Part II

Food Price Volatility at International Food Commodity Markets

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

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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

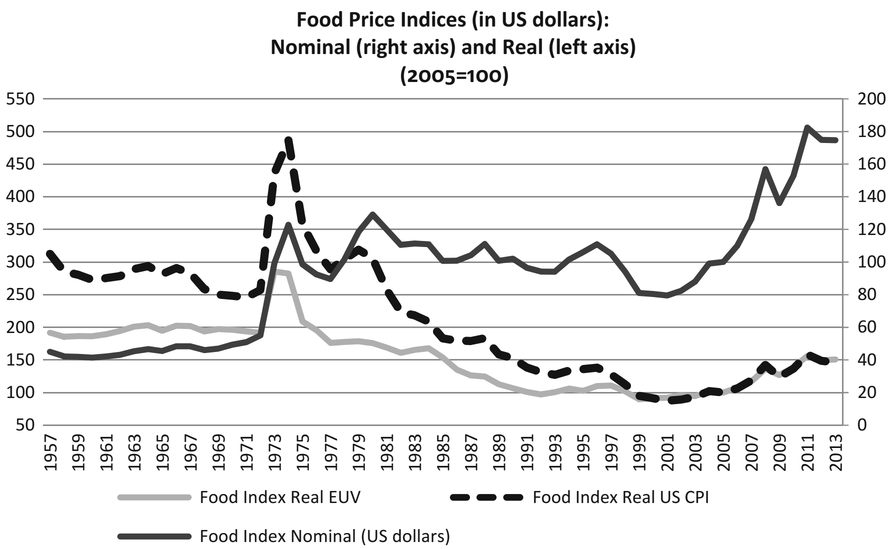

Fig. 2.1 Nominal and real food price indices. The IMF Food Price Index includes sub-categories for cereals, vegetable oils, meat, seafood, sugar, bananas and orange price indices *Source*: Author calculations based on data from the IMF

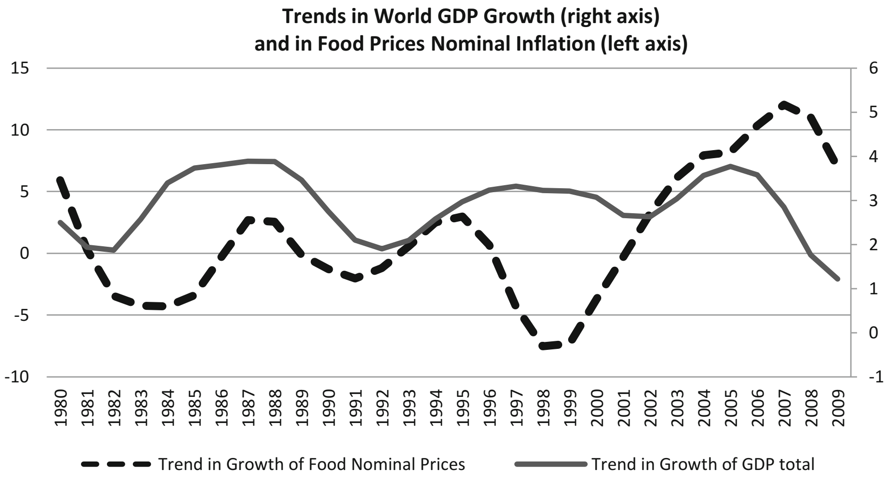

Fig. 2.2 Trends in world growth and inflation of nominal food prices. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

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.

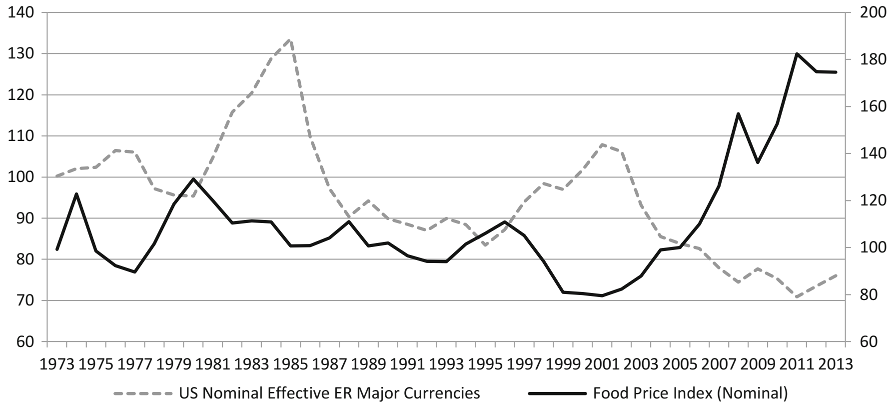

Fig. 2.3 Effective US exchange rate (nominal) (*left axis*) and nominal food price index (*right axis*). *Source*: Author calculations based on data from the International Monetary Fund (IMF) and the US Federal Reserve

[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.

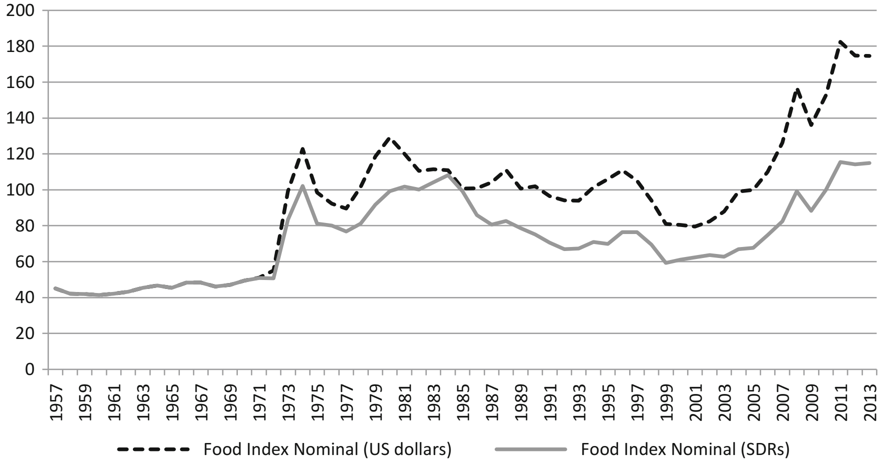

Fig. 2.4 Nominal food price indices in the US dollar and SDR (2005 = 100 for the US index). *Source*: Author calculations based on data from the International Monetary Fund (IMF)

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.

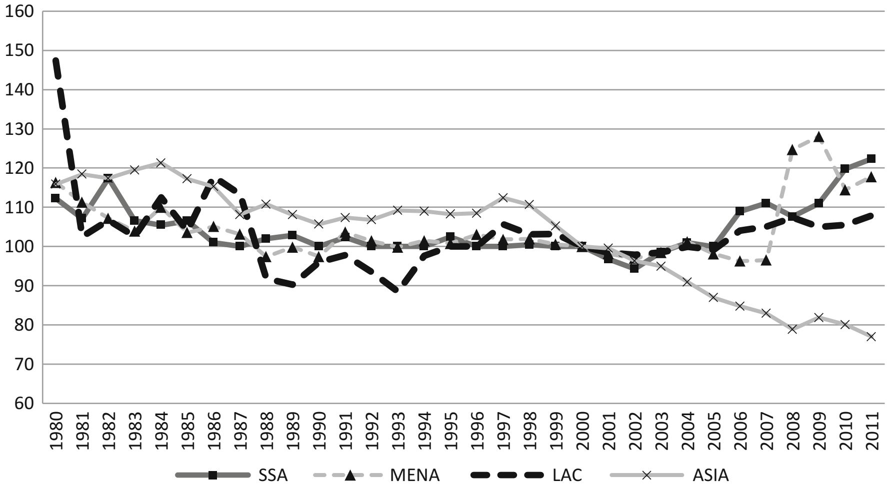

Fig. 2.5 Terms-of-trade index, median value (2000 = 100), 1980–2011. *Source*: Author's calculations based on World Bank (2014). *Note*: This corresponds to the median values for 36 countries for SSA, 17 for LAC, 6 for MENA, and 12 for Asia

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

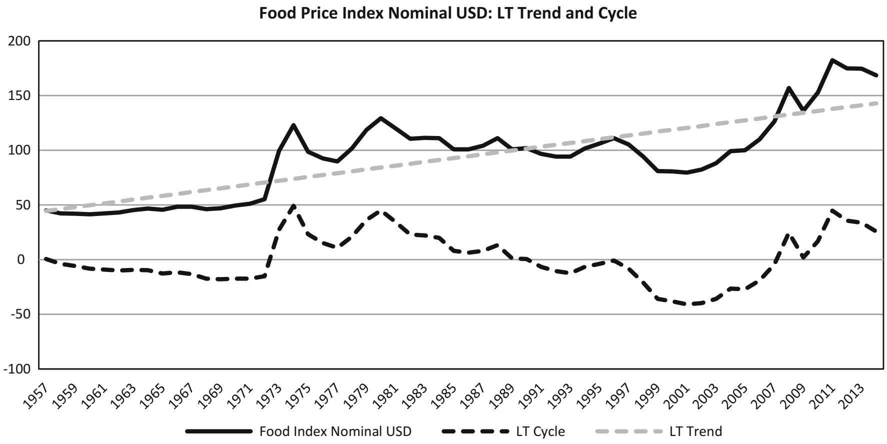

Fig. 2.6 Lineal trend

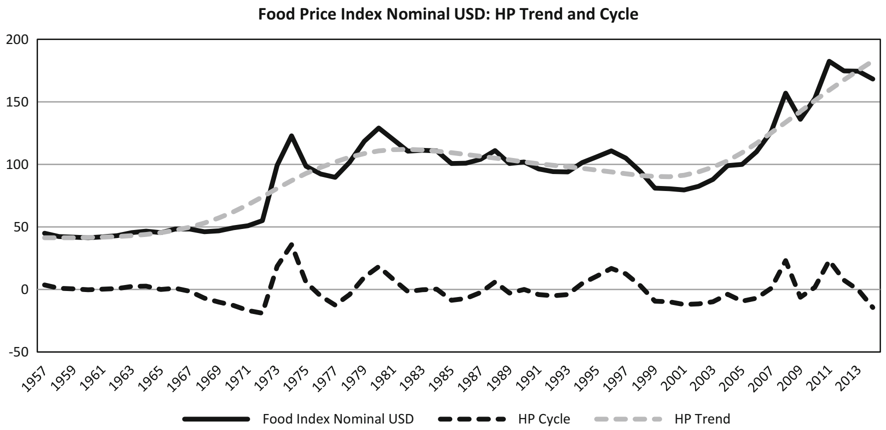

Fig. 2.7 Hodrick–Prescott filter. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

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.

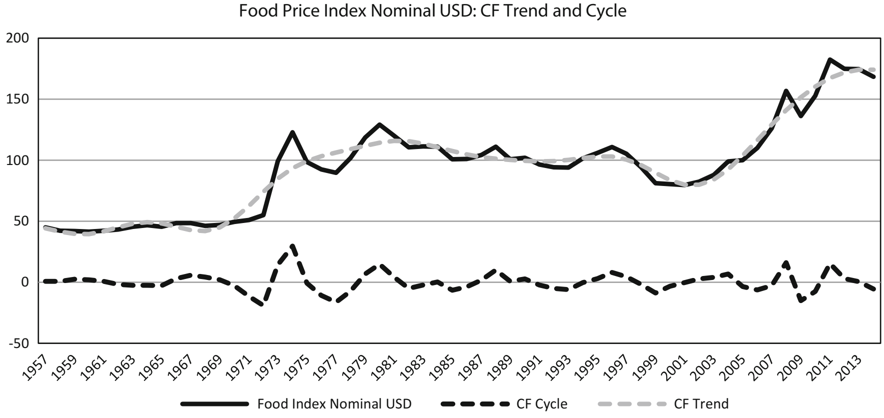

Fig. 2.8 Christiano–Fitzgerald filter. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

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

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.

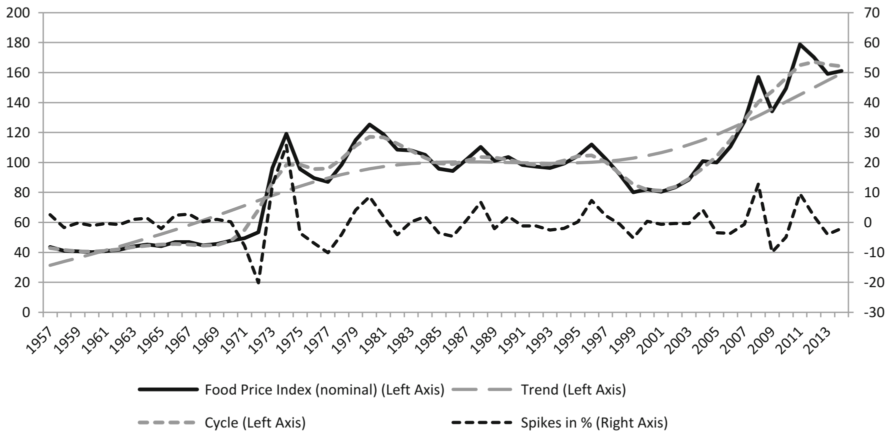

Fig. 2.9 Trends, cycles, and spikes. *Source*: Author calculations based on data from the International Monetary Fund (IMF)

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

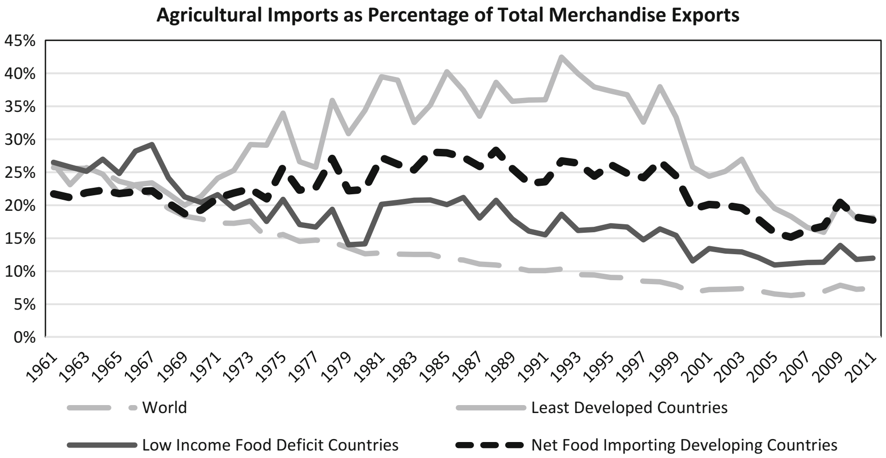

Fig. 2.10 Agricultural imports as percentage of total exports. *Source*: Author calculations based on data from FAOSTAT

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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Drivers and Triggers of International Food Price Spikes and Volatility

3

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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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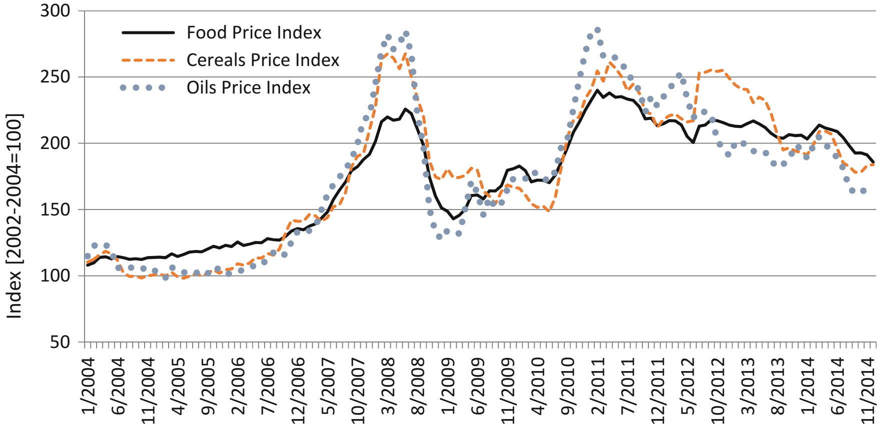

Fig. 3.1 FAO food price indices from January 2004 to November 2011. *Source*: FAO (2011)

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

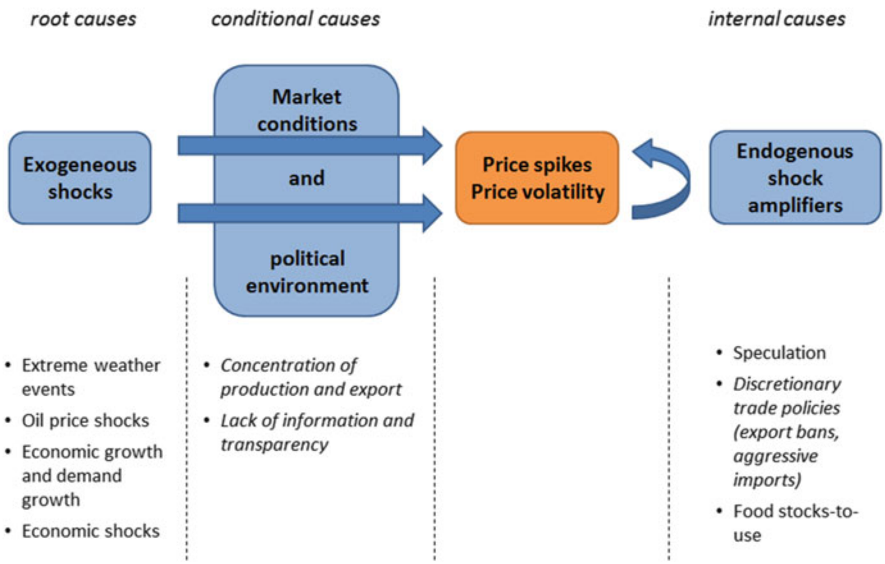

Fig. 3.2 Stylized framework of the causes of global food price volatility and spikes. *Source*: authors' elaboration. *Note*: Exogenous shocks are the "root" causes of price volatility and price spikes. The extent to which exogenous shocks translate to food price changes depends on the market conditions 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 $\text{cov}\left(\varepsilon_{it}, \varepsilon_{jt}\right) \neq 0$ 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 $SS = \frac{|Q_t - HQ_t|}{HQ_t}$, 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.

[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

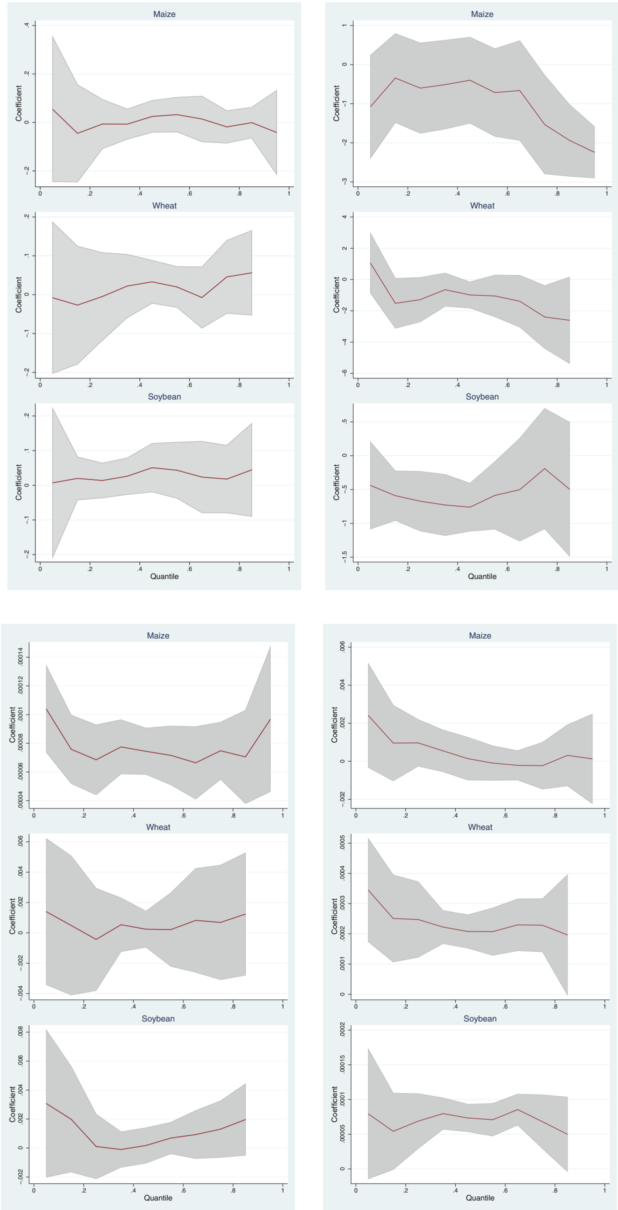

Fig. 3.3 Triggers of food price spikes. *Source*: Authors' estimation based on data explained in Sects. 3.3 and 3.4. *Note*: The *middle line* shows the coefficient which explains price spikes using (**a**) oil price shocks, (**b**) production shocks, (**c**) excessive speculation, and (**d**) stock-to-use 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

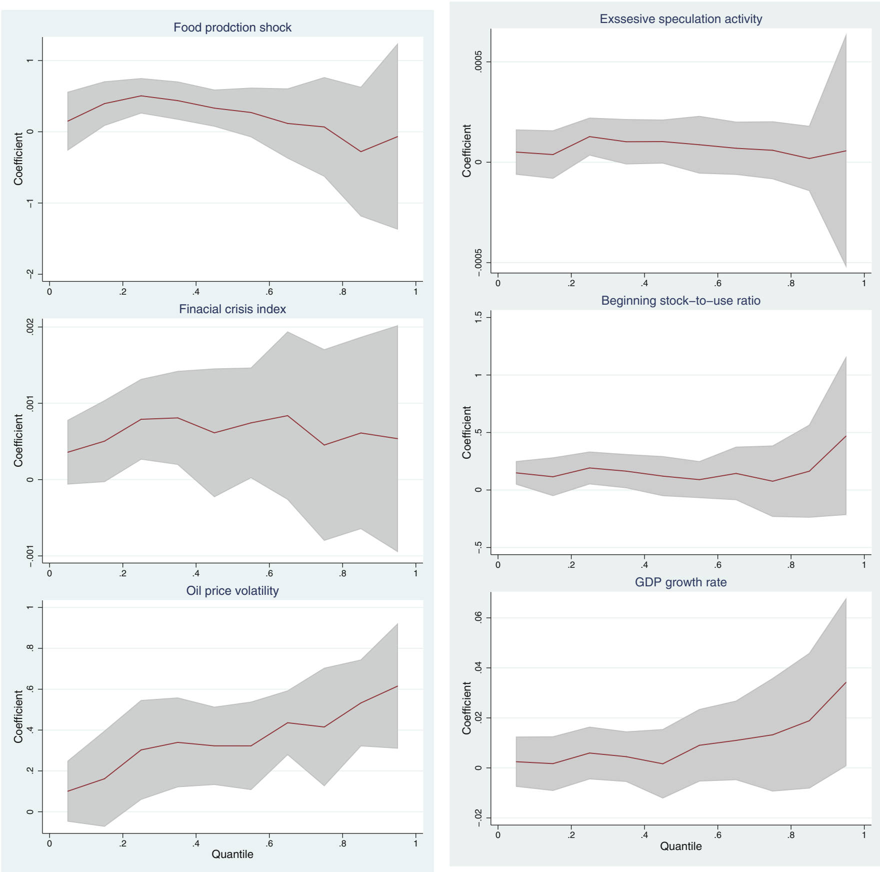

Fig. 3.4 Triggers of global food price volatility. *Source*: Authors' estimation based on data explained in Sects. 3.3 and 3.4. *Note*: The *middle line* shows the coefficient which explains food price volatility using different explanatory variables. The quantile regression shows the coefficients for 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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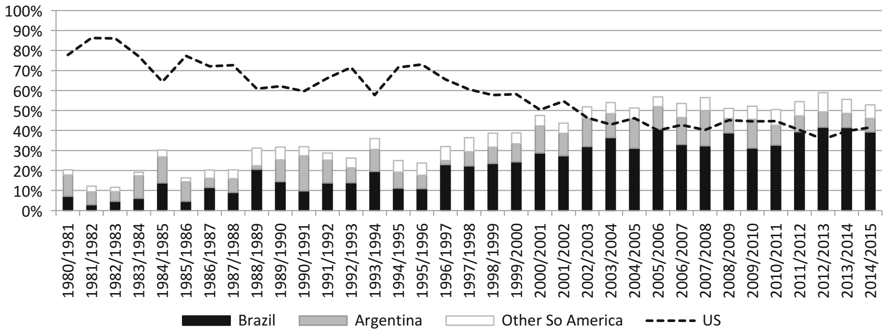

Fig. 4.1 Share of global soybean exports. *Source*: US Department of Agriculture *Production*, *Supply*, *and Distribution Database*

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 $\bar{y}_i > 0$ 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

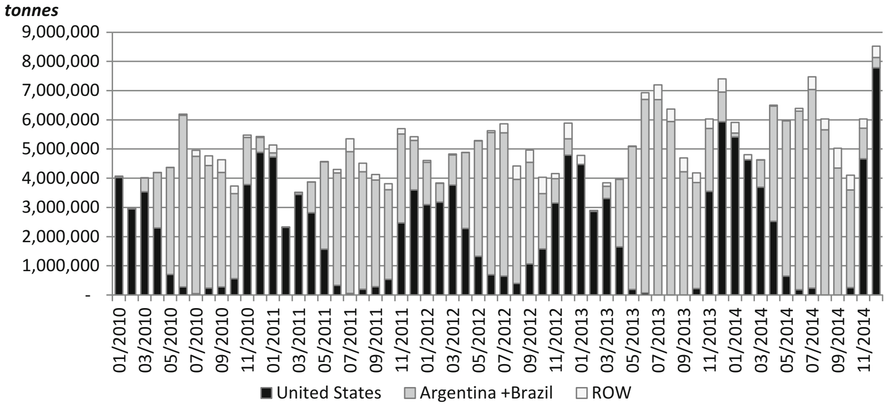

Fig. 4.2 Monthly China soybean imports by origin. *Source*: Global Trade Information System

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]

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[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

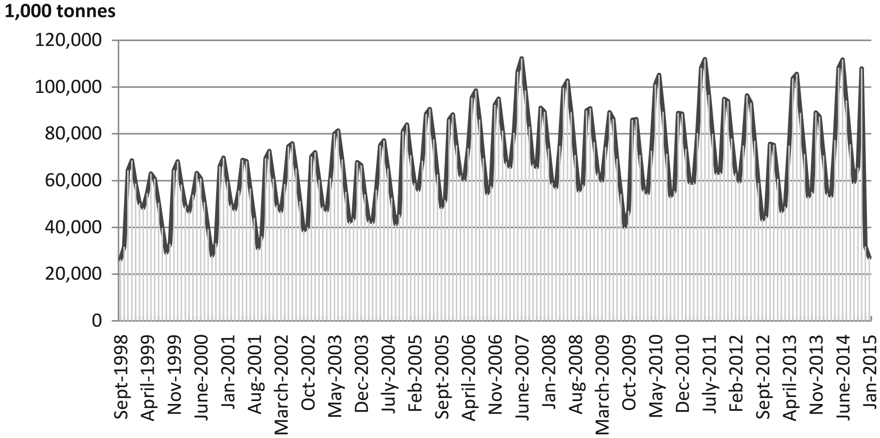

Fig. 4.3 Monthly ending stocks of the major exporters (the USA, Brazil, and Argentina). *Source*: USDA, *based on monthly crush and export numbers from Oil World and Global Trade Information System*

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

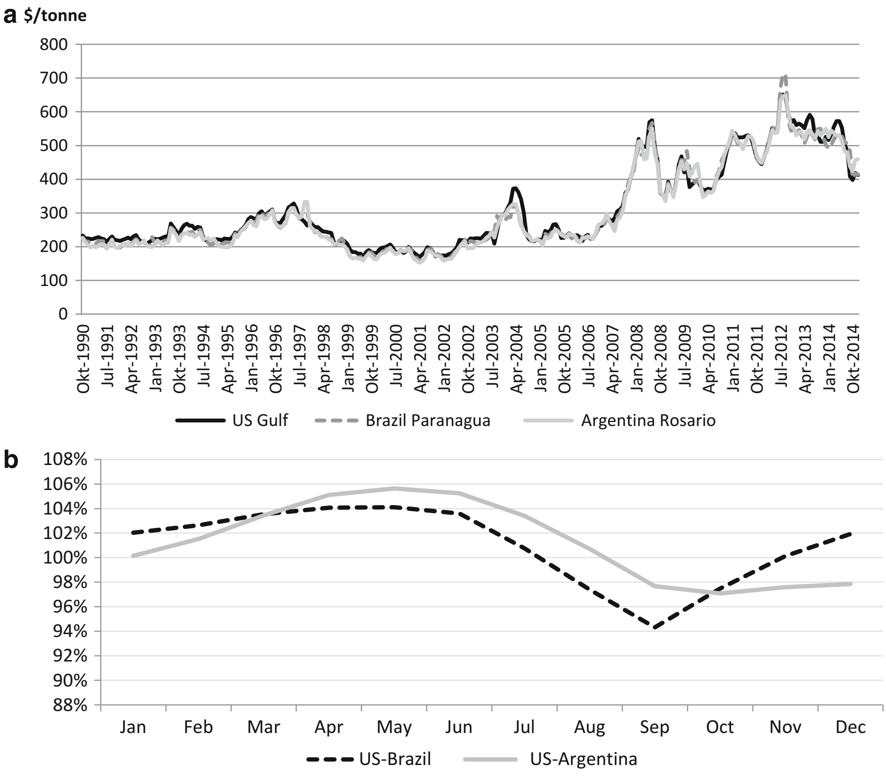

Fig. 4.4 (**a**) Soybean export prices. *Source*: USDA, Foreign Agricultural Service, *Oilseeds: World Markets and Trade*. (**b**) US price as a percentage of prices in Brazil and Argentina, average 2005–2014. *Source:* USDA, Foreign Agricultural Service, *Oilseeds: World Markets and Trade*

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.

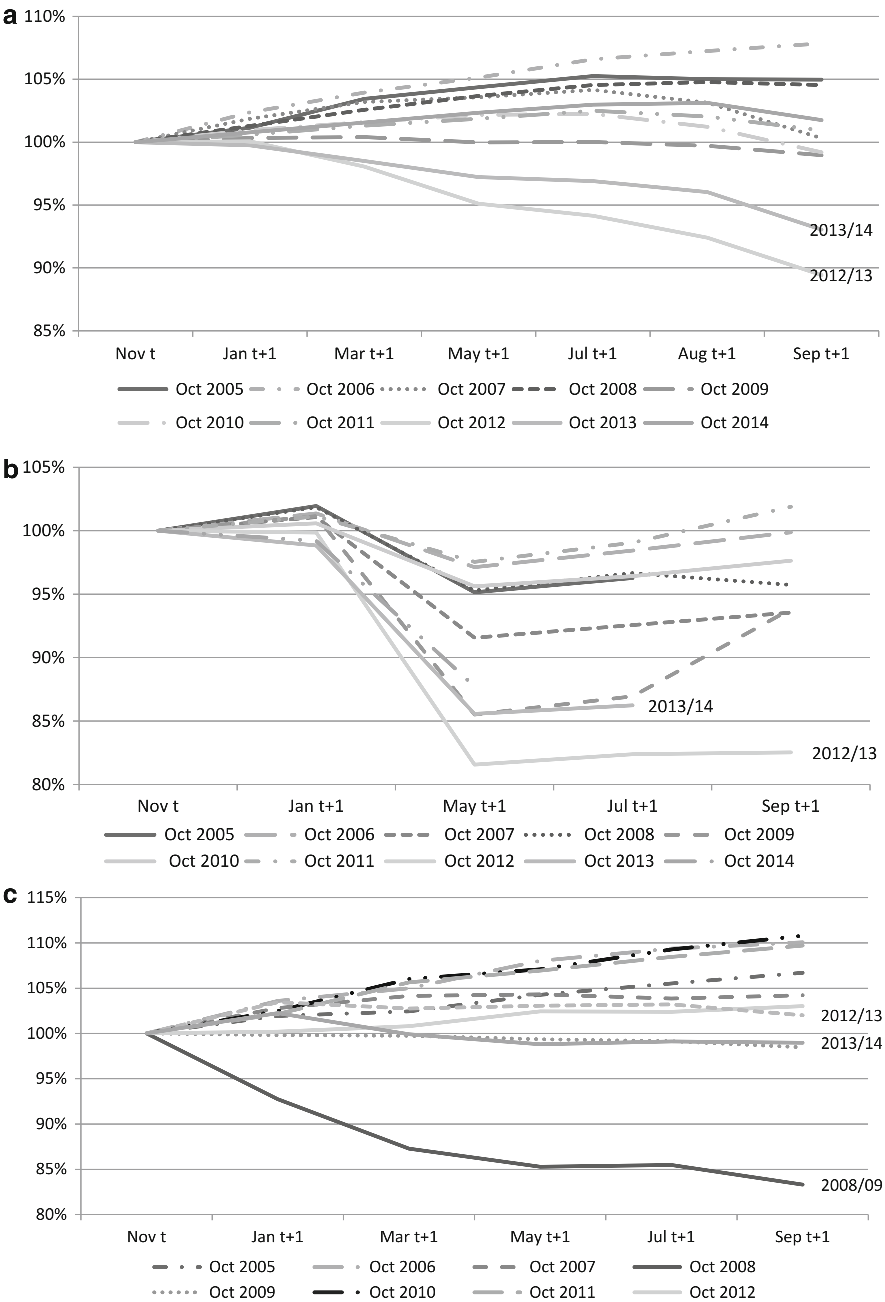

Fig. 4.5 (**a**) Soybean futures—Chicago Mercantile Exchange. *Source*: Chicago Mercantile Exchange. (**b**) Soybean futures—Bolsa de Comercio de Rosario. *Source*: Bolsa de Comercio de Rosario (Argentina). (**c**) Soybean futures—Dalian Commodity Exchange. *Source*: Dalian Commodity Exchange (China)

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 %

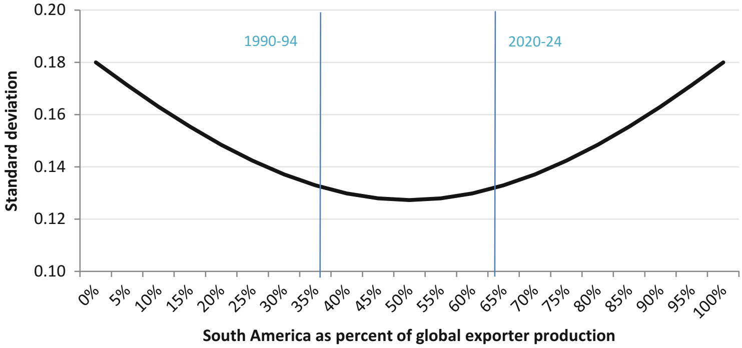

Fig. 4.6 Annual yield variability of major exporting countries. *Note*. The standard deviation of normalized yields in South America and the USA are assumed equal to 0.18 (Table 4.1)

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

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

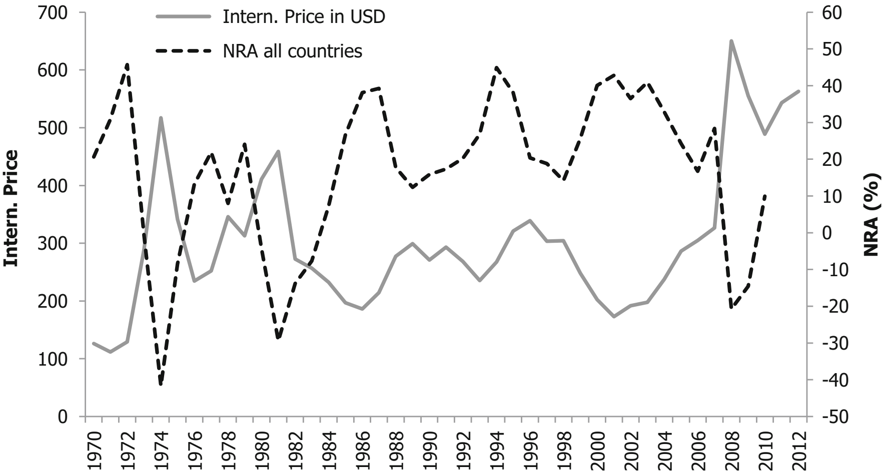

Fig. 5.1 World prices and the average protection rate for rice. *Source*: Calculations based on data from http://www.worldbank.org/agdistortions. *Note*: NRA = nominal rate of assistance. See Anderson (2009)

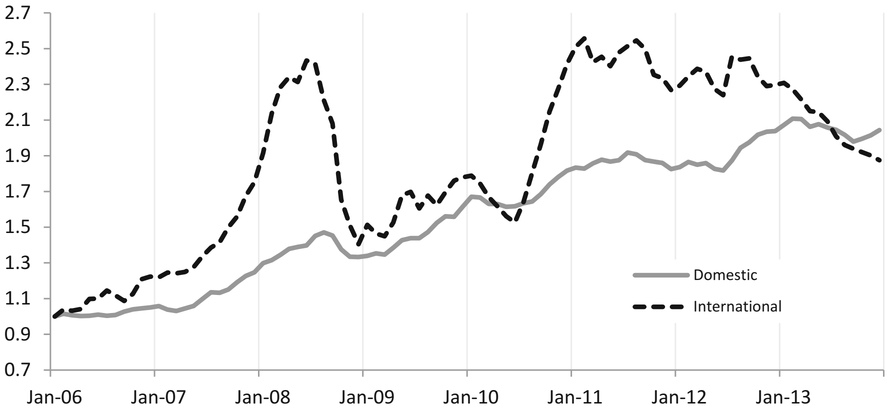

Fig. 5.2 Domestic and world price index of rice, wheat, maize, oil, and sugar, developing countries. *Source*: Ivanic and Martin (2014b)

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).

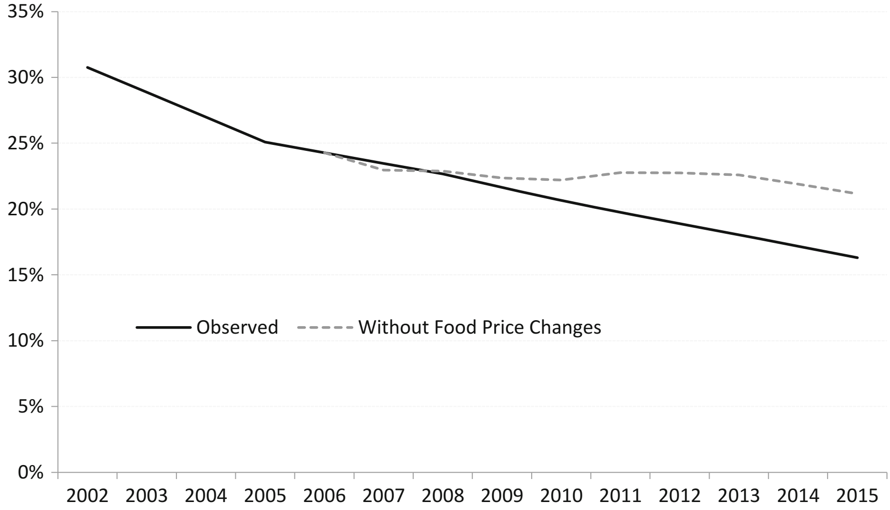

Fig. 5.3 Global poverty headcount: estimated versus without food price changes

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

6

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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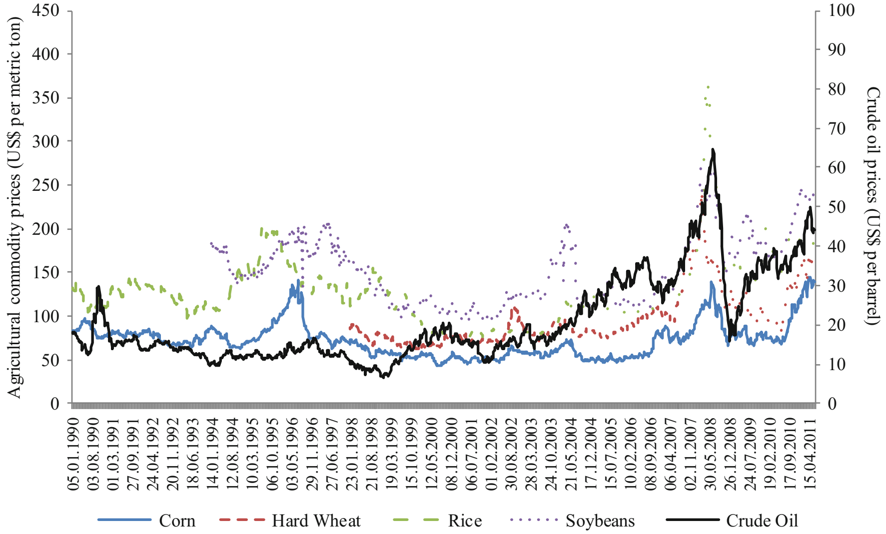

Fig. 6.1 Inflation-adjusted prices of agricultural commodities and oil, 1990–2011 (weekly data). Note: corn is U.S. no. 2 yellow, wheat is U.S. no. 2 hard red winter, rice is white Thai A1 super, soybeans is U.S. no. 1 yellow, and crude oil is spot price from Cushing, Oklahoma WTI. *Source*: FAOSTAT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

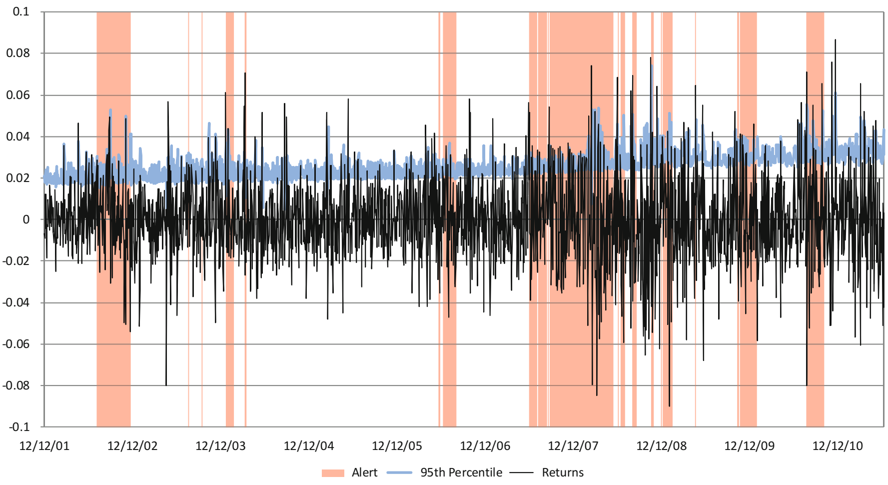

Fig. 6.2 Excessive food price volatility for hard wheat. *Note*: This figure shows the results of a model of the dynamic evolution of daily returns based on historical data going back to 1954 (known as the Nonparametric Extreme Quantile (NEXQ) Model). This model is then combined with extreme value theory 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

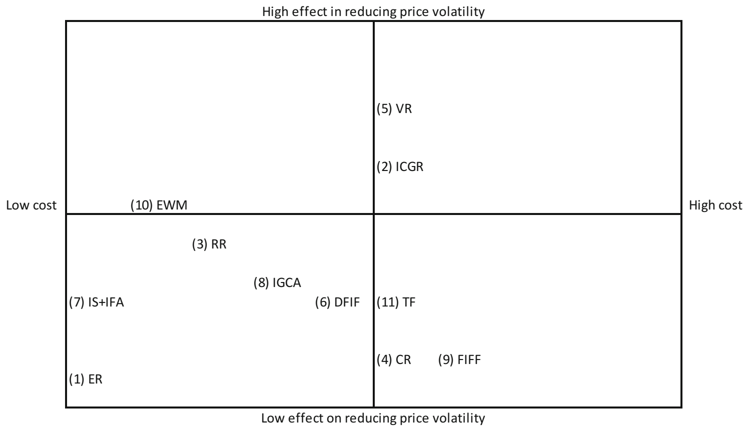

Fig. 6.3 Proposals for reducing price volatility. *Note*: The vertical axis refers to the potential effect in reducing price volatility and the horizontal axis to the costs required for its implementation. (1) ER = emergency reserve, von Braun and Torero (2009a, b), it requires US$7.5 Mpa but is to alleviate 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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Worldwide Acreage and Yield Response to International Price Change and Volatility: A Dynamic Panel Data Analysis for Wheat, Rice, Corn, and Soybeans

7

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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

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

where Q_{ikt} denotes the total production (or area under cultivation) of crop i (1 = wheat, 2 = corn, 3 = soybeans, and 4 = 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, $\mathrm{vol}(p)_{jk,t_{i,k}}$ 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), $\mathrm{YS}_{ik,t_{i,k}}$ 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).

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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

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

(continued)

Table 7.2 (continued)

	Production				Acreage			
Variable	Wheat	Corn	Soybeans	Rice	Wheat	Corn	Soybeans	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

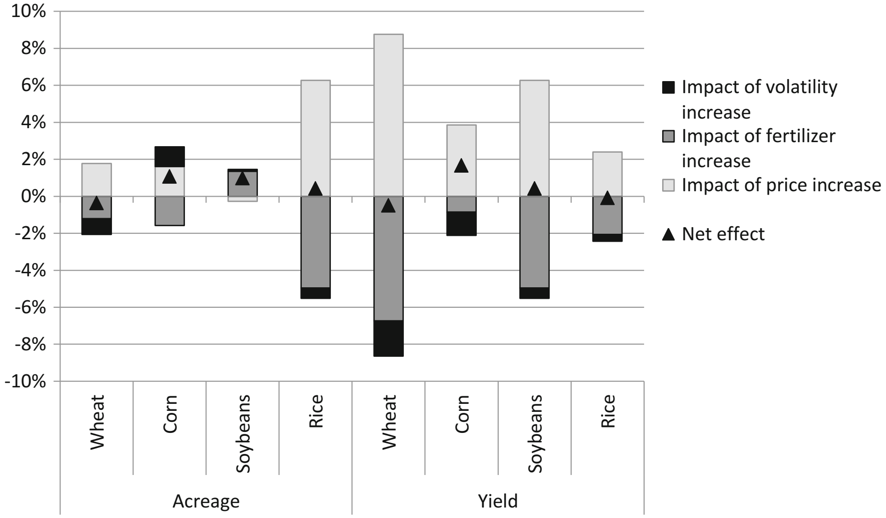

Fig. 7.1 Impacts of the 2006–2010 price dynamics on acreage and yield. *Note:* The figure shows the impact of output and fertilizer prices and output price volatility on acreage and yield compared with a counterfactual scenario where these values were set to their long-term average. The net effect is 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

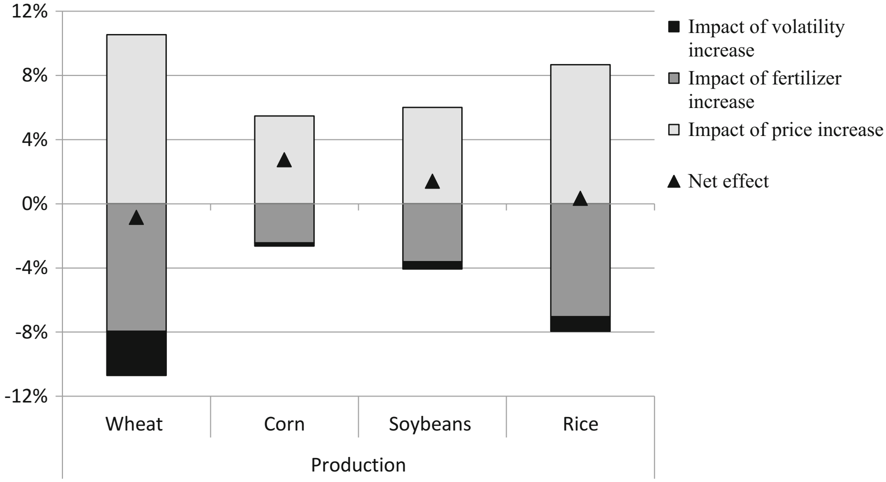

Fig. 7.2 Impacts of the 2006–2010 price dynamics on production. *Note:* See simulation assumptions detailed in Fig. 7.1

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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[13]For short-run export taxes during an episode of high price volatility, tax revenue is rarely the main objective of a government applying such measures.

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Part III

Commodity and Financial Market Linkages