these tools to have relatively low crop yields.[8] We included the average yield variable to control for these innate characteristics of farmers, which may also affect their price prediction error.

20.3.2.1 Measuring Prediction Error[9]

We used four alternative, but related, measurements as proxies for smallholders' price prediction errors (or accuracy). Suppose t and $t+1$ refer to the current sowing and the upcoming harvesting periods, whereby the former refers to the time of production decision. Therefore, t refers to the time when farmers form their price expectations for the period $t+1$. Suppose also that e denotes expectation; subscripts c, i, and v denote crop-, farmer-, and village-specific prices, respectively; n is the number of crops that a farmer grows and for which they report price expectations. The alternative measures of a farmer's price prediction error are defined as follows.

(a) *Absolute mean price prediction error (AMPPE)*
We measured the AMPPE as the ***absolute mean*** deviation of the farmer's expected prices from the realized prices in the respective grain markets for n crops that the farmer grows

$$\text{AMPPE}_i = \frac{1}{n}\sum_{c}^{n}\left(\left|p_{c,t+1} - p_{ic,t}^{e}\right|\right).$$

(b) *Relative mean price prediction error (RMPPE)*
This is similar to the above measure except that we took the ***relative mean*** deviation of farmer's price expectations from the realized prices in the respective grain markets—instead of the absolute deviation.

$$\text{RMPPE}_i = \frac{1}{n}\sum_{c=1}^{n}\frac{\left(\left|p_{c,t+1} - p_{ic,t}^{e}\right|\right)}{p_{c,t+1}}.$$

The above two measurements assume that a farmer gives equal weight to each crop in his price expectations. However, a farmer may invest more in acquiring better information regarding a crop that he produces for a market compared to a crop that he produces for home consumption. This, in turn, affects his price prediction accuracy of the respective crops. To take this into account, we calculated the deviation of market share-weighted expected prices from

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[8]A simple linear regression of ownership of assets on past average crop yield supports this statement: ownership is strongly and positively correlated with crop yield.

[9]In this study, we refer to the quality of farmers' price expectations—that is, the deviation of farmers' expected prices from realized prices—alternatively as price prediction error (accuracy), forecasting error (accuracy), and expectation error (precision).

similarly weighted realized prices. We used the market share of each crop to calculate price indices for each farmer and district. Using the farmers' reported and expected prices for sowing and harvesting periods, we obtain price indices for the respective seasons. Village-level price indices were similarly calculated using observed prices in the respective nearby grain markets. Furthermore, we normalized (both farmer- and district-specific) harvesting time price indices by the respective sowing time indices in order to consider the general trend of grain prices. Accounting for such price trends is important to overcome endogeneity in the estimation that may arise due to heterogeneities in the farmers' understanding of the overall inflation or deflation on their price predictions. Analogous to the two measures of prediction error mentioned above, we calculated the absolute and relative index price prediction error for each smallholder farmer.

(c) *Absolute index price prediction error (AIPPE)*
We calculated the AIPPE as an ***absolute*** deviation of ***indices*** of farmers' expected prices from the realized price ***indices*** in the respective markets/villages as

$$\mathrm{AIPPE}_i = \left|\mathrm{NPI}_{v,t+1} - \mathrm{NPI}^e_{i,t}\right|,$$

where $\mathrm{NPI}_t = \frac{\sum_c^n \alpha_c p_{c,t}}{\sum_c^n \alpha_c p_{c,t-1}}$ refers to the normalized price index—where the denominator (sowing period price) is normalized at 100—for each village v or for each household i. α_c refers to the market share of each crop.

(d) *Relative index price prediction error (RIPPE)*
RIPPE is calculated as the ***relative*** deviation of ***indices*** of farmers' expected prices from the realized price ***indices*** in the respective markets/villages.

$$\mathrm{RIPPE}_i = \frac{\left(\left|\mathrm{NPI}_{v,t+1} - \mathrm{NPI}^e_{i,t}\right|\right)}{\mathrm{NPI}_{v,t+1}}$$

Figure 20.2 illustrates how we measured PE using self-reported prices for the crops of interest in this study. The area in the dotted circle refers to realized (p_{t+1}) and expected (p^e) prices of the new harvesting period. The latter are price expectations of farmers made at sowing time, t. The graph in the right panel is a replication of the corn example for better illustration. The vertical distance between the realized and expected price, indicated by the red arrow line, is the prediction error.

The above measures of price prediction error combine multiple crops that a farmer grows. This might result in an "averaging-out" effect if a farmer who has a large expectation error for one crop tends to have a small error for the other. In other words, these measures are inadequate if a farmer's price forecasts have

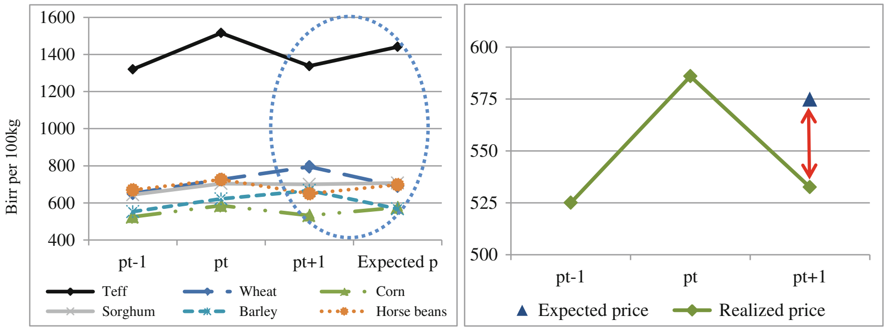


Fig. 20.2 Illustration of prediction error using self-reported prices

Table 20.3 Consistency of farmers' prediction errors between crops

Crop-to-crop errors	Reg. coef.	Corr. coef.
Barley and wheat	0.49*** (0.10)	0.38***
Corn and sorghum	0.82*** (0.16)	0.47***

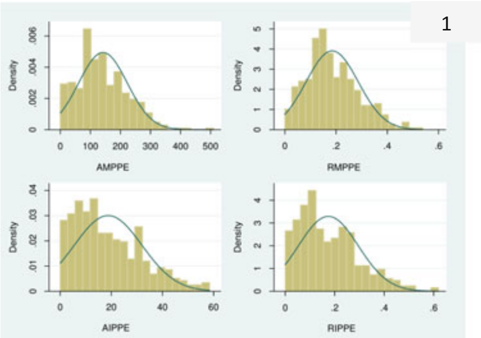
Notes: Standard errors are in parentheses
** denotes statistical significance at the 1 % level or less

large discrepancies across different crops. In order to shed some light on this, we computed regression and correlation coefficients between the magnitudes of individual farmer's forecasting errors for corn to that of sorghum and for wheat to that of barley.[10]

The coefficients in Table 20.3 illustrate a significant degree of consistency in prediction errors between crops for the same farmer. The farmers who made large errors in their corn price prediction also tended to make large errors for sorghum. This is also true for the expectation errors of farmers growing both wheat and barley. This hinted that the mean deviation would not cause the error for one crop to be offset by the error for another, suggesting also that crop diversification would not lead to any better resource allocation for the farmer.

Moreover, the data showed that the crop-specific price forecasting (prediction) errors, on average, range between 19 and 20 % with comparable standard errors. This provided an additional clue for the absence of any large systematic difference in the difficulty of forecasting prices of different crops. There is also an economy of scale advantage for a farmer to invest in acquiring information on multiple crops.

[10] We chose these crops because of the larger number of farmers producing the respective crop pairs.



2

Variable	Original		IHS Transformed	
	Mean	(SD)	Mean	(SD)
AMPPE	141.84	(80.74)	5.38	(1.00)
AIPPE	18.73	(13.28)	3.28	(0.97)
RMPPE	0.18	(0.10)	0.18	(0.10)
RIPPE	0.17	(0.12)	0.17	(0.12)

Fig. 20.3 Summary statistics and distribution of the dependent variable

20.3.2.2 Estimation Technique

The nature of the dependent variable (price prediction error), an absolute value of a narrowly dispersed variable, requires paying special attention to the estimation method used. Because the prediction error has a zero lower bound, it has a positively skewed distribution (Fig. 20.3, Panel 1). This variable has a relatively small range, 0–0.6 with a mean close to zero, in the relative measures. As measured by RIPPE, for instance, the magnitudes of the prediction error made by smallholder farmers in our sample ranges from 0 % to as far as 60 %, with a mean value of 17 % (Fig. 20.3, Panel 2). This indicates that some farmers forecasted prices correctly, and the dependent variable has natural zero values. A quasi-maximum likelihood (QML) Poisson estimator would be appropriate in such situations (Cameron and Trivedi 2010; Nichols 2010; Wooldridge 2010). In fact, Santos Silva and Tenreyro (2006) argued that QML Poisson regression is preferred to an ordinary least squares (OLS) regression on a log-linear equation regardless of a count or a continuous dependent variable.[11] Because the mean and the variance of our dependent variables are not equal—that is, the distribution is not Poisson—we needed to use the robust sandwich standard errors (Cameron 2009).

An OLS estimation can be used if the residuals are normally distributed. We transformed the alternative dependent variables using the inverse hyperbolic sine (IHS) method to get residuals that are approximately symmetrically distributed.[12] We favored using IHS over logarithmic transformation as some households in our sample have zero prediction errors, the log of which is not defined.[13] The IHS is a logarithmic-like transformation that retains zero and negative values, unlike

[11]We refer to an interesting Stata Blog post by Bill Gould about using a Poisson regression model (http://blog.stata.com).

[12]The IHS transformation of variable x can be given as: $\text{ihs}(x) = \ln\left\langle \theta x + \left(\theta^2 x^2 + 1\right)^{1/2} \right\rangle$ and the scale parameter θ is assumed to be unity in most applications.

[13]Because the dependent variable (when measured in relative terms) is not a proportion where values above one are infeasible, a logit transformation is not needed for an OLS estimation.

logarithmic transformation, and has been applied in several studies (Bellemare et al. 2013; Burbidge et al. 1988; Moss and Shonkwiler 1993). This transformation allows us to interpret the OLS estimated coefficients as semi-elasticities. The marginal effects should be interpreted in percentage points in the case of the relative measures of the dependent variable (RMPPE and RIPPE).

20.4 Results and Discussion

Table 20.4 presents the estimation results of the maximum-likelihood Poisson regression model, specified as a generalized linear model (GLM) with a log-link function. The four columns differ in terms of the alternative measurements of prediction error, as discussed above. Although results are mostly consistent across the different specifications, we discuss the results from our preferred measure of prediction accuracy: the RIPPE. Besides accounting for the general grain price trend, this measure also weights crop prices with their respective market shares.

Controlling for access to ICT and grain markets, and other confounders, the estimated coefficients indicated that female-headed households had more accurate price expectations than male-headed households. Moreover, as expected a priori, households with an older (more experienced) head had statistically significant smaller forecasting errors. Not surprisingly, the precision of smallholders' price expectations was closely linked with the self-reported proxy for time preference (i.e., the discount rate). The results in Table 20.4 show that smallholders with higher discount rates, who tend to undervalue future gains and who therefore invest less in production but also information acquisition, have larger forecasting errors. This is consistent with the implication of the theoretical model.

As expected a priori, smallholders who had access to ICT such as radios, televisions, or mobile phones were more likely to make more precise price expectations than those who do not own any of these assets. Ownership of these assets enables them to access additional information on prices cheaply. More specifically, access to ICT was associated with about a 10 % decrease in the conditional mean of a smallholder's prediction error ($100 \times \left[e^{-0.11} - 1\right]$, in column [4] of Table 20.4). This means that the prediction error made by smallholder farmers who own any of the ICT tools was smaller by a factor of 0.89 than those who did not own any ICT tools, ceteris paribus. Smallholders who followed price information through radio or television or mobile telephony tended to forecast prices more accurately. This finding supports the theoretical model that indicates a negative impact of large information costs on the quality of the price signal. The interaction variable (ICT ownership and source of price information, $ICT \times InfoSource$) is not statistically significant in all specifications. This indicates that information assets might have improved a farmer's price prediction accuracy mainly through access to non-price information, such as weather.

Table 20.4 Factors that affect price prediction accuracy of smallholders

Dependent variable: relative mean/index price prediction error				
Variables	AMPPE	AIPPE	RMPPE	RIPPE
Male head	0.0328***	0.1089**	0.0353	0.1090**
	(0.0120)	(0.0460)	(0.0300)	(0.0430)
Age of head	−0.0004	−0.0027**	−0.0007**	−0.0026***
	(0.0010)	(0.0010)	(0.0000)	(0.0010)
Family size	−0.0108***	0.0054	−0.0112***	0.0067
	(0.0030)	(0.0110)	(0.0020)	(0.0100)
Head's years of schooling	0.0049	0.0001	0.0052***	−0.0008
	(0.0030)	(0.0060)	(0.0020)	(0.0050)
ICT	−0.0240	−0.1117***	−0.0557**	−0.1074***
	(0.0300)	(0.0410)	(0.0280)	(0.0260)
ICT × InfoSource	−0.0344	0.0885	−0.0207	−0.0724
	(0.0660)	(0.0610)	(0.0470)	(0.0620)
Past average crop yield	0.0090	−0.0525	−0.0028	−0.0478
	(0.0310)	(0.0600)	(0.0230)	(0.0370)
Share of farm income	0.0822	−0.0667	0.0587	−0.0429
	(0.0990)	(0.1690)	(0.1830)	(0.1810)
Market share	−0.0929	0.2323	−0.1631***	0.2591
	(0.0850)	(0.1460)	(0.0530)	(0.1700)
Per capita livestock value	−0.0177***	−0.0185***	−0.0158***	−0.0185***
	(0.0040)	(0.0050)	(0.0050)	(0.0050)
Per capita farm size	−0.0307	0.0061	−0.0043	0.0034
	(0.1320)	(0.1440)	(0.1490)	(0.1340)
Dist. to grain market	−0.0047	0.0301***	−0.0029	0.0296***
	(0.0030)	(0.0040)	(0.0070)	(0.0050)
Dist. to extension agents' office	0.0042	−0.0207	0.0032	0.0198
	(0.0130)	(0.0150)	(0.0100)	(0.0190)
Discount rate	0.0350***	0.0227***	0.0378***	0.0201**
	(0.0080)	(0.0070)	(0.0060)	(0.0090)
No. of crops	0.0706	−0.1092***	0.1038***	−0.1042***
	(0.0430)	(0.0350)	(0.0220)	(0.0260)
Constant	4.7818***	3.9814***	−1.7674***	−0.8357**
	(0.2980)	(0.6110)	(0.2040)	(0.3950)
District dummies	Yes	Yes	Yes	Yes
N	400	400	400	400

Notes: Standard errors are bootstrapped and clustered in seven *kebeles* (villages)
*, **, *** denote statistical significance at 10 %, 5 %, and 1 % level, respectively

We included two proxy variables for wealth, per capita value of livestock and farm size, to take into account any possibility that richer smallholders may have had better price forecasts using information from channels other than the aforementioned information assets. The results confirmed that (regardless of ownership of information assets) wealthier farmers have better price forecasts, as indicated by the statistically significant and negative estimated coefficient of the per capita value of livestock value. The lagged historical crop yield variable, which captures poor farming skills and management ability of farmers, turned out to be statistically insignificant. Although farmers who do not own ICT may share such common farmer characteristics, these innate characteristics did not have a causal effect on their price forecasting accuracy.

Another important factor which determines the cost of access to information is the proximity of households to major local grain markets. The empirical finding is consistent with the theoretical model: the costs of acquiring information were higher for households located farther away from grain markets. All other factors remaining constant, halving the "effective" distance to a nearby grain market reduces the forecasting error of a farmer who is located at an average distance away from the market by about 14 % ($100 \times \left[e^{-4.73 \times 0.03} - 1\right]$). This is consistent with the descriptive statistics as most households reported that they had usually visited nearby grain markets to obtain price information. In contrast, access to extension services—measured by distance from extension service offices—did not appear to be effective in providing information that helps smallholders improve their price forecasting performance. This may be partly explained by the training level of extension agents and the extent to which farmers trust the information they receive from agents.

We measured "access to ICT" by ownership of any of the information assets, namely radio, television, or mobile phone. It may, however, be necessary to investigate the differential impacts (if any) of each ICT. Table 20.5 presents the results using an exclusive ownership of mobile phone (column 2) and radio (column 3) as alternative measures of access to information.[14] Column (1) in this table is the same as the last column in Table 20.4, and the dependent variable is RIPPE in all cases. The results suggest that mobile telephony alone played a statistically significant role in improving the price forecasting accuracy of farmers. However, the marginal effect of exclusive ownership of mobile phones is smaller than the effect of our preferred measure of information access (an estimated coefficient of −0.05). Smallholders may use the information assets as a substitute or complement depending on several factors. The results also highlighted that ownership of a radio alone did not have a statistically significant effect on price prediction errors (column 3).

The last column in Table 20.5 controlled for interaction terms to test if the effects of access to ICT is conditional on some of the covariates (e.g., age and distance to market). Older household heads have more experience and are more likely to have better price forecasts, whereas younger heads do better if they have access to ICT. More specifically, the estimated coefficient of the interaction term of ICT and age of the head was positive (Column 4). The positive estimated coefficient of the

[14]Since only less than 10 % of our sample owns a television (8 %) or all three assets (7 %), we only consider exclusive ownership of a mobile or a radio as alternative proxies for access to ICT.

Table 20.5 Differential impacts of access to ICT on price prediction (RIPPE)

Variables	(1)	(2)	(3)	(4)
Male head	0.1090**	0.0937**	0.0973*	0.0957***
	(0.0430)	(0.0440)	(0.0520)	(0.0370)
Age of head	−0.0026***	−0.0026***	−0.0025*	−0.0092***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
ICT × Age				0.0088***
				(0.002)
Family size	0.0067	0.0036	0.0032	0.0054
	(0.0100)	(0.0060)	(0.0060)	(0.0060)
Head's years of schooling	−0.0008	−0.0019	−0.0013	0.0021
	(0.0050)	(0.0040)	(0.0040)	(0.0040)
ICT[a]	−0.1074***	−0.0513**	−0.0249	−0.4494***
	(0.0260)	(0.0230)	(0.0430)	(0.1540)
ICT × InfoSource	−0.0724			−0.0727
	(0.0620)			(0.0600)
Past average crop yield	−0.0478	−0.0554	−0.0521	−0.0378
	(0.0370)	(0.0640)	(0.0700)	(0.0700)
Share of farm income	−0.0429	−0.1386	−0.1236	−0.0027
	(0.1810)	(0.1690)	(0.1090)	(0.1510)
Market share	0.2591	0.2433	0.2406	0.2594
	(0.1700)	(0.1930)	(0.1590)	(0.1630)
Per capita livestock value	−0.0185***	−0.0182***	−0.0174***	−0.0199***
	(0.0050)	(0.0030)	(0.0050)	(0.0060)
Per capita farm size	0.0034	−0.0222	−0.0219	−0.0036
	(0.1340)	(0.1530)	(0.1060)	(0.1260)
Dist. to grain market	0.0296***	0.0296***	0.0296***	0.0417***
	(0.0050)	(0.0040)	(0.0040)	(0.0060)
ICT × dist. to market				−0.0145*
				(0.008)
Dist. to extension agents' office	0.0198	−0.0164	−0.0175	−0.0218*
	(0.0190)	(0.0100)	(0.0170)	(0.0120)
Discount rate	0.0201**	0.0184***	0.0184***	0.0204***
	(0.0090)	(0.0060)	(0.0070)	(0.0070)
No. of crops	−0.1042***	−0.1078***	−0.1109***	−0.0970***
	(0.0260)	(0.0280)	(0.0290)	(0.0370)
Constant	−0.8357**	−0.7023	−0.7423	−0.6864
	(0.3950)	(0.5420)	(0.6500)	(0.6620)
District dummies	Yes	Yes	Yes	Yes
N	400	400	400	400

Notes: Standard errors are bootstrapped and clustered in seven *kebeles* (villages)
*, **, *** denote statistical significance a 10 %, 5 %, and 1 % level, respectively
[a]*Access to ICT* is measured as ownership of either a phone, radio, or TV in (1 & 4), only a phone in (2), only a radio in (3)

interaction term indicates that ownership of ICT tools has larger impacts on price prediction accuracy for households headed by younger farmers. This can be due to better knowledge of younger farmers with regard to using ICT tools and better understanding of the transmitted information.

Another interesting finding is that proximity to grain markets did not provide any more advantage in terms of predicting future prices as long as farmers have access to ICT. The estimated coefficient of the interaction term of ICT and distance from nearby grain markets was negative and statistically significant. In other words, the beneficial impact of ICT on price forecasting is stronger for smallholders located farther away from grain markets. Based on the estimated coefficients, the beneficial impact of access to ICT on price forecasting accuracy outweighs the detrimental impact of access to grain markets for farmers located as far as 15 km away from grain markets. This is because the interaction term indicates that prediction error increased by a factor of $e^{0.03} = \left(e^{0.04-0.01}\right) = 1.03$ for every kilometer increase in distance to markets (an increase by this factor for every 15 km is approximately equal to the decrease in prediction error because of ownership of ICT). This suggests that ownership of information assets can serve as an alternative way to gain access to market information for farmers residing far away from grain markets but not for those located more than 15 km away. Ceteris paribus, simultaneously providing access to ICT and halving the "effective" distance to nearby grain markets, improved the prediction accuracy of farmers by as much as 45 % $(100 \times \left[e^{\{-0.45+(-4.73\times 0.03)\}} - 1\right])$.

20.4.1 Robustness Checks

We estimated Eq. (20.7) using an OLS method on the IHS-transformed variables. The results are reported in Tables 20.7 and 20.8 in Appendix. The OLS results were largely consistent with the ML Poisson estimation results.[15] The control variables in our empirical model explained only a small but significant proportion of the variation in the farmers' forecasting errors.[16] Ethiopia is one of the countries in which agricultural commodity prices have experienced significant variability in recent years (Rashid 2011; Tadesse and Guttormsen 2011). High price volatility reduces the accuracy of producers' and consumers' forecasts of crop prices (Binswanger and Rosenzweig 1986), even though the impact is ambiguous in our theoretical model. Given the stochasticity of output prices, a lucky farmer gets his expected

[15]Note that comparison of OLS and Poisson regression coefficients is inappropriate as they are interpreted differently. One can calculate the average marginal effects, $\sum_i \frac{\partial E\left(y_i \middle| x_i\right)}{\partial x_{ij}} = \bar{y}\widehat{\beta}_j$, after the GLM regression and compare them with the corresponding OLS coefficients.

[16]The coefficients of determination, computed as a square of the correlation coefficients of the respective fitted and actual prediction error values, are comparable to the reported R-square in the OLS regression results.

price close to the actual value. Thus, the ‘luck factor’ could probably explain some of the remaining variation of smallholders’ forecasting errors. There also appears to be a widespread exchange of price and other information among households, thereby suggesting that the private information of a farmer who has the most timely and relevant information could be open to the public domain.

As a further robustness check, we employed a maximum likelihood estimation (MLE) technique with normal distribution to simultaneously estimate the mean price and its heteroskedastic variance term. In the mean equation, the realized price was estimated using the (farmer-reported) expected price.[17] The residual $\varepsilon_i \sim N\left(0, \sigma_i^2\right)$ is the difference between expected and realized price. The variance of the residual is household-specific and normally distributed; it measures the forecasting error of the household. In the variance equation, the log variance was estimated conditional on the same set of explanatory variables X as before. Hence, the maximum likelihood regression reads:

$$p_{ic,t+1} = \alpha + \beta p^e_{ic,t} + \varepsilon_i, \tag{20.8a}$$

$$\ln\ \sigma_i = a_c + X'\gamma. \tag{20.8b}$$

The maximum likelihood estimation results are reported in Table 20.6. We first observed that farmers have unbiased price expectations (at least in the year of our survey) as α was not statistically different from zero. Furthermore, the results for the variance regression were mostly consistent with both the QML Poisson and OLS estimation results.

20.5 Conclusions

A time lag between production decisions and output realization is intrinsic in agriculture; therefore, price expectations play a crucial role in the production, marketing, and agricultural technology adoption decisions of a farmer. The literature widely explores the effect of access to information—in particular access to market information systems, and to information and communication technologies—on a variety of economic variables, at both a macro and a micro level. The current study complements the existing literature by investigating the role of access to information on the precision of smallholders’ price expectations. Producers invest money and time in searching for price and other information, which they believe would improve their price expectations. This process is costly for an individual farmer. The cost of information is therefore crucial for farmers in deciding on their level of investment

[17]This approach relies on empirical tests for unbiased or rational expectations, as typically used for assessing efficiency on commodity markets. See, e.g., Algieri and Kalkuhl (2014). Rational expectations are usually tested against $\alpha \neq 0$ and $\beta \neq 1$.

Table 20.6 Factors that affect price prediction accuracy of smallholders, MLE

Variables	(1)	(2)	(3)	(4)
Equation 1: Observed market price (ln) is the dependent variable				
Farmer expected price (ln)	1.0076*** (0.0009)			
Constant	0.0048 (0.0039)			
Equation 2: Ln (sigma) serves as a proxy for the natural log of prediction error				
Male head	0.0649* (0.0338)	0.0560* (0.0335)	0.0563* (0.0335)	0.0712** (0.0343)
Age of head	−0.0024** (0.001)	−0.0023** (0.001)	−0.0022** (0.001)	−0.0034* (0.0019)
ICT × age				0.0011 (0.0022)
Family size	−0.0073 (0.0071)	−0.0118* (0.0068)	−0.0126* (0.0069)	−0.0107 (0.0072)
Head's years of schooling	0.0055 (0.0056)	0.0051 (0.0056)	0.0056 (0.0056)	0.0045 (0.0057)
ICT[a]	−0.0882** (0.0432)	−0.0664** (0.0302)	−0.0265 (0.0442)	−0.0946** (0.0409)
ICT × InfoSource	0.0198 (0.0343)			0.1682 (0.1842)
Past average crop yield	−0.0227 (0.0324)	−0.0230 (0.0321)	−0.0234 (0.0324)	0.0281 (0.0384)
Share of farm income	0.0653 (0.2000)	−0.0402 (0.1004)	−0.0207 (0.1002)	0.0713 (0.1126)
Market share	−0.0591 (0.1069)	−0.1112 (0.1055)	−0.1129 (0.1052)	−0.0882 (0.1099)
Per capita livestock value	−0.0120** (0.0061)	−0.0140** (0.0057)	−0.0135** (0.0057)	−0.0154** (0.0062)
Per capita farm size	0.0326 (0.0644)	0.0129 (0.0624)	0.0115 (0.0626)	0.0296 (0.0658)
Dist. to grain market	0.0080* (0.0045)	0.0084* (0.0045)	0.0087* (0.0045)	0.0336*** (0.0125)
ICT × dist. to market				−0.0277** (0.0129)
Dist. to extension agents' office	−0.0075 (0.0065)	−0.0047 (0.0066)	−0.0067 (0.0065)	−0.008 (0.0065)
Discount rate	0.0304 (0.0187)	0.0222 (0.0170)	0.0243 (0.0171)	0.0246 (0.0174)
No. of crops	0.2656*** (0.0159)	0.2668*** (0.0161)	0.2603*** (0.0157)	0.2670*** (0.0159)

(continued)

Table 20.6 (continued)

Variables	(1)	(2)	(3)	(4)
Constant	−2.3036*** (0.3390)	−2.2150*** (0.2726)	−2.2116*** (0.2747)	−2.8668*** (0.3285)
District dummy	Yes	Yes	Yes	Yes
Wald chi2 test (*p*-value)	0.000	0.000	0.000	0.000
N	2394	2400	2400	2394

Notes: *, **, *** denote statistical significance a 10 %, 5 %, and 1 % level, respectively
[a]*Access to ICT* is measured as ownership of either a phone, radio, or TV in (1 & 4), only a phone in (2), only a radio in (3)

in information acquisition. In this study, we employed access to ICT and distance to markets as measures of costs of acquiring information. The theoretical model, which has been explained in Sect. 20.2, unambiguously showed that the level of farmer's investment in acquiring information is negatively influenced by the costs of accessing information.

Using a primary survey dataset that elicits smallholders' price expectations for the next harvesting period, we empirically evaluated the impact of access to ICT and grain markets and other variables of interest on smallholders' price prediction accuracy. The findings suggest that farmers who have access to ICT and who reside closer to grain markets have smaller forecasting error margins, supporting the implications of the theoretical model. This calls for improving the information and physical infrastructure in rural areas of the country in order to reduce costs of obtaining information. The beneficial effect of access to ICT was larger for households that reside farther away from grain markets and for those headed by relatively younger farmers. From a policy perspective, these differential impacts are compelling as younger farmers and farmers living farther away from grain markets are among the households that hold larger potential for increasing agricultural productivity in the country. This is because farm plots that are located very close to markets are highly degraded, and older farmers are less willing to adopt new technologies.

In agreement with the theoretical model, the empirical findings showed that farmers with higher discount rates were more likely to have larger forecasting errors. This has implications for assisting farmers in reducing future price and income uncertainties, and for enhancing their risk-management strategies. There are some institutions such as the Ethiopian Grain Trade Enterprise (EGTE), the Ethiopian Commodity Exchange (ECX), and the Agricultural Transformation Agency (ATA) that could potentially improve smallholders' access to market information in the country. These institutions may assist farmers in providing and disseminating reliable and timely central wholesale prices.

Access to extension agents did not have any statistically significant contribution to improving price prediction accuracy of farmers in our sample. Extension agents in Ethiopia serve more as a source of credit and inputs rather than a source of information on optimal input use and market information (Spielman et al. 2012).

Extension service, with agents who have valuable market information and better knowledge of how to use inputs than rural farmers, is important for improving the production decision of smallholders. However, past research has shown that Ethiopian extension agents have little practical experience and poor communication skills (Belay and Abebaw 2004). This could explain why farmers may not trust extension agents and hence do not adopt their advice. Because the Ethiopian government is expanding the extension service program throughout the country, it is important to consider disseminating reliable price and market information through extension services in the country to farmers with limited access to such information.

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Appendix. OLS Estimation Results

Table 20.7 Factors that affect price prediction accuracy of smallholders

Dependent variable: relative mean/index price prediction error				
Variables	AMPPE	AIPPE	RMPPE	RIPPE
Male head	0.1121**	0.1590**	0.0059	0.0186***
	(0.0551)	(0.0622)	(0.0037)	(0.0043)
Age of head	0.0009	−0.0039*	−0.0001	−0.0004**
	(0.0014)	(0.0021)	(0.0001)	(0.0002)
Family size	−0.0068	0.0029	−0.0020***	0.0009
	(0.005)	(0.008)	(0.0006)	(0.0008)
Head's years of schooling	0.004	−0.0168***	0.0012***	−0.0004
	(0.0085)	(0.0060)	(0.0004)	(0.0006)
ICT	−0.0682***	−0.0435	−0.0102**	−0.0182***
	(0.0245)	(0.1080)	(0.0043)	(0.0068)
ICT × InfoSource	−0.0474	0.0176	−0.0028	0.0123
	(0.0757)	(0.1569)	(0.0097)	(0.0092)
Past average crop yield	−0.1102*	−0.0194	−0.0003	−0.0085
	(0.0613)	(0.1254)	(0.0064)	(0.0089)
Share of farm income	−0.1538	−0.0625	0.0085	−0.0092
	(0.2139)	(0.2765)	(0.0275)	(0.0298)
Market share	−0.1091	0.0273	−0.0308***	0.0328
	(0.1015)	(0.1788)	(0.0116)	(0.0315)

(continued)

Table 20.7 (continued)

Dependent variable: relative mean/index price prediction error				
Variables	AMPPE	AIPPE	RMPPE	RIPPE
Per capita livestock value	−0.0132*** (0.0051)	−0.0079 (0.0097)	−0.0031*** (0.001)	−0.0026*** (0.0007)
Per capita farm size	0.0044 (0.1041)	0.0264 (0.1234)	0.0001 (0.0245)	0.0009 (0.0254)
Dist. to grain market	−0.0158** (0.0076)	0.0261** (0.0130)	−0.0005 (0.0006)	0.0054*** (0.0012)
Dist. to extension agents' office	0.0111 (0.0151)	−0.0268 (0.0432)	0.0008 (0.0022)	−0.0039 (0.0033)
Discount rate	0.1011*** (0.0184)	−0.0376*** (0.0109)	0.0072*** (0.0014)	0.0031*** (0.0010)
No. of crops	0.1169** (0.0484)	−0.1324** (0.0520)	0.0208*** (0.0057)	−0.0169*** (0.0060)
Constant	6.1571*** (0.4752)	4.2603*** (1.1827)	0.1646*** (0.0623)	0.3296*** (0.0925)
District dummies	Yes	Yes	Yes	Yes
Wald chi2 test (*p*-value)	0.00	0.00	0.00	0.00
Root MSE	0.912	0.913	0.095	0.111
Adjusted *R*-square	0.20	0.15	0.15	0.20
N	400	400	400	400

Notes: Standard errors are bootstrapped and clustered in seven *kebeles* (villages)
*, **, *** denote statistical significance at 10 %, 5 %, and 1 % level, respectively. Note that since the dependent variable is either IHS-transformed (APPME & AIPPE) or expressed as a ratio (RMPPE & RIPPE), the coefficients can be considered as economically relevant

Table 20.8 Differential impacts of access to ICT on price prediction

Variables	(1)	(2)	(3)	(4)
Male head	0.0186*** (0.0043)	0.0164** (0.0070)	0.0169*** (0.0062)	0.0171** (0.0087)
Age of head	−0.0004** (0.0002)	−0.0004*** (0.0001)	−0.0004** (0.0002)	−0.0017*** (0.0002)
ICT × age				0.0016*** (0.0002)
Family size	0.0009 (0.0008)	0.0005 (0.0009)	0.0004 (0.0013)	0.0008 (0.0014)
Head's years of schooling	−0.0004 (0.0006)	−0.0006 (0.0006)	−0.0005 (0.0008)	0.0000 (0.0005)
ICT[a]	−0.0182*** (0.0068)	−0.0082* (0.0045)	−0.0047 (0.0050)	−0.0851*** (0.0233)

(continued)

Table 20.8 (continued)

Variables	(1)	(2)	(3)	(4)
Past average crop yield	−0.0085 (0.0089)	−0.0092 (0.0106)	−0.0086 (0.0080)	−0.0070 (0.0105)
Share of farm income	−0.0092 (0.0298)	−0.0263 (0.0284)	−0.0241 (0.0205)	−0.0046 (0.0284)
Market share	0.0328 (0.0315)	0.0326 (0.0285)	0.0324 (0.0270)	0.0332 (0.0212)
Per capita livestock value	−0.0026*** (0.0007)	−0.0026*** (0.0006)	−0.0025*** (0.0007)	−0.0028*** (0.0009)
Per capita farm size	0.0009 (0.0254)	−0.0022 (0.0259)	−0.0019 (0.0155)	0.0012 (0.0249)
Dist. to grain market	0.0054*** (0.0012)	0.0054*** (0.0009)	0.0054*** (0.0009)	0.0075*** (0.0015)
ICT × dist. to market				−0.0026** (0.0013)
Dist. to extension agents' office	−0.0039 (0.0033)	−0.0033* (0.0019)	−0.0035** (0.0016)	−0.0042** (0.0021)
Discount rate	0.0031*** (0.0010)	0.0029*** (0.0011)	0.0029** (0.0012)	0.0031*** (0.0010)
No. of crops	−0.0169*** (0.0060)	−0.0174*** (0.0048)	−0.0179*** (0.0061)	−0.0156** (0.0061)
Constant	0.3296*** (0.0925)	0.3473*** (0.0926)	0.3419*** (0.0784)	0.3666*** (0.1150
District dummies	Yes	Yes	Yes	Yes
Wald chi2 test (*p*-value)	0.00	0.00	0.00	0.00
Root MSE	0.111	0.111	0.111	0.111
Adjusted *R*-square	0.20	0.15	0.15	0.21
N	400	400	400	400

Notes: Standard errors are bootstrapped and clustered in seven *kebeles* (villages)
*, **, *** denote statistical significance at 10 %, 5 %, and 1 % level, respectively
[a]*Access to ICT* is measured as the ownership of either a phone, radio, or TV in (1 and 4), only a phone in (2), only a radio in (3)

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Coping with Food Price Shocks in Afghanistan

21

Anna D'Souza and Dean Jolliffe

21.1 Introduction

Elevated global food prices have eroded the purchasing power of households throughout the developing world, many of whom spend the majority of their income on food. Given the potential implications for poverty, health and nutrition, and the outbreak of food riots, the short- and long-term impacts of high food prices are of much concern to governments, nongovernmental organizations, and aid agencies. During the 2007/2008 food price crisis, many households were pushed into or kept in poverty (World Bank & International Monetary Fund 2012) and were forced to reduce the quantity and quality of food they consumed (International Fund for Agricultural Development 2008; Sanogo 2009). Field observations by the World Food Programme found that households also used nonfood coping strategies, such as migrating, selling assets, taking children out of school, begging, and selling land (Ruel et al. 2010).

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Much of the literature has emphasized the impact of food price increases on poverty rates. A smaller set of literature has examined the impact on nutrition-related outcomes, such as undernourishment rates, calorie levels, and dietary diversity. Until now, little has been done to look at the implications of high food prices or food price increases on nonfood outcomes, such as nonfood expenditure or school enrollment. For the most vulnerable populations, living at or near subsistence levels, reducing the quality and quantity of food consumed, or cutting back on human capital investment (e.g., health and education expenditure) can have both immediate (e.g., wasting, increased illness) and long-lasting (e.g., stunting, intergenerational transmission of poverty) implications. More specifically, even short stints of poor nutrition can be detrimental to those with high nutritional needs like children, lactating and pregnant women, and the elderly (UNICEF 2009); and pulling children out of school could lead to long-term reductions in human capital accumulation since children are less likely to return to school after beginning to work (Guarcello et al. 2010).

In this chapter, we present evidence on household coping strategies from a nationally representative household survey collected in Afghanistan before and during the 2007/2008 food price crisis. These unique data come from the 2007/2008 National Risk and Vulnerability Assessment (NRVA) and cover over 20,000 households. During this period, due to a confluence of domestic (drought), regional (export bans), and international (food price crisis) factors, the price of wheat flour (the dietary staple) doubled. This represented a serious shock to Afghan households, who spend about 60 % of their budget on food and who derive over half their calorie intake from wheat. We look at how Afghan households adjusted their expenditure patterns on food and nonfood items. We look at changes in various dimensions of food security, including calorie, dietary diversity, and nutrient intake. The last two indicators reflect the quality of food consumed and are related to "hidden hunger," a term that refers to micronutrient deficiencies which have serious implications for long-term human capital formation. And we look at the purchase of food on credit, the sale of productive assets, school enrollment, and migration.

We found strong evidence that the wheat flour price increases affected the well-being of Afghan households, who reduced both their food and nonfood expenditures. The reductions in the value of food consumed were reflected in reductions in the quantity and quality of food consumed, including reduced nutrient intake. Households reduced their nonfood expenditures across several categories, including health, clothing, grooming, communication, transportation, cigarettes and tobacco, and culture. And households purchased food on credit more frequently. We failed to find changes in educational expenditure or school enrollment, the sale of productive assets, or migration.

Since much of food security policy is concerned with those living at or below subsistence levels, it is important to allow for the possibility that the behavioral responses of vulnerable households differ from other households in ways that are policy relevant. Therefore, the food security analysis allows for differential price effects based on a household's food security level. We used the UQR estimator, proposed by Firpo et al. (2009b), to identify price effects for households located at specific points on the unconditional distributions (such as the 20th or 80th quantiles) of the food security indicators.

The evidence indicated that Afghan households, across the distribution, experienced a decline in the quantity and quality of food consumed as a result of the 2008 wheat flour price increases. We found disparities in the behavioral responses of households with respect to where the household lies on the unconditional distribution of the particular food security measure of interest. Households at the top of the calorie distribution, who can afford to cut back, experienced the largest declines in per capita daily caloric intake. The most vulnerable households—that is, those at the bottom of the calorie distribution—cannot afford to make substantial cuts to their caloric intake since they are close to or below the minimum daily energy requirements; accordingly, we found no statistically significant decline in their caloric intake.

Households at the bottom of the dietary diversity distribution—often very poor households—experienced very large declines in dietary diversity as a result of the wheat flour price increases (although even households at the top of the distribution experienced substantial declines). The bottom households are likely unable to make major cuts to caloric intake and thus must adjust the compositions of their diet to maintain energy levels. Such declines can exacerbate already high levels of malnutrition in Afghanistan.

This chapter is an extended version of the study by D'Souza and Jolliffe (2014). It provides an additional analysis of nonfood-based coping responses (i.e., adjustments to nonfood expenditures and behaviors). For completeness, we included the main results from D'Souza and Jolliffe (2014), which examined food-based household coping responses. Our work contributes to the understanding of how the people of Afghanistan were affected by and how they coped with staple food price shocks, providing a rare insight into the short-term coping mechanisms in a poor, conflict country. Such analysis is particularly crucial in conflict countries, which may be most susceptible to shocks but for which usually very little quantitative data are available.

In the next section, we provide details on Afghanistan during the study period. We then discuss the evidence regarding food-based and nonfood-based household coping responses. Thereafter, we describe the household data, the variables of interest, and our sample. We then present the empirical specifications and estimation techniques. We next discuss the results and conclude the chapter in the final section with a discussion of the major implications.

21.2 Background: Afghanistan Circa 2007/2008

After decades of external and internal conflicts,[1] along with prolonged droughts, the landlocked Afghanistan has one of the poorest, least well-nourished populations in the world. Despite strong growth, with real GDP growth averaging approximately 10.8 % per year between 2003 and 2009, nearly 30 % of the Afghan population did not meet the minimum daily food requirements of 2100 kilocalories per person in 2008 (MoE Islamic Republic of Afghanistan and the World Bank Economic Policy and Poverty Sector 2010). The IMF (2009) estimated that the gross domestic product (GDP) per capita in Afghanistan was $350 in 2007 and $457 in 2008 (current US$).[2] Based on a broader set of development indicators used in the UNDP Human Development Index (e.g., health, education, living standards), Afghanistan ranked 181 out of 182 countries in 2008 (UNDP 2009). Approximately 60 % of children under five suffered from chronic malnutrition (stunting), and 8 % suffered from acute malnutrition (wasting) (Johnecheck and Holland 2007).

The Afghan economy is largely based on agriculture; major crops include wheat, rice, maize, barley, vegetables, fruits, and nuts. Approximately 70 % of cultivated crop area is devoted to wheat, and about 15 % is devoted to rice, barley, and maize (Chabot and Dorosh 2007). Wheat is both a major production crop and the main staple of the Afghan diet, contributing to 54 % of the total caloric intake. Due to violence and large fluctuations in weather, however, wheat production is highly volatile, and the country is dependent on its trading partners to meet any shortfalls. Pakistan is Afghanistan's major supplier of wheat (mostly in the form of flour) due to close historical ties and a shared 1600 km border; Pakistan's share of the Afghan wheat and wheat flour import market is estimated to range from 59 % (Chabot and Dorosh 2007) to 79 % (Maletta 2004).

Levels of food insecurity vary greatly across the country, which is not surprising given Afghanistan's diverse terrain, climate, and agricultural zones. Seasonality plays an important role in food security in Afghanistan. Temperatures can vary dramatically across seasons, with hot summers and frigid winters, and the climate in the highlands varies with elevation. In many cases, severe winter conditions affect transportation, and in high mountainous areas, roads are often blocked throughout the winter due to heavy snow accumulation.

According to the World Food Programme, Afghanistan is among the world's most vulnerable countries in terms of absorbing food and fuel price shocks; such

[1] Afghanistan has a long history of conflict involving both intra- and interstate groups; for an overview of the conflict over the past 30 years, see Giustozzi and Ibrahimi (2012). In this chapter, we do not distinguish between different actors; rather we define conflict based on incidents of violence in which there are fatalities and/or casualties; more details are provided in the data section.

[2] In a country like Afghanistan though, where the drug economy is large, the official National Income Accounting data are likely to significantly understate GDP. UNODC (2008) estimates that in 2007 the farm gate value of opium cultivation was US$1 billion, but this dropped to US$730 million in 2008. The potential export value in 2007 of opium, morphine, and heroin at border prices in neighboring countries was $4 billion (or, in per capita terms, about $160).

countries have consistently high levels of food insecurity, are heavily dependent on food and fuel imports, and have large populations of poor people who spend significant shares of their income on food (Sanogo 2009). Also, mountainous terrain and poor infrastructure, coupled with weak governance, insecurity, and corruption, have limited the government's ability to manage its food distribution and supply networks.

International prices of food commodities increased substantially in 2007 and rapidly in early 2008, peaking around May–July 2008. During this period, Afghanistan experienced several shocks that led to a disruption of its food supply network, causing prices to soar throughout the country. Due to drought and early snow melt, the 2008 wheat harvest of 1.5 million metric tons was the worst since 2000 (Persaud 2010). The price impact of the large shortfall in wheat production was magnified by export bans in Pakistan and rising international food prices. In February 2008, the Afghan government eliminated import tariffs on wheat and wheat flour (tariffs had been set at 2.5 %), but due to export bans in Pakistan, Iran, and Kazakhstan, the action brought about little downward effect on prices. Between fall 2007 and summer 2008, the prices of domestic wheat flour increased by over 100 %; Figure 21.1 displays retail wheat flour prices from 2002 to 2013 for four major urban centers collected by the FAO Global Information and Early Warning System (GIEWS).

In 2007/2008, total inflation was largely driven by the surge in food prices; Figure 21.2 depicts the consumer price indices (CPI) for food and nonfood items in urban areas from 2005 to 2011.[3] During the survey time frame

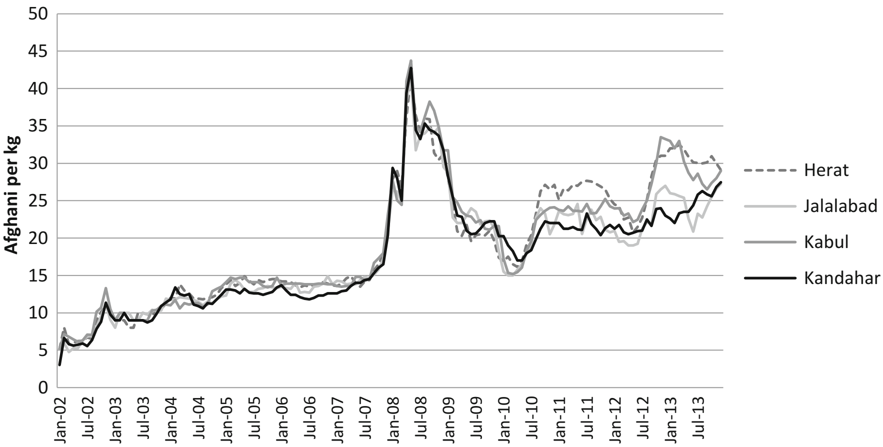

Fig. 21.1 Retail wheat flour prices, 2002–2013. *Source*: FAO GIEWS (2014)

[3]The indices were constructed by the Afghan Central Statistics Organization and are based on data from six urban areas.

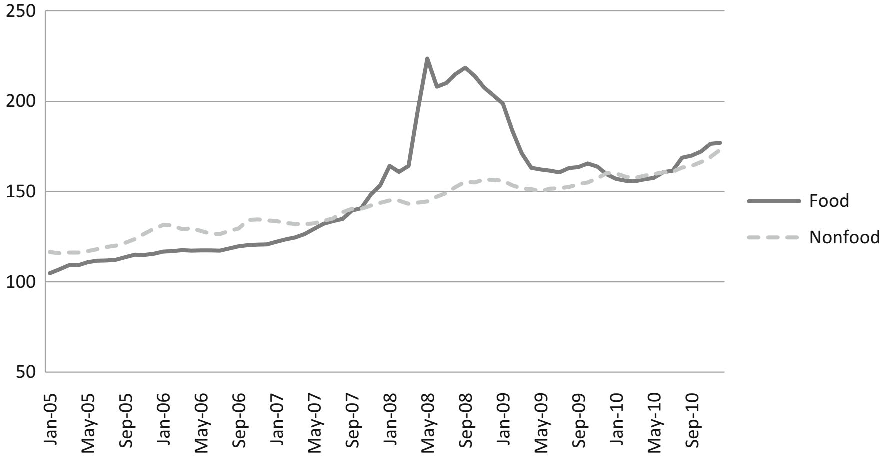

Fig. 21.2 Consumer price indices, 2005–2011

(August 2007–September 2008), the urban food CPI increased by nearly 60 %, while the nonfood CPI increased by only 10 %. Our calculations using price data collected in the NRVA also indicated a 60 % increase in food prices in urban areas during this period, with an overall increase of 40 % at the national level.

21.3 Household Coping Strategies

In response to price shocks or, more generally, negative shocks (e.g., income shocks, drought or natural disaster, death of main income earner), households employ a variety of coping strategies or responses. They may rely on family assistance, sell off assets, work more, borrow money, or—in the most desperate cases—reduce intake of food and nutrients. Such responses can be characterized as nonfood based or food based, and families can employ one or both of them (FAO 2008). Increases in food prices represent a decline in purchasing power for households.[4] Nonfood-based coping strategies to deal with the reduced purchasing power include increasing time spent working for adults (and, in some cases, children); reducing expenditure on health, education, and other nonfood items; and changing household composition (e.g., migrating or sending children to live with relatives). In some instances, households remove children from school to save on school fees and to use the children as labor (at home, on the farm, or in the marketplace). Food-based coping strategies include changing the type and quantity of food a household consumes and the people who consume the food in a household. Households may

[4]Below we discuss the potential income effect of increasing food prices for households that are net sellers of food.

reduce the quantity (e.g., smaller meals, less frequently), quality, and diversity of foods consumed by moving toward cheaper food groups and cheaper foods within food groups.

Some of these strategies are reversible; for example, if prices decline, households can go back to purchasing higher-quality food. But other strategies are irreversible; for instance, after selling off productive assets, households may not be able to repurchase them even when food prices decline (Hadley et al. 2012). Furthermore, some of these responses can have long-term consequences for health and human capital development. For example, disinvesting in children (with respect to nutrition and/or schooling) can perpetuate the intergenerational transmission of poverty. Moreover, with over two billion people estimated to be suffering from mineral and vitamin deficiencies worldwide (Micronutrient Initiative and UNICEF 2009), further reductions in nutrition can have deleterious effects on households living below or near subsistence levels.

In this section, we discuss the current literature on food-based and nonfood-based coping responses to high food prices. (See Ruel et al. (2010) for a more detailed review of the literature on the effects of economic crises on well-being, and see Compton et al. (2010) for a thorough review of the literature on the impacts of the 2007/2008 food price crisis.) Most recent studies on high food prices examined the implications for poverty rates rather than specific household coping responses. The studies often relied on data collected during periods of relatively stable prices and used the limited variation in prices to estimate price elasticities. Then these studies used simulation models to estimate the short-run effects of larger price shocks on measures of household welfare, primarily poverty rates, with many studies focusing on differences between outcomes for rural and urban areas. Examples of such studies include Wodon et al. (2008), who examined 12 African countries; Ivanic and Martin (2008), who examined nine low-income countries; Ul Haq et al. (2008), who examined Pakistan; Simler (2010), who examined Uganda; Robles and Torero (2010), who examined four Latin American countries; and De Hoyos and Medvedev (2011), who examined 73 low- and middle-income countries. In those studies, the magnitude of the impact of the crisis varied greatly among households and countries, and it depended on several factors, including the degree of price transmission, dependence on food imports, whether staple foods are traded internationally, whether the household is a net buyer or a net seller of food, and the household's reliance on staples. But the general finding was similar: national poverty rates increased, with urban areas on average suffering larger increases.

With this chapter, we are contributing to a smaller set of literature that examines the impact of recent high food prices on nutrition-related outcomes. Using data from eight developing countries, Anríquez et al. (2013) simulated the effects of staple food price increases on household undernourishment (defined as falling below daily calorie thresholds) for the average household, for urban and rural households, and by expenditure decile. The study showed that mean calorie levels generally declined with increasing staple food prices; however, countries varied in terms of the people who were the most negatively affected (e.g., poorest or middle quintiles, rural or urban populations) and in terms of the household-level determinants of the nutritional responses. Tiwari and Zaman (2010) also found that undernourishment rates increased across all major developing country regions assuming minimal levels of price transmission from international to domestic markets. Brinkman et al. (2010) looked at the impact of high food prices (and the global financial crisis) on food consumption, nutrition, and health outcomes for specific developing countries as well as several developing regions. Bibi et al. (2009) found that food poverty and undernourishment increased among children in Mali. In a study of rural Bangladesh, Torlesse et al. (2003) found that as rice prices fell, households reduced rice expenditure and increased non-rice food expenditure, thereby improving the quality of their diets. Klotz et al. (2008) provided a more nuanced view that households are likely to reduce the quality of food consumed before reducing the quantity of food consumed, and for this reason, individuals will experience micronutrient deficiencies before weight loss.

We are also contributing to the literature (including qualitative and quantitative studies) that examines nonfood-based coping responses (often in addition to food-based ones) to increases in food prices. Compton et al. (2010) examined the literature and summarized the variety of nonfood-based coping strategies, which include reducing nonfood expenditure, pulling children out of school and increasing child labor, planting more food crops, increasing labor, increasing migration, selling nonproductive or productive assets, going into socially unacceptable livelihood activities (such as begging), and receiving increased aid from the government or nongovernmental organizations. Tandon and Landes (2014) found that in response to food price increases, Indian households decreased dietary diversity and delayed the purchases of health-related goods, clothing, and durable goods.

Sulaiman et al. (2009) showed that households in Bangladesh cut back on the number and quality of meals when food prices increased; they also found that households reduced expenditure on clothing, health, transportation, and cooking fuel. Looking at households in Somalia, Holleman and Moloney (2009) found reductions in nonfood expenditure (including money spent on medicine), increases in financial assistance (e.g., remittance, cash gifts, loans, credit purchases), and a drop in school enrollment. They also found that households switched to cheaper foods, for example, from imported rice to locally produced sorghum. And finally, Hadley et al. (2012) provided qualitative evidence from urban Ethiopia that increases in food prices can have an impact on important cultural practices, such as funerals, because households can no longer afford standard cultural practices at their socioeconomic level.

In studies based on simulation models, it is largely impossible to identify separately the extent to which the simulated estimates resulted from actual changes in household well-being or from modeling assumptions. Most studies have focused on the short run, assuming that (1) households and producers have no behavioral responses to the price increases, (2) there are no changes in input prices or wage rates, and (3) the proportional changes in consumer and producer prices are equivalent. In a recent contribution, Minot and Dewina (2013) demonstrated the sensitivity of poverty results to these standard assumptions.

The need to simulate the welfare effects of a price increase is driven (partially) by a lack of comparable data before and after the price increase. Our study represents one of a handful of empirical analyses that have overcome the need to simulate welfare effects by using nationally representative household data collected prior to and during a significant price shock. Friedman et al. (2011) used nationally representative data from Pakistan to estimate reductions in calorie availability due to the 2008 food price spike and found an 8 % reduction between 2006 and the first half of 2008. They also found that rural households with access to agricultural land fared better than urban households. Examining the same price spike and using nationally representative rural household data from Bangladesh, Balagtas et al. (2012) found an increase in poverty rates and demonstrated that the determinants of poverty change over time. And using nationally representative data from South Africa, Jacobs (2010) found that household hunger levels increased as a result of the food price and financial crises of 2007–2009. These studies employed various other methodologies and focused on different household-level outcomes, but like the present chapter, they were all able to observe (and estimate) behavioral responses to large increases in food prices (given the available data) rather than through modeling assumptions or simulations.

21.4 Data

Our primary data are from the NRVA 2007/2008, which was conducted by Afghanistan's Central Statistics Organization and Ministry of Rural Rehabilitation and Development. The survey was administered between August 2007 and September 2008 and covered over 20,500 households (over 150,000 individuals) in 2572 communities in all 34 provinces of Afghanistan. The long time frame made it possible to obtain seasonally representative estimates of household food security and allowed for the coverage of conflict areas.

The sample was selected based on a stratified, multistage design. The survey was stratified explicitly, geographically, and implicitly over time.[5] The 11 provinces with the most populous provincial centers were each stratified into urban and rural areas. The remaining provinces were treated as separate rural strata, and the nomadic Kuchi population was treated as a separate stratum. The stratification resulted in 46 domains or strata. In the first stage of selection, 2441 primary sampling units (PSU) from urban- and rural-settled populations and 131 PSUs from Kuchi populations were drawn. In the second and final stage, eight households were selected from each PSU.

The implicit stratification over time was a key element of the survey design. The population frame was sorted both spatially and temporally to ensure that (with a systemic interval selection) the selected sample would be seasonally

[5]The population frame is based on a 2003–2005 national household listing.

representative.[6] Thus each quarterly sample of the NRVA survey is representative at the national level. In a country where agriculture is an important form of livelihood, seasonal variations in consumption patterns are to be expected; thus it is critical to capture nationally representative measures of household food security throughout the year. Appendix Table 21.10 displays key demographic, educational and health, and infrastructure indicators across the four quarters. While we observed some statistical differences in means across quarters, there is little evidence of systematic differences in the samples based on these generally time-invariant characteristics.

Another key feature of the survey was the yearlong fieldwork, which allowed for coverage of conflict-affected areas. The enumerators informally secured permission from local leaders in conflict areas, and when a primary sampling unit (PSU) was considered too dangerous to interview at the scheduled time, it would be reconsidered at a later date within the quarter, instead of being replaced immediately. This flexible design helped to ensure a low replacement rate. While the majority of replacements were due to security issues, only 68 PSUs were replaced from the planned 2441 PSUs in the sample design (less than 3 % replacement rate).[7] It is often difficult to obtain reliable data from conflict areas; thus the current analysis provides a rare insight into the relationship between food insecurity and conflict.

The household survey module includes 20 sections—6 administered by female interviewers to female household members and 14 administered by male interviewers to the male household head. The enumerators traveled in teams of two (one male and one female) since females are not able to travel by themselves in Afghanistan and because it is important that interviews be conducted between individuals of the same sex due to the strong cultural norms regarding separation between the sexes outside the family. Households were asked questions about consumption, demography, housing infrastructure and access, maternal and child health, education, income sources, agriculture and livestock, migration and remittances, and assets and credit.

To collect data on nonfood expenditure, respondents (male and female, depending on the category) were asked about the amount of afghani spent on various items or categories of items over the past month or year (depending on the category). Below we describe how we constructed the nonfood expenditure measures; in the caveats section, we discuss potential biases that could result from the various recall periods.

The food consumption data include the frequency and quantity of consumption of 91 food items over the previous week, including food bought on the market, produced, or obtained through other methods like food aid or gifts. The NRVA's broad coverage of foods, including seasonal varieties, allows for better calculation of caloric and nutrient intake than surveys which take fewer items into account.

Household consumption data do not typically account for food wastage, and thus estimates of food intake may be larger than actual values. We assume that in a poor country like Afghanistan, wastage is relatively small and therefore not a significant

[6] See Kish (1965, pp. 235–236) for a discussion of implicit stratification.

[7] Replacement PSUs were primarily selected from the nearest secure district.

source of bias. Generally, in low-income countries like Afghanistan, much less food is wasted at the consumer level than at early and middle stages of the food supply chain (FAO 2011). A potentially more challenging concern is if wastage is correlated with price volatility. If the amount of food wasted is negatively correlated with food prices (as might be expected), then the coefficients of the price of wheat flour in the regressions that examine food consumption and caloric intake will have positive biases.[8] However, we maintained the assumption that wastage is low and any potential bias is small.

The price data were obtained from a district price survey, which included prevailing prices of the food items included in the consumption section as well as domestic and imported grains and fuel. The local price data were important for obtaining accurate estimates of price effects in a mountainous country with poor infrastructure, where transportation and transaction costs vary greatly.

Finally, we also used confidential geo-coded conflict data obtained from the United Nations Department of Safety and Security (UNDSS) that cover the survey time frame from August 2007 to September 2008. The UNDSS collects information on fatalities, injuries, and, in general, violent incidents. According to the official UN definition, violent incidents include the following: abduction, air strike, armed clash, arrest, assassination, finding a weapons' cache, confrontation/dispute, crime, demonstration, IED (improvised explosive device) detonation, finding an IED, information, intimidation, mine/UXO (unexploded explosive ordnance) incident, narcotic incident, standoff attack, suicide attack, and others. Over the survey year, there were 506 violent incidents across the country, with 421 associated fatalities and 322 associated injuries.

21.4.1 Measures of Nonfood-Based Coping Responses

Our main measures of nonfood-based coping responses were nonfood expenditures. We constructed a measure of real per capita monthly nonfood expenditure, total expenditure, and expenditure for eight major categories: health, education, clothing (including shoes), grooming (including laundry fees), tobacco and cigarettes, transportation, communication, and culture.[9] We also constructed several complementary measures: recent migration of household members, selling of livestock (which are productive assets), enrollment of children in school (at the individual level), and a categorical variable denoting the frequency with which households report buying food on credit (1–4: never, sometimes, often, and always). We classified the last

[8]The sign of the bias is determined by the product of the correlation coefficients of (1) food waste and wheat flour prices and (2) food waste and food expenditure or caloric intake. If both correlation coefficients are negative, then their product, and thus the sign of the bias, is positive.

[9]The recall period for grooming, tobacco and cigarettes, and communication expenditures is the past 30 days. The recall period for health, education, clothing, and culture expenditures is the past 12 months.

measure as nonfood based because it relates to credit and debt rather than changes in actual food consumption. Alternatively, one could classify this measure as a food-based coping strategy. In this chapter, however, we adopted the FAO categorization, in which food-based coping strategies correspond to changes in the quantity or quality of food consumed (FAO 2008). To convert nominal values into real values, we used the nonfood price index from the Consumer Price Index for Afghanistan. The index accounts for temporal, but not spatial, differences in prices.

21.4.2 Measures of Food-Based Coping Responses

We constructed three main measures of household food-based coping responses for use as dependent variables in the regression analysis: food consumption, per capita daily caloric intake, and household dietary diversity. The first, real monthly per capita food consumption is an informative measure of household well-being and a core component of poverty indicators. It has been used as a measure of food security in the literature as well; for an early example, see Green and Kirkpatrick (1982). The second is a widely used measure of health and undernourishment. And the third has been shown to be linked to the nutritional status of children and adults (Arimond and Ruel 2004; Ruel 2003; Steyn et al. 2006) and has been lauded as a cost-effective, quick, informative measure of food security (Headey and Ecker 2013; Tiwari et al. 2013). Although much of the economics literature has focused on caloric intake as a nutritional measure and a measure of food security, there is a growing recognition of the importance of dietary quality to short- and long-term health, cognition, and productivity outcomes; therefore, we incorporated and highlighted measures of dietary quality in our work.

The real value of food consumption (in afghani) is calculated by combining quantity data from the consumption module with price data from a district price survey. Food consumption data include food which was bought, produced, or obtained through other methods, e.g., food aid and gifts. Weekly values were multiplied by 4.2 to get monthly values. Prices were matched by month, item, and district. Since not all food items were available in all district markets at all times of the year, we imputed the missing elements to obtain a complete price matrix.[10] We calculated average prices for domestic and imported varieties separately to account for differences in price and quality between domestic and imported wheat and rice.[11] The value of the expenditure on food away from home was included in the

[10]The imputation process filled in missing values using the first-feasible methodology according to the following order: (1) median of the 20 nearest neighboring districts of that month, (2) province median of that month, (3) national median of that month, (4) median price of 20 neighboring districts of the quarter, (5) province median of that quarter, and (6) national median of that quarter.

[11]The survey includes questions about the percentages of imported wheat and rice consumed; these percentages were used to calculate the total expenditure on these items.

calculation of food consumption, but it was not included in the calculation of caloric intake since quantity data on such food were not collected.

We adjusted the food consumption estimates to take into account spatial and temporal variation in prices in order to identify correctly those households that fall below the food poverty threshold (described below) and, in the regression analysis, to estimate the impact of the price increases on real values. We used a Laspeyres price index estimated by quarter for each region. The food price index was based on a reference bundle of goods consumed by relatively poor households; the reference bundle was constructed to reflect regional diversity in consumption patterns. There are eight regions in Afghanistan, as defined in Islamic Republic of Afghanistan and World Bank (2011). Real food consumption is relative to the chosen base: urban areas in the Central Region in quarter 1; the capital, Kabul, is located in the Central Region.

We used the FAO Food Composition Tables for the Near East to convert daily food quantities into kilocalories; we then divided the daily caloric intake by the effective household size to get the per capita daily caloric intake.[12] The effective number of household members incorporates guests eating meals within the home and decreases when household members do not regularly take meals at home.[13] The effective number of household members is greater than the household size for the richer households and lower for the poorer households.

To measure household dietary diversity, we used the food consumption score (FCS), which is developed by the World Food Programme (WFP) and used in food security assessments throughout the world. It is a weighted sum of the frequencies with which households consume foods within eight food groups over the previous week.[14] The food groups include grains, pulses, vegetables, fruit, meat/fish, milk/dairy, sugar, and oil/fat. Higher scores denote a more varied diet and are suggestive of a higher-quality diet with a potential for higher micronutrient intake.

It is challenging to account for food consumption and expenditure on meals away from home. The survey asked how many meals were eaten away from home by household members over the past 7 days and the value of food and drinks consumed outside the home over the past 30 days; however, there was no information on

[12]Spices, water, and "other" foods do not contribute to total calories. USDA sources were used for a few items that were not available in the FAO tables.

[13]Some studies use household size to calculate per capita amounts, but the prevalent custom of sharing meals in Afghanistan makes it important to account for guests eating meals from the household cooking pot. We do not use equivalency scales to account for differences in consumption of adults and children when calculating measures of well-being but rather opt to include variables for household composition directly into the regression model to control for such differences.

[14]Weights for the food groups range from 0.5 to 4 based on nutrient density. Condiments receive zero nutritional weight. Frequencies are truncated at 7 for each food group. The measure ranges from 0 to 112.

what food is consumed outside the household.[15] Therefore, we did not include any calories from food eaten away from home in the caloric intake calculation, and food consumed away from home also did not impact the food consumption score. These measures may not accurately capture all food consumed by members of the household. Without detailed food diaries however, it is difficult to obtain sufficient information. Note that food away from home constituted about 2 % of total food expenditure on average; it accounts for less than half a percent for the poorest 20 % of the population and about 4 % for the richest 20 % of the population.

21.4.3 Summary Statistics

The effective sample size of our analysis was 20,483 households.[16] Table 21.1 displays the population means of key household characteristics for the full sample over the survey year. On average, households had 8.6 members living in about 3.6 rooms (or tents for the Kuchi population). A typical household consisted of 2.1 men, 2 females, and 4.5 children (under 16). The head of a household was on average about 45 years old; nearly all were married, and most of them were illiterate. Approximately 80 % of the households resided in rural areas. Very few households reported having members who migrated or reported selling livestock recently (over past year). Finally, about 16 % of the households reported that they were often or always purchasing food on credit; the remainder of the households reported that they had never (27 %) or sometimes (57 %) purchased food on credit. Approximately 59 % of the households reported borrowing money over the prior year; and 70 % of those households reported that the money was used mainly to purchase food.

Table 21.2 displays the population means for the total nonfood and the total food expenditure as well as caloric intake and dietary diversity by quarter and for the survey year. The raw data revealed the instability of household food security in Afghanistan; we observed large declines in food expenditure, caloric intake, and dietary diversity, with the worst levels observed in quarters three and four. Changes in nonfood expenditures were less stark, although the nonfood expenditures on many categories declined over the survey year. Overall, these patterns lend support to the evidence that the poverty rate had increased, as reported by the Government of

[15]We use the questions on meals eaten outside the home and the value of food and drinks consumed to calculate average expenditure on food away from home for each household, which is included in the total value of food consumption.

[16]The household response rate was 99.8 %, and the PSU replacement rate was 3 %. Thirty-two households were dropped due to missing female questionnaires; all of these households were located in four communities, suggesting a relatively small systematic error in field operations. Fifty-two households were dropped due to missing consumption data, and seven households were dropped due to missing asset data. Information on household size was missing for one household, and therefore, the household was dropped because per capita measures of consumption and food security could not be calculated.

Table 21.1 Household characteristics

Age of household head	44.87
Number of males	2.09
Number of females	2.01
Number of children under 16 years	4.51
Share of households with married head	0.95
Share of households with literate head	0.32
Share of agricultural households	0.57
Share of households in rural areas	0.80
Share of households in plain areas	0.74
Share of households in plateau areas	0.22
Share of households in mountainous areas	0.39
Share of households with recent migrant	0.08
Share of children between 8 and 16 years in school	0.95
Share of households purchasing food on credit often or always	0.16
Share of households that sold live livestock recently	0.03
Total observations	20,483

Source: NRVA 2007/2008. *Note*: Estimated population-weighted means. Share of children in school is derived from individual child-level data set with 35,893 observations

Table 21.2 Population statistics by quarter and over survey year

Real per capita monthly expenditure (afghani)	Quarter 1 (fall)	Quarter 2 (winter)	Quarter 3 (spring)	Quarter 4 (summer)	Survey year
Total	2022.00	1718.78	1519.39	1477.69	1672.31
Food	1201.19	961.47	789.45	797.60	928.65
Nonfood	586.91	549.62	496.20	462.06	521.01
Health	80.70	74.38	77.32	81.41	78.44
Education	7.38	5.56	5.18	5.27	5.80
Clothing	98.17	90.19	89.11	90.85	91.90
Grooming	77.81	60.11	49.86	54.15	59.97
Tobacco and cigarettes	9.49	8.25	8.09	8.22	8.48
Transportation	94.59	79.92	79.48	81.86	83.63
Communication	28.67	26.09	23.60	23.49	25.35
Culture	109.86	96.04	91.27	91.47	96.73
Daily per capita caloric intake	2885	2725	2446	2387	2601
Food consumption score	68	61	58	58	61

Source: NRVA 2007/2008. *Note*: Population-weighted means. Real values reflect adjustments for spatial and temporal price differences, covering 13 months of field work. Food expenditure includes the value of home production, gifts, and food aid; see text for details

Afghanistan; the official poverty rate increased from 23.1 % in fall 2007 to 46 % in summer 2008 (MoE Islamic Republic of Afghanistan and the World Bank Economic Policy and Poverty Sector 2010).

To further explore how the food security status of the most vulnerable households was affected by the wheat flour price increases, we controlled for heterogeneous

Table 21.3 Population statistics across the distribution and across the survey year

Quantile	10th	20th	30th	40th	50th	60th	70th	80th	90th	Mean
Full survey year										
Real per capita monthly food consumption	474	572	650	727	810	903	1026	1198	1514	929
Daily per capita caloric intake	1695	1937	2113	2279	2441	2629	2861	3166	3688	2601
Food consumption score	34	42	49	56	61	66	71	78	88	61
Quarter 1										
Real per capita monthly food consumption	552	685	818	937	1058	1201	1371	1585	2020	1201
Daily per capita caloric intake	1740	1992	2236	2452	2679	2938	3240	3628	4262	2885
Food consumption score	40	50	57	64	69	74	79	86	95	68
Quarter 2										
Real per capita monthly food consumption	492	600	684	771	855	954	1083	1264	1566	961
Daily per capita caloric intake	1764	2030	2234	2414	2589	2780	3022	3322	3835	2725
Food consumption score	34	41	47	55	60	66	72	80	92	61
Quarter 3										
Real per capita monthly food consumption	446	528	594	653	720	794	880	1004	1190	789
Daily per capita caloric intake	1663	1899	2062	2217	2351	2499	2678	2937	3311	2446
Food consumption score	32	40	47	53	58	63	69	75	83	58
Quarter 4										
Real per capita monthly food consumption	458	545	614	674	735	806	884	998	1195	798
Daily per capita caloric intake	1610	1873	2023	2144	2279	2426	2617	2861	3263	2387
Food consumption score	33	42	49	55	59	63	67	71	79	58

Source: NRVA 2007/2008. *Note*: Population-weighted estimates at each decile and at the mean, for the survey year and by quarter

price effects on household food security based on a household's level of food security. In Table 21.3, we present the mean of real per capita monthly food consumption, daily per capita caloric intake, and household dietary diversity at each decile (for the survey year and by quarter).

Nearly 30 % of the Afghan households failed to meet the conventional nutritional benchmark of 2100 calories per day, while those at the top of the calorie distribution were well above the threshold. The mean per capita daily caloric intake was approximately 2601.[17] This estimate is in line with worldwide calorie estimates obtained using macroeconomic data; between 2007 and 2009, the average daily calories per capita were 2810 in the world, 2670 in developing countries, and 2380

[17]We assumed the figure has been slightly overestimated due to some food waste and telescoping. For example, Deaton and Kozel (2005) noted that in the case of India, a 7-day food recall period produces higher daily food estimates than a 30-day recall period.

in South Asia (excluding Afghanistan and Bhutan) (FAO 2012).[18] The estimate is also in line with the estimates obtained using nationally representative household data for the region; daily calories per capita was between 2392 and 2593 in Pakistan during the period from 2005 to 2008 (Friedman et al. 2011), and this figure was 2536 in Nepal in 2010/2011 (National Planning Commission and Central Bureau of Statistics 2013).

The mean food consumption score was 61, ranging from 34 at the bottom decile to 88 at the top decile. The WFP uses 48 as a cutoff for an acceptable diet in countries like Afghanistan where most households consume staples and oil every day. Under this categorization, approximately 80 % of the population in Afghanistan has acceptable diets, which is consistent with the food security assessments conducted by the WFP on several other developing countries in recent years. Based on their assessments, the percentages of households with acceptable diets are as follows: Uganda, 78 % in 2013; Rwanda, 79 % in 2012; Malawi, 75 % in 2010/2011; Cambodia, 81 % in 2008; and Pakistan, 82 % in 2008.[19] Recent work has suggested that the cutoff points of the FCS classifications may be too low, for example, when compared with estimates of calorie deficiency (Weismann et al. 2009).

Households at the top of all three distributions experienced the largest declines in food security in percentage terms, while those households at the bottom of the distributions experienced smaller declines in food security. It is important to note that the most food-insecure households were consuming relatively poor diets, and even small declines in quantity and quality of food consumed could have major repercussions on the short- and even long-term nutrition of children in their early development stages.

21.4.4 Price Data

Our analysis focused on the price of domestic wheat flour, the form of wheat most commonly purchased by households. Most wheat is consumed in the form of naan, a type of local unleavened bread that is prepared by households after purchasing either refined wheat flour or whole grain wheat (Chabot and Dorosh 2007). Wheat and other grains constituted 48 % of food expenditure and 70 % of calories consumed.

Table 21.4 displays the mean price of domestic wheat flour by quarter and over the survey year; it also includes other important commodities that we used in the

[18] FAOSTAT provides estimates of dietary energy supply (in kilocalories per person per day), averaged over 3 years and weighted by population. These estimates were calculated using macroeconomic supply data and may be less reliable than estimates derived from household survey data.

[19] Estimates were drawn from WFP reports, available at http://www.wfp.org/food-security/assessment-bank.

Table 21.4 Average prices by quarter and over the survey year

	Quarter 1 (fall)	Quarter 2 (winter)	Quarter 3 (spring)	Quarter 4 (summer)	Survey year
Price of domestic wheat flour	18.09	23.52	34.19	36.51	28.45
Price of vegetable oil	64.81	76.93	88.90	91.70	81.16
Price of domestic rice	33.93	33.99	46.16	55.29	42.77
Price of lamb	182.34	186.20	189.28	180.27	184.44
Price of milk	23.44	25.66	27.23	30.75	26.94
Price of kerosene	43.15	45.77	46.82	55.48	48.12

Source: NRVA 2007/2008. *Note*: Population-weighted means. Prices are in afghani per kilogram or liter

regression analysis to control for simultaneous price increases.[20] The NRVA price data showed patterns which are similar to the FAO GIEWS data in Fig. 21.1, with a marked increase in prices in quarter three of the survey. We chose milk, lamb, rice, and vegetable oil because they (1) represent several key food groups and (2), along with wheat flour, make up a large percentage of monthly household food expenditure; for example, the relatively poor (20th to 50th quantile of the total consumption distribution) spend 80 % of their food expenditure on these five food items. We included kerosene because it is the most commonly used cooking fuel.

A major limitation of this analysis is that we could not disentangle the impacts of the price increases due to three different sets of conditions: the 2007/2008 global food crisis, the 2008 poor harvest, and seasonal variations due to weather and harvest quality. Therefore the results below identify the effect of overall price changes on household food security. If food prices follow a cyclical pattern, dropping in the months after harvest (September–October) and slowly increasing throughout the year as stocks deplete, then we would expect that the price increases were due to the global food crisis and compounded by the cyclical domestic pattern. However, we do not believe that seasonality was a major driver of the price increases. (Recall that Fig. 21.1 displays the retail prices of wheat flour in four major urban centers from 2002 to 2013.) The 2008 price spike was larger than the observed seasonal variation in prices by orders of magnitude. In fact, there is little evidence that monthly prices fluctuate drastically throughout the harvest calendar. Because of transportation costs, it is likelier that prices in remote areas experience greater fluctuations. However, if seasonal wheat flour price patterns were indeed very significant in Afghanistan, we would have observed them in these major urban areas in the years prior to the 2008 spike, but we do not.

The ability to disentangle the causes of the price changes from each other would presumably alter the approach to policy prescription. For example, if the price changes are local rather than global, the policy response would be more

[20]Prices were aggregated to the stratum level in order to mitigate potential measurement error in district-level prices. Strata are based on urban and rural designation within provinces.

targeted, such as releasing grain from reserves to the affected area. If the price changes are global, then the appropriate policy response may be more oriented toward macroeconomic and trade policies. If the price changes are due to anticipated seasonal variations, policies aimed at helping households to smooth consumption, such as improved grain storage, might be desirable. Whereas if the price change is due to a fully unanticipated price shock, which we believe to be largely the case, then the policy response might be more oriented toward short-run safety net programs that focus on nutrition.

21.5 Methodology

We estimated the following reduced-form model of the impact of the wheat flour price increases on measures of household nonfood-based and food-based coping responses:

$$\begin{aligned} \text{ihs}\left(\text{resp}_{\text{h}}\right) = & \beta_0 + \beta_1 \log\left(\text{price wheat flour}_{\text{apq}}\right) + \theta \log\left(\text{prices}_{\text{apq}}\right) \\ & + \alpha \text{HH}_{\text{h}} + \delta \text{DIST}_{\text{dq}} + \eta \log\left(\text{conflict}_{\text{qp}}\right) + \Pi_{\text{p}} + \varepsilon_{\text{h}} \end{aligned} \tag{21.1}$$

where h denotes household, a denotes area (urban or rural), d denotes district, p denotes province, and q denotes quarter. resp represents one of the household coping responses described above. Prices represent a vector of commodity prices, HH represents a vector of household characteristics, DIST represents a vector of district-level variables, Π denotes province dummy variables, and ε is an idiosyncratic error term.

Instead of transforming the dependent variable by taking the logarithm (with or without adding some arbitrary small value to the zero values), we used the inverse hyperbolic sine (IHS) transformation, which reduces the importance of extreme observations (similar to taking logs) but has the additional benefit of being well defined at zero values. The IHS transformation, first proposed by Johnson (1949), was introduced to econometrics by Burbidge et al. (1988).[21] It has been used as an alternative to log transformations for the dependent variable (Burbidge et al. 1988; MacKinnon and Magee 1990) and for explanatory variables (Layton 2001) with variables that can take on zero or negative values. Results can be interpreted in percentage terms, as in log models.

In order to isolate the effect of changes in wheat flour prices, we controlled for simultaneous price increases in other important commodities since (1) household purchasing decisions are based on relative price movements, and (2) omitting such

[21]The IHS function is defined as $\sin h^{-1} = \log\left(x + \left(x^2 + 1\right)^{\frac{1}{2}}\right)$.

variables could bias our coefficient of interest.[22] The price vector includes the prices of milk, lamb, rice (a potential substitute for wheat flour, though not commonly consumed in Afghanistan), vegetable oil, and kerosene for reasons mentioned above.

We included the following household characteristics: dummy for agricultural households (households who report owning or operating agricultural land); log values of durable assets, housing, and livestock; age of household head; dummy for households in which heads are literate; dummy for households in which heads are married; and, separately, the numbers of men, women, and children. We included the agricultural household dummy because these households are able to produce their own food and are thus less reliant on the market. Furthermore, some of these households could benefit from increased wheat flour prices if they are net sellers of wheat. We included the household composition variables to control for differences in consumption requirements between children and adults and for economies of scale in consumption.[23]

The asset values were intended to control for wealth effects and were assumed to be quasi fixed in the short run. Poorer and richer households may have different constraints on their abilities to cope with price increases. For example, richer households have more assets to sell in order to smooth consumption. In a recent contribution, Carter and Lybbert (2012) showed that poorer households are unable to smooth total consumption as well as richer households when responding to weather shocks.[24] Additionally, richer households may have more food-based coping strategies available since they usually consume a more diversified diet of more expensive foods; they then have the option to move toward cheaper foods and food groups as prices increase.

The value of durable goods was estimated based on a detailed inventory of household assets; it accounted for depreciation and the opportunity cost of the funds tied up in the good. The value of housing was estimated using a hedonic model based on characteristics of the structure, as well as the location, to derive an imputed rental value from this.[25] All values are in real afghani.

[22]Given that food prices are often positively correlated with each other and negatively correlated with some of the dependent variables, like food expenditure and caloric intake, omitting the other food price variables would lead to a negative bias on the coefficient of the log of wheat flour price.

[23]An alternative approach to account for such differences employs equivalency scales that take into account nutritional requirements based on age and, sometimes, gender when calculating per capita measures. For an early example, see Buse and Salathe (1978).

[24]It is often assumed the poorer households smooth consumption in the face of shocks; however, using a poverty trap model, Carter and Lybbert (2012) show that below a critical wealth level, poorer households smooth (or protect) assets rather than consumption due to high marginal values of assets and the potential of future-negative shocks.

[25]The estimated housing value is the log of imputed, monthly rental value based on a hedonic model of the housing structure. The log value of assets is a self-assessed valuation based on a list of 13 assets including items such as stoves, refrigerators, radios, sewing machines, and bicycles. For details of the estimation, see Islamic Republic of Afghanistan, Central Statistics Organization (Islamic Republic of Afghanistan et al. 2011).

At the district level, we included dummies for topography—plateau and mountainous areas (plains areas make up the excluded category). Topographical characteristics are related to both agricultural yields and access to markets and thus can affect a household's level of food security. At the province-quarter level, we included a measure of conflict since the level of conflict can be correlated with food prices, as well as household coping responses.[26] We used the ratio of the number of individuals killed or injured in each province during each survey quarter to the province population (in tens of thousands) as our measure of conflict. Finally we also included province dummy variables to control for observable and unobservable time-invariant province-level factors, which could confound the results.

21.5.1 Model Estimation

We used two estimation techniques. For the nonfood-based coping responses, we estimated the parameters above using ordinary least squares (OLS), a commonly used estimator that provides the marginal effect for the mean household. For the food-based coping responses, we estimated the model using both OLS and the unconditional quantile regression (UQR) estimator proposed by Firpo, Fortin, and Lemieux (2009b, hereafter referred to as FFL). The UQR estimator allows the marginal effects to vary based on a household's location on the unconditional distribution of the dependent variable.[27] From a policy perspective, we were interested in heterogeneous price effects on vulnerable households (e.g., those at the bottom of the calorie distribution); we were less interested in how the price effects vary for those who spend a lot or a little on, for example, clothing, and thus we limited the UQR analysis to the food-based coping responses.

For our OLS estimates, we used a standard Huber–White correction to estimate the sampling variance, which allows for the correlation of the residuals within PSUs. The standard errors are also corrected for stratification. For the UQR estimates, we used a PSU-level bootstrap (1000 replications) that accounted for the correlation of the residuals within the PSUs but did not account for the stratification.

[26]In D'Souza and Jolliffe (2013), we examined the relationship between food security and conflict in Afghanistan. We found strong evidence of a negative relationship, as well as evidence that households in provinces with more conflict experience muted declines in food security as a result of wheat flour price increases. We posited that the latter result is because those households were more disconnected from markets (and may have had better coping mechanisms).

[27]By construction, OLS estimates are constant over the entire distribution of the dependent variable and thus cannot elucidate heterogeneous effects for subsets of households. Ex ante, we do not know whether the UQR estimator will provide qualitatively different information than OLS. There is some evidence that the conditional quantile regression estimator provides substantively different estimates. For example, Koenker and Bassett (Koenker and Bassett 1982) show that in the presence of a heteroskedastic error distribution, the quantile estimator will typically differ from the OLS estimator.

The UQR estimator was proposed in 2009 and is becoming a more commonly used tool in policy analysis. The UQR estimator is based on influence functions, which were introduced by Hampel et al. (1988) as a tool in robust estimation techniques.[28] Using notation (largely) defined by FFL, consider some distributional statistics, $\nu(F_y)$, such as the median, inter-quantile range, or any quantile. The influence function, $\mathrm{IF}(Y; \nu, F_y)$, represents the influence of an individual observation on the distributional statistic, $\nu\ (F_y)$, where Y is the dependent variable. A key innovation by FFL is that they added $\nu(F_y)$ to the influence function to center it. This new function is called a recentered influence function (RIF). By design, the expectation of the RIF is the value of the distributional statistic, or more formally, $E(\mathrm{RIF}(Y; \nu, F_y)) = \nu\ (F_y)$.[29]

FFL defined $m_\tau(X) = E(\mathrm{RIF}(Y; \tau, F_y) \mid X)$ as the unconditional quantile regression model.[30] The RIF regression parameter estimates are unconditional quantile marginal effects (UQME) or partial derivatives with respect to the price of wheat flour, as described by the following expression:

$$\frac{\partial Q_{\mathrm{fs}}\ (\tau)}{\partial \text{price wheat flour}} \tag{21.2}$$

where Q_{fs} is the unconditional quantile function of our food-based coping response measures, and τ represents quantiles of the unconditional distribution. For our analysis, we estimated the marginal effects at all deciles (10th, 20th, ..., 90th) of the food-based coping response distributions while controlling for the covariates in our model specification. The large observed variations in our food-based coping response measures (Table 21.3) suggested that the UQME could differ for households at the bottom and top of the distributions.

An alternative to the UQR is the conditional quantile regression (hereafter CQR) estimator (Koenker and Bassett 1978), which allows behavioral responses to vary across the distribution of the dependent variable after conditioning on the observed covariates (e.g., see Chamberlain 1994). This estimator is based on the conditional population distribution; however, policy questions are typically phrased

[28]Robust statistics are statistics and estimators that are not influenced heavily by deviations from model assumptions nor influenced by single observations. Influence functions provide a formal way of measuring the extent to which a particular estimator is affected by a single observation in the sample.

[29]This is in contrast, for example, to the least absolute deviation (LAD) estimator, whereby the expectation of the LAD is not equal to the median.

[30]FFL provided an estimation method based on transforming the dependent variable into the RIF and subsequently using OLS estimation. FFL have shown that this approach yields a consistent estimator of the average marginal: effect, $E[d\ \Pr[Y > \tau \mid X]/\mathrm{d}X]$, if $\Pr[Y > \tau \mid X = x]$, is linear in x. In order to estimate the standard errors, we followed the methodology proposed by FFL (Firpo et al. 2009b) and used a bootstrap estimator of the sampling variance. For readers who are interested, FFL (Firpo, Fortin, and Lemieux 2009a) derived the asymptotic properties of the estimator and provided the analytical standard errors.

in the context of the unconditional distribution.[31] For example, policymakers may be interested in knowing how price shocks affect the caloric intake of households at the bottom 20th percentile of the calorie distribution of the total population but not the conditional 20th percentile. A key distinction between the two is that the bottom of the unconditioned distribution consists of those who have very low caloric intake, whereas the conditioned distribution need not have low caloric intake (just low caloric intake conditional on their attributes, such as education level). The estimated marginal effects based on the unconditioned distribution can be valuable in targeting vulnerable people for safety net and poverty alleviation programs and in allocating resources in general. The results were robust to using this estimation technique; the observed signs and significance of the results were similar to those of our main results, although with some differences in the magnitudes.

21.6 Results and Discussion

The empirical analysis demonstrated that Afghan households employed both nonfood- and food-based coping strategies in response to the rapid increase in wheat flour prices in 2007/2008. We observed large reductions in real household expenditure across nearly all nonfood categories (Table 21.5). [32] In response to increasing wheat flour prices, households reduced the amount spent on health, clothing, grooming, tobacco and cigarettes, transportation, communication, and cultural activities and practices. (They also reduced food expenditure, which we discuss in more detail below.)

The largest reduction was observed in health expenditure. Such reductions can have serious implications, but we have to be cautious when drawing strong inferences from these results since health expenditures are particularly challenging to interpret. In particular, a decline in health expenditure could indicate either a reduction in the need to treat health problems (i.e., better health) or a failure to take appropriate actions to treat an illness, which would lead presumably to much worse health outcomes. We argue that it is unlikely that a food price shock would be positively correlated with better health outcomes in a food-insecure country like Afghanistan; therefore, we assumed that food prices are either independent of or negatively correlated with health outcomes. In such cases, the observed reduction in health expenditures would indeed represent a coping behavior, whereby health needs are sacrificed to mitigate the shock to food consumption.

In the development literature, there is evidence that household behavior differs with respect to adult goods and child goods (Deaton and Paxson 1998). Expenditure

[31] As an exception to this assertion, Buchinsky (1994) provides an example in which the question posed is best answered by the CQR estimator and not something akin to the UQR. He examined the distribution of wages in the USA and, using the CQR estimator, provides insight into how wage inequality within groups (i.e., conditional on being in a specific group) changes over time.

[32] The tables display the coefficients of interest. Full results are available upon request.

Table 21.5 Effects of wheat flour price increases on real per capita expenditure

Nonfood	Health	Education	Clothing	Grooming	Cigarette and tobacco	Transportation[a]	Communication	Culture	Food
−0.121***	−0.432***	−0.037	−0.084*	−0.330***	−0.177*	0.310*	−0.255**	−0.262*	−0.423***
[0.044]	[0.085]	[0.089]	[0.051]	[0.053]	[0.101]	[0.168]	[0.128]	[0.146]	[0.036]

Note: Coefficients and standard errors are from separate, population-weighted regressions. The dependent variable is real per capita expenditure for each group (listed at the top of the columns), transformed by the inverse hyperbolic sine (IHS) function. Control variables are listed in the text

*, **, and *** denote significance at 10 %, 5 %, and 1 %, respectively; [a]In the transportation regression, the log of the price of gasoline is included as an additional control variable. Total observations: 20,483. Standard errors are clustered bootstrap estimates

Table 21.6 Effects of wheat flour price increases on real per capita expenditure

Adult clothing	Children's clothing
−0.113**	0.092
[0.051]	[0.074]

Note: Coefficients and standard errors are from separate, population-weighted regressions. The dependent variable is real per capita expenditure for each group (listed at the top of the columns), transformed by the inverse hyperbolic sine (IHS) function. Control variables are listed in the text. Total observations: 20,483. Standard errors are clustered bootstrap estimates
*, **, and *** denote significance at 10 %, 5 %, and 1 %, respectively

Table 21.7 Effects of wheat flour price increases on other nonfood-based coping responses

Sold livestock	Member migrated	Child in school	Purchased food on credit
−0.014	0.007	−0.0028	0.084**
[0.010]	[0.022]	[0.018]	[0.043]

Note: Coefficients and standard errors are from separate, population-weighted regressions. The dependent variable is indicator variable for action listed at the top of the column except for the last column; purchased food on credit is a categorical variable ranging from 1 (never) to 4 (always). Control variables are listed in the text. Total observations in column 1 and 2: 20,483; total observations in column 3: 15,924 (in the child-level regression). Standard errors are clustered bootstrap estimates
*, **, and *** denote significance at 10 %, 5 %, and 1 %, respectively

on grooming and on tobacco and cigarettes is typically categorized as adult goods, in addition to alcohol (not solicited in the NRVA survey) and adult clothing. The NRVA data allowed us to distinguish between clothing and shoes for adult and child. As shown in Table 21.6, we observed that households reduced the amount spent on adult clothing but did not make adjustments to child clothing expenditure. Furthermore, we did not find any effect of the price increases on education, which is a children's good. We interpret these results as evidence of Afghan households prioritizing—to a certain extent—child goods over adult goods in their nonfood-based coping responses.

We did not find evidence of the use of other nonfood-based coping responses, with the exception of an increase in frequency at which households purchase food on credit (Table 21.7).[33] We failed to find evidence of changes in the sale of livestock, in the migration of household members, and in school enrollment. Selling productive assets and migrating are extreme responses and could be potentially irreversible;

[33]The variable for purchasing food on credit is categorical, with values ranging from one to four. The displayed coefficient comes from an OLS model; however, the results are qualitatively similar to the coefficient from an ordered probit model.

therefore, it is not surprising that households chose other coping strategies in lieu of these. As with educational expenses, households might have chosen to protect the investment in children by keeping them enrolled in school. Given the substantial decline in purchasing power, it is not surprising that households purchased food on credit more frequently; incurring even small amounts of debt could encumber a household and perpetuate the cycle of poverty.

Our nonfood-based coping response findings are consistent with the qualitative evidence presented by Lautze et al. (2002), who examined the coping strategies employed during times of drought in Afghanistan using focus groups across the country. In addition to reducing the quality, quantity, and frequency of their meals, Afghan households reported taking on debt and decreasing cultural celebration expenses related to Qurbani Eid. They also found that households sold off assets, increased migration, and increased their reliance on remittances.

For the food-based responses, we estimated the price effects for the mean household using OLS and for households at each decile of the unconditional distribution of the dependent variable using the UQR estimator (Table 21.7). For the mean Afghan household, we observed a large decline in real per capita food consumption and relatively smaller declines in calories and dietary diversity. We interpreted these results as a trade-off between quality and quantity that the household made in order to maintain energy levels in the face of declining purchasing power. More specifically, the mean Afghan household adjusted the composition of its diet in order to buffer the price shock to a certain extent (i.e., calories and diversity decline less than food expenditure).

Additionally, in the regressions above, we allowed the price effects to vary based on whether the household owned or operated agricultural land (the results are available in D'Souza and Jolliffe 2014). During periods of high food prices, these households may not be hurt as much as other households because they are able to produce their own food and are less dependent on the market. Furthermore, if they produce more food than they consume (i.e., net sellers), they can sell the food on the market and profit from the high prices. The NRVA data did not allow us to identify net sellers of wheat, and so we used a dummy for agricultural households. We did not find any strong systematic patterns that were consistent with the literature (i.e., agricultural households are better able to cope with the price increases). Nevertheless, the severe drought of 2008 would have limited the number of net sellers of wheat in Afghanistan at that time. The drought was the worst in the ten preceding years, with losses reported on both rainfed and irrigated wheat crops (Foreign Agricultural Service 2008).

The UQR estimates showed that increases in the wheat flour prices were associated with statistically significant declines in these food-based coping responses across much of the respective unconditional distributions. We observed the largest percentage decline in food consumption and calories for the Afghan households at the top of the respective distributions, with smaller declines observed as one moves lower on the distributions.[34] At a very basic level, these households had more to give as they are well above food poverty thresholds and daily energy (calorie) requirements; they also hosted more guests and ate more away from home, on average, than poorer households.[35]

Households at the first decile of caloric intake were living below the threshold of energy requirements (with average daily per capita caloric intake of 1670) and presumably were unable to cut back on calories without suffering serious nutritional consequences. Accordingly we found no evidence of a decline in their caloric intake. Even those at the second decile experienced negligible changes, equivalent to less than a third of a standard naan (one piece of Afghan bread). Sulaiman et al. (2009) found that Bangladeshi households at the third and fourth income quintiles experienced more wasting than the poorest households in the case of food price increases. Furthermore, there has been some empirical evidence that by moving to cheaper foods and employing nonfood-based coping strategies, households may be able to maintain energy levels despite food price increases. For example, Jensen and Miller (2008) found no reduction in calories among poor households in China's Hunan province and a very small reduction in calories among poor households in Gansu province (indistinguishable from typical seasonal declines) when food prices increased in 2006. They also found evidence of consumers moving away from more expensive foods and a slight reduction in nonfood expenditure.

The strong pattern of the price effects on food consumption and calories stands in contrast to the standard result in the literature that poorer households have larger food price elasticities.[36] The standard result hinges on the fact that richer households devote a much smaller share of their budgets to food and thus are not as affected by food price increases as poorer households. In Afghanistan, however, food (in particular, wheat) makes up a large portion of the budget for rich and poor households alike. Over 80 % of the population spends more than half of their total budget on food. Those in the bottom quintile of the income distribution spend approximately 66 % of their budget on food (44 % on wheat flour); even those in the top quintile spend approximately 49 % of their budget on food (20 % on

[34]We note here the standard caution that the regression coefficients represent estimated effects from small, marginal price changes. This caution against using estimated marginal effects as a basis for simulating large, non-marginal price changes is particularly warranted in the case of quantile estimators where different estimated effects across the distribution of the dependent variable imply a changing shape of this distribution due to price changes. Variation in the estimated marginal effects at different points on the distribution can readily imply re-rankings of observations (in terms of the dependent variable) with large enough simulated changes. But this exercise would be nonsensical as one would expect that as the shape of the distribution changes, so too would each of the estimated marginal effects.

[35]For example, households in the top quintile of the calorie distribution spend nearly double on food away from home than households in the bottom quintile, and they provide more meals (approximately two per week) to guests.

[36]The elasticities are not completely comparable since we looked at calorie-price elasticities based on where the household lies on the calorie distribution, and in the literature the analyses often focus on demand for food based on a household's income quintile.

Table 21.8 Effects of wheat flour price increases on food security across the distribution

Quantiles	10th	20th	30th	40th	50th
Real per capita monthly food consumption	−0.131** [0.0521]	−0.199*** [0.0448]	−0.268*** [0.0440]	−0.338*** [0.0446]	−0.431*** [0.0475]
Daily per capita calorie intake	−0.00531 [0.0439]	−0.0724** [0.0296]	−0.120*** [0.0277]	−0.156*** [0.0258]	−0.192*** [0.0268]
Food consumption score	−0.239*** [0.0575]	−0.242*** [0.0520]	−0.241*** [0.0479]	−0.181*** [0.0369]	−0.168*** [0.0302]
Quantiles	60th	70th	80th	90th	OLS
Real per capita monthly food consumption	−0.505*** [0.0486]	−0.590*** [0.0546]	−0.706*** [0.0660]	−0.721*** [0.0759]	−0.423*** [0.036]
Daily per capita calorie intake	−0.225*** [0.0287]	−0.266*** [0.0335]	−0.313*** [0.0372]	−0.377*** [0.0477]	−0.187** [0.0243]
Food consumption score	−0.152*** [0.0309]	−0.151*** [0.0300]	−0.188*** [0.0334]	−0.185*** [0.0329]	−0.183** [0.0270]

Note: Coefficients and standard errors for the log of wheat flour prices are from separate, population-weighted regressions. The dependent variable is transformed using the inverse hyperbolic sine function and is listed in the first column. Control variables are listed in the text. Total observations: 20,483. UQR standard errors are clustered bootstrap estimates. OLS standard errors are corrected for clustering and stratification

*, **, and *** denote significance at 10 %, 5 %, and 1 %, respectively

wheat flour). Given the importance of food in the budget of Afghan households, it is plausible that even those households at the top of the distributions could have been affected significantly by the wheat flour price increases.

The estimates from the FCS regressions revealed that Afghan households had to make large concessions in dietary quality as a result of the food price increases (Table 21.8). In the case of Haiti, Brinkman et al. (2010) found similar declines in the FCS when rice prices increased. These findings indicated that households changed the composition of their diets, perhaps by cutting back on more expensive, nutrient-rich foods and moving toward cheaper foods. Since the UQR coefficients are related to a specific quantile of a specific distribution, we could not establish a link between the results for the three food-based coping responses. That is, households in a certain quantile on one distribution do not necessarily fall in the same quantile on another distribution; therefore, each set of coefficients must be interpreted separately. While we acknowledge that households may be giving up quality for quantity, we could not provide direct evidence using the UQR.

Our overall findings on food security are consistent with the literature on the impact of economic shocks on nutritional outcomes. For example, Klotz et al. (2008) argued that during times of economic crisis and when households cannot increase the amount that they spend on food, they are forced to cut back on expensive, micronutrient-rich foods to maintain their consumption of core staples. Therefore, economic shocks will lead to micronutrient deficiencies before weight loss. Jensen and Miller (2008) similarly found that in the face of food price inflation, poor urban households in China substitute more expensive foods with cheaper foods. Diagana et al. (1999) also found decreases in the level of dietary diversity and changes in food consumption patterns after the 1994 devaluation of the CFA franc using data from West Africa.

Our results also highlight the importance of moving beyond price effects on mean households when conducting policy analysis; in some instances, we observed stark differences between the coping responses of the average household and households at other points on the distributions. Figure 21.3a and b depict the UQR and OLS point estimates and the 95 % confidence intervals for the food consumption and calorie regressions, respectively.

There are substantial differences between the UQR and OLS estimates for the food consumption and calorie regressions. OLS overestimated the responses of those at the lower portion of the distributions and underestimated the responses of those at the upper portion of the distributions. This could have policy implications.

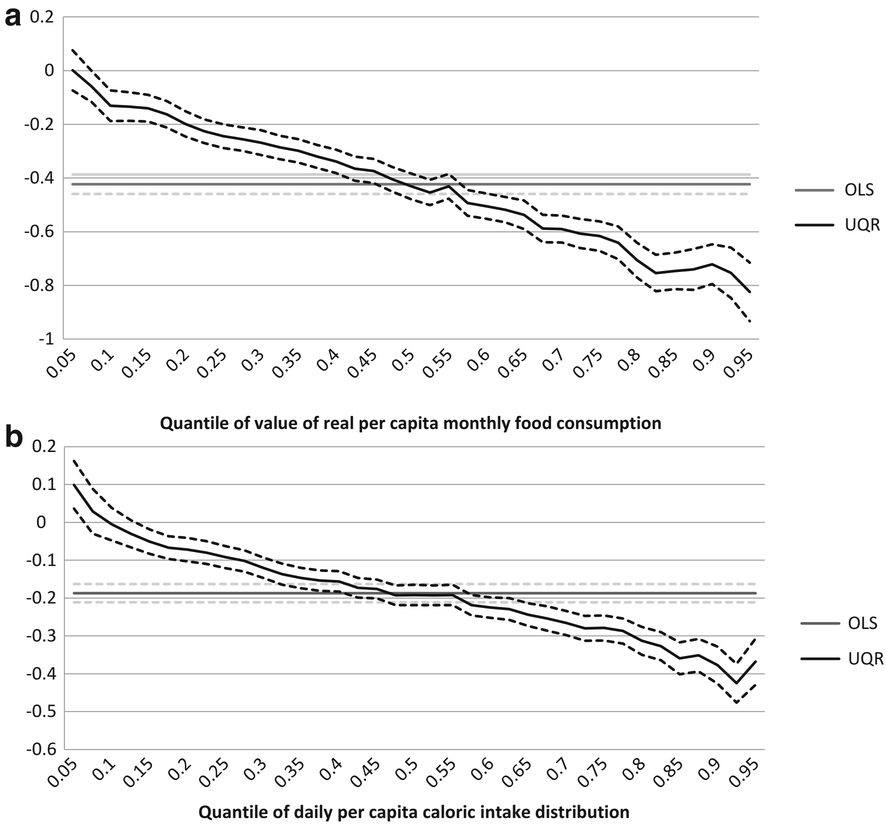

Fig. 21.3 (**a**) Food consumption-price effects (with 95 % confidence intervals). (**b**) Calorie-price effects (with 95 % confidence intervals)

For example, if policymakers consider solely the OLS results for calories and then assume that all households, including the most vulnerable, reduce their caloric intake in response to the price increases, this could lead to blunt policy responses which focus on the provision of staple foods alone. These sorts of policies would not only exacerbate the price shock by shifting up the demand for staple food (through government purchases), but they are likely to be a relatively more expensive safety net option (given that price increase of the staple). More importantly, the UQR results showed that the most vulnerable households do not cut back on calories, and thus other policies may be more beneficial. It is likely that some of these households were forced to make other concessions, such as moving to lower quality and/or less nutritious foods; in this case, interventions like nutrient supplementation programs or the fortification of staple foods could address better the needs of those households.

21.6.1 Supplemental Results

To explore further the impact of the price increases on food security, we looked at several supplemental indicators of diet quality to examine the potential nutritional consequences of dietary changes. We examined three essential micronutrients (retinol, beta-carotene, iron) and the three macronutrients (protein, carbohydrates, fat). Retinol and beta-carotene are forms of vitamin A, an important nutrient for vision and immune system functions. Iron is critical for growth and development, immune system functions, and overall metabolism. Both vitamin A and iron deficiencies are ubiquitous in developing countries and have been recognized as major public health challenges (Dufour and Borrel 2007; Fanzo and Pronyk 2010; Ramakrishnan 2002). The three macronutrients provide energy (or calories) to the body and are essential—in large quantities—for survival. Similar to the food-based coping response regressions above, we used the inverse hyperbolic sine function to transform these dependent variables and used the UQR estimator to estimate the price effects based on a household's position on the unconditional distribution of the respective nutrient intake variable.

We observed declines in nutrient intakes as a result of the wheat flour price increases (Table 21.9). The results differed by the type of nutrient as well as the position of a household on the distribution of nutrient intake. We found declines in the intake of iron, retinol, and beta-carotene for most households, with the lowest deciles of the distributions being an exception (and for beta-carotene, those in the top deciles as well). The general declines are consistent with the findings of Ecker and Qaim (2011), who found negative staple food price elasticities (at population means) for iron and vitamin A (and protein) in Malawi.

In terms of macronutrients, we found a decline in the intake of protein, fat, and carbohydrates; the intake of the first two macronutrients showed larger declines, as may have been expected since protein and fat are more expensive sources of calories than carbohydrates. We found that households at the lower end (e.g., first and second deciles) of these distributions did not experience statistically significant declines.

Table 21.9 Effects of wheat flour price increases on micronutrient and macronutrient intakes

Quantile	10th	20th	30th	40th	50th	60th	70th	80th	90th
Iron	0.055	−0.00752	−0.0633*	−0.0891***	−0.123***	−0.140***	−0.157***	−0.181***	−0.189***
	[0.0554]	[0.0388]	[0.0342]	[0.0315]	[0.0310]	[0.0318]	[0.0352]	[0.0399]	[0.0462]
Retinol	−0.000***	−1.427***	−1.030***	−0.679***	−0.712***	−0.640***	−0.553***	−0.420***	−0.431***
	[0]	[0.405]	[0.297]	[0.180]	[0.142]	[0.116]	[0.108]	[0.105]	[0.100]
Beta-carotene	−0.127	−0.0925	−0.123	−0.301**	−0.337***	−0.349***	−0.294***	−0.188*	−0.0933
	[0.151]	[0.156]	[0.146]	[0.121]	[0.102]	[0.101]	[0.0933]	[0.101]	[0.112]
Carbohydrate	0.00623	−0.038	−0.0875***	−0.134***	−0.162***	−0.202***	−0.222***	−0.250***	−0.356***
	[0.0478]	[0.0340]	[0.0284]	[0.0290]	[0.0299]	[0.0304]	[0.0341]	[0.0378]	[0.0497]
Fat	−0.00129	−0.145***	−0.196***	−0.258***	−0.310***	−0.350***	−0.389***	−0.455***	−0.457***
	[0.0606]	[0.0438]	[0.0375]	[0.0354]	[0.0381]	[0.0368]	[0.0386]	[0.0500]	[0.0519]
Protein	−0.00297	−0.0572*	−0.122***	−0.179***	−0.237***	−0.289***	−0.413***	−0.685***	−2.533***
	[0.0470]	[0.0338]	[0.0316]	[0.0317]	[0.0323]	[0.0362]	[0.0467]	[0.0920]	[0.736]
Animal-source	−1.275***	−0.618***	−0.606***	−0.571***	−0.493***	−0.443***	−0.466***	−0.404***	−0.587***
protein	[0.382]	[0.151]	[0.117]	[0.100]	[0.0914]	[0.0800]	[0.0745]	[0.0733]	[0.0839]
Nonanimal-source	0.0357	−0.0564*	−0.106***	−0.150***	−0.221***	−0.269***	−0.369***	−0.579***	−2.813***
protein	[0.0507]	[0.0315]	[0.0302]	[0.0305]	[0.0318]	[0.0383]	[0.0494]	[0.0959]	[0.878]

Note: Coefficients and standard errors are from separate, population-weighted regressions. The dependent variable is per capita nutrient intake transformed by the inverse hyperbolic sine (IHS) function. Control variables are listed in the text. Total observations: 20,483. Standard errors are clustered bootstrap estimates
*, **, and *** denote significance at 10 %, 5 %, and 1 %, respectively

We further separated protein-based food into two categories: animal-source foods and nonanimal-source foods. Higher animal-source and nongrain food expenditures have been linked to lower levels of malnutrition as measured by child stunting (Sari et al. 2010). We found that the expenditure on animal-source protein declined much more than nonanimal-source protein when food prices increase; the former is a more expensive source of calories than the latter. The largest change overall was the decline in protein from animal sources for those consuming at the lowest decile. Across each of the deciles, the negative elasticity of protein from animal sources was the largest change of the macronutrients. These findings are consistent with the fact that as purchasing power declines, households move away from more expensive and often nutritious calories, such as meat, to cheaper less nutritious ones, such as pulses and beans. The findings are also consistent with previous literature on economic shocks. Martin-Prevel et al. (2000) and Block et al. (2004) found reductions in maternal and child nutritional status following a currency devaluation and a financial crisis.

21.7 Conclusion

Unique household and price data collected before and during the 2007/2008 food price crisis provided a rare opportunity to examine empirically nonfood-based and food-based coping strategies used by households in Afghanistan in response to sharp increases in the price of wheat flour, their dietary staple. In a country where decades of conflict, political instability, and recurring drought have led to a precarious state of food insecurity and poverty, understanding how households cope with price increases and other economic shocks can provide vital information to policymakers and aid organizations tasked with creating and implementing programs and policies to address acute and chronic food insecurity and poverty in Afghanistan.

In response to wheat flour price increases, we found that Afghan households reduced food expenditure and also expenditure on health, grooming, communication, transportation, cigarettes and tobacco, and culture. The reductions in health expenditures are of particular concern, especially in a country that ranks at the bottom of many development, health, and nutritional rankings. Such coping responses could have long-term consequences if they represent reductions in important medical care or health investments.

We did not find changes in educational expenses, school enrollment, or child clothing, which can be categorized as child goods. The reductions in expenditures on grooming, adult clothing, and cigarettes and tobacco suggest Afghan households were more willing to reduce spending on adult goods than child goods. While we did not observe any increase in the sale of productive assets (livestock) or in migration, we did find an increase in the frequency at which households used credit to purchase food.

The food price increases also led Afghan households to employ several food-based coping strategies. Households reduced the real per capita monthly value of food consumed and as a result experienced reductions in daily per capita caloric intake and household dietary diversity. Rather than reducing calories by the same amount as the reductions in the value of food consumed, households adjusted the types of foods they ate; most likely, they switched to lower quality, cheaper foods, or food groups.

We further analyzed the food-based coping responses by examining the differences in the behavioral response of a household based on its location on the distribution of the respective food-based coping response indicators. Those wishing to target policies and programs at vulnerable, food-insecure households may be interested in knowing the unique set of trade-offs that these households face. Households at the bottom of the caloric intake distribution made very small to no reductions in caloric intake. Households living near caloric-subsistence levels are vulnerable to many adverse health effects and need to find ways to absorb the price shock without further reducing calories. These vulnerable households may have limited options in buffering food price shocks; while we know that food purchases make up the vast majority of their total consumption, they cannot easily scale back on calories. Whereas we found that households at the top of the distribution did experience significant declines in caloric intake. Similarly, households at the top of the food consumption distribution experienced larger declines than those at the bottom of the distribution, though unlike in the calorie regressions, even those at bottom experienced significant declines. Such differences in behavioral responses show that a quantile estimator (or any estimator that allows marginal effects to vary across the distribution) can reveal important information, particularly when examining welfare-related outcomes.

We also found evidence of declines in dietary diversity across the entire distribution of households in Afghanistan, underscoring the vulnerability of Afghan households to food price increases. Long-run policy solutions recognize that vulnerable households are likely to be disproportionately hurt by negative shocks. Antipoverty programs aimed at increasing the income of the poor and improving access to infrastructure and education could better protect people from price shocks by providing them with better coping strategies (e.g., drawing down savings rather than decreasing health expenditure).

A long-run approach alone can, however, leave the population vulnerable to shocks in the short and medium run. Short-run interventions can play a potentially important role in protecting the population from long-run adverse effects of food price shocks. As an example, our analysis demonstrated that dietary quality (dietary diversity, as well as nutrient intake) declined significantly during a period of high food prices. Examples of interventions that focus on diet quality include micronutrient supplementation programs (such as "sprinkles"), expansion of the fortified school biscuit program, wheat flour fortification (e.g., with iron, folic acid, or vitamin A), and biofortification of staple crops. Such interventions play a relatively small role in food assistance programs. For example, between 2005 and 2009, more than 1.12 million metric tons of food aid was delivered to Afghanistan to provide emergency food relief and nutritional support to vulnerable and acutely food-insecure households; more than three-fourths of this aid was comprised of wheat products. It is important to note that our findings do not argue against the provision of calories through the release of staple crop reserves. Even though we found that those whose calorie consumption is at the margin of basic caloric needs are not reducing their caloric intake during an adverse price shock, this does not mean that the provision of some form of calories will not be of help to them. The receipt of a staple crop could very well be a useful transfer, allowing the household to supplement the staple crop with a more diverse diet or purchase necessary nonfood items. The standard response to food crises—increasing the distribution of grains—is useful because it essentially increases the ability of a household to consume a more diverse diet. The key findings in this analysis, though, put more emphasis on the importance of enhancing the current standard policy response with interventions aimed directly at addressing dietary diversity through micronutrient interventions, such as fortification of grains or nutrient supplementation.

Another policy implication related to the monitoring of a population's vulnerability to food insecurity. In their guidelines for assessing household-level food security, the Food and Agriculture Organization of the United Nations and the World Food Programme (2009) suggested the construction of a food consumption score, food expenditure estimates, and caloric intake. The guidelines have been written to provide assistance to on-the-ground teams which assess whether action needs to be taken to address the potential problems of food insecurity. The guidelines are intended to be practical responses to data-poor environments and suggest that information on any of these indicators could be informative, but our findings are less optimistic about the informativeness of calories as a proxy for food security in the short run. Our findings indicated that calories are relatively insensitive (at least in the short run) to adverse shocks, while dietary diversity is more sensitive to shocks. This is consistent with the findings of Ruel (2003), who found that dietary changes can be detected before changes in micronutrient status. The key point is that policies designed to be triggered by a decline in caloric intake to below the subsistence level will fail to detect the onset of food insecurity in a timely way.

Finally our findings shed some light on the costs and benefits of collecting data on diversity and calories. Household survey consumption modules often include questions about the quantity of food consumed and food expenditure, but questions about the frequency of food consumption are seldom asked. Given its low cost, it may be beneficial to consider augmenting household surveys by adding such questions, particularly for populations that are vulnerable to food insecurity. Measures of dietary diversity are a useful tool when detailed food journals or anthropometric data are not available. A common view is that there is a trade-off between different measures, such as the food consumption score and calorie measures. Calorie data is time consuming to collect, but it is presumably a better indicator of food security, while dietary diversity data is easier to collect, but it is a cruder, less informative measure. Alexander and Thomson (1992) discussed the importance of collecting frequency data in addition to quantity intake data. They demonstrated that both the quantity and frequency of food intake are important determinants of diet-induced diseases, and they argued that looking solely at quantity data could be misleading. Our findings suggest that using dietary diversity indicators may be the best approach to measuring the onset of food insecurity. This view is supported by recent literature comparing various measures of food security (Headey and Ecker 2013; Tiwari et al. 2013).

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Appendix

Table 21.10 Key indicators across quarters

	Quarter 1 (fall)	Quarter 2 (winter)	Quarter 3 (spring)	Quarter 4 (summer)	All
Demographic Indicators					
Average household size*	8.7	9.0	8.4	8.5	8.6
Average age (years)	20.6	20.4	20.7	20.5	20.6
Household members %, age <15)	47.9	48.7	48.4	48.7	48.5
Age dependency ratio	131.6	134.2	133.6	134.0	133.4
Education and health indictors					
Full Immunization (%, age 12–23 months)*	33.0	41.1	34.8	37.6	36.7
Literate household head (%)*	34.4	28.8	28.4	29.5	30.1
Ever attended school (%, age >18)*	21.7	21.3	18.9	21.6	20.9
Education level of persons (age >18)	2.0	1.9	1.6	1.9	1.9
Access to services and infrastructure indicators					
Sanitary toilet (% households)	5.9	5.6	4.5	4.0	4.9
Electricity (% households)	40.9	42.2	41.5	39.8	41.1

Source: NRVA 2007/2008. *Note*: Population-weighted means
* denotes estimates that are statistically different at 10 % across quarters in some cases

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Hedging Seasonal Food Price Risks: The Impact of Cereal Banking in the Gambia 22

Raymond Jatta

22.1 Introduction

In rural communities of the Gambia, as in the case of most other arid and semiarid countries in the world, cereal banking is a common practice to store food at harvest for use during lean periods. It is a community-based strategy of making food available throughout the year and managing seasonal food price dispersions by maintaining physical food reserves (Beer 1990). It aims at managing price and climate risks.

Rainfall variability and food price volatility are some of the most important risk factors that affect lives and livelihoods of poor rural households in import-dependent countries such as the Gambia (Vicarelli 2011, p. 2; Wright and Cafiero 2009). This is due in part to their primary sector-based economy (which is sensitive to climate conditions), their reliance on food imports, and their low levels of human development and food accounting for a major part of their income and expenditure (Kalkuhl et al. 2013; Wheeler and von Braun 2013; FAO 2011). These factors account for high human costs resulting from climate and market shocks (FAO 2011; von Braun and Tadesse 2012; Ivanic and Martin 2008).

In this chapter, we assess how cereal banking can be used as a viable option in rural communities to enhance food and livelihood security in the face of climate and price risks. In spite of cereal banking's popularity in most of the arid and

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semiarid rural communities (Basu and Wong 2012; Bhattamishra 2012), the practice has received little empirical scientific research.

22.2 Context

Our study was conducted in 134 rural communities, in a total of 13 districts from three of six rural regions in the Gambia. 78 % of the active population in the Gambia is engaged in rain-fed subsistence farming as a source of income and food. Households in rural areas are generally larger (>12 members) and poorer, with 48 % of the households below the national poverty line of $1.08 a day (GoG 2010). The traditional land tenure system allows for small land holdings inequitably distributed among men and women (von Braun et al. 1989; Carney 1992). In addition to other socioeconomic factors—such as urbanization, population growth, inadequate input supply and the use of crude technology—rainfall variability has an important multiplier effect on the ability of households to feed themselves. The Gambia's climate is Sahelian semiarid. Its location has been described as a hotspot for climate change and food insecurity (Ericksen et al. 2011). The climate consists of two seasons: a 4-month rainy season (June–September) and an 8-month dry season. Because the rainy season is short, only a single cropping season is feasible for rain-fed agriculture[1] (Ceesay 2004). Only about 50 % of the country's food needs is produced locally (WFP 2011). The Gambia is thus regarded as a food-deficit, import-dependent country. Inter-annual variations in food production generally follow rainfall trends and variability.

Figure 22.1 shows an almost perfect positive correlation between rainfall variability and cereal production variability. Variability in Fig. 22.1 is a measure of dispersion of each annual rainfall or production figure from their mean between 1991 and 2012, normalized by their standard deviation.

Figure 22.2 shows the gap between domestic consumption and production. Rainfall variability has the potential to reduce domestic production. When coupled with a global food crisis and a price hike, it could cause food prices to rise drastically, eroding purchasing powers and resulting in poverty and malnutrition among many Gambians (Kalkuhl et al. 2013). Given the country's dependence on food imports[2] (60 % estimated by Tadesse et al. 2013), any changes in global food availability and food prices will definitely affect foreign exchange rates, causing inflationary pressures on food and non-food imports.

Food production, affordability, and consumption in rural areas of the Gambia follow the agricultural cycle (Barrett 1996), as in most developing countries. During harvest season, food is in abundance, and most households become net suppliers of food. In the Gambia, the harvest season spans from October to February. Food supplies tend to move from rural to urban areas because of higher prices (a

[1] Irrigated area is less than 6 % of arable land.

[2] WFP (2011) estimates 81 % dependence on rice imports, the country's staple food.

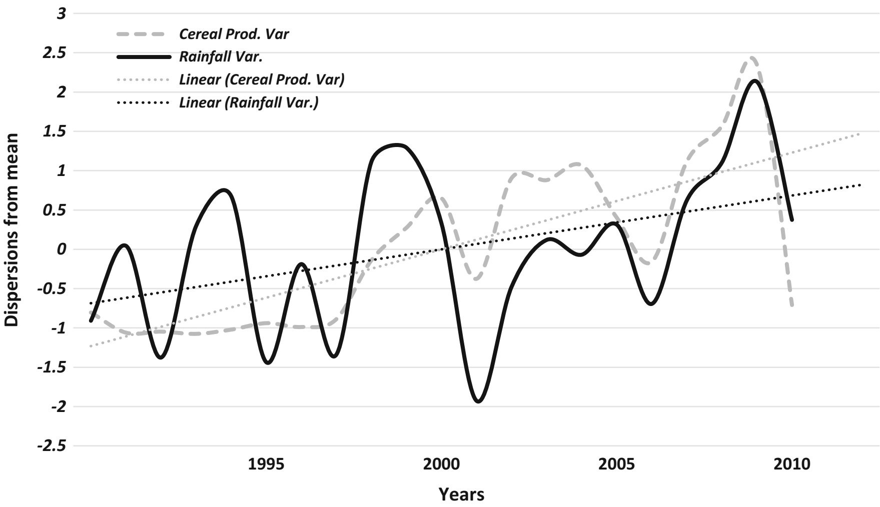

Fig. 22.1 Crop production and rainfall variability, 1991–2012. *Source*: Department of Water Resources, Gambia

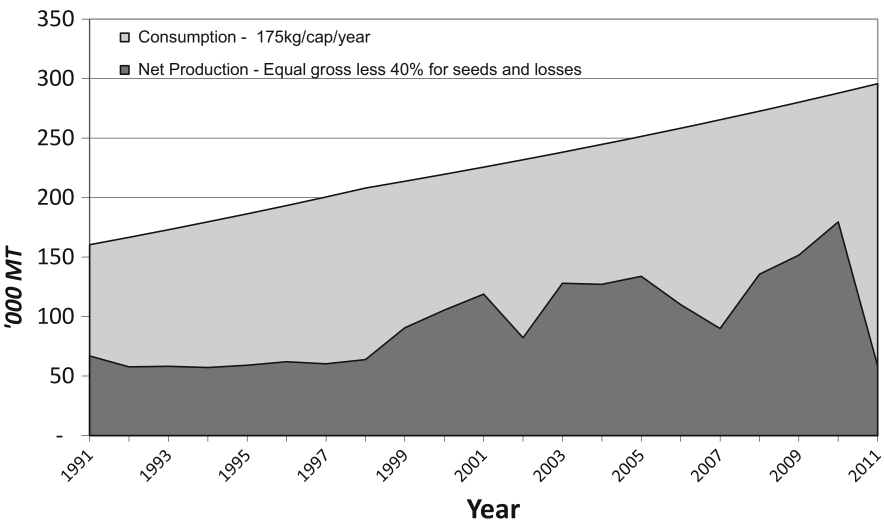

Fig. 22.2 Consumption requirement vs. net cereal production 1991–2011. *Source*: World Food Programme—WFP (2011). Note: consumption requirement in the Gambia in 1000 metric tons to meet a cereal demand of 175 kg/cap/year

consequence of higher demand) in the urban areas (Barrett 1996). However, food is usually in short supply when approaching the rainy season (FAO 2011). Rural households and communities become net buyers and often have to rely on imported food from the urban areas. The reversal of food flow begins driving upwards food prices in rural areas. Production constraints, exacerbated by the absence of large storage schemes and credit constraints, tend to worsen the price changes and the spatial and temporal food availability (Barrett 1996). The transition in terms of the duration of the food gap is influenced by rainfall patterns, among other things. In years with low rainfall, inter-seasonal food price dispersion can be as high as up to 400 % (von Braun et al. 1999). This dynamic affects rural households and communities more—eroding incomes and causing seasonal food and nutrition insecurity (WFP 2011). As a result, the problem of food insecurity is more seasonal than chronic in rural areas of the Gambia. Every year, poor households in the rural areas face the "hungry season," a period of 3–4 months between July and September, when household food stocks are low or depleted (FAO 2011). The Comprehensive Food security and Vulnerability Assessment Report (WFP 2011) observed that in the months of August and September, about 80 % of the rural households reported food-insecure conditions, while only 10 % reported being food insecure between December and April. Similar studies on seasonal food security programs in East Indonesia and Bangladesh (Basu and Wong 2012; Khandker 2009 respectively) observed similar seasonal food insecurity dynamics.

22.3 Methodology

Our methodology is based on a large scale randomized control trial (RCT) implemented in the Gambia called the Community Driven Development Project (CDDP). The project, funded by the World Bank, was implemented in the Gambia from 2008 to 2011. Using a poverty index as a basis for stratification, 930 out of about 1800 villages were eligible, and of the 930 eligible villages, 495 were randomly chosen for the CDDP intervention (Arcand et al. 2010). 35 of the 495 villages chose cereal banking from a wide range of possible projects based on the needs and aspirations of their communities.[3]

We note that while selection for CDDP intervention was randomized, the choice of subprojects such as cereal banking was not. It was likely influenced by endogenous village characteristics. Evaluating the impact of such subprojects requires the use of quasi-experiments (Abebaw and Haile 2013).

Subsequently, we have to investigate the determinants making these villages choose cereal banking for their subproject. These factors must be controlled to minimize selection bias and fulfil the Conditional Independence Assumption (CIA) (Heckman et al. 1997; Angrist and Pischke 2008).

[3]Participatory project identification methods were used; villagers chose the subproject at village meetings.

22.3.1 Propensity-Score Matching

In propensity-score matching (PSM), researchers try to balance groups by matching treatment and control units based on the characteristics that affected their probability of receiving treatment—which, in this case, is cereal banking (Heckman et al. 1997; Caliendo and Kopeinig 2008). PSM ensures that at baseline and on average, groups are identical in terms of observed characteristics (Heckman et al. 1997; Caliendo and Kopeinig 2008). The method requires finding a control group which bears similar characteristics as the treatment group in all respects; however, the control group does not receive treatment. If a treated group and a potential control group have matching propensity scores, then the difference between outcomes of the two groups is an unbiased estimator of the treatment effect (Heckman et al. 1997; Ravallion 2007; Abebaw and Haile 2013). However, this assumption becomes invalid if there are important unobservable factors that affect treatment and outcomes (Caliendo and Kopeinig 2008). The method can be improved by using fixed effects which captures time-invariant unobserved heterogeneities (Olken 2012).

We estimate the propensity of a community participating in a cereal banking scheme using a nonparametric logit model:

$$P\,(\mathrm{CB}) = \beta \mathrm{Vc}(i) + \varepsilon(i), \tag{22.1}$$

where $P(\mathrm{CB})$ is the probability of participating in a cereal bank; β represents parameters that must be estimated; $\mathrm{Vc}(i)$ is a vector of a village's preexposure level of social, economic, livelihood, natural, and market characteristics; and ε is an error term. On the basis of the CDDP assignment, we conducted PSM using two subsamples:

- Matching cereal banking villages with CDDP-funded villages that opted for subprojects other than cereal banking (partial control group)
- Matching cereal banking villages with villages that neither benefitted from the CDDP funding, nor had cereal banking schemes (pure control group)

22.3.2 The Propensity-Score Matching Results

Data for the PSM were obtained from the 2003 National Population Census data and National Agricultural Sample Survey 2007. From a total of 827 villages in all the six rural regions in the Gambia, 22 pretreatment village variables were generated for our PSM. Relative to the sample size of the treatment group (35), the large sample size of possible control villages (780) ensures that the pretreatment mean differences between the treated and their matched counterfactuals converge to zero (Chabé-Ferret 2010), thus reducing sample selection based on observables (Baker 2000; Heckman et al. 1997). A one-to-one nearest-neighbor matching algorithm without replacement was employed as it enhances efficiency and reduces biases (Caliendo and Kopeinig 2008, p. 9). It also matches each treatment village to a unique village from the pure control and the partial control groups.

The results of our PSM indicate the variables that influenced the villages to choose cereal banking. Overall, the R^2 indicates that our PSM model [Eq. (22.1)] has strong explanatory power for the probability of a village choosing cereal banking. Out of the 22 variables, 13 were statistically significant at 10 % significance level, while 9 were statistically significant at 5 % significance level. Our coefficients are expressed in odd ratios and not in marginal effects, but the p values indicate the level of significance for each of the variables (Table 22.1).

The PSM results provide the following insights:

- Coefficient of variation of the prices[4] (Huchet-Bourdon 2011) of the main food crops in a village market, or in the market closest to the village,[5] indicates price dispersion and price risk. Our results show that communities facing high price risk tend more to choose cereal banking. This is in agreement with existing studies (Bhattamishra 2012; Cortès and Carrasco 2012).

Table 22.1 Results of propensity-score matching

	Partial control PSM		Pure control PSM	
Variable	Coefficient	$P > \|z\|$	Coefficient	$P > \|z\|$
Coefficient of variation (rainfall)	13.8706	0.286	16.076	0.246
Coefficient of variation (price)	660.3531	0.006**	681.091	0.018*
Poverty	7.2494	0.035*	2.695	0.408
Availability of fruit trees	−0.0512	0.033*	−0.043	0.102
Millet grown	0.00134	0.004**	0.001	0.009**
Proportion of crop farmers	46.2541	0.029*	32.713	0.053
Average HH size	0.7248	0.209	−0.283	0.501
Prop of Hhs without daily market	0.1836	0.046*	0.152	0.058
Prop of Hhs without improved trans.	0.5373	0.009**	0.476	0.038*
Dominant ethnicity gr. 3	14.6823	0.003**	7.953	0.09**
Dominant ethnicity gr. 2	7.4451	0.004**	3.842	0.113
Connected and lowland villages	1.1066	0.109	1.618	0.039*
Distance to market	0.5274	0.038*	−0.446	0.033*
Proximity of the LGA	33.20208	0.024*	33.592	0.02**
Proximity of the district	2.873271	0.021*	−3.023	0.016*
Cov_Price2	1128.559	0.004**	−1157.499	0.016**
No. of observations	451		422	
R2	0.4549		0.3947	

*$P < 0.05$, **$P < 0.01$

[4]See Huchet-Bourdon (2011).

[5]The price data is collected from 28 markets in the Gambia on a monthly basis.

- Access to market is measured by the distance from a village to the closest weekly market. The availability of improved transport systems indicates if a village is connected or remote. The more isolated a community is, the higher the probability that it will choose cereal banking. This is similar to findings of existing studies (Afrique Verte 2010; Bhattamishra 2012). A great distance to markets may motivate communities to store food because households in these villages may incur high transaction and transportation cost, Daviron and Douillet 2013).
- The probability of choosing cereal banking is significantly different between communities with food surplus and those with food deficit (Bhattamishra 2012; Cortès and Carrasco 2012). Lowland villages, which are in close proximity to the River Gambia—a source of fresh water for irrigation—often have more favorable environment for farming (Ceesay 2004; von Braun et al. 1989). In most cases, they produce more food crops, especially rice, relative to the villages located in the upland. A review of the choice of subprojects for the CDDP show that most of the communities in the lowlands opted for production enhancement equipment, access to fields, and gardening, rather than cereal banking (Arcand et al. 2010).

In general, the results of the PSM show that villages that are poor, remotely located, and susceptible to rainfall and price volatility are more likely to choose and maintain a cereal banking schemes (Cortès and Carrasco 2012; Bhattamishra 2012). This highlights the importance of targeting the right villages when implementing a program since not all communities equally need, or can sustain, a cereal banking schemes.

The *T*-test (in Annex on Table 22.5 below) shows that before matching, some significant differences between treated and non-treated villages were observed. However, after matching, there are no significant differences between the two groups. Unlike earlier researches that used PSM, our method gives superior results because the PSM is built on both stratification and randomization (Arcand et al. 2010; Abebaw and Haile 2013). Using propensity-score nearest-neighbor matching, we were able to generate a control group similar enough to the treatment group, so that the impacts of cereal banks can be evaluated.

22.4 Impact Evaluation

Based on the PSM results, 134 villages were selected for the survey. Then we randomly selected 10 % of the households in each village (a total of 460 households). Using this cross-sectional data (Olken 2012), we estimated the average treatment effect (ATE) and the average treatment effect on the treated (ATET). Our analysis focuses on indicators of food security, nutrition security, and livelihood security. Taking our cue from recent literatures about the conceptualization and measurement of food and nutrition security (Hoddinott 1999; Pangaribowo et al. 2013; Pieters et al. 2013; Laborde Debucquet et al. 2013; Kalkuhl et al. 2013;

von Braun and Tadesse 2012), we considered various aspects of food security: availability, accessibility, utilization, and stability.

22.4.1 Empirical Strategy

In the first set of analysis, we compared the mean outcomes to determine if there are any differences in DIM between the treatment, pure control, and partial control groups. This is to determine if any of the effects can be reasonably attributed to the treatment. Since the pretreatment characteristics of villages were considered in the matching process, any differences in the outcomes can be attributed to the treatment (Ravallion 2007). Therefore, the DIM indicates the ATE.

22.4.2 Comparison of Means: Treated and Control Villages

As in the PSM, we found that most of the villages remained unchanged in their physical and socioeconomic features 4 years after implementing the project. This further validated our PSM. However, among villages, there are also some important DIM, some of which indicate the ATE of the program (Becker and Ichino 2002).

The households had a food gap of more than 2.5 months on average. The food gap, also called the lean period or hungry season (FAO 2011), represents the number of months a household reports not having adequate food stocks or money to buy food. The households often need to hire out their own labor for money or to take out a loan. We observed significant differences in the length of lean period among the households sampled.[6] While households in treated villages experienced an average 2.1 months of food gap, the pure control group experienced almost 3 months of food gap, and the partial control group 2.5 months. Comparing the treated group and the pure control group, cereal banking reduces the length of lean period by 25 %.

The results for the selling prices of cash crops (groundnut at harvest) and the buying prices of food crops (millet and maize during the lean period) also indicate a significant difference between the treatment and control villages. The price effect is more significant when comparing treated villages and partial control villages. This indicates that variations in food and cash crop prices is higher in partial control villages than in the other two groups, suggesting that in the absence of a food storage, households may produce more food and yet achieve lower incomes. Variation is defined as the difference between prices of food crops (rice, maize, and millet) reported in August (lean period) and price of cash crops (groundnut) reported in December (harvest period) minus the yearly average prices of the same crops.

Figure 22.3 shows that at harvest, when most rural households are net sellers, the selling prices of excess production are 16 % lower in control villages than treated villages. In contrast, during the lean period, when most rural households are net

[6]The lean period or hungry season in the Gambia often starts in July–September.

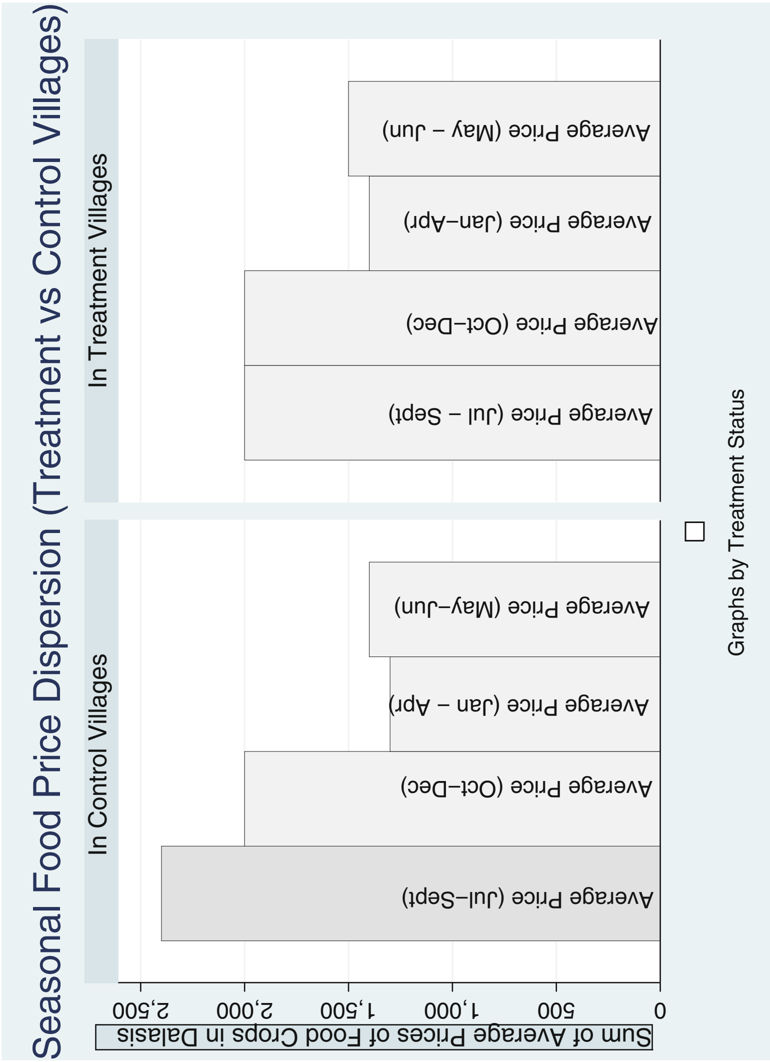

Fig. 22.3 Seasonal food dispersion across treatment status. *Source:* own illustration

buyers, the buying prices of cereals are significantly lower in control villages than treated villages (about 15 % lower). This implies selling farm produce at lower prices and buying food at higher prices for households in control villages compared to those in treatment villages, contrary to conclusion in Kent (1998).

The following may explain the differences in prices and price variability:

- Households in treated communities reported higher dependency on their own production for food than those in control group. Thus, treated communities sell less of their food crops at harvest and buy less food during the lean period, signifying that they become net buyers of food much later than the control group.
- Cereal banking schemes disincentivize speculative arbitrage, often carried out by middlemen, moneylenders, and input lenders (Cortès and Carrasco 2012; Kent 1998). As shown in the DIM in Table 22.2, middlemen are more active in control villages than in treated villages. In the Gambia, middlemen and moneylenders lend food or inputs to households. Similar to the findings of other empirical studies in this field (Cole et al. 2012; Morduch 1995; Cortès and Carrasco 2012), it was observed that when risk management strategies or one form of credit scheme are in place, there will be less demand for other forms of credit (Gilbert 2012).
- Similar to other research findings, inter-seasonal price changes are more significant for domestically produced food (millet and maize). Compared to other similar studies (Afrique Verte 2010; von Braun et al. 1999; Bhattamishra 2012), this study found a slightly lower, but nonetheless significant, inter-seasonal price change between harvest and lean seasons: 53 % in treated villages and 84 % in control villages. The treated villages showed a 31 percentage point reduction in inter-seasonal price variation.

Table 22.2 Mean outcomes—treated and control villages

	Treated	Pure control	Test	Partial control	Test
Food gap	2.170	2.830	0.000**	2.490	0.047*
Price cash crop—harvest	726.470	625.000	0.003**	587.230	0.000**
Price food crop—lean	918.570	1057.970	0.002**	959.780	0.177
Variation[a] in cash crop prices—harvest	−178.180	−192.910	0.350	−246.660	0.026*
Variation in food crop prices—lean	114.280	262.640	0.000**	238.630	0.000**
Price of imported rice	1159.14	1155.850	0.775	1153.640	0.639
Self-help groups	1.9	1.6	0.665	1.7	0.872
Ward Development Committee membership	2.645	1.927	0.894	1.979	0.895
Moneylenders/middlemen	1.4	1.72	0.025	1.68	0.482
Number of villages	35	48		55	

*$P < 0.05$, **$P < 0.01$

[a]Variation in cash crops at harvest and food crops at the lean period are the difference of the price at harvest/lean minus the mean price during the year

Our study also found that there are more local self-help groups in the treated villages than the control villages. This indicates that when compared to the control villages, the treated villages are likely to have created more internal networks and have better capacity to initiate, implement, and sustainably manage their self-help projects. The treated villages are also significantly more socially connected, having much more representation in ward- and district-level organizations, such as the Ward Development Committee (WDC).

In addition, households in the treated villages tend to be more effective at adapting to changes (Maxwell and Smith 1992) than their counterparts in the control villages. For example, treated communities were more likely to introduce new varieties of crops and use extensive production systems (although the latter is not always sustainable), and their population less likely to migrate.

22.4.3 Estimating Treatment Effect on the Treated

To evaluate the impact of the cereal banking scheme, we conducted a regression analysis to estimate the actual ATET or the intention to treat (ITT) (Arcand et al. 2010; Duflo et al. 2007).

Our regression model at village level can be described using the equation:

$$Y(i) = \alpha(w) + \pi V(i) + \beta T(i) + \varepsilon(i), \tag{22.2}$$

where $Y(i)$ is the outcome variable of village i, α represents baseline village characteristics which allows for estimation with and without fixed effects (w), $V(i)$ is a vector of village level characteristics, T is the cereal bank dummy ($T = 1$ if treated, 0 otherwise), and $\varepsilon(i)$ is the error term. α is the baseline outcome, and π and β are parameters that need to be estimated. The dummy T is included in Eq. (22.2) to assess the impact of the CDDP treatment on treated and partial control villages. We also estimate the models using fixed effects, comparing the treated villages with the pure control and partial control villages. The combination of fixed-effect estimation and propensity-score matching reduces the selection bias caused by time-invariant missing variable endogeneity or selection on unobservable bias (Duflo et al. 2007).

Two main indicators are identified after reviewing current literature on food and nutrition insecurity.

Food Gap Effects

The food gap, a proxy for food availability, is the number of months in a year households report having inability to satisfy their food needs (Maxwell and Smith 1992). Households and communities in the Gambia with food deficit experience food gap because of the unavailability or high cost of food during the lean period. This affects food and micronutrient intakes as well as farm investments and yields. We therefore use the food gap as a measure of household food availability.

Comparing with pure control and partial control villages, villages with cereal banks saw a significant reduction in food gap, with and without fixed effects

(Table 22.3). Middlemen reduce the food gap as well, even though the extent of their influence is debatable. The distance of a village to a main road, which is a proxy for market access, is positively correlated to the food gap.

The further away a village is from lowland areas, the larger the food gap is. This is understandable since lowland areas have higher crop-growing potentials and can allow for off-season gardening (Ceesay 2004). Some of the lowland villages are also able to practice double cropping of rice (von Braun et al. 1989; Carney 1992).

The prices of food crops during the lean period (July–September) also significantly increased the food gap in all cases. Thus, managing inter-seasonal prices could be an effective way of shortening the lean period in rural areas of the Gambia.

Although the CDDP intervention reduced food gap, it does not significantly shorten the lean period. This is because the CDDP had various other community subprojects, some of which may not have a direct and immediate impact on food production and smoothing consumption. Using fixed effects is important because it increases the precision of our model, evident in the R^2 and the standard error values of our treatment variables.

Price Variability

Inter-seasonal changes in prices of the three major crops in the Gambia[7] is a proxy for food accessibility. In Amartya Sen's book *Poverty and Famines* written in 1981, he argued that the problem of hunger or food insecurity is not only about food availability, but there could also be structural, cultural, or economic circumstances that deny some people access to food, even when food is available. Thus, some of the key indicators of food insecurity include household income, food prices, and household expenditure (von Braun 2011). High food prices during the lean period inhibit food-deficit poor households from buying and consuming adequate amount of food (Gilbert 2012). When food prices are high, poor households in rural areas often adopt various strategies to alleviate the situation. These strategies include reducing frequency and quantity of food intake, foregoing other basic needs, and taking out loans or working to purchase food. The strategies can, however, further exacerbate their indebtedness and poverty (Action Aid 2011). To capture the changes in inter-seasonal price variability, we constructed a price variability model:

$$\text{Log}\,(P_{\text{l}}–P_{\text{h}}) = \alpha(w) + \pi V(i) + \beta T(i) + \delta\text{CDDP}\,(i) + \varepsilon(i), \qquad (22.3)$$

where P_{l} and P_{h} are prices of food crops during lean period and harvest period respectively.

Our results in Table 22.4 show that cereal banking leads to a significant reduction in the inter-seasonal food price deviation between harvest and lean period. The

[7]Rice, millet, and groundnut

Table 22.3 Food gap

	(1) Food gap Treatment dummy	(2) Food gap CDDP dummy	(3) Food gap District fixed effects	(4) Food gap Pure cont plus FE	(5) Food gap Part. cont plus FE
Treatment	−0.515	−0.473	−0.470	−0.509	−0.366
	(0.194)**	(0.214)*	(0.216)*	(0.250)*	(0.322)
CDDP villages		−0.082	0.036		
		(0.175)	(0.181)		
District 9 (Fulladu)			−1.296	−0.960	−1.044
			(0.456)**	(0.665)	(0.711)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	112	112	112	73	71
R-squared	0.40	0.40	0.50	0.54	0.54

Standard errors in parentheses *significant at 5 %; **significant at 1 %

NB: district 9 (Fulladu East) is a rice growing area in which some villages have access to irrigation

Table 22.4 Price variability

Variables	(1) Log price dev Treatment dummy	(2) Log price dev CDDP dummy	(3) Log price dev District fixed effects (FE)	(4) Log price dev Pure cont plus FE	(5) Log price dev Part cont plus FE
Treatment	−0.412*** (0.121)	−0.406*** (0.132)	−0.436*** (0.121)	−0.435** (0.179)	−0.411** (0.172)
Middlemen	0.250** (0.100)	0.249** (0.101)	0.144 (0.112)	0.262 (0.170)	0.128 (0.190)
District 9 (Fulladu)			−0.478** (0.238)	−0.447 (0.348)	−0.552 (0.363)
CDDP villages		−0.0116 (0.0986)			
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	113	113	113	74	71
R-squared	0.593	0.594	0.669	0.717	0.701

$*P < 0.05$, $**P < 0.01$

coefficient on the treatment indicates that cereal banking reduced inter-seasonal price changes by an average of 41 %.

Similar to findings in another study (Oguoma et al. 2010), our results show that the speculative behavior of middlemen increases inter-seasonal food price variability. The influence of middlemen on the market, prices, and food security at the local level is debatable; most evidence indicates that middlemen exploit farmers and erode profits. Oguoma et al. (2010) argued that the intervention by middlemen increases buying prices for consumers and reduces selling prices for producers, lowering the farmers' profit margins. Often the middlemen engage in temporary arbitrage (Kent 1998), which may also cause the food prices to increase further. This negatively affects the food security of farmers, who shift from being net seller at harvest to net buyers during the lean periods (Bhattamishra 2012).

The district dummies in the fixed-effect model highlighted the importance of double cropping, a practice applicable to district 9 (Fulladu East). In contrast to district 1, district 9 saw a reduction in the inter-seasonal price deviation and food gap.

Other social indicators are changes in demographic characteristics, population growth, and membership in Ward Development Committee (WDC)—a proxy for social capital (Jaimovich 2012). The cereal banking scheme provides a platform for debates about community actions, and gives members an opportunity to organize and manage a program for their community. Over time, the social interaction within a community may enhance intra-village social relations and build the capacity of the community to participate and contribute to other development initiatives.

22.5 Conclusion

The results support the hypothesis that cereal banking is an important part of enhancing the food and nutrition security of communities by improving food availability, accessibility, and stability. Cereal banking could reduce food price variability and food gap by more than 25 %. This can be attributed to communities having sufficient food during the lean periods, thus reducing speculations.

While community cereal banking schemes may be effective in addressing inter-seasonal price variations and idiosyncratic risks, they are less effective against covariate risks, especially climate risks. In addition to the risk of embezzlement, there is a high failure rate during periods of poor rainfall.

The results of the propensity-score matching analysis emphasize the need to target a program at appropriate villages based on village characteristics, which influence the choice, sustainability, and impact of the program.

Compared with food aid or humanitarian aid, cereal banking is a more engaging solution that helps vulnerable communities to secure their livelihood and build up their resilience. It empowers affected households to participate and take up ownership. Thus, it could be an effective and participatory channel for food aid delivery during drought. This is very important because price and climate risks are reoccurrences (Cortès and Carrasco 2012).

While food reserves at the macro level require more careful management and present a large logistical and financial challenge, cereal banking at the community level has the unique advantage of being less cumbersome—the closer proximity to vulnerable communities results in lower transportation and administrative costs (Coulter 2009).

Appendix

Table 22.5 Test of differences (matched treated and control villages)

Variable	Sample	Treated	Partial control	*T*-stat	Treated	Pure controls	*T*-stat
Coefficient of variation—price	Unmatched	0.2647	0.2428	2.92	0.264	0.247	1.68
	Matched	0.2644	0.2625	0.19	0.264	0.266	−0.18
Poverty index	Unmatched	0.7061	0.6543	2.7	0.7061	0.6604	2.262
	Matched	0.7061	0.732	−1.23	0.7061	0.705	0.053
Millet grown	Unmatched	227.289	148.82	2.15	227.29	170.247	1.41
	Matched	227.289	221.77	0.08	227.29	178.034	0.8
Availability of fruit trees	Unmatched	4332.19	5795.61	−1.61	4332.191	5281.032	−1.13
	Matched	4332.19	3811.68	0.76	4332.191	3165.702	1.83
Pp of crop farmers	Unmatched	0.9657	0.921	4.14	0.966	0.927	3.76
	Matched	0.96574	0.9681	−0.41	0.966	0.97	−0.83
Av. HH size	Unmatched	11.419	11.12	0.62	11.419	11.245	0.35
	Matched	11.419	11.64	−0.33	11.419	11.71	−0.44
No daily market	Unmatched	81.476	62.65	4.24	81.477	66.731	3.46
	Matched	81.47	82.54	−0.27	81.477	80.683	0.2
Distance from market	Unmatched	43.308	41.83	0.55	43.309	40.949	0.9
	Matched	43.3	45.168	−0.77	43.309	44.634	−0.53
HHs without improved transport	Unmatched	98.22	91.72	3.43	98.23	92.968	3.06
	Matched	98.229	97.668	0.54	98.23	97.415	0.72
Remote and upland villages	Unmatched	0.5106	0.4108	1.31	0.5546	0.4208	1.88
	Matched	0.5106	0.5106	0	0.5546	0.55	0

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23 Stocks and Storage Behavior of Traders in Ghana: Insights from a Trader Survey

Lukas Kornher and Felix A. Asante

23.1 Introduction and Motivation

Grain markets in many African countries exhibit large price volatility which is driven by strong seasonality. Seasonal production and limited storage are identified as major causes of intra-annual price variation (Jones 1972; Sahn and Delgado 1989). Price spikes often occur as a consequence of stock-outs at the end of the marketing season (Shively 2001; Osborne 2004; Tadesse and Guttormsen 2011). The adverse consequences of seasonal hunger and poverty are well acknowledged, and functional markets are recognized as a prerequisite to resolve these problems (Vaitla et al. 2009; Maxwell 2013; van Campenhout et al. 2015).

The structure and efficiency of markets have been improving since the liberalization process in the 1980s. But the price surges and international food crisis in 2007/2008 brought grain marketing and public intervention back on the agenda of policymakers around the world (Kaminski et al. 2014). This is partly driven by the lack of confidence in free markets and the competitive behavior of traders (Osborne 2005; Sitko and Jayne 2014) and a growing fear for the political economy of food prices (Arezki and Brückner 2011; Brückner and Ciccone 2011). Governmental interventions in the form of price stabilization programs and trade policies are often made without profound knowledge of the marketing system. "Under these circumstances, [...] interventions [are likely to] impair the functioning of the system more than they improve it" (Jones 1972, p. 4). Thus, evidence-based research is

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indispensable to endow policymakers with adequate information so that they can design successful agricultural policies aimed at enhancing food security.

In this study, Ghana is chosen as a country case study as it is a typical sub-Saharan African country in many respects. Although the country has made considerable progress in poverty alleviation and the fight against hunger over the past 20 years, food price volatility in the country remains among the highest in the world, and seasonal food insecurity prevails in many parts of the country, especially the north (Quaye 2009). On the other hand, Ghanaian markets are at a crossroad. Wheat and rice imports are becoming more important with a growing free-spending middle class. Poultry and fish farming as well as increasing demand for processed food items shifts market shares toward the industrialized food sector. These changes will undoubtedly make an impact on the traditional marketing system.

The empirical literature on grain markets in Ghana is divided. On the one hand, time series econometrics approaches are used to explain the dynamics and variability of wholesale market prices (Alderman and Shively 1996; Shively 1996, 2001) and spatial market integration (Badiane and Shively 1998; Abdulai 2000). All of the above-mentioned studies focus on maize, the most important domestic crop in Ghana. On the other hand, market analyses based on survey data stress the role of the various actors in the value chain. Much of these studies are of qualitative nature and give insights on marketing channels, spatial trade patterns, and transaction costs (Alderman 1992; Armah and Asante 2006).

None of the existing studies examine storage behavior of larger wholesale traders and companies in order to predict national stocking trends, which is the main objective of this chapter. This is of particular importance since wholesale traders play a key role in guaranteeing sufficient food supply throughout the year. The present work fills this gap in the literature by evaluating primary data collected from July to November 2013. This contains quantitative data from a survey among wholesale traders with significant storage capacity on their operation in spatial trade and intertemporal storage. Qualitative interviews were conducted with processing companies, market experts, and other relevant stakeholders. The information is put into context and policy implications are deduced. In doing so, the findings can also be seen as a starting point and input for future research.

23.2 Price Instability and Trade Patterns

There is a natural imbalance between the production and consumption of agricultural commodities. More specifically, consumption is primarily stable, while production is highly volatile, in particular in rainfed agricultural systems, which are the predominant type of agricultural system in many African countries. Therefore, commodity prices are subject to natural instability. Besides, the seasonality of production requires intertemporal arbitrage and causes a deterministic price gap between harvest and lean season, owing to the costs arising from storing food between the seasons.

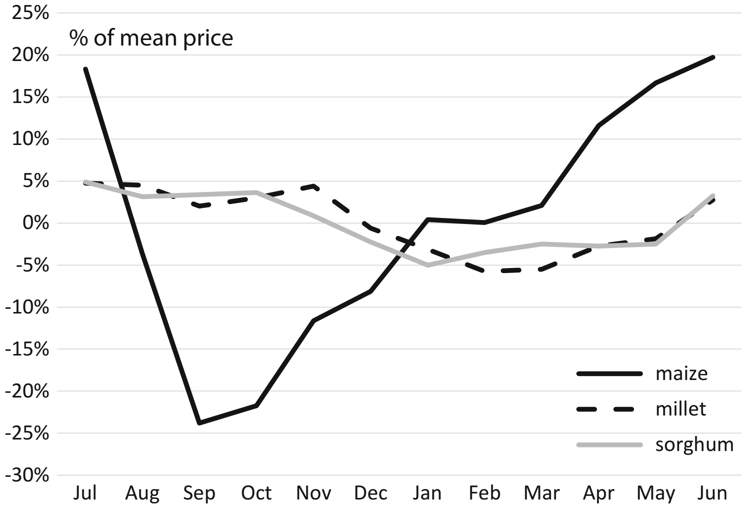

Fig. 23.1 Seasonality of local staples. *Source*: Authors' computation based on SRID (2014)

Ghana is no exemption in this respect. In order to distinguish irregular price variability from the fixed seasonal trend, we applied an Unobserved Component Model to market-level wholesale price data. The average seasonal price trend for locally produced grains is shown in Fig. 23.1.

Seasonal price instability is highest for maize, with a seasonal gap of more than 40 %, followed by millet and sorghum, with around 10 %. As proposed by the theory of storage, the inter-seasonal price gap is solely attributed to the cost of storage, since market demand and supply equate prices between two periods. (Williams and Wright 1991). Alternatively, market failures, such as the lack of insurance markets to hedge against price risks, are identified as the reason for limited storage, causing inadequate supply (Newbery and Stiglitz 1981). In line with this, wholesale market prices exhibited at least three major price spikes during the last 15 years. All these spikes were transitory and persisted for 1–2 months only. This hints at temporal supply shortage at the end of the marketing year as a consequence of traders' stock-outs (Shively 2001).

Generally, markets within Ghana are found to be well connected, but high transportation costs (due to poor infrastructure) impede full market integration (Abdulai 2000; Quaye and Ameleke 2008; Cudjoe et al. 2010) and link asymmetric adjustment between prices in the central and local markets to inventory adjustment of traders. Therefore, storage decisions are made by taking into account the current and future prices at distant markets, which affect stocking decisions via spatial and temporal arbitrage conditions, as illustrated in Fig. 23.2.

In addition to this, prices are driven by annual domestic production levels and the prospect of speculative exports to neighboring countries (Shively 1996). International prices are likely to have limited impact on domestic price dynamics,

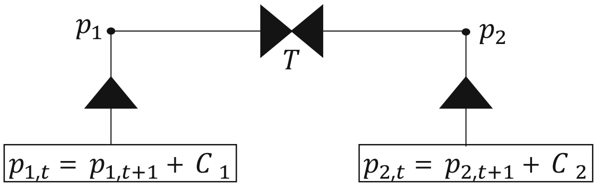

Fig. 23.2 Schematic representation of equilibrium price equations. *Source*: Adapted from Roehner (1995). *Note*: T denotes transport costs between market 1 and market 2, while C_1 and C_2 are costs of storage in both markets. In theory, spatial and intertemporal arbitrage take place only when price differentials exceed costs. The equilibrium price conditions induce interdependencies between current and future prices in different markets

which is related to the minor relevance of international and regional imports (Conforti 2004; Cudjoe et al. 2010).[1] By contrast, domestic rice production makes up only about 30 % of the total national supply, causing local rice prices to follow the price dynamics of imported rice without noticeable seasonality (Amikuzuno et al. 2013). A 20 % import tax (10 % for wheat) is imposed on all food commodities; the import duty was suspended for rice in 2008 and 2009. In addition to that, port charges further increase the price of imports and limit the linkage to international prices (Minot 2011).

Last, food markets in Africa are often publicly regulated by national food companies that are also involved in food marketing. Historically, Ghana's agricultural sector has been characterized by large state involvement by the Ghana Food Distribution Cooperation (GFDC) and the Grain Warehousing Company (GWC).[2] After a short period of complete market liberalization, the National Food Buffer Company (NAFCO) was founded in 2010 to manage the country's emergency and intervention stock. Public stocks are accumulated through market purchases at predetermined prices, while distribution is arranged when market prices exceed target thresholds. Benin et al. (2012) review the operations of NAFCO but are unable to assess its impacts on price dynamics. The main problem is the non-transparency in the operational decision-making by NAFCO. However, target stock levels only represent a small portion of the annual production, and thus NAFCO's purchase and release decisions are unlikely to influence market prices directly.[3] In contrast, the determination and public announcement of the minimum guaranteed price (paid

[1]Food prices are also affected by high inflation pressure, which is considered the major challenge to macroeconomic stability. After a short period of single-digit inflation, the growth rate of the consumer price index has returned to a level of above 10. In accordance with this, the Ghana Cedi (GHS) has depreciated greatly since 2013. The exchange rate is free-floating since 2006, while a redenomination was implemented in 2007 by canceling four digits (1 GHS = 10,000 GHC). GHC: Ghana Cedi; GHS: New Ghana Cedi.

[2]See Sijm (1997) for a comprehensive overview.

[3]NAFCO stock levels are (1) operation stocks, maize (30,000 mt), rice (15,000 mt), and soybeans (1000 mt), and (2) emergency stocks, maize (10,000 mt), rice (10,000 mt), and soybeans (1000 mt).

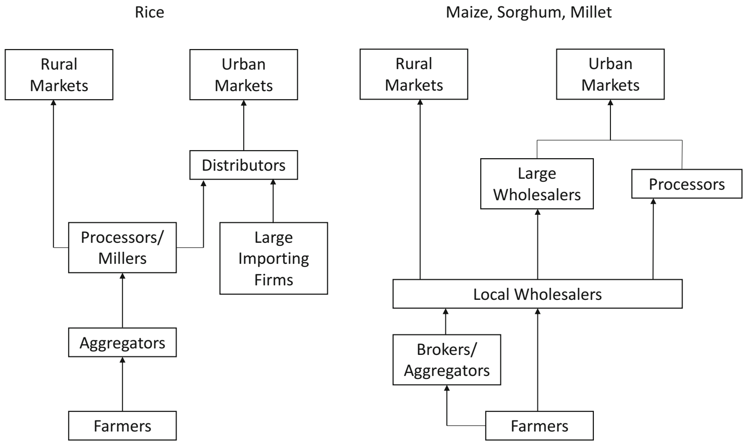

Fig. 23.3 Outline of the value chain of important staples. *Source*: Authors' illustration

to farmers) have an impact on markets because they can strengthen the bargaining position of farmers in negotiations with traders.

The differences between rice and the three other food commodities—maize, sorghum, and millet—are also reflected in the characteristics of their respective value chains, which are depicted in Fig. 23.3. The distribution of imported rice differs substantially from the marketing of locally produced crops. A few large importing companies divide the majority of the market among themselves (Kula and Dormon 2009). They sell their rice stocks to wholesale traders and supermarkets around the country through their wide local distribution network, but they also run their own outlet stores. Their business activities are highly industrialized and include the operation of large warehouses around the country.

In contrast, the locally produced rice is usually marketed via two distinct channels: first, through aggregators and local wholesalers/processors for sales in rural markets; second, via larger wholesale traders to markets in urban centers. For small and medium size farmers, rural assemblers act as collectors who aggregate surpluses and then sell them to wholesalers in larger towns. Then, wholesale traders sell the produce not only to processors, millers, and retail traders but also directly to consumers. In contrast, larger farmers tend to sell their produce directly to wholesale traders. Maize, sorghum, and millet also pass through the hands of the food industry on their way to becoming final consumer goods; the proportion of formal trade for maize is substantially higher than for millet and sorghum.

Since no value is added to the commodity by having multiple agents involved in the value chain, farmers earn higher profits when selling to wholesale traders directly (Sitko and Jayne 2014). Furthermore, the literature acknowledges that traders play an important role in the functioning of markets in that they provide farmers with inputs and credits (Antons 2010; Sitko and Jayne 2014). There is also little evidence that the market structure of domestic grain trading is noncompetitive, apart from the high concentration among few large rice-importing firms (Abdulai 2000; Swinnen et al. 2010; ACET 2014). It is to note that retailers in urban centers usually organize themselves into associations. In doing so, market queens, the elected heads of these female retail trader groups, have manifested themselves as an influential counterpart to wholesale traders (Langyintuo 2010).

Transporting commodities from surplus regions in the middle belt and the northern part of the country to consumption and industrial centers is the major challenge for a long-distance trader. Poor road infrastructure is reflected in the long travel times needed for a relatively short distance. Compared with the well-understood structure of the value chain, research about how marketing and trade flows change in the course of a year is still lacking. In other words, it is clear how grain finds its way from producers to consumers, but little is known about how the grain gets from harvest to lean season. Precisely, the agent who stores the grain and the amount and time frame of storage are still unknown. Furthermore, the heterogeneity among wholesale traders is not well considered.

To understand both the spatial distribution and seasonal patterns of storage behavior, it is crucial to start by examining the marketing behavior of farmers. Without providing exact figures on the quantities, farmers' sales of all types of grains exhibit strong seasonality, with a peak after harvest (GSS 2007; Chapoto et al. 2014). From past surveys, it is well known that only a portion of production is formally traded (Armah and Asante 2006; EAT 2012). Therefore, the actual share of stocks held by traders is presumably low (Jones 1972; Alderman 1992). In contrast, the observed increment in the market purchase made by farmers indicates that commodities must be stored somewhere and then sold back to farmers at the end of the marketing year (GSS 2007; Chapoto et al. 2014).

Moreover, there are also massive changes happening in Africa's food marketing. On the one hand, the introduction of modern telecommunication technologies drastically reduces transaction costs (Overa 2006; Tack and Aker 2014) and also eases market access for farmers and small traders. On the other hand, food markets are becoming increasingly industrialized. The number of supermarkets is growing, and with it comes an increasing demand for processed final consumer goods. For this reason, food processing companies are increasing their production volume and claiming a larger share of marketed production. This has wide-ranging consequences on grain marketing. First, the industrialized sector prefers to make purchases in large quantities in order to reduce transaction costs. Second, quality standards gain importance, and this presents challenges to proper handling by value chain actors. Third, retail companies will affect the whole market structure and are likely to occupy a prominent position in the market. The trading sector will be compelled to adjust to these developments in order to preserve its role in the marketing system.

23.3 Storage Behavior

23.3.1 Description of the Data

The analysis of storage behavior in Ghana is largely based on a trader survey which provides quantitative data on grain storage and trade. The survey was undertaken as a joint research between the Center for Development Research (ZEF) and the Institute for Statistical, Social and Economic Research (ISSER) at the University of Ghana, Legon, and was held at major market sites in Ghana between August and November 2013. Subsequent to the survey, follow-up telephone interviews were conducted in April and May 2014. Qualitative information from a baseline survey in 2012 and from consulting experts during August and November 2013 enrich and underpin the quantitative data.

First, there are no business directories for traders in Ghana. The lists of traders identified during the research contained invalid phone numbers and information about companies that no longer exist. Therefore, randomization-based sampling techniques were inapplicable. Second, the total number of traders who engage in intertemporal arbitrage is not large, and a larger sample size is considered to be better. For this reason, the sampling was conducted with the intention to create a sample that is representative of the aggregate market behavior. Traders were identified using two unofficial lists: a list of NAFCO contractors published on its webpage and the business directory of Ghana Web, an online news platform.[4] Contact information of traders was also obtained from governmental publications and other publicly available documents. Furthermore, snowball sampling was used in order to increase the number of respondents.

Generally, traders were contacted by phone and asked about their willingness to participate in the survey. In this way, the response rate was close to 100 %. For the follow-up telephone interviews, the respondents of the first survey were contacted. The interviews were structured as follows: First, general information on the enterprise was collected. The second part of the interview aimed at obtaining a general overview of grain trading activities. The heart of the questionnaire was the section about storage activities; in this section, respondents were asked to state their purchases and historical inventory levels during the prior marketing year, that is, 2012/2013. Third, respondents were asked to evaluate specific statements to deduce their perception of risk associated with storage. Last, the interview ended with a survey on the traders' expectations of future price changes, and this section also assessed the traders' market knowledge of tariff rate and historic rainfall and geographical production patterns. Moreover, the telephone interview also asked traders to evaluate specific factors that influence price dynamics and induce market risk. The interview also attempted to obtain information on different cost components.

[4] Available at http://www.ghanaweb.com/GhanaHomePage/telephone_directory/.

In total, 36 traders were surveyed in the first round. Only 20 traders were ready to answer to the telephone questionnaire. Several qualitative interviews were also conducted; most notably are interviews with processing companies and practitioners. Since farmers hold a substantial amount of stocks, it is essential to incorporate their behavior into the analysis. The Ghana Living Standard Survey (GLSS) contains an exhaustive section on agriculture, including a section on the seasonality of sales and market purchases. Nevertheless, a few qualitative interviews with farmers and farmer associations were conducted. The ZEF-ISSER Trader Survey is different from most existing trader surveys in two respects. First, this survey focused on interviewing traders who engage in intertemporal arbitrage rather than spatial arbitrage or retailing. Second, related to the first point, intertemporal arbitrageurs who own or rent warehouses are sometimes large companies which are also involved in other businesses. Consequently, the average storage capacity of the respondents is around 10,000 metric tons (mt), and roughly 60 % of the traders had at their disposal storage facilities of 500 mt and above. Apart from inference about the aggregate storage behavior of the market, information on individual stocking trends and trader characteristics allows individual trading behavior to be analyzed in more detail. For this reason, the presentation of research findings from the survey is divided into these two aspects.

23.3.2 Motives for Trader Storage

23.3.2.1 Speculative Storage

As predicted by the economic theory, the most prominent motive for storage is the speculation on a future price increase. Speculation is defined as the engagement in risky transactions to benefit from fluctuation in market values. The supply of storage model is extensively discussed in the literature and widely accepted as best way to describe the price dynamics of storable commodities. In brief, storers would choose to provide additional storage as long as the marginal costs of storage do not exceed the expected return from storage in the subsequent period. Generally, it is possible to hedge against any risk associated with storage by trading future contracts or through informal forward contracting. In this way, the price risk is transferred to another institution. However, commodity exchanges and forward contracting are uncommon in most developing countries. Anticipated stocks are a special variant of speculative stocks. They are not held for speculation of higher prices but in anticipation of changes in demand (Minner 2000). Rice traders in Ghana reported keeping anticipated stocks by increasing their stocks before Christmas and Easter to satisfy the increase in demand (ZEF-ISSER Trader Survey 2013).

Speculative storage should not be confused with hoarding, which food traders are often accused of in times of scarcity in the market. The literature defines hoarding as excessive speculation. In theory, hoarding can only arise from imperfect competition (Osborne 2005) or overestimation of price changes (Ravallion 1985). Under the intertemporal arbitrage condition, two major determinants of storage quantity are price expectations and storage costs. Storage costs are high in many developing countries due to high interest rates. Ghana is no exemption in this respect (Armah and Asante 2006). Therefore, the amount of stocks in Ghana is likely to be substantially lower than in industrialized countries. Commodity prices in Ghana remain largely driven by seasonality (with the exception of rice), as discussed in the previous section. For this reason, speculative returns are unlikely to be realized from interannual storage. The only justification for speculative stocks at the end of the marketing year is given by uncertainty about the timing of the next harvest (Peterson and Tomek 2005). In contrast, high seasonal price variation generates a great opportunity for traders to benefit from intra-annual price changes. In theory, everyone who possesses stocks can participate in speculation. In reality, however, because speculation binds capital for a longer period, mostly larger and highly liquid enterprises are capable of speculative storage. Indeed, the survey reveals that traders who speculate also diversify their risks by being involved in spatial trading to realize low-risk profits. The respondents also noted that stocks need to be depleted before the end of the marketing year because of an anticipated decline in market prices (ZEF-ISSER Trader Survey 2013). In a typical marketing year, speculative stock levels are expected to be highest when prices are lowest. However, traders prefer to store grain stocks at lower moisture levels. For this reason, maize harvested in August/September in the southern parts of Ghana is usually not kept for long, and existing stocks are depleted again before the next harvest comes in.

23.3.2.2 Safety Stocks

Safety stocks are mainly known from the logistic and supply chain management literature. They are describe as extra stocks that are carried to moderate the risk of stock-outs and associated incapability to satisfy demand. The need for safety stocks arises from uncertainty in demand and supply (Guide and Srivastava 2000). Since inventory holding is costly, safety stocks should be kept at a minimum. Optimal safety stocks are chosen depending on uncertainty in demand, supply, and processing time (Minner 2000). In contrast to speculative stocks, safety stocks are not related to expected future prices but rather to the quantity demanded from the enterprise. In the context of Ghana, two types of market participants are likely to carry safety stocks: processors and animal feed manufacturers and traders, especially retailers. A trader survey conducted during October 2013 by the World Food Program (WFP) found replenishment times of the vast majority of retailers and wholesale traders who responded to be below 1 week (WFP 2014). This indicates that the retailers and wholesale traders attempt to possess sufficient stocks at all times. An explanation may be the high importance of maintaining a continual business relationship by fostering confidence through short-term deliveries. This is evident in that 19 out of 36 respondents ranked “the risk of losing business partners when stopping to supply for 3 month” as a high risk (28/36 as medium or high risk) in the ZEF-ISSER Trader Survey, in particular those traders who are less likely to hold speculative stocks. Retailers hold safety stocks to foster long-term relationship with customers. Consumers who are unable to find what they want in a retail shop will presumably buy the goods elsewhere and are less likely to return to the shop because they expect not to find the goods there again. Fafchamps

(2004) emphasizes contractual risk in many African countries as the cause of traders keeping large inventories. The risk of late delivery and poor-quality goods drive firms that experience late delivery to hold more than two times more stocks than firms that do not encounter late delivery. Processing firms in Ghana stated that they have enough inventories to sustain production for 1–2 months (ZEF-ISSER Trader Survey 2013). The rise of supermarkets in many African countries in the past years has changed the agro-food system dramatically, causing a shift toward a greater variety of products. Van Donk (2001) projects that the level of safety stocks will increase in order to satisfy the demand for multiple food products at the same time. By definition, safety stock levels are roughly constant throughout the year and will never fall to zero since they are independent of current market prices. However, stock levels are likely to increase by the end of the marketing year as low availability makes input supply uncertain.

23.3.2.3 Aggregation Stocks

The literature on grain marketing in developing countries emphasizes the importance of small-scale traders at village and town level. They play an important role when many farmers do not have access to markets or the costs of traveling to the market are prohibitively high (Sitko and Jayne 2014). As described above, these assembly traders sell their goods to larger wholesale traders, who transport commodities across the country. The aggregation of stocks is an artifact of the characteristics of the value chain. Wholesale traders are likely to collect only larger quantities from village- and town-level markets. Thus, assembly traders aggregate stocks in order to ensure that the transaction process with their trading partners remains efficient. The aggregation of stocks can also occur at central markets when wholesale traders are asked to aggregate large quantities of stocks (more than 1000 mt) for industrial consumption or purchases made by NAFCO and the WFP, as reported in the survey. This form of stock aggregation is usually performed only when the purchase of the aggregated stocks is guaranteed or even pre-financed. The nature of this form of trade means that stocks will be totally depleted when the target quantity is reached and the goods are delivered to the contractee. There are no reasons for traders not to repeat the procedure several times in the course of a year, yet traders make sure that their stocks are depleted before stocks from the new harvest comes in.

23.3.3 Operational Costs

The profitability of storage depends on the costs of operation. Traders incur direct costs from marketing, transport, and storage (Angelucci 2012). Cleaning, drying, and packaging are usually done at the farm level before the produce reaches the market. The main challenge of proper handling is to reduce the moisture content of fresh crops for storage to decrease the incidence of discoloration (Armah and Asante 2006). In some instances, traders support farmers in this process by providing drying facilities or functional bags for adequate storage (Antons 2010).

Table 23.1 Transport costs on selected roads in May–June 2011

Route	Bag (kg)	Price/bag	Price/mt	Distance	Cost mt/km
Kumasi-Accra	50	2.31	46.28	272	0.17
Kumasi-Tamale	50	2.9	57.83	382	0.16
Kumasi-Ejura	50	3	60.16	98	0.61
Kumasi-Nkoranza	50	3	60.16	150	0.4
Kumasi-Wenchi	50	2.31	46.28	155	0.29
Accra-Tamale	50	4.04	80.98	654	0.12
Wenchi-Sunyani	130	6.94	53.39	97	0.56
Wenchi-Techiman	130	4.63	35.59	29	1.23
Wenchi-Accra	130	11.57	88.98	427	0.21

Source: World Bank (2012). *Note*: Prices converted to GHS with the market exchange rate of 1.74 GHS/USD

The postharvest losses of traders are substantially lower than the losses incurred when produce is kept on-farm since traders usually have at their disposal proper storage facilities and information about appropriate handling. On the other hand, traders have to take additional costs into account. First, storage in warehouses and the treatment of stored commodities are costly. In addition, traders incur the opportunity cost of capital. Last, traders usually bear the costs of transporting goods to their storage facilities and, after storage, to their customers; this includes the loading at point of departure. Exact estimates of transport and storage costs are difficult to obtain and also vary by orders of magnitude and in terms of quality (ZEF-ISSER Trader Survey 2013).

Table 23.1 presents the surveyed transport costs for frequently used destinations in Ghana in 2011. The unit cost of transporting over short distances is more expensive than transporting over standard trade routes between the urban centers Tamale, Kumasi, and Accra. Generally, the transport costs are significant when measured against the wholesale price of a mini bag of maize (50 kg; 30–35 GHS) and maxi bag (130 kg; 40–80 GHS) at that time. During the field survey, loading costs were reported to be 1 GHS for a maxi bag.

The per-unit storage costs cannot be easily calculated.[5] Therefore, in the interview, traders were asked how much they need to add to the purchase price in order not to make any losses (1) if they buy and immediately sell and (2) if they buy, store for 3 months, and then sell. In the latter case, the reported amount should yield the sole costs of storage without the trader's markup, while in the former case, the reported amount captures mainly the transport costs and also the fixed costs of administration and marketing. The results are reported in Table 23.2.

Transport and administrative costs reported are in gross accordance with the costs estimated by the World Bank (2012). Large firms in Accra and Kumasi reported the smallest amount of storage costs, which is unsurprising. Conversely, it is striking

[5]Due to the large share of fixed costs

Table 23.2 Transportation and storage costs from trader survey

Description	Reported costs
Large firms in urban centers	Storage costs: 12–18 GHS per ton
	Transport and admin costs: 25–30 GHS per ton
Traders in Brong-Ahafo	Storage costs: 1–1.5 GHS per 50 kg
	Transport and admin costs: 1–2 GHS per 50 kg
Traders in the Northern Region	Storage costs: 2–8 GHS per 100 kg
	Transport and admin costs: 5–12 GHS per 100 kg

Source: ZEF-ISSER Trader Survey (2013). *Note*: Differences across crops could not be observed, but the sample size for rice and soybeans was small; traders choose their preferred unit to report the costs

that the transport and administration costs are much higher than the storage costs for 3 months.[6] A comparable proportional relationship between the transport and storage costs can also be found in other studies (e.g., Angelucci 2012; EAT 2012; Angelucci et al. 2013). From our own survey, it can be deduced that the total operational costs constitute between 5 and 50 % of the purchase price.

In Ghana and elsewhere, it is generally observed that storage facilities are built to exploit economies of scale (Monterosso et al. 1985) or the proximity to processing companies in urban centers (EAT 2012). Benirschka and Binkley (1995) explain this phenomenon by the presence of opportunity costs that decrease with distance to the producing market. In consequence, market supply takes place in a sequential manner. Firms located far away from the market release their stocks only after those firms located closer to the market have fully released their stocks. This implies that as soon as grain supply in production regions is exhausted, grains will be transported back from urban centers to rural markets. In this way, transport costs are incurred twice: initially when grain is shipped from rural to urban areas after harvest and subsequently in the reverse direction during the hunger season (Barrett 1996).

Taking into account the high costs of transport, traders need to increase their sales price in order to break even. In light of this, seasonal price changes of around 50 % in selected years appear quite reasonable, and thus transport costs are a potential driver of the high seasonality of prices. Conversely, the costs of storage alone (excluding transportation costs) cannot account for the strong seasonality in prices.

23.3.4 Aggregated Results: Seasonality in Storage and Trade

The aggregated turnover of the survey respondents represents a significant portion of the total quantity marketed for rice and maize only.[7] The figures presented in Table 23.3 suggest that sorghum, millet, and soybeans pass through the hands of

[6]The figures should be interpreted cautiously with respect to the total size of the cost reported.

[7]Turnover is the total purchase of a trader within one marketing year.

Table 23.3 Stylized facts of grain markets and survey

	Maize	Rice	Sorghum/millet	Soya
National consumption 2013 (FAO GIEWS)	1,700,000	950,000	450,000	150,000
National production 2013 (FAO GIEWS)	1,800,000	300,000	470,000	150,000
Industrial use	20	n.a	n.a.	70
%—formally traded	50	>80	<20	85
No. of traders in sample	29(+2)	14(+8)	3	11
Turnover captured by the survey	94,000	377,000	–	7400

Note: Figures for soya are from MoFA (2013). The quantities for soybeans refer to raw commodities. Instead, soybean cake and oil are also imported. Estimates on industrial use are taken from EAT (2012). () indicate number of traders that purchase yellow maize and imported rice, respectively

wholesale traders less often than maize and rice. In addition, soybeans are used for human consumption only to a small extent. The figures indicate that processing firms, rather than traders, are largely involved in the storage of sorghum, millet, and soybeans. Therefore, the subsequent discussion is limited to maize and rice.

The sample cannot be considered representative with regard to the composition of the traders. Large wholesale companies are overrepresented, while the portion of traders with a capacity of a few dozen bags was relatively too small. The respondents of the survey purchase and sell commodities to different market actors. While the vast majority of the respondents buys their commodities from farmers or aggregators, about half of the respondents also purchases from other wholesale traders. With respect to sales, only seven respondents sell to consumers directly. In contrast, the vast majority interacts with other wholesalers, processing companies, and retail traders (ZEF-ISSER Trader Survey 2013).

The first indication of the seasonal variability of stocks is shown in Fig. 23.4, which illustrates the best time to stock in and to release stocks as specified by the survey respondents. For maize, stocking-in mostly takes place from August to September and November to January. This largely corresponds to the time of harvest, and thus the time of the year at which prices are lowest. Interestingly, some traders continue to build stocks throughout the year. In line with this, stock releases also occur throughout the year. Nevertheless, most traders prefer to sell their maize stocks from April to June in order to benefit from higher prices at that time. Results for rice are different. Stocks of imported rice exhibit less intra-annual variation apart from the fact that stocks are built before Christmas to satisfy the increasing demand. In contrast, traders stock up local rice between November and January with the intention to sell the local rice between March and June; this exemplifies the seasonality of rice prices.

Seasonal variation of actual stocks is deduced from the survey in the following way. First, stock levels of respondents are interpolated in order to fill gaps in the questionnaire. Second, estimated stock levels are aggregated by commodity. In doing so, large wholesale traders carry over-proportional weight, while stocks of smaller traders hardly change aggregated stock level. Figure 23.5 shows the

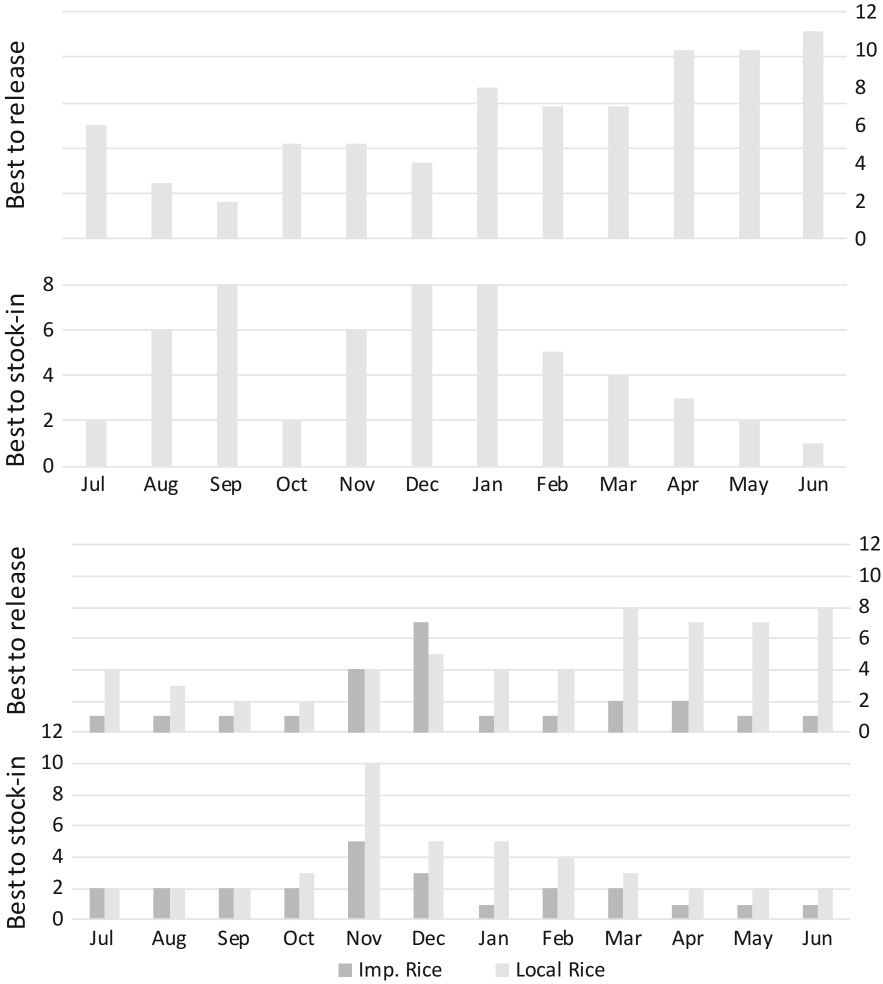

Fig. 23.4 Best time to stock in and stock out (no. of respondents). *Source*: ZEF-ISSER Trader Survey (2013)

seasonality of the observed stocks within the survey period. The estimates are in accordance with the preferred time of stocking-in and releasing stocks.

For maize, this is an increasing function until February/March. Maize stocks were accumulated in the course of the year and distributed toward the new harvest season. Over the survey period, maize stocks vary significantly between 10,000 and 45,000 tons. It seems that on-farm stocks dominate at the beginning of a marketing year, and trader stocks take over only in the last few months before the next harvest. This observation is different from what is known about traders' storage pattern in other countries, whereby stocks are usually highest after harvest and decline

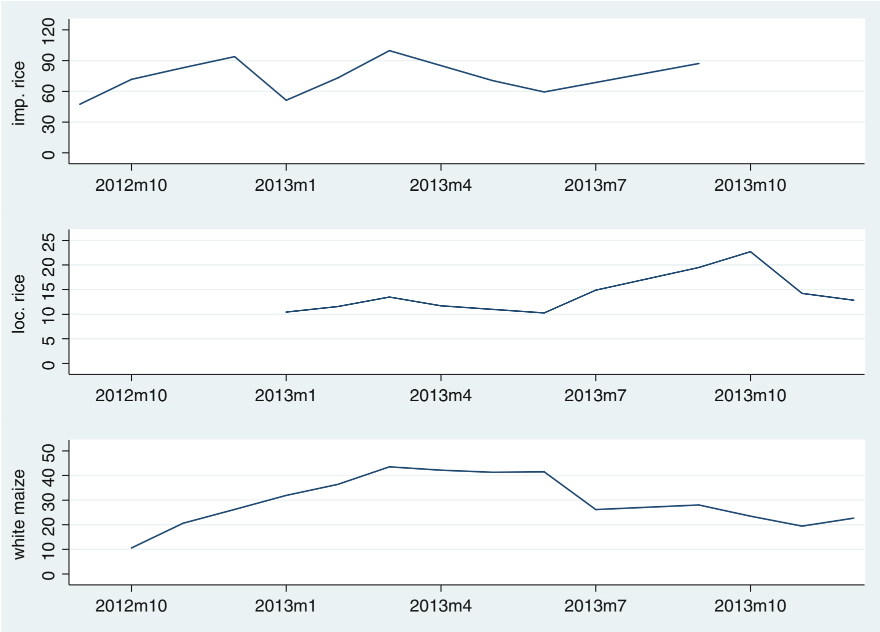

Fig. 23.5 Aggregated stock trend (in 1000 mt). *Source*: ZEF-ISSER Trader Survey (2013)

throughout the year.[8] From the qualitative interviews, we know that the safety stocks of maize processing companies are able to sustain their total production for 1–2 months. With the knowledge that 20 % of the total national consumption is used for industrial use, the level of stocks held by processors is estimated to be 40,000 mt. Similarly, we can estimate the amount of stocks held by retail traders from the daily consumption needs of the market.[9] Assuming that retailers hold enough stocks for 5 days, the national aggregate for retail trader stocks would be around 12,000 mt. Therefore, even if the survey respondents represented a large share of the market, wholesale traders would still carry the largest amount of maize stocks compared to other market participants.

Unlike maize, rice stocks did not show a similarly strong seasonality. Imported rice stocks were built up before Christmas and Easter and declined as a result of releases during festival time. Local rice stocks did not exhibit similar peaks around Christmas and Easter. On the contrary, the stock level reached its lowest point in June, and before that, rice was constantly accumulated. Similar to maize, local rice is processed, and millers are expected to also hold stocks throughout the year. The

[8]For example, see private stock data on South Africa by South African Grain Information Service (SAGIS).

[9]This is achieved by dividing the amount of maize marketed (850,000 mt) by 365 days.

same applies to both the imported and local rice stocks of retail trader. However, wholesale rice traders carry by far the largest amount of stocks throughout the whole year. Due to imports constituting a large share of the total rice stocks, rice stored by farmers is not important for rice.

23.3.5 Micro Results: Heterogeneity of Traders

Seasonal patterns of storage provide interesting insights into the market behavior on the national scale. The diversity of storage motives, as elaborated earlier, suggests heterogeneity in storage strategies among traders or groups of traders. In this section, we assess whether these differences are actually observable and discuss possible explanations. Individual stock-holding patterns by traders are shown in Figs. 23.6, 23.7, and 23.8.

A single common storage strategy cannot be observed among maize traders. By contrast, similarities in the behaviors of imported rice traders can be observed. None of the traders have entirely depleted their stocks in the course of the observation period. Furthermore, all traders tended to increase their stock level toward the end of 2013. Like maize, heterogeneous patterns can be observed in the stock level of local rice, apart from an increase in the stock level between September and December 2013, which is common for all traders. Overall, there are similarities between the

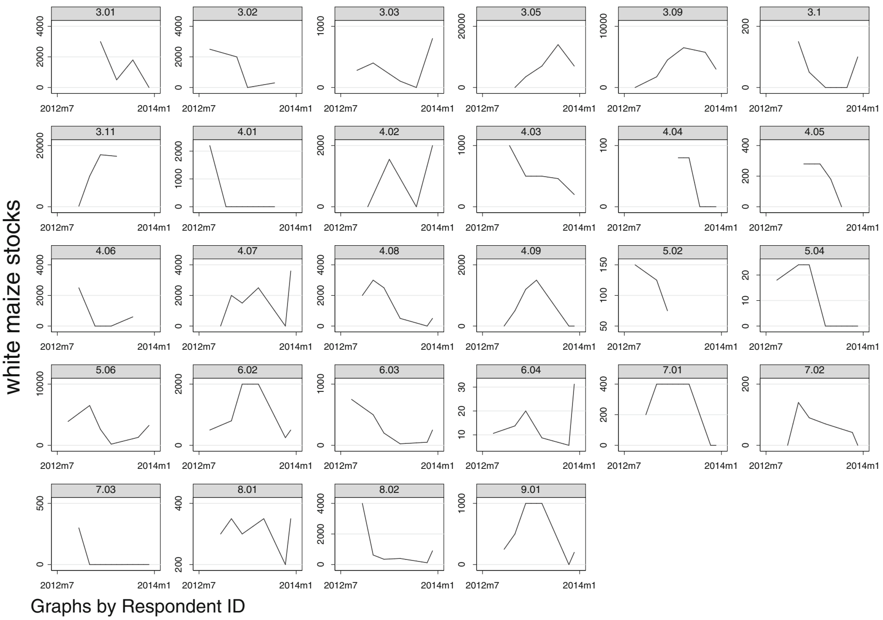

Fig. 23.6 Stocks by respondent (white maize). *Source*: ZEF-ISSER Trader Survey (2013)

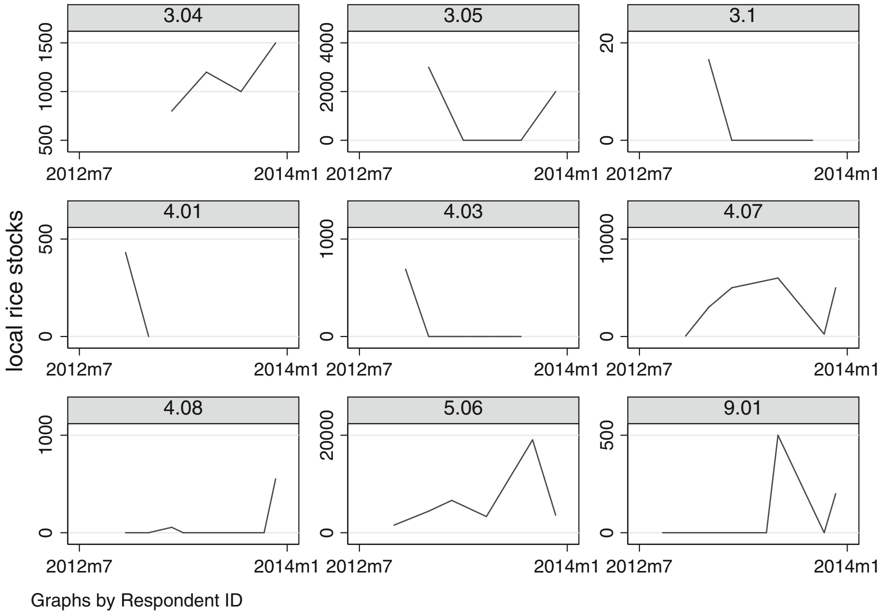

Fig. 23.7 Stocks by respondent (local rice). *Source*: ZEF-ISSER Trader Survey (2013)

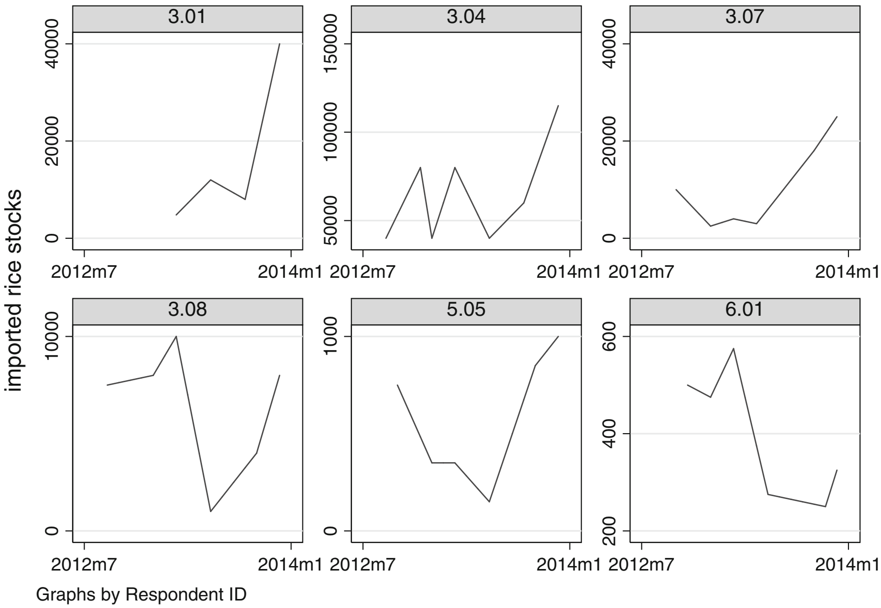

Fig. 23.8 Stocks by respondent (imported rice). *Source*: ZEF-ISSER Trader Survey (2013)

stocking trends of maize and local rice, while storage of imported rice seems to be determined by other factors.

From the discussion about storage motives, we recognize two distinct types of traders: aggregators, who accumulate predetermined amounts of stocks for delivery to their customers on a mutually agreed date; and speculators, who hold stocks to benefit from seasonal variation in prices. By contrast, we do not observe any stock trends which imply that stocks are held purely as safety stocks. This could be because the sample includes large wholesale traders but not retailers. However, it may also be because parts of the grain stocks, in particular of imported rice, are safety stocks that are held with the intention of guaranteeing continuous distribution.

To further analyze stocking patterns, we use a simple approach to differentiating stocking strategies. We distinguish between a U-shape and a reverse U-shape storage curve. A reverse U-shape curve represents the holding of stocks until mid 2013, which hints at a speculative strategy. Conversely, a U-shape curve implies purchases in late 2012 including more or less immediate sales and restocking in late 2013. The latter better describes the stocking pattern of an aggregator.[10]

Extrapolating on the stocking strategy from the seasonal variation in stocks only rests on fragile foundations. Instead, it is critical to understand what drives traders to follow a particular strategy that maximizes their profits or expected utility. In other words, what makes a trader a speculator and what makes them an aggregator or distributor. In this study, we will not go into detail on this, but we will briefly outline possible explanations, as illustrated in Fig. 23.9. Further research is necessary to validate the explanations.

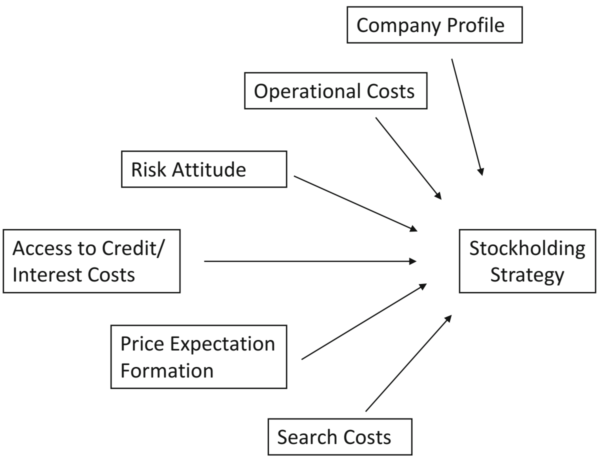

Fig. 23.9 Determinants of the stock-holding strategy. *Source*: Authors' illustration

[10]In total, we identify (U shape/reverse U shape) for maize (9/15), local rice (5/3), and soya (8/1).

The profile of a trading company includes characteristics like the field of business, legal status, and the size of the company. Many trading companies maintain other businesses besides their grain storage activity. These businesses can be closely related to storage, but this is not a sufficient condition for commodity trading activities. For instance, many rice importers in Ghana also engage in importing a variety of other goods (e.g., motorcycles). Other than that, commodity trading is considered to be an investment which yields a return on asset, like buying shares of a company. The main challenge of concentrating solely on grain trading is the cyclical nature of business earnings, which makes it particularly difficult for small traders to move into intra-annual speculations because returns are only realized at the end of the season. On the other hand, a trader in a company owned by many shareholders does not have the pressure to generate continuous revenue to make money for living. On the same account, large firms are more likely to have at their disposal sufficient financial resources to survive one or multiple years with limited business success.

Transportation and storage costs usually are the main components of operational costs. Theoretically, one would expect aggregators to have a comparative advantage in minimizing loading and transportation costs since they generate revenue from the collection and transportation of commodities only. This involves having dense networks of suppliers at village level. On the other hand, speculators are expected to face lower costs in storage activities, including the access to capital and the interest costs incurred when borrowing money to buy grains in bulk after the harvest. Differences in transportation and storage costs incurred by traders could also be attributed to traders owning warehouse structures and/or vehicles for transportation. In this case, traders are relieved of paying interest to the banks and face lesser costs of storage.

Most definitely, risk attitudes play a prominent role in business activities. Stocking commodities over a longer time period with uncertainty about future prices is riskier than spatial trading, and risk aversion will result in the reduction of storage levels when futures markets do not exist (Sarris 1984). Conversely, traders inclined to taking risks are more likely to engage in speculation without being fully certain about future prices. The heterogeneity of risk attitudes of traders has not been extensively discussed in the risk literature, which has mainly focused on farmers and small-scale traders. However, the diversity of the ownership structure of trading companies is likely to be correlated with and implies the presence of heterogeneous risk preferences.

Apart from storage costs, the classical supply of storage model links stocking decisions to expectations of future prices (Williams and Wright 1991). The traditional version of the competitive storage model is built on the rational expectation hypothesis, which implies that market actors perfectly process all available information that is relevant for the formation of prices. All associated errors are therefore considered to be random (Gustafson 1958; Muth 1961). However, the literature on economic behavior of agents identifies at least four different types of price expectations: naive, adaptive, quasi-rational, and rational expectations. The types of price expectations differ by the amount of information which is taken into account to predict the future price. The heterogeneity in expectation formation processes among traders yields a variety of views on what the future will bring and may explain why traders carry different amounts of stocks at any given time.

Furthermore, Chavas (1999) argues that gaining market information is costly and heterogeneous expectations are caused by the costs and benefits specific to an individual. On the same account, the search for price information itself can be costly. These costs reflect a trader's specific ability to process market information or the degree the trader is interlinked with other value chain actors in the marketing system, which makes it easier for him to collect information. Lower search costs allow a trader to undertake a higher investment in searching, resulting in the trader finding the best deal (Stigler 1961). In the context whereby prices are dispersed and market information is not easily accessible due to limited quality of market information systems or digital infrastructure, variation in knowledge ability is possible and might explain the different storage strategies used by traders to maximize profits or utility from their storage operations (Jensen 2007; Tack and Aker 2014).

23.4 Discussion and Policy Implications

In this chapter, the intertemporal storage behavior of wholesale traders is analyzed and discussed. Unlike earlier studies, traders are found to hold a substantial amount of grain stocks, especially toward the end of the marketing year. With the exception of imported rice, most of these stocks are held by traders for speculative reasons, with the intention of profiting from the seasonal increase in prices. Other wholesalers accumulate stocks in large quantities for sale to industrial clients. Due to the likely decline in prices with the incoming harvest in July/August, traders attempt to deplete their stocks before prices drop. However, this is often not possible in a bumper crop year. Carrying stocks over to the next marketing year is usually associated with losses. Thus, annual carry-over stocks are kept at a minimum. In contrast to maize and local rice, imported rice stocks exhibit less variation throughout the year. These stocks are built up in anticipation of demand peaks. Apart from trader storage, safety stocks are carried by industrial producers to guarantee that their production can be maintained even when facing delivery problems. Safety stocks are also held by retailers to satisfy market demand throughout the year.

An additional finding of the survey is the heterogeneity of storage strategies among traders. In other words, the respondents' individual stocking trends did not show a uniform pattern. Several explanations have been discussed based on the theory of storage, including heterogeneity in risk attitudes, operational costs, firm characteristics, and price expectations. Future research may consider verifying the relevance of these explanations in the context of Ghana.

It is not within the scope of the study to give a definite answer as to why price dynamics in Ghana are characterized by strong seasonal variation and occasional price spikes. The price spikes at the end of the marketing year may be attributed to trader stock-outs induced by the high risk of making losses if stocks are carried into the next year. High seasonal price increases often reflect high real transaction costs that are related to physical infrastructure, and the increases also explain price dispersion across space and time. In particular, if storage structures are located far away from production markets, then commodities will have to be transported over large distances when storing stocks as well as when releasing stocks (Barrett 1996).

Hence, effectively mitigating seasonal price variability appears to be a challenge. In particular, it is important to bear in mind that seasonal price increases are also necessary to make storage profitable, given the high costs of storage and transportation. However, the large share of stocks held by private traders suggests that their behavior can affect the market dynamics. Understanding the drivers of their behavior can be helpful in employing the right tools to enhance private storage. Private storage could be enhanced by investing in infrastructure and storage facilities located close to production areas or by providing a warehouse receipt system that enables traders and farmers to store relatively small quantities without the risk of their goods deteriorating. Alternatively, better and cheaper access to market information and facilitating hedging against price risk through organized commodity exchanges may potentially incentivize investments in commodity storage.

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