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

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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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M. Kalkuhl et al. (eds.), *Food Price Volatility and Its Implications for Food Security and Policy*, DOI 10.1007/978-3-319-28201-5_1

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

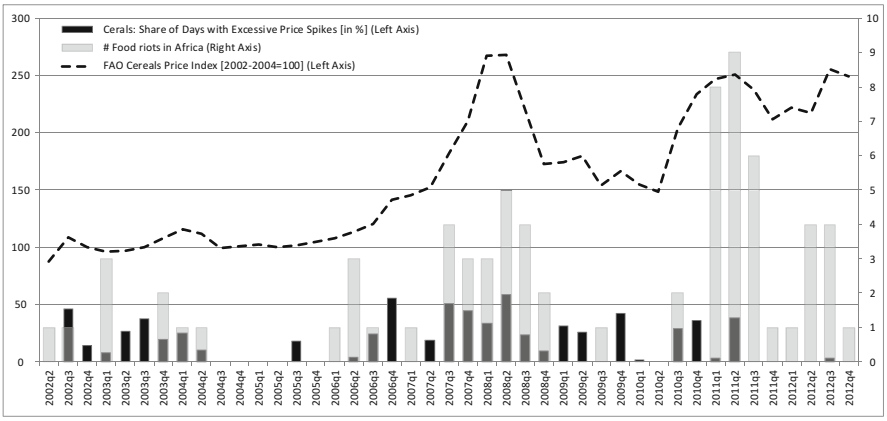

Fig. 1.1 Food prices, excessive volatility, and social unrests. *Note*: Average share of days with excessive price spikes for maize, wheat, and rice futures returns as reported by IFPRI's NEXQ model (see explanation below in the text). All values per quarter. *Source*: Own illustration based on data 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
$V = SD[r_t]$	$V = \frac{SD[p_t - \overline{p_t}]}{\overline{p_t}}$	$\sigma_n^2 = \gamma V_L + \sum_{i=1}^{q} \alpha_i \varepsilon_{n-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{n-i}^2$	$C = f(\sigma^2, \cdot)$	$r_t = m(X_t) + \sigma^2(X_t)\varepsilon_t$ $r > q(\alpha \mid X_t)$
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 $\sigma^2(X_t)$; 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-

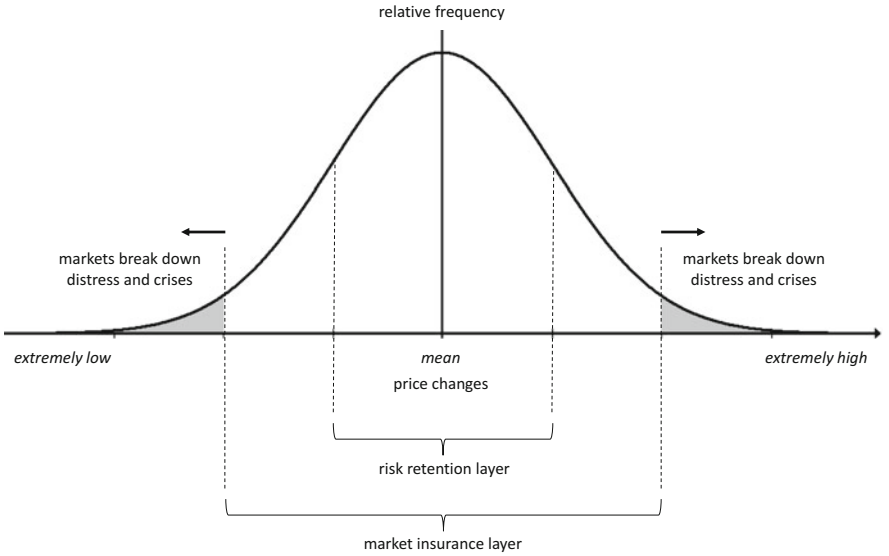

Fig. 1.2 Risk layers and extreme events. *Source*: Own illustration based on World Bank (2005) and Sarris (2014)

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

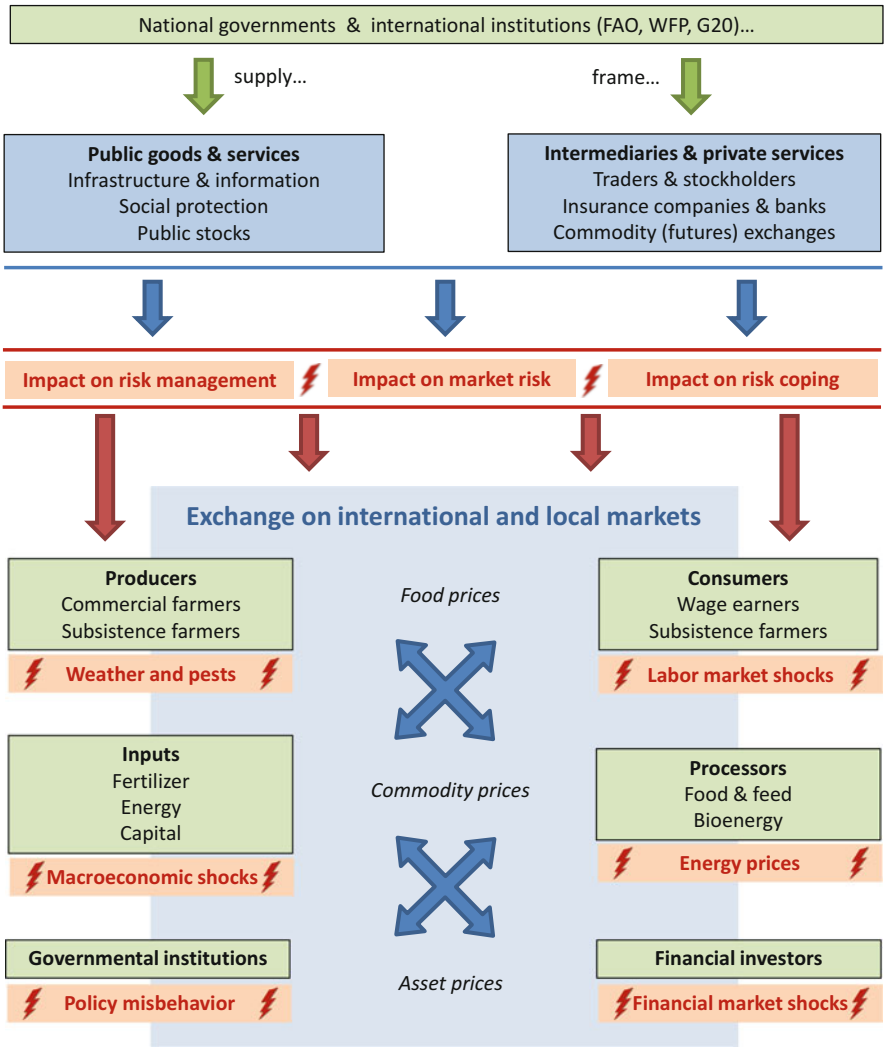

Fig. 1.3 Conceptual framework of the casual impacts of price volatility. *Source*: Own illustration

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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