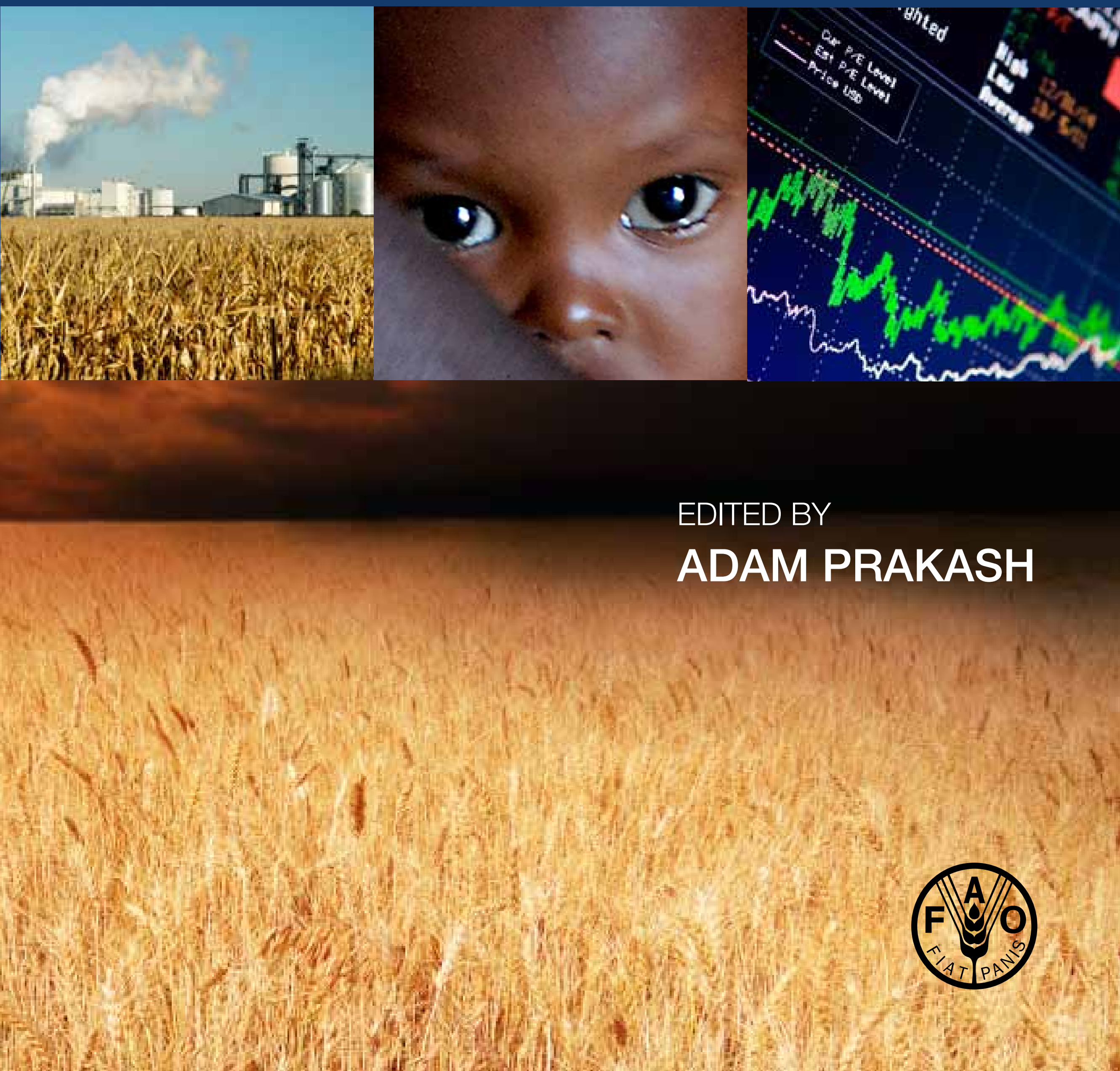
SAFEGUARDING FOOD SECURITY IN VOLATILE GLOBAL MARKETS



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Safeguarding food security in volatile global markets

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Chapter 8

Price transmission and volatility spillovers in food markets

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This chapter focuses on assessing the persistence of food price volatility and the mean and volatility spillover between world food markets and the markets of selected developing countries. Spillover in the mean denotes the transmission of price changes from the world to domestic prices and vice versa in terms of levels. Volatility spillover reflects the comovement of the price variances in these markets. A better understanding of the price mean and variance relationships between the world market and the markets of developing countries can assist policy formulation. Increases in food price volatility have important negative implications for economic welfare in developing countries where agricultural commodities form the basis for household income and food consumption.

Chapter 2 identifies that commodity prices in general, both at the world and domestic markets, tend to be non-stationary processes that are integrated of order one. Non-stationarity implies that shocks to the series are permanent, rendering the mean dependent on time. In addition to this property, the first differences of commodity prices often tend to be leptokurtic. This is indicative that shocks result in volatility clustering, suggesting that the variance may be also time variant. In this chapter, I model price transmission, or mean spillover, within a Vector Error Correction (VECM) framework. This allows us to reveal the dynamics of adjustment of prices to their long-run equilibrium relationship. The analysis of volatility spillover is based on the application of multivariate Generalized Autoregressive Heteroscedasticity (GARCH) on the innovations of the VECM. GARCH models were introduced by Engle (1982) and generalized by Bollerslev (1986) and take into account that variances vary over time. Although there are many applications of vector autoregressions and GARCH models in the finance literature (see for example De Goeij & Marquering, 2004; Hassan & Malik, 2007; Qiao et al., 2008; and Alizadeh et al., 2008), such analyses are uncommon in agricultural economics.

I study food markets in six different developing countries. I analyse the relationship between the world market and the wheat market in Peru and the maize market in Mexico. In Asia, I investigate price transmission and volatility spillover in the rice markets of India and the Philippines. I also select two African markets, maize in Malawi and sorghum in the Niger.

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Background

Sustained food price increases will have a significant impact on the rate of poverty incidence. A number of studies suggest that most of the poor are net consumers of food and therefore, are adversely affected by the food price upswing (Poulton et al., 2006 and Christiaensen & Demery, 2006). Poor rural households are often characterized by a lack of, or insignificant, marketed surplus. Small land assets and limited access to inputs owing to cash constraints, as well as limited access to output markets because of distance and poor infrastructure contrive to the households being predominantly net buyers of food. A number of researchers have attempted to measure the implications of food price surges for poverty in developing and less developed countries (Ivanic & Martin, 2008; Polaski, 2008; Wodon et al., 2008; and Rapsomanikis, 2009). These analyses utilize several different methodologies and apply them to household survey data from a number of developing countries. As highlighted in Chapter 3, increases in food prices will have very diverse effects across countries, depending on the structure of the economy, the linkages of agriculture with other sectors, the households' net position towards food markets, as well as the distribution of households around the poverty threshold. Nevertheless, in most cases increases in poverty occur more frequently than reductions. In general, the results suggest that, on average, food price surges result in increased poverty.

Persistent price volatility, especially in the presence of liquidity constraints and inadequate assets can result in economic inequality within rural populations and create poverty traps (Zimmerman & Carter, 2003). Households minimize their exposure to risk from such covariate shocks by developing risk management strategies, such as crop and income diversification, and attempt to develop self-insurance by smoothing consumption. The diversification of activities inhibits efficiency gains from specialization in production and hinders the development of the agricultural sector (Carter, 1997; Kurosaki & Fafchamps, 2002). Income risks may also blunt the adoption of technologies necessary for agricultural production efficiency, as producers may decide to apply less productive technologies in exchange for greater stability (Larson & Plessman, 2002).

A fundamental issue when analyzing the impact of food price episodes on developing countries is the extent to which prices in developing countries respond to price shocks in the international market. Price transmission between food markets is central in assessing the impact on producers and consumers and understanding how they adjust to price shocks. In general, the absence of market integration, or of complete pass-through of price changes from one market to another has important implications for economic welfare. Most developing countries are subject to incomplete price transmission either owing to trade and other policies, or to high transaction costs arising from poor transport and communication infrastructure. In general, poor transmission results in a reduction in the price information available to economic agents and leads to decisions that contribute to less elastic demand and supply responses.

The transmission of prices and the spillover of volatility

Across countries, domestic prices for food exhibit diverse patterns of price transmission from international prices. Often, the impact of international prices on the markets of developing countries is either small or delayed, and producers and consumers are subject to price variability that arises owing to domestic shocks (Rapsomanikis & Sarris, 2008). Food prices exhibit wide variability owing to seasonality, climatic phenomena and poor infrastructure that does not facilitate the transport of food from surplus to deficit areas. During periods of international market tranquillity, increased exposure to global markets could result in a reduction in food price volatility, as international markets may act as a "buffer" absorbing large domestic supply and demand shocks. Imperfect price transmission may, to a certain extent, shield some countries from external shocks, while significantly affecting both the price level and volatility in others. This poses a policy dilemma highlighting the need for policies to achieve market integration and mitigation of the negative effects of price surges.

Studies on the transmission of price signals are based on the concept of competitive pricing. The classical paradigm of the Law of One Price suggests that, in the long run, price transmission is complete with prices of a commodity sold on competitive foreign and domestic markets differing only by transport costs. Such a complete price pass-through is attained through trade and reflects the integration of markets. Changes in supply and demand in one country will affect prices that will in turn instigate trade with other countries. Just as arbitrage and trade restores the market equilibrium, prices in the domestic market tend to equalize with those in foreign markets except for transport costs - hence the term "Law of One Price".

In practice, price transmission can be slow, or far from complete owing to a number of reasons including the implementation of policies, transport costs, non-competitive supply chains and consumer preferences. The implementation of ad valorem import tariffs or export taxes allows international price changes to be fully transmitted to domestic markets in proportional terms in the absence of other costs. Nevertheless, prohibitively high tariffs or taxes eliminate opportunities for arbitrage and result in domestic and international prices moving independently of each other, as if an import or export ban were implemented.

In the context of food price hikes, many governments in developing countries have implemented short-run border measures, such as import tariff reductions or exports bans, in order to curb domestic price increases and shield consumers from increased food expenditure. Such decreases in import tariffs facilitate price transmission, especially if tariffs were initially set at high levels. For food exporters, export bans, if effective, hinder the transmission of price signals from the international market and prevent the domestic price level from rising.

Policies that aim to stabilize domestic prices at a certain level are often implemented in conjunction with border measures. Government intervention in the form of food commodity procurement or sale and inventory management is commonly practiced across African and Asian countries. Such policies impede price transmission depending on the government's price targets, its capacity and budget to realize food purchases at certain price levels and its ability to manage food inventories and trade continuously. Even then, depending on domestic market fundamentals, trade takes place and the international and domestic prices may not be completely unrelated, with the intervention policy resulting only in weak international price pass-through.

Apart from policies, domestic markets can also be insulated by large margins that arise because of high transport and marketing costs. Especially in developing countries, poor infrastructure, transport and communication services give rise to significantly high costs of delivering the locally produced commodity to the border for export or the imported commodity to the domestic market for consumption. Such high margins hinder the transmission of price signals. As a consequence, changes in international prices are not fully transmitted to domestic prices, resulting in producers and consumers adjusting only partly, if at all, to shifts in global supply and demand.

Oligopolistic behaviour and collusion among domestic traders may keep price differences between international and domestic prices on levels higher than those determined by transport costs. Concentration in the food marketing and processing sectors and imperfectly competitive behaviour beyond the farmgate implies that processors or middlemen may have power over prices. Therefore, they may exercise pricing strategies that result in a quick and complete pass-through of increases in the international price and a slow and incomplete transmission of decreases in the international price to domestic prices upstream as their margins are squeezed.

Consumer preferences may also result in incomplete price transmission even under competition and free market conditions. Domestically produced food often has different attributes than those characterizing internationally traded food commodities. If consumers preferred the attributes of the domestically produced food, the possibilities of substitution in consumption between domestic and imported foods would be limited. For example, in Eastern and Southern Africa, as well as in Mexico, consumers generally prefer white maize rather than the internationally traded yellow maize. As consumers are unwilling to substitute one type of maize for another, domestic prices may depend mainly on regional supply and demand shocks for white maize rather than global market conditions. If transmission were found incomplete, some white maize producing countries may have experienced increases that are attributable to domestic market fundamentals and not to the upturn of the international price of yellow maize.

Across developing countries, these factors have a diverse effect on the transmission of international price to both the domestic price level, as well as the volatility around this level. Rapsomanikis & Sarris (2008) find that a large part of the domestic price and the agricultural income variability in Peru and Viet Nam is because of domestic shocks. While domestic prices for tradable agricultural commodities exhibit diverse patterns of price transmission from international prices, the impact of international prices is found to be small, mainly because of imperfect pass-through from the international markets.

Rapsomanikis and Sarris' empirical work provides some answers related to the impact of total exposure to international prices on income variability. In general, their results suggest that, during periods of relative international market tranquility, increased exposure to international markets may result in a reduction in agricultural income volatility, as international markets may act as a "buffer" absorbing domestic shocks. For example, in Malawi during the last decade, prices of maize, the locally produced main staple, exhibited extreme spikes in the beginning of 2002 and during the first months of 2006, both periods characterized by calm international maize markets. During the 2008 food price surge, the Malawian price spike was more pronounced in both magnitude and duration as compared with the surge in international price. Between 2000 and 2010, prices of wheat, a mainly imported food, in Peru exhibited frequent bouts of volatility, resulting in significant price spikes, as in 2003. However, as in the case of maize in Malawi, the 2008 food price surge was transmitted to the Peruvian food markets and brought prices to the highest level of the last decade.

The model

Given prices for a commodity in two spatially separated markets pdt and pwt, the Law of One Price and the Enke-Samuelson-Takayama-Judge model (Enke, 1951; Samuelson, 1952; and Takayama & Judge, 1971) postulate that at all points of time, allowing for transfer costs

m, for transporting the commodity from one market to another, the relationship between the prices is as follows:

$$p_{1t} = p_{2t} + m \tag{1}$$

If a relationship between two prices, such as (1), holds, then the markets can be said to be integrated. However, this extreme case is unlikely, especially in the short run. At the other end of the spectrum, if the joint distribution of two prices were found to be completely independent, then one might feel comfortable saying that there is no market integration and no price transmission. In general, spatial arbitrage is expected to ensure that prices of a commodity will differ by an amount that is at most equal to the transfer costs with the relationship between the prices being identified as the following inequality:

$$p_{2t} - p_{1t} \leq m \tag{2}$$

Fackler & Goodwin (2002) refer to the above relationship as the spatial arbitrage condition and postulate that it identifies a weak form of the Law of One Price, the strong form being represented by equality (1). They also emphasize that relationship (2) represents an equilibrium condition. Observed prices may diverge from relationship (1), but spatial arbitrage will cause the difference between the two prices to move towards the transfer cost. The condition encompasses price relationships that lie between the two extreme cases of the strong form of the Law of One Price and the absence of market integration. Depending on market characteristics, or the distortions to which markets are subjected, the two price series may behave in a plethora of ways, having quite complex relationships with prices adjusting less than completely, or slowly rather than instantaneously and according to various dynamic structures, or being related in a non linear manner.

Within this context, complete price transmission between two spatially separated markets is defined as a situation in which changes in one price are completely and instantaneously transmitted to the other, as postulated by the Law of One Price presented by relationship (1). In this case, spatially separated markets are integrated. In addition, this definition implies that if price changes are not passed-through instantaneously but after some time, price transmission is incomplete in the short run but complete in the long run, as implied by the spatial arbitrage condition. The distinction between short-run and long-run price transmission is important and the speed by which prices adjust to their long-run relationship is essential in understanding the extent to which markets are integrated in the short run. Therefore, there are various reasons that price changes at one market may need some time to be transmitted to other markets such as policies, the number of stages in marketing and the corresponding contractual arrangements between economic agents, storage and inventory holding, delays caused in transportation or processing or "price-levelling" practices.

The spatial arbitrage condition implies that market integration lends itself to a cointegration interpretation with its presence being evaluated by means of non-cointegration tests. Cointegration can be thought of as the empirical counterpart to the theoretical notion of a long-run equilibrium relationship. If two prices in spatially separated markets p_{1t} and p_{2t}, contain stochastic trends and are integrated of the same order, say I(d), the prices are said to be cointegrated if:

$$p_{1t} - \beta p_{2t} = u_t \tag{3}$$

where u_t is stationary and β is the cointegrating parameter. Evidence for cointegration reflects that prices are jointly determined. The concept of cointegration has an important implication purported by the Granger Representation Theorem (Engle & Granger, 1987). According to this theorem, if two trending, say I(1), variables are cointegrated, their relationship may be validly described by a VECM and vice versa. In the case that prices from two spatially separated markets are cointegrated, the VECM representation is as follows:

$$\Delta p_t = \mu + \Pi p_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta p_{t-i} + v_t \tag{4}$$

where $v_t|\Omega_{t-1} \sim \mathcal{N}(0, H_t)$ are normally distributed disturbances conditional on past information with zero mean and a variance-covariance matrix denoted by H_t, while the operator Δ denotes that the I(1) variables have been differenced in order to achieve stationarity. Πp_{t-1} states the long run relationship while the matrix P can be decomposed in $\Pi = \alpha\beta'$ as follows:

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} (p_{1t-1} - \beta p_{2t-1}) + \sum_{i=1}^{k} \Gamma_i \begin{pmatrix} \Delta p_{1t-i} \\ \Delta p_{2t-i} \end{pmatrix} + \begin{pmatrix} \nu_{1t} \\ \nu_{2t} \end{pmatrix} \tag{5}$$

The inclusion of the levels of the prices alongside their differenced terms is central to the concept of the VECM. Parameters contained in matrices Γ_i measure the short run effects, while β is the cointegrating parameter that characterizes the long-run equilibrium relationship between the two prices. The levels of the variables enter the VECM combined as the single entity $(p_{1,t-1} - \beta p_{2,t-1})$ that reflects the errors or any divergence from this equilibrium and correspond to the lagged error term of equation (3). The vector $(\alpha_1, \alpha_2)'$ contains parameters, commonly called error correction coefficients, which measure the extent of corrections of the errors that the market initiates by adjusting the prices towards restoring the long-run equilibrium relationship. The speed with which the market returns to its equilibrium depends on the proximity of α_i to unity. Within this context, short run adjustments are directed by, and consistent with, the long run equilibrium relationship, allowing the researcher to assess the speed of adjustment that shapes the relationship between the two prices.

The model also allows to test for causality in the Granger sense, providing evidence regarding which direction price transmission is occurring, as well as the decomposition of the forecast error variance in parts that are owing to international and domestic shocks respectively. The cointegration-VECM framework takes into account that prices are stochastic processes that have time-dependent means, and replicates their systematic behaviour being essentially a description of the conditional process of realizing the data.

While the VECM provides the conditional expected means of the variables, in order to examine for higher moment relationships that reflect volatility spillovers, the VECM's errors v_t are specified as a bivariate GARCH model (Bollerslev, 1986). I employ the Full Term (BEKK) parameterization by Engle & Kroner (1995), which incorporates quadratic forms in such a way so that the covariance matrix is positive semi-definite, a requirement that is necessary for the estimated variances to be non-negative. The BEKK parameterization is given by:

$$H_{t+1} = C'C + B'H_t B + A'\nu_t \nu_t' A \tag{6}$$

where H_{t+1} is the conditional variance matrix, C is a 2×2 lower triangular matrix with three parameters and B and A are 2×2 matrices of parameters restricted to be diagonal. In this parsimonious specification the conditional variances are a function of the lagged conditional variances and error terms. Expanding equation (6) gives the variance-covariance equations:

$$\begin{aligned} h_{11,t+1} &= c_{11} + b_{11}^2 h_{11t} + a_{11}^2 v_{1t}^2 \\ h_{22,t+1} &= c_{22} + b_{22}^2 h_{22t} + a_{22}^2 v_{2t}^2 \\ h_{12,t+1} &= c_{12} + b_{12}^2 h_{12t} + a_{12}^2 v_{1t} v_{2t} \end{aligned} \tag{7}$$

where $b_{12}^2 = b_{11}^2 b_{22}^2$ and $a_{12}^2 = a_{11}^2 a_{22}^2$. The b_{ii}^2 measure the extent to which current levels of conditional variances are related to past conditional variances. The a_{ii}^2 assess the correlations between conditional variances and past squared errors reflecting the impact of shocks on volatility. This specification does not arise from economic theory. However, it retains the intuition and interpretation of the univariate GARCH model and provides a good basis to model time varying volatility and heteroscedasticity, which is typically found in prices of assets and commodities.

Univariate GARCH models have been proved successful in predicting volatility that is clustered over time. Unexpected news, reflected in the specification by the lagged errors v_t tends to affect the variance of prices, with "good news", reducing volatility and "bad news" resulting in volatility increases. Often, in times of crisis, volatility not only increases but clusters. Especially in times of price surges, large variances tend to be followed by large variances, giving rise to periods characterized by high volatility. Such a phenomenon may be owing to "herd-like" behaviour where market agents pay less attention to market fundamentals and trade following the price trend. In the model, volatility clustering is captured by specifying the variance being determined by its past behaviour as reflected by the lagged h_t.

Multivariate GARCH models, such as BEKK, allow the modelling of temporal interactions between shocks in different markets by means of the estimation of the conditional covariance, $h_{12,t+1}$. This allows not only the examination of the impact of news on the covariances, but also the assessment of time-varying correlations between the shocks in different markets and the extent to which volatility spills over.

Empirical results

Data and preliminary analysis

I use logarithmic transformations of monthly domestic prices measured in USD per tonne from January 2000 to December 2009. The data on domestic prices are collected from FAO's Global Information and Early Warning System. Data on the corresponding international market prices are collected from the IMF's International Financial Statistics database.

I apply the VECM-BEKK model to investigate spillover between the world market and the wheat market in Peru and the maize market in Mexico. In Peru, wheat and wheat products accounted for 11 percent of the total dietary energy supply in 2003-05. Peru relies mainly on wheat imports. On average in 2004-08, the self-sufficiency ratio of wheat and wheat products was 11 percent. In Mexico, white maize is the main staple food while yellow maize is imported for animal feed. Average 2004-08 per capita annual food consumption of maize and maize products was 140 kg. During the same period, the self-sufficiency ratio of maize and maize products was 75 percent.

I focus on Asia, investigating price transmission and volatility spillover in the rice markets of India and the Philippines. India is a major producer and exporter of rice. It is fully

Table 8.1: Food prices: tests for non-stationarity

	Augmented Dickey Fuller		Phillips - Perron	
	p_t	Δp_t	p_t	Δp_t
Peru -wheat	-0.23-	-9.89	-3.30	-11.75
Mexico - maize	-1.01	-6.11	-1.04	-10.53
India -rice	-0.48	-12.31	-0.12	-12.46
Philippines - rice	-1.50	-9.30	-1.49	-9.44
Malawi - maize	-3.08	-7.01	-2.23	-6.67
Niger - sorghum	-2.29	-7.90	-2.60	-7.13
World market -wheat	-1.67	-8.56	-1.66	-8.58
World market –rice	-0.51	-6.77	-0.48	-6.32
World market – maize	-1.36	-8.42	-1.31	-8.42
World market - sorghum	-1.27	-9.33	-1.52	-9.37

Note: The 5 percent and 1 percent critical values for both tests are -2.88 and -3.48, respectively.

self-sufficient in rice, which is the main staple food throughout the country. Rice accounted for 30 percent of the total dietary energy supply in 2003-05. In the Philippines, where rice is also the main staple, the self-sufficiency ratio of rice was, during the 2004-08 period, about 85 percent.

I also select two African food markets, those of maize in Malawi and sorghum in the Niger. In Malawi, maize is the main staple food produced and consumed throughout the country. Maize and maize products accounted for 52 percent of the total dietary energy supply in 2003-05. On average in 2004-08, per capita annual consumption of maize was 127 kg. The self-sufficiency ratio of maize was 97 percent. Sorghum is one of the main staple foods in the Niger, accounting for 12 percent of the total dietary energy supply in 2003-05. On average in 2004-08, per capita annual consumption of sorghum was 43 kg.

The order of integration of the price series is assessed by the Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979) and the Z_r test by Phillips & Perron (1998). All series were found to be non-stationary and integrated of order 1 (Table 8.1).

Table 8.2 presents a range of descriptive statistics for the differenced prices Δp_t. The sample moments for all differenced prices indicate non-normal distributions. Zero excess kurtosis is rejected for all series suggesting leptokurtic distributions with heavy tails. In general, the statistics indicate that the differenced prices exhibit time-varying variance and volatility clustering with large changes being likely to be followed by further large changes.

The Jacque-Bera test is used to test the hypothesis that the differenced prices are normally distributed. In all cases, the probability values are smaller than 0.01, rejecting the null. I also calculated the sample autocorrelation functions, which provided evidence for autocorrelation, at least for the first and the second lag.

Empirical results

VECMs: Price transmission or mean spillover

For each of the food markets, I test for cointegration between the domestic and world prices using the Full Information Maximum Likelihood method developed by Johansen (1995). This

Table 8.2: Differenced food prices: descriptive statistics

	Wheat		Rice			Maize		Sorghum	
	Peru	World	Philippines	India	World	Malawi	World	Niger	World
Mean	0.007	0.006	0.004	0.004	0.008	0.005	0.005	0.011	0.005
Median	0.002	0.002	0.006	0.004	0.003	0.013	0.004	0.014	0.005
Maximum	0.644	0.229	0.174	0.246	0.412	0.484	0.167	0.259	0.189
Minimum	-0.621	-0.219	-0.105	-0.319	-0.190	-0.705	-0.246	-0.623	-0.278
Standard Deviation	0.169	0.065	0.031	0.055	0.068	0.177	0.063	0.129	0.069
Skewness	0.670	-0.048	1.338	-0.880	2.541	-0.773	-0.645	-1.2667	-0.693
Kurtosis	8.008	4.913	12.959	14.380	16.706	5.483	5.106	7.175	5.208
Jarque-Bera	133.256	18.197	527.352	657.530	1 059.564	42.427	30.256	118.291	33.705
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Ljung-Box lag=1	-0.204	0.225	0.520	0.234	0.493	0.404	0.238	0.353	0.142
	0.024	*0.013*	*0.000*	*0.010*	*0.000*	*0.000*	*0.009*	*0.000*	*0.081*
Ljung-Box lag= 2	-0.155	0.065	0.184	-0.004	0.075	0.034	0.049	-0.099	0.056
	0.018	*0.035*	*0.000*	*0.032*	*0.000*	*0.000*	*0.027*	*0.000*	*0.241*

Note: Probabilities in italics.

test is based on the rank of matrix P in equation (4) and is the most commonly encountered in the price transmission literature. A rank equal to zero indicates non-cointegration. In our bivariate case, a rank of one would suggest cointegration between the domestic and world prices. For $n+1$ variables Johansen derived the distribution of two test statistics for the null of at most n cointegrating vectors referred to as the Trace and the Eigenvalue tests.

Table 8.3 presents the results of the non-cointegration Trace tests for the food markets under consideration. In all cases, there is strong evidence that the domestic prices and the world prices are cointegrated, with the Johansen test rejecting the null of no cointegration, but failing to reject the null of one cointegrating vector. These results suggest that the domestic markets of these commodities are well integrated with the world markets in the long run.

I formulate VECMs in order to assess the dynamics and the speed of adjustment. The estimated VECMs are presented in Table 8.6. For the Peruvian wheat market, the estimated ECM suggests that the adjustment process of the domestic price to the world price is fast. On average, over the 2000-09 period, about 0.40 percent of the divergence of the domestic wheat price from its notional long run equilibrium with the world price is corrected each month. This reflects that wheat prices in Peru adjust fully to price changes in the international market in just over two months. The non-significant error correction coefficient in the world price ECM suggests that the world price is weakly exogenous, identifying a causal relationship, in the Granger sense, which runs from the world to the Peruvian market, as expected for a small importing country. For the Mexican maize market, the error correction coefficient indicates that each month about 12 percent of the divergence of domestic prices from their long run equilibrium is corrected. On average during the past decade, it would take some ten months for maize prices in Mexico to fully adjust to a change in the international maize price.

Table 8.3: Trace statistic tests for cointegration in food markets				
	Number of cointegrating vectors:		Cointegrating vectors	
	0	1	Domestic price	World price
Peru – wheat	16.03	2.47	1	-1.24
Mexico – maize	14.04	1.48	1	-0.62
India – rice	18.50	0.03	1	-0.47
Bangladesh – rice	22.09	0.11	1	-0.43
Malawi – maize	14.22	2.60	1	-0.81
Niger – sorghum	14.62	2.28	1	-0.72

Note: In all cases the critical values for no cointegration and one cointegrating vector at the 5 percent level are 15.49 and 3.84 respectively. The appropriate lag length was chosen on the basis of the Schwartz-Bayes information criterion.

The statistical significance of both error correction coefficients in the Indian-world rice market VECM suggests that both prices are endogenous, with the world price or rice influencing the Indian market price and vice versa. This is not surprising, given the importance of India in the world rice market. The results indicate that both the Indian and the world prices adjust to their long run equilibrium, correcting about 16 percent of the divergence each month. Such a low rate of adjustment between the Indian and international rice prices can be attributed to policies such as public procurement and reserve management implemented by the Indian government to ensure food security, as well as to provide incentives to rice farmers. The estimated error correction coefficients in the Philippines rice price VECM suggest that the international price is weakly exogenous. Rice prices in the Philippines adjust to international market changes relatively rapidly, with about 20 percent of the divergence from the long run equilibrium being corrected each month.

Maize is an important staple food in Malawi. The estimated VECM suggests that the world maize price is the long-run driver of the price of maize in Malawi. The domestic maize price adjusts to changes in the world maize price quite slowly. About 11 percent of divergences from the long-run path are corrected during the period of one month. A similar speed of adjustment is estimated for the sorghum price in the Niger. In both of these countries, the food prices under examination will fully adjust to changes in the international prices in a period equal to approximately ten months.

BEKK: Conditional variances or volatility spillover

The estimation of the BEKK parameterization of the multivariate GARCH is carried out by maximizing the conditional non-linear log-likelihood function following Engle & Kroner (1995). The numerical maximization method used was the Berndt, Hall, Hall and Hausman (BHHH) algorithm. The Schwartz-Bayes criterion was used to choose the appropriate lag length. The estimated parameters are shown in Table 8.4.

The estimated parameters of the own lagged innovations quantify the effects of "news" on the variances (ARCH effects), while the parameters of the lagged variances measure the extent of volatility clustering (GARCH effects) and thus reveal the persistence of volatility. The covariance equations capture the volatility spillovers between the domestic food markets under consideration and the world market. On the whole, the parameters are significant, indicating the presence of strong ARCH and GARCH effects.

Table 8.4: Estimated multivariate GARCH model

	Peru-world (wheat)	Mexico-world (maize)	India-world (rice)	Philippines-world (rice)	Malawi-world (maize)	Niger – world (sorghum)
c_{11}	0.004	0.001	0.000	0.000	0.007	0.000
	0.000	*0.000*	*0.118*	*0.087*	*0.344*	*0.327*
v^2_{1t-1}	0.857	0.371	0.431	0.561	0.077	0.356
	0.000	***0.0036***	***0.000***	***0.000***	***0.073***	***0.000***
h_{11t-1}	0.293	0.004	0.566	0.362	0.619	0.662
	0.000	*0.937*	*0.000*	*0.000*	*0.001*	*0.000*
c_{22}	0.000	0.000	0.000	0.000	0.000	0.002
	0.190	*0.725*	*0.454*	*0.257*	*0.455*	*0.262*
v^2_{2t-1}	0.114	0.07	0.358	0.089	0.125	0.8841
	0.001	*0.075*	*0.000*	*0.000*	*0.000*	*0.000*
h_{22t-1}	0.496	0.910	0.517	0.867	0.824	0.025
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.471*
c_{12}	0.000	0.000	0.000	0.000	0.000	0.002
	0.711	*0.725*	*0.001*	*0.251*	*0.224*	*0.005*
v^2_{1t-1} v^2_{2t-1}	0.312	0.167	0.393	0.223	0.098	-0.561
h_{12t-1}	0.496	0.062	0.541	0.530	0.824	0.128

Note: Probabilities in italics.

In all developing markets volatility, as reflected by the conditional variances, is shown to be persistent. Persistence can be measured by sum of the ARCH and GARCH coefficients, $b^2_{ij} + a^2_{ij}$, which, with the exception of the maize market in Mexico, is either close to or over unity. In all covariance equations, with the exception of the sorghum market in the Niger, the estimated parameters of the cross past innovations $v^2_{1,t-1}$ and $v^2_{2,t-1}$ are positive, suggesting that if shocks in the domestic and world markets have the same sign, the covariance will be affected in a positive manner reflecting the possibility for volatility spillover between the domestic and world markets under consideration.

Rather than focusing on the parameters themselves, I discuss the time plots of the estimated conditional variances over the period 2000-09. I also calculate the conditional

Table 8.5: World wheat and maize price conditional variances

World price conditional variance	Constant	Trend	R2
Wheat	0.002 *5.246*	0.035 *7.897*	0.35
Maize	0.001 *3.893*	0.048 *9.297*	0.46

Note: *t*-ratios in italics.

correlation as follows:

$$\rho_{12,t+1} = h_{12,t+1} / \left(\sqrt{h_{11,t+1}} \sqrt{h_{22,t+1}} \right) \tag{8}$$

Figures 8.1 to 8.6 present the conditional variances and correlations of the markets examined. The plots show that the conditional variances and correlations of food commodities in all markets are far from being constant over time. The conditional variances of the world wheat and maize prices appear to follow a positive trend, suggesting that volatility in these markets has been steadily increasing during the 2000-09 period.

I then regressed both conditional variances on a time trend to corroborate this observation. In both regressions, the estimated time trend parameter was statistically significant (see Table 8.5). While on the other hand, the variances of the domestic food prices do not appear to follow a trend; most tend to cluster during the 2008-09 period following, to differing degrees, the world price volatilities. The conditional correlations are extremely variable, changing from negative to positive sign quite frequently, as well as from a low to high value in an abrupt way. This suggests a weak relationship between shocks in the international market and the markets of developing countries.

The conditional variance of the Peruvian wheat price is characterized by dramatic increases in 2000, the first months of 2004, as well as the end of 2008 and the first months of 2009, suggesting volatility spillover from the international market (Figure 8.1). It is worth noting that during this period, the conditional variance is at least 60 percent higher than its estimated values during 2004, suggesting that the food commodity price episode did not only lead to a delayed volatility clustering in the wheat market of Peru, but that its effect was probably exacerbated by domestic factors. Although in general, during the 2000-09 period, the volatility faced by wheat producers and consumers in Peru was, at times, significantly higher that that of the international wheat market, the recent price surge has affected the price variance in a disproportionate manner. The estimated conditional correlation exhibits sudden changes, ranging from 0.36 to 0.4 during 2000-09, revealing, on average, a weak relationship between international and domestic market shocks.

Although the estimated conditional variance of the world maize price follows an increasing trend since 2005, maize prices in Mexico are characterized by sudden bouts of volatility which at times (such as late 2001, summer 2003 and the first months of 2003) result in higher variances that those prevailing in the world maize market (Figure 8.2). The estimated price conditional variance also suggests that domestic maize prices were subject to high volatility during the recent price episode, indicating that volatility spilled over from the international to the Mexican market.

During this period, the Mexican Government pursued public-private partnerships and announced a price freeze on 150 basic-basket food products until the end of 2008 as part of

Figure 8.1: Peruvian and world wheat prices: domestic price conditional variance, world price conditional variance and conditional correlation

an agreement with the National Confederation of Chambers of Industry (Concamin). Food processors affiliated with the largest Mexican industrial trade groups agreed not to pass on their rising production cost to consumers, enabling the government to achieve price controls without direct economic intervention. Nevertheless, as in the case of Peru, the conditional variance of domestic maize prices since the summer of 2008 attained its highest values since 2000. This, in conjunction with high and positive values of the estimated conditional correlation, indicates that during times of high international price volatility there is significant and persistent volatility spillover onto the Mexican maize market.

Both the world and the Indian rice markets appear to be characterized by very low volatility up to the year 2007 (Figure 8.3). Indeed, since the mid-1980s, prices have been low and quite stable (Dawe, 2002). The world rice market is quite thin, with only about 7 percent of world production being traded, while all major producers manage their domestic markets mainly through trade policy measures. The Indian government intervenes in the rice market through procurement, stocking and distribution policies (Gulati & Dutta, 2010). The conditional variance of the Indian market prices exhibits sharp spikes in 2002-03 (owing to climatic conditions during that harvest period) and in 2008 (during the food price surge). These price hikes were however, to a certain extent, much lower that those of the international prices.

The conditional correlation of the Indian and world rice prices assumes positive values for most of the 2000-09 period and also exhibits sharp increases during 2002-03 and, most importantly during the 2008 price surge, indicating volatility spillovers. Although our findings indicate significant volatility persistence and spillover, volatility in the Indian market was significantly lower than in the world market during the recent price episode owing to the Government of India's intervention in stabilizing the domestic price level. Indeed, during the 2008 price surge, the imposed rice export ban resulted in less domestic price volatility in India, while at the same time other major rice exporting countries imposed export restrictions and the world price of rice increased sharply and became more volatile.

Figure 8.4 presents the conditional variance and correlations for the price of rice in the Philippines. While domestic prices are characterized by low volatility during the period 2000-07, the conditional variance exhibits a dramatic increase during the first quarter of 2008. This increase in variance is proportionately similar to the increase in variance of the world price with the conditional correlation between the world and domestic price shocks taking high values and suggesting that volatility spilled over from the world to the domestic rice market.

Figure 8.2: Mexican and world maize prices: domestic price conditional variance, world price conditional variance and conditional correlation

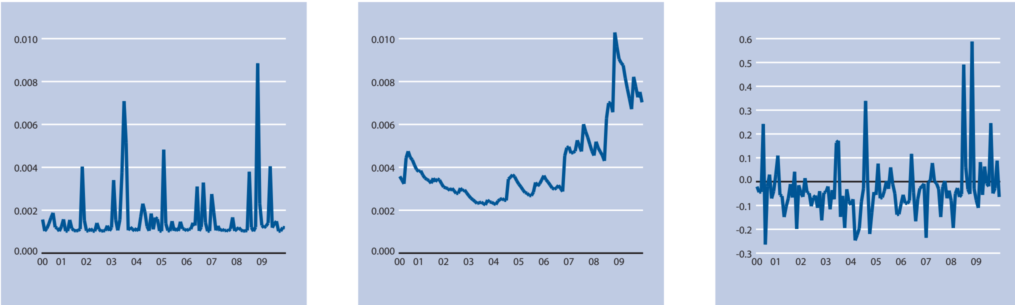


Figure 8.3: Indian and world rice prices: domestic price conditional variance, world price conditional variance and conditional correlation

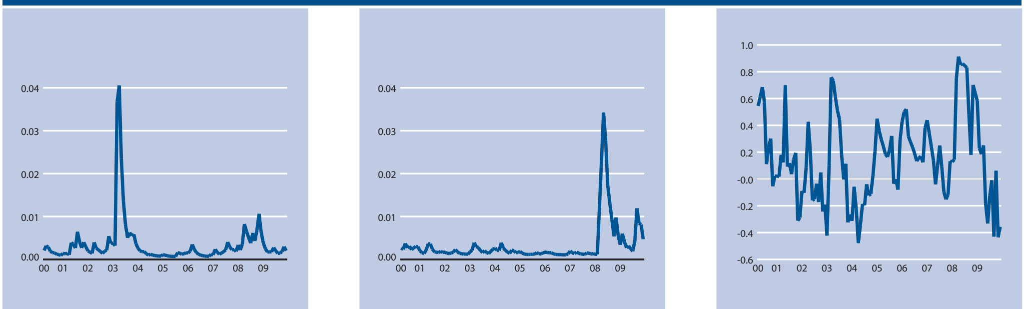
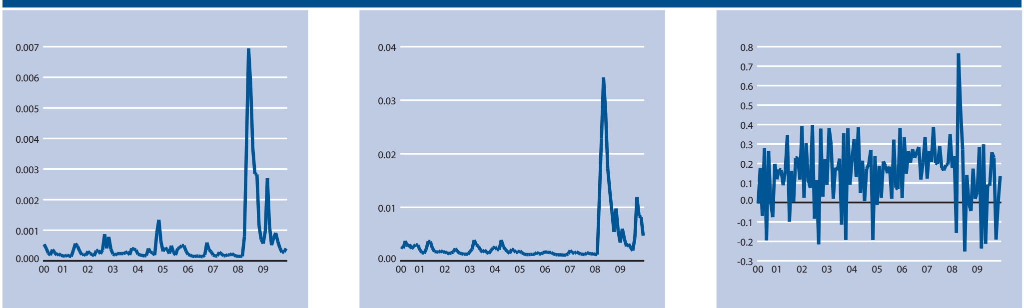


Figure 8.4: Philippine and world rice prices: domestic price conditional variance, world price conditional variance and conditional correlation



This is surprising for a country that manages the rice market through a parastatal marketing board mandated to stabilize prices. However, in recent years the country has imported rice in order to add to domestic supplies and to keep the price at a pre-determined level. On average, during the period 2006-08, the Philippines imported about 2 million tonnes, making the country the biggest importer of rice (Balisacan et al., 2010). In the first quarter of 2008, the government, facing low levels of public stocks, put out large tenders paying increasingly

Figure 8.5: Malawi and world maize prices: domestic price conditional variance, world price conditional variance and conditional correlation

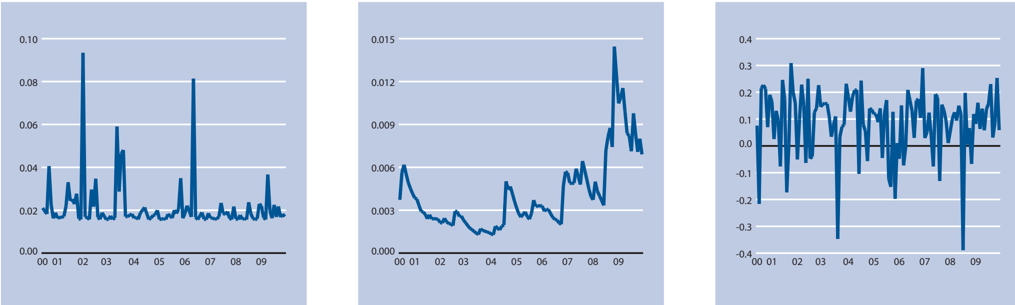
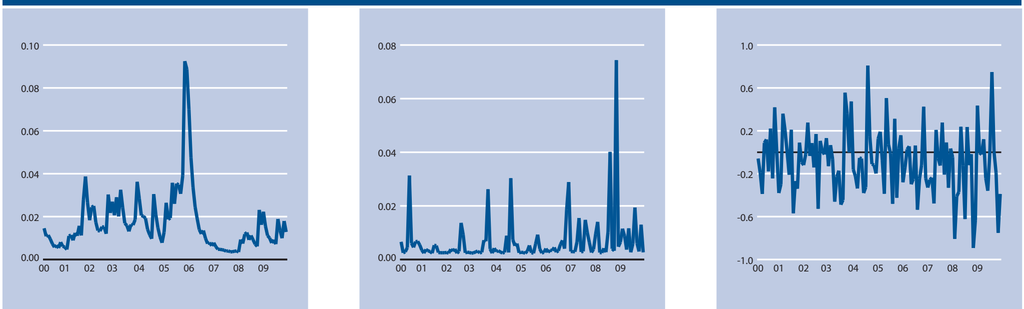


Figure 8.6: Niger and world sorghum prices: domestic price conditional variance, world price conditional variance and conditional correlation



high prices. Such strong buying behaviour contributed to the uncertainty in the markets, fuelling speculation in the Philippines as well as globally (Timmer & Dawe, 2010).

During the whole period 2000-09, maize prices in Malawi were extremely volatile (Figure 8.5). The country experienced episodes of extreme volatility associated with a price surge in 2002 caused by the failure to harvest sufficient staple maize owing to a drought. Similar increases in volatility took place in 2005-06. In 2002, adverse weather resulted in crop failures and food shortages, but the causes of the food crisis in Malawi were complex, also including errors in early warning systems, distortions in domestic markets, and mismanagement of food reserves. Such significant increases in the volatility of the price of maize are in line with the result of the previous section and the estimated VECMs. Slow adjustment to world market prices points out a partly insulated market with limited buffer capacity to contain domestic shocks over periods of relative market tranquillity. The bout of price volatility instigated by the 2008 price surge appears to be small, as compared with past extreme volatility values. This does not suggest that during international commodity price surges there is limited volatility, but highlights that domestic volatility is equally important.

The maize market in Malawi is characterized by a dual marketing structure where the government operates along the private sector through parastatal marketing boards and food security programmes intervening in the market. Both parastatals, the Agricultural Development and Marketing Corporation (ADMARC) and the Food Reserve Agency maintain a strong presence in the market. In addition to unfavourable climatic conditions, which generate wide shocks, discrete and largely unexpected policy responses increase domestic volatility. For example, during the food price surge of 2008, based on estimates of surplus production in May 2008, the government requested that the ADMARC accumulate stocks by initiating purchases in the domestic market. Within an environment of upward trending world maize prices, ADMARC progressively increased its price in order to outbid private traders and secure the requested quantities. Competition for maize between traders and the board was likely to have led to the domestic price increasing and remaining to high levels even after the world maize price decrease in the autumn of 2008 (Chirwa, 2009; Rapsomanikis, 2009). Poor transmission of price signals and unexpected policy responses have probably given rise to conditional correlations that change abruptly from positive to negative values. Again, irrespective of the signs, the conditional correlations are low, indicating that in general, volatility spillover from the world market may be limited, while the domestic maize price volatility remains extreme, persistent and, in general, determined by domestic shocks.

The case of sorghum in the Niger reveals the impact of both transaction costs and trade policies on domestic price volatility. The Niger is a less-developed landlocked country that regularly produces about 70 percent or more of the country's cereal needs and exports to neighbouring countries. Figure 8.6 presents the conditional variance and correlation for the price of sorghum in the Niger. The estimated variance suggests that from 2000 to 2006 the sorghum price in the Niger is characterized by high volatility. The extreme peak of the conditional variance during 2005-06 is associated with a domestic shock - an early end to the 2004 rains - which resulted in a food crisis and increased both price level and volatility. The conditional variance plot suggests that the 2008 international price surge had little effect on domestic price volatility. Although prices increased during this period, the Niger, together with other West African exporters of coarse grains, such as Burkina Faso, Mali and Nigeria, imposed export restrictions in an attempt to protect domestic consumers from the surging prices. Such policy response, though it resulted in keeping prices relatively low and less volatile as compared with the international price, increased the cost of food to the consumers of the region's traditional trading partners.

Policy implications and concluding thoughts

The effect of food price shocks on developing countries receives considerable attention whenever there are major international commodity price booms or slumps, such as the recent price surge in 2008. Our main empirical findings can be summarized as follows. Price volatility in the world and maize markets has been increasing since 2000. In most of developing countries examined, world price changes are partly transmitted to domestic markets. Although domestic markets are integrated with the world market in the long run, the adjustment of food prices in these countries to world market changes is slow. On average during the 2000-09 period, most of the food importing countries completed full adjustment to world price changes after a period of nine to ten months. This does not mean that international price surges are not transmitted to the domestic markets, but that the evolution of price upswings is different and timing of the price slump is delayed. Most markets examined exhibited sharp price increases during the end of 2008 and the first part of 2009. Often, in times of crisis, transmission is faster, as "bad news" affects the markets faster than "good news".

Panic and badly thought out policies often tend to accelerate the transmission of price spikes and exacerbate their impact on the domestic markets. Volatility spillover is also quite

Table 8.6: Domestic and international food prices: vector error correction models

	Peru - wheat		Mexico - maize		India - rice		Philippines – rice		Malawi - maize		Niger - sorghum	
	Δp_{dt}	Δp_{wt}	Δp_{dt}	Δp_{wt}	Δp_{dt}	Δp_{wt}	Δp_{dt}	Δp_{wt}	Δp_{dt}	Δp_{wt}	Δp_{dt}	Δp_{wt}
u_t	-0.406	-0.011	-0.117	0.133	-0.163	0.172	-0.212	0.079	-0.112	-0.008	-0.125	0.0134
	-5.588	*-0.289*	*-2.358*	*1.641*	*-2.574*	*2.547*	*-4.080*	*0.604*	*-3.359*	*-0.654*	*-3.514*	*0.627*
Δp_{dt-1}	-0.048	-0.006	-0.009	0.118	-0.032	0.033	0.378	0.282	0.520	-0.056	0.408	0.056
	-0.537	*-0.156*	*-0.093*	*0.764*	*-0.330*	*0.317*	*4.428*	*1.298*	*5.955*	*-1.563*	*4.858*	*1.112*
Δp_{dt-2}			0.179	-0.288	0.047	-0.0372	-0.069	-0.437	-0.060	0.089		
			1.824	*-1.895*	*0.489*	*-0.362*	*-0.850*	*-2.105*	*-0.676*	*2.443*		
Δp_{wt-1}	-0.131	0.216	0.0592	0.271	-0.149	0.576	0.044	0.595	0.575	0.247	0.043	0.149
	-0.605	*2.246*	*0.869*	*2.575*	*-1.712*	*6.195*	*1.124*	*5.953*	*2.539*	*2.655*	*0.275*	*1.610*
Δp_{wt-2}			0.083	0.076	-0.056	-0.114	0.082	-0.178	-0.663	0.009		
			1.286	*0.723*	*-0.611*	*-1.170*	*1.900*	*-1.630*	*-2.871*	*0.093*		
c	0.003	0.004	0.006	0.008	0.005	0.004	0.002	0.006	0.0030	0.003	0.005	0.004
	0.268	*0.710*	*0.501*	*0.442*	*1.174*	*0.928*	*1.113*	*1.100*	*0.217*	*0.551*	*0.448*	*0.584*

Note: The appropriate lag length was chosen on the basis of the Schwartz-Bayes information criterion.

limited during periods of world market tranquillity. None of the wheat and maize markets examined exhibit increasing price volatility, although this characteristic is evident in the world market. In general, domestic price volatility is persistent and mainly owing to domestic shocks, rather than world market shocks. Nevertheless, spillovers take place during extreme volatility episodes. All markets exhibited volatility clustering during the 2008 food price episode to a different extent, depending on the policies that were implemented at the time.

The analysis of the Indian rice market is of particular interest. India's power in the world market results in a bi-directional causal effect between domestic and world prices. Changes in the price of rice in one market will affect the other. The results suggest that volatility is characterized by the same relationship. Nevertheless, price stabilization policies in India, and more specifically the imposition of export restrictions during the recent price surge, dampened domestic market volatility while increasing volatility in the world market. Concerted implementation of export restrictions by major exporters renders the world market unreliable as a source of food (FAO, 2010). Government control over exports and imports and food reserve management to defend pre-determined prices characterizes the rice sectors of most Asian rice producing countries. During the 2008 price surge, bans in rice export triggered substantial instability in the market, especially because governments announced the export bans without clarifying their duration.

Completely banning food exports was also a common reaction to the food price surge across Africa, with many countries, including the Niger, a traditional exporter of sorghum and millet, closing their borders. Although export bans can generally lower domestic food prices and dampen volatility, there are also a number of negative consequences. First, export bans imply a tax on producers and lower the incentive to respond to the world price rise by increasing supply. In the long term, export restrictions may discourage investment in agriculture and thus can have negative implications for food security. Second, in the short term, export restrictions can harm traditional trading partners. For example, during the height of the food price surge in 2008, the National Cereals and Produce Board, the state marketing board of Kenya, was not able to import sufficient quantities of maize mainly owing to export bans implemented by a number of countries in the region. Finally, export bans, especially in Africa, add to the already high transaction costs and result in high welfare losses.

The analysis points out that a two-prong policy approach is necessary to reduce food price volatility in developing countries. First, in developing countries where markets are insulated (such as in Malawi), the focus should be on domestic policies leading to reductions in domestic volatility. Second, there is need for international community action to mitigate the negative effects of international price volatility on developing countries. Price volatility contributes significantly towards the vulnerability to poverty and inhibits development. It results in significant income risks that blunt the adoption of technologies necessary for agricultural production efficiency, as producers may decide to apply less productive technologies in exchange for greater stability.

Significant investment increases are needed to build better infrastructure and increase productivity. Poor infrastructure results in partial integration with the world market and increases the incidence of significant domestic price surges. It also results in markets failing to provide incentives to increase food production and engage in trade in the longer run. Low productivity inhibits the resilience of agriculture to international price shocks. Investments in infrastructure, extension services, education, as well as in research and development specific to small-scale agriculture can increase food supply in developing countries and improve the functioning of local agricultural markets and result in less volatile prices.

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