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Effects of International Grain Prices on Volatility of Domestic Grain Prices in 24 Developing Countries

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This paper discusses transmission relationships of price volatility relationships between the international and domestic prices of three grains in 24 developing countries during 2005 to 2013, using a modified Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) models. Findings indicate that the international price of rice exerts significant negative effects on the volatility of domestic rice prices in Burundi and Tunisia, and significant positive effects in Chad and Sri Lanka; in addition, international wheat prices have significant negative effects on the volatility of domestic wheat prices in Brazil and Mauritania; further, international prices for maize exert significant effects on the volatility of domestic maize prices in the Dominican Republic, Niger and the Philippines. Volatility in international rice price has significant positive impact on the volatility of rice prices in Nicaragua, however, it has a significant negative affect in Cape Verde; the volatility of international wheat price has significant positive influence in Georgia and Mauritania.

Key words: pricevolatility, GARCH model, international/domestic price

INTRODUCTION

Following global price–hikes for grain between 2007 and 2008 and resurgent high food prices in 2010, numerous studies have investigated price transmissions from international to domestic markets in developing countries. Unstable prices for food staples pose a significant risk to developing economies and their poor households (Minot, 2014).

Minot (2011) examined the degree to which changes in world food markets influence prices of staples in Sub–Saharan Africa. A statistical analysis spanning five to ten years indicated long–term relationships in only 13 of 62 African nations and that rice prices were more closely linked to world markets than maize prices. Abbott and de Battisti (2011) investigated price transmission in several African countries (as well as in other countries such as China and Brazil, for comparison) by plotting international and local commodity price indices and estimating price transmission elasticities. They found great variation in price transmission, ranging from nearly none in China to virtually complete in Brazil. Nigeria and Ethiopia appeared closely linked to world markets, whereas most other countries showed limited and/or lagged responses, suggesting that their domestic markets resist world market pressures.

Generally, earlier studies investigated price transmission from the perspective of price movements, although price volatility in food markets has received attention as markets endured sharp price fluctuations in last eight years, especially between 2007 and 2008. Volatility is not defined by price levels but by their degree of variation by calculating the annual standard deviations of price changes. Prices that vacillate rapidly over short periods exhibit high volatility; those that seldom change exhibit low volatility. Therefore, rising grain prices do not in themselves indicate volatile food markets. Large movements when prices are high may exhibit volatility comparable to smaller movements when prices are lower. Price volatility is a key measure of market movements and fundamentals, and price movements at any level of volatility can affect traders and consumers. When accepting price risk, it is important to test price movements and price volatility (Mastrangelo, 2007). Volatility spillover reflect the co–movements of the price variances in markets. A better understanding of the price mean and variance relationships between the global markets and developing countries aids policy formulation. Increases in food price volatility have important implications for economic welfare in developing countries where agricultural commodities form the basis for household income and food consumption (Prakash, 2011).

Minot (2014) examined patterns and trends in food price volatility using an unusually rich database of African staple foods and found no evidence of greater food price volatility between 2007 and 2010, when international grain prices have become quite volatile in recent years. This finding contradicts widespread views of food prices that have become more volatile in the region since

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the global food crisis of 2007–2008. In addition, Minot's results suggest price volatility is less for processed and tradable foods than for non–tradable foods, the volatility of which is lower in major cities than in secondary cities, and that volatility in maize prices is greater in countries where the governments intervene actively to stabilise them. These findings suggest that attention should be paid to (high) levels of food prices in Africa rather than to volatility per se, that regional and international trade can reduce their volatility, and that efforts to stabilise food prices may be counterproductive.

Kroner (1993) used a multivariate GARCH–in–mean model of the reduced form of multilateral exports to examine relationships among nominal exchange rate volatility and export flows and prices. Unlike conventional two–step strategies, the model imposed rationality on perceived exchange rate volatility. Testing five industrialised countries during the post–Bretton Woods era found that GARCH conditional variance had a statistically significant impact on reduced form equations for all five. For most sampled countries, the magnitude of the effect was stronger for export prices than quantities, and estimated magnitude of the impact of volatility on exports was not robust to using the conventional estimation strategy.

Most studies that examined grain prices between 2007 and 2008 investigated price transmission from international to domestic markets; few compared the effects of price volatility in both markets. Therefore, this study analyses price volatility. It discusses how the international prices of three grains influence volatility of domestic prices in 24 developing countries, focusing on the behaviour and role of volatility.

This study employed a GARCH (1,1) model to calculate volatility of international grain prices and a modified GARCH (1,1) model, in which we introduced international grain prices and their volatility to be an exogenous variable, to estimate whether and how international prices and their volatility influence domestic markets.

DATA AND METHODS

DATA

Data include retail grain price series for rice, wheat and maize in international and 24 domestic markets in developing countries. Prices cover Laos and the Philippines (East Asia and the Pacific); Kyrgyzstan, Armenia and Georgia (Europe and Central Asia); Guatemala, Nicaragua, Brazil, the Dominican Republic, Panama and Peru (Latin America and the Caribbean); Tunisia (Middle East and North Africa); Nepal, Pakistan and Sri Lanka (South Asia); and Benin, Niger, Burundi, Chad, Madagascar, Togo, Cameroon, Cape Verde and Mauritania (Sub–Saharan Africa). These countries represent prevailing types of developing nations and span low (≦$1,035), lower middle ($1,036～$4,085) and upper middle ($4,086～$12,615) income groups (World Bank, 2013).

International data are monthly times series from January 2005 to July 2013 obtained from the website of the International Financial Statistics (IFS) and World Economic Outlook Database published by the International Monetary Fund (IMF). Domestic grain prices are from the Food and Agriculture Organization (FAO) website (GIEWS Food Price Data and Analysis Tool). All prices are nominal in USD/tonne.

METHODS

This study design tests the ARCH effects of grain prices using Auto Regressive Conditional Heteroskedasticity (ARC) model and estimates how international grain prices and their volatilities influence the volatility in domestic prices a modified Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) model.

In the first step, this study checked the stability of variables using Augmented Dickey–Fuller test (ADF) (Dickey and Fuller, 1979) and Phillips and Perron tests (PP) (Phillips and Perron, 1988). If they are not stable, we converted the unstable to stationary variables.

In the second step, we employed ARCH model to test for ARCH effects that determined whether we ran the GARCH model (Engle, 1982).

$$\begin{cases} y_t = C + \varepsilon_t & (1) \\ h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i . \varepsilon_{t-1}^2 & (2) \end{cases}$$

where,

$y_t = \log P_t - \log P_{t-1}$;

P_t: grain price at time t;

h_t: conditional variance of ε at time t, defined as the sum of residual lag–weighted squares;

$\sum_{i=1}^{q} \alpha_i . \varepsilon_{t-1}^2$: the ARCH term. If highly significant, grain price volatility shows significant clustering, and fluctuation will expand with $\alpha_i > 1$; otherwise the fluctuation will shrink.

ARCH family models expose heteroscedasticity, indicating that variances in a random series differ. We focus on grain price volatility in this research. When the ARCH effect is present—i.e. heteroscedasticity is found—it is valid to test grain price volatility via this method. Clustering means that heteroskedasticity effects may gather during an examined period. When small fluctuations prompt other smaller fluctuations, clustering might be shrinking. The opposite suggests expansion. We ran the GARCH model only after ascertaining price data displayed ARCH effects.

In the third step, employed a GARCH (1,1) model (Bollerslev, 1986) to calculate volatility in international grain prices.

$$\begin{cases} y_t = C + \varepsilon_t & (3) \\ \sigma_{e,t}^{\ 2} = \phi_0 + \phi_1 \varepsilon_{e,t-1}^{\ 2} + \phi_2 \sigma_{e,t-1}^{\ 2} & (4) \end{cases}$$

where,

$y_t = \log P_t - \log P_{t-1}$;

P_t: grain price at time t;

$\varepsilon_{e,t-1}^{\ 2}$: the ARCH term, the square of error terms at times t according to $\varepsilon_{e,t}$;

ϕ_0: mean value;

$\sigma_{e,t}^2$, $\phi_2\sigma_{e,t-1}^2$: GARCH terms at t and t–1.

We regarded sequences of variances in the GARCH (1, 1) model ($\sigma_{e,t}^2$) as evidence of volatility in international grain prices. If the estimate of ϕ_2 was significant and indicated model results were reliable, we sought to derive results for volatility in international grain prices.

In the last step, we applied a modified GARCH (1,1) model introducing an exogenous variable to the model (Ashok, *et al.*, 2011, Peng, *et al.*, 2011) to model the domestic grain price volatility and test how the international grain prices and their volatilities influence the price volatility of domestic prices in the 24 countries.

$$\begin{cases} y_t = C + \varepsilon_t & (5) \\ \tau_{e,t}^2 = \pi_0 + \pi_1\,\varepsilon_{e,t-1}^2 + \pi_2\,\tau_{e,t-1}^2 + \pi_3 P_t^I & (6) \end{cases}$$

$$\begin{cases} y_t = C + \varepsilon_t & (7) \\ \tau'^2_{e,t} = \pi'_0 + \pi'_1\,\varepsilon_{e,t-1}^2 + \pi'_2\,\tau_{e,t-1}^2 + \pi'_3 V_{P_t^I} & (8) \end{cases}$$

where,

$y_t = \log P_t - \log P_{t-1}$;

P_t: grain price at time t;

P_t^I: international grain price at time t;

$V_{P_t^I}$: volatility of international grain prices;

$\varepsilon_{e,t-1}^2$: the ARCH term, square of error term at time t;

π_0 and π'_0: mean value;

π_1 and π'_1: the estimated coefficients of the ARCH term;

π_2 and π'_2: t the estimated coefficients of the GARCH term at time t–1;

π_3: the estimated coefficients for the effect of international price on the domestic price volatilities in equation (6);

π'_3: the estimated coefficients for the effect of volatility in international price on the volatilities of domestic price in equation (8);

$\tau_{e,t}^2$, $\tau_{e,t-1}^2$: GARCH term at t and t–1 for equation (6).

$\tau'^2_{e,t}$, $\tau'^2_{e,t-1}$: GARCH term at t and t–1 for equation (8).

This study introduced an exogenous variable to the models, shown in Equations (6) and (8). This study estimated whether international grain prices influence volatility of domestic grain prices and calculated the effect using Equation (6). And it also evaluated whether the volatility of international grain price influences volatility of domestic and calculated its effect using Equation (8). If estimates of π_3 and π'_3 were significant and endorsed model results (after Q–Statistics and arch test), we concluded that international grain prices and volatility of international grain prices may significantly influence volatility of domestic prices in developing countries.

RESULTS

Stability valuation

The Augmented Dickey–Fuller (ADF) test and Phillips–Perron (PP) test determined that log return forms of international and domestic grain prices were stable at 1%, 5% and 10% significance levels (Detailed results available upon request).

Results of ARCH test for ARCH model

Estimated results confirmed ARCH effects for international prices of rice and wheat but not for maize. Therefore, we ran the GARCH model to calculate the volatility of rice and wheat prices in next step.

ARCH effects appeared among rice markets in 16 countries: Benin, Brazil, Burundi, Cape Verde, Chad, Guatemala, Laos, Madagascar, Mauritania, Nepal, Nicaragua, Panama, Philippines, Sri Lanka, Togo and Tunisia. No ARCH effect appeared for domestic rice prices in these 5 countries, such as, Cameroon, Dominican, Niger, Pakistan and Peru. ARCH effects appeared in wheat prices among 7 countries: Brazil, Georgia, Kyrgyzstan, Mauritania, Nepal, Pakistan and Peru; however, no this kind of ARCH effect for rice price in Armenia, Burundi, Cameroon, Cape Verde and Sri Lanka. Seven countries exhibited ARCH effects for domestic maize prices: the Dominican Republic, Nicaragua, Niger, Panama, Peru, Philippines and Togo. There was no ARCH effect for maize prices in Benin, Burundi, Cameroon, Chad and Guatemala. We applied the GARCH model to evaluate how international grain prices affect volatility of corresponding grain prices in these countries, where ARCH effects were evident.

Volatility of international prices

Results of international price volatility

Using the GARCH model as per Equation (4), we calculated the volatility of international prices. Results are in Table 1. The results indicate that the ARCH term (ϕ_1) last month and GARCH term ($\phi 2$) last month may significantly affect the volatility of international prices (GARCH term current).

After estimating the GARCH model, it is necessary to test model appropriateness through the residual test (Q–Statistics) and the residual arch test. Only no residual and no arch effect for GARCH model, the estimating the GARCH model were acceptable.

At first, the residual test–squared residuals (Q–Statistics) were used to examine whether this model was proper or not. If the probability was larger than 0.05, the null hypothesis of no serial correlation in the residual or error terms can be accepted, and this indicates that the model may be proper. Otherwise, it may not be proper. The choice of time lags affects detection of squared residuals. Tsay (2002) suggests valuing time lags as the natural logarithm of the sample number (ln(103)≈4.6≈5 here), but Yi (2002, P. 193) recommends square roots of the sample number ($\sqrt{103}$≈10.15≈11 here). They have different comments about this question, in order for a sake of pursuing steady effects, and

Table 1. Estimates of GARCH model for Equation (4)

Items	Variables	Mean equation	Variance equation		
		C	ϕ_0	ϕ_1	ϕ_2
international rice	Coefficients	0.000	0.000*	0.518***	0.545***
	Z–statistics	–0.126	1.666	3.736	4.897
	Std. Error	0.003	0.000	0.139	0.111
	Prob.	0.900	0.096	0.000	0.000
international wheat	Coefficients	0.001	0.002*	0.317**	0.438*
	Z–statistics	0.161	1.923	2.045	1.897
	Std. Error	0.008	0.001	0.155	0.231
	Prob.	0.872	0.055	0.041	0.058

Note: *, ** and *** indicate10%, 5% and 1% significance.

this study used the lag numbers–36, which is an automatic we used 36 lags, default choice for Eviews 8.0 and larger than those numbers in the two references above, to do the serial correlation test.

As follows is another necessary test, which is arch test for GARCH model. The null hypothesis is no arch effect. If the probability of Chi–Square is larger than 0.05, we cannot reject the null hypothesis; namely, it has no arch affect, so the GARCH model is proper. After estimating the mean and variance equations together, an arch test is conducted to remove or eliminate the residual arch effect.

According to the results of residual test–squared residuals (Q–Statistics test) and arch test, it may be concluded that GARCH model is proper. And also, the variance series of GARCH (1, 1) is regarded as the volatility of international prices. Fig. 1 and 2 show volatilities of international prices.

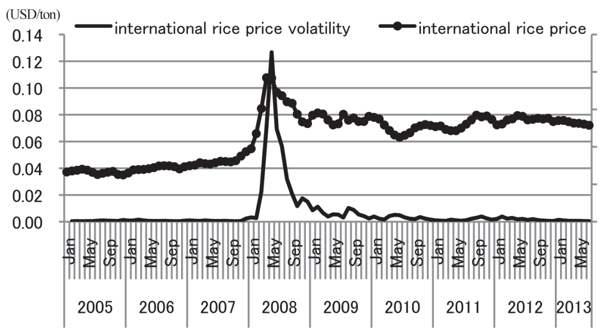

Fig. 1. International rice prices and their volatility.

Fig. 1 showed that international rice price sharply up and down in April 2008, the fluctuation of rice price in other periods relatively flat; similar with the trend of international rice price, the volatility of international rice price had sharply increasing and decreasing in 2008; however, the top point is in May 2008, one month later than international rice price. This because that the change of international price causes the volatility of international rice price.

Fig. 2 shows three obvious tops in international wheat prices: February 2008, May 2011 and November 2012. However, there are five distinct fluctuations in volatility for international wheat prices: September 2007 and December 2007, April 2008 and September 2008, October 2010 and December 2010 and June 2012 and November 2012. Fluctuation of volatility is different from a change in prices and the former more obviously reflect the trend of price movement.

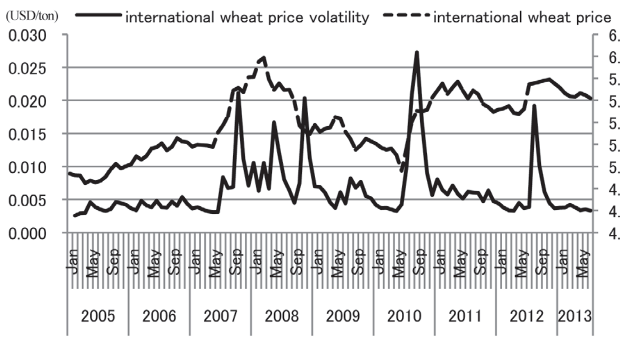

Fig. 2. International wheat prices and their volatility.

Influence of international grain prices on the volatility of domestic grain prices

Results appear in Table 2, which indicates whether and how international grain prices influence domestic grain prices in the 24 developing countries in this study. This section examines how international grain prices influenced the volatility of domestic grain prices during January 2005 and December 2013. The results of π_3 in the variance equation thus warrant attention.

As previously stated, we had to judge whether the GARCH model produces acceptable results by applying Q–Statistics test and arch test for GARCH model before analysis of π_3. The results showed that the value of π_3 at 0.0054 (Table 2) is not significant in estimating the influence of international rice price on the volatility of rice price in Benin. There is no arch test for the GARCH model; however; the Q–Statistics test indicated residual serial correlation implying that the GARCH model is unacceptable. Therefore, the study cannot estimate how international rice prices influence volatility in Benin rice prices.

The parameter estimation for rice of π_3 in Chad at

Table 2. Results of GARCH model for Equation (6): Influence of international price on domestic price volatilities

Countries	Grains		Mean equation	Variance equation				Results	Problems
			C	π_0	π_1	π_2	π_3		
Benin	rice	Coeff.	−0.0028	0.0020***	0.3603**	−0.0469	0.0054	NO	○
		Z–stats.	−0.6638	5.0077	2.4689	−0.3463	1.5375		
Brazil		Coeff.	0.0086*	0.0003	0.4253*	0.5561***	0.0068	OK	
		Z–stats.	1.8592	0.8588	1.7663	2.8045	0.9806		
Burundi		Coeff.	0.0095	0.0023	0.0953	0.4332	−0.0079***	OK	
		Z–stats.	1.5262	1.1803	0.9574	1.0299	−2.6317		
Cape Verde		Coeff.	0.0075*	0.0004**	0.2781**	0.5212***	0.0008	OK	
		Z–stats.	1.6977	2.1331	2.0156	2.9147	0.5009		
Chad		Coeff.	0.0002	0.0005	0.0241	0.8609***	0.0140***	OK	
		Z–stats.	0.0317	1.1320	0.3369	7.6232	2.0144		
Guatemala		Coeff.	0.0038***	0.0000***	0.2589***	0.4869***	0.0008***	NO	○△
		Z–stats.	4.5045	3.1955	3.1460	5.1253	7.6023		
Laos		Coeff.	0.0130**	0.0002***	−0.1195***	1.0071***	0.0044	NO	○
		Z–stats.	2.4769	3.1018	−40.1686	16.6997	1.6241		
Madagascar		Coeff.	−0.0009	0.0010***	0.5023**	0.2373*	0.0060	NO	○
		Z–stats.	−0.1509	3.8877	2.4339	1.8201	1.5449		
Mauritania		Coeff.	0.0002	0.0016***	0.4888**	−0.0519	−0.0031	OK	
		Z–stats.	0.0490	3.1500	2.5456	−0.1941	−1.2731		
Nepal		Coeff.	−0.0045	0.0005**	0.1853**	0.7395***	−0.0085***	NO	○
		Z–stats.	−0.7893	2.2001	2.1158	9.2770	−3.2894		
Nicaragua		Coeff.	0.0020	0.0004***	0.8194***	−0.0386	0.0015	OK	
		Z–stats.	0.7291	4.3003	3.1500	−0.7109	0.7391		
Panama		Coeff.	−0.0011	0.0013**	0.2763	0.4331**	−0.0037***	NO	○△
		Z–stats.	−0.0980	1.9773	1.4659	1.9787	−3.0195		
Philippines		Coeff.	0.0066***	0.0001*	0.6984***	0.2404	0.0007	NO	○
		Z–stats.	4.5566	1.7554	3.3018	1.4420	1.1999		
Sri Lanka		Coeff.	0.0087*	0.0022***	0.3297***	−0.1544	0.0107***	OK	
		Z–stats.	1.6786	2.9951	2.6328	−0.5869	4.0873		
Togo		Coeff.	−0.0013	0.0005*	0.3021*	0.6847***	0.0288	NO	○
		Z–stats.	−0.1624	1.7652	2.4501	8.9436	0.3786		
Tunisia		Coeff.	0.0077	0.0013***	0.1242	0.4649**	−0.0041***	OK	
		Z–stats.	0.8036	4.8128	1.3476	2.2518	−6.8168		
Brazil	wheat	Coeff.	0.0111***	0.0022***	0.3738	−0.0654	−0.0089***	OK	
		Z–stats.	3.8916	4.0248	1.6389	−0.5526	−2.7698		
Georgia		Coeff.	0.0033	0.0012***	0.2356**	0.1214	0.0018	NO	○
		Z–stats.	0.5955	2.9334	2.0226	0.5185	0.6371		
Kyrgyzstan		Coeff.	−0.0038***	0.0002***	1.6763***	0.1820***	0.0050***	NO	○
		Z–stats.	−3.4611	4.0628	7.1900	3.8508	9.5321		
Mauritania		Coeff.	0.0001	0.0000	1.0565***	0.5094***	−0.0003***	OK	
		Z–stats.	0.0457	1.1561	7.3194	14.4128	−4.0574		
Nepal		Coeff.	0.0059	0.0002	0.3222***	0.6481***	−0.0013	NO	○
		Z–stats.	1.5635	1.1662	2.4344	5.8154	−0.5782		
Pakistan		Coeff.	0.0016	−0.0000	0.0734*	0.9189***	0.0029***	NO	○
		Z–stats.	0.5244	−0.4432	1.8597	19.3033	4.3578		
Peru		Coeff.	0.0040***	0.0000	0.3373***	0.6245***	0.0004***	NO	○
		Z–stats.	4.2820	1.4093	2.6234	5.1809	3.2137		
The Dominican Republic	maize	Coeff.	−0.0020	0.0148***	0.0558***	−0.9325***	0.0282***	OK	
		Z–stats.	−0.3568	7.9972	3.0414	−19.0876	4.2289		
Nicaragua		Coeff.	0.0114	0.0047***	0.3931***	0.3194***	−0.0322***	NO	○
		Z–stats.	1.2452	14.4108	2.6820	4.9576	−6.4710		
Niger		Coeff.	0.0106***	0.0003*	0.6127***	0.3671***	0.0053***	OK	
		Z–stats.	2.9715	1.8005	4.0663	3.2248	2.5839		
Panama		Coeff.	0.0073	0.0013***	0.4815**	0.347**1	0.0054	OK	
		Z–stats.	0.9523	2.7383	2.0810	2.0358	1.0215		
Peru		Coeff.	0.0087***	0.0010***	0.1736	−0.3293	−0.0046***	NO	○
		Z–stats.	3.2148	4.8066	1.1985	−1.4477	−8.8363		
Philippines		Coeff.	0.0039	0.0002	0.1629	0.8011***	−0.0027*	OK	
		Z–stats.	0.9172	1.2574	1.4260	6.2797	−1.6459		
Togo		Coeff.	0.0004	0.0198***	0.1488*	0.6104***	−0.2205***	NO	○
		Z–stats.	0.0199	4.5851	1.9004	8.1304	−5.7613		

Note: OK indicates acceptable GARCH test results and NO indicates unacceptable results; ○ indicates serial correlation in residual; △ is residual arch effect.

0.0140 is statistically significant. The result indicated that it has no residual serial correlation after the Q–Statistics test and that here is no residual arch effect after arch test for the GARCH model. Overall, the GARCH model is reliable. Therefore, we conclude that international rice prices significantly affects the domestic volatility of rice price in Chad: when the former increases 1 unit, the latter increases 0.0140 units. Repeating this analytical procedure for rice prices in 16 countries, we found that international prices exert significant but opposing effects. When international prices raise 1 unit, price volatilities decline 0.0079 units in Burundi and 0.0041 units in Tunisia; however, they increase 0.0140 units in Chad and 0.0107 units in Sri Lanka. International rice prices have no significantly effects on domestic volatility of rice prices in Brazil, Cape Verde, Mauritania and Nicaragua. However, their domestic volatility of rice prices in these countries may be significantly influenced by its previous information (ARCH term) or its previous month's rice price volatility or both of them.

Results indicate that international wheat prices

Table 3. Estimates of GARCH model for Equation (8): Influence of international price volatility on domestic price volatilities

Countries	Grains	Variables	Mean equation	Variance equation				Results	Problems
			C	π'_0	π'_1	π'_2	π'_3		
Benin	rice	Coeff.	–0.0018	0.0025***	0.2700***	–0.0745	–0.0181	OK	
		Z–stats.	–0.3512	3.4184	2.7602	–0.2785	–1.5137		
Brazil		Coeff.	0.0066	0.0005	0.1114	0.5757*	0.1020	OK	
		Z–stats.	1.3688	1.2823	0.9125	1.7369	0.6783		
Burundi		Coeff.	0.0045	0.0031**	0.0053	0.4555	–0.0348***	NO	△
		Z–stats.	0.4963	2.0337	0.0726	1.5913	–5.0441		
Cape Verde		Coeff.	0.0097***	0.0002***	0.1724***	0.7149***	–0.0070***	OK	
		Z–stats.	3.7746	4.7227	3.1093	14.4568	–4.5021		
Chad		Coeff.	–0.0012	0.0038**	0.2288	–0.1995	0.1815	OK	
		Z–stats.	–0.1522	2.3961	0.9696	–0.5340	0.6380		
Guatemala		Coeff.	0.0034***	0.0000**	0.6784***	0.1712	0.0075	NO	○
		Z–stats.	3.5461	2.0618	2.9320	0.8464	0.7583		
Laos		Coeff.	0.0108***	0.0014***	–0.1471***	–0.3779	0.1086	NO	○
		Z–stats.	3.2932	3.7675	–3.1302	–0.8883	1.1035		
Madagascar		Coeff.	0.0018	0.0007**	0.4571**	0.3470**	0.0195	NO	○
		Z–stats.	0.2882	2.1205	2.4445	2.0930	0.7873		
Mauritania		Coeff.	–0.0009	0.0015***	0.5039**	–0.0522	0.0011	OK	
		Z–stats.	–0.2048	3.3714	2.5157	–0.2214	0.0375		
Nepal		Coeff.	0.0043	0.0028***	0.3624**	0.0442	–0.0246***	NO	○
		Z–stats.	0.6853	4.5939	2.1071	0.2407	–5.9719		
Nicaragua		Coeff.	0.0024	0.0003***	0.4398***	–0.2913***	0.1372***	OK	
		Z–stats.	1.0755	4.1458	3.6732	–13.3786	2.9881		
Panama		Coeff.	0.0015	0.0020***	0.1650	0.4863***	–0.0237***	NO	○
		Z–stats.	0.1079	2.6456	1.5702	2.7951	–4.2914		
Philippines		Coeff.	0.0074***	0.0001	0.4432*	0.2150	0.0332*	NO	○
		Z–stats.	4.3616	0.9700	1.7740	0.7655	1.9514		
Sri Lanka		Coeff.	0.0016	0.0020	0.1069	0.1979	–0.0181	NO	○
		Z–stats.	0.2371	1.0606	0.7774	0.2625	–0.7971		
Togo		Coeff.	–0.0016	0.0003	0.3524***	0.6793***	0.0173***	NO	○
		Z–stats.	–0.2056	1.2905	2.9591	9.6483	2.1553		
Tunisia		Coeff.	0.0024	0.0001	0.0207	0.4137	0.0756	OK	
		Z–stats.	0.8757	1.6225	0.2090	1.0075	1.3235		
Brazil	wheat	Coeff.	0.0106**	0.0012	0.4533**	0.0139	0.0700	OK	
		Z–stats.	2.2275	1.0984	2.0537	0.0434	0.6151		
Georgia		Coeff.	–0.0029	–0.0004	0.2707***	0.4164***	0.1744**	OK	
		Z–stats.	–0.9184	–1.6043	2.7154	3.3360	2.4997		
Kyrgyzstan		Coeff.	–0.0020	–0.0009***	0.6428***	0.0450	0.3231***	NO	○
		Z–stats.	–1.1948	–2.9092	2.8496	0.5468	3.5215		
Mauritania		Coeff.	–0.0002	–0.0001***	1.4231***	0.3984***	0.0293***	OK	
		Z–stats.	–0.2463	–4.9365	7.6848	14.4027	5.0218		
Nepal		Coeff.	0.0058	0.0002	0.3232***	0.6445***	–0.0092	NO	○
		Z–stats.	1.5513	1.1416	2.6740	5.9288	–0.4224		
Pakistan		Coeff.	0.0027	–0.0002***	0.0797	0.7533***	0.0664***	NO	○
		Z–stats.	0.8941	–2.9452	0.9372	9.6509	3.3656		
Peru		Coeff.	0.0039***	0.0000	0.6087**	0.3939***	0.0113**	NO	○
		Z–stats.	3.0619	–1.3943	2.4743	2.6309	2.4729		

Note: ○ indicates Autocorrelation Partial Correlation, △ indicates ARCH effect. *, ** and *** indicate 10%, 5% and 1% significance.

exert significant negative effects in Brazil and Mauritania. When they increase 1 unit, volatility of wheat prices in Brazil and Mauritania decline 0.0089 units and 0.0003 units, respectively.

Performing the same analytical procedure for 7 developing countries, including Dominican Republic, Nicaragua, Niger, Panama, Peru Philippines and the Togo, revealed that international maize prices affect volatility of domestic prices in the Dominican Republic, Niger and the Philippines. When the international maize price increases 1 unit, volatility of maize prices in the Dominican Republic and Niger increase 0.0282 units and 0.0053 units, respectively, and decline 0.0027 units in the Philippines. International rice prices have no significant effects on domestic volatility of rice prices in Panama. However, its domestic volatility of rice prices may be significantly influenced by its previous information (ARCH term) and its previous month's rice price volatility.

Influence of international grain price volatility on the volatility of domestic grain prices

Because international maize prices have no ARCH effect, we could not calculate its volatility. Therefore, this section examines whether and how international price volatility influences volatility of domestic prices in the 24 developing countries in rice and wheat market.

Based on estimations of the GARCH model in Table 3 and examination of arch test and Q–Statistics test for the GARCH model in Equation (8), it may be possible to judge whether and how the volatility of international rice and wheat prices influence the volatility of domestic prices in the 24 developing countries.

Results indicated that the volatility of international rice prices significantly and positively influence volatility of rice prices in Nicaragua: when the former increases 1 unit, the latter increases 0.1372 units (Table 3). For Cape Verde, volatility in international prices significantly and negatively affects the volatility of rice prices in Cape Verde: when the former increases 1unit, the latter declines 0.0070 units. Although the GARCH model is appropriate for estimations in Benin, Brazil, Chad, Mauritania and Tunisia, results indicated that volatility of international rice prices have no significant influence on the domestic rice prices volatility in these five developing countries. However, the volatility of domestic rice prices may be influenced significantly by its previous information (ARCH term) in Benin and Mauritania; the volatility of Brazil rice price may be influenced by its previous month's rice price volatility. Results from the arch test and Q–Statistics tests can not indicate the effects of price volatility in Burundi, Guatemala, Laos, Madagascar, Nepal, Panama, Philippines, Sri Lanka and Togo.

Volatility in international wheat prices significantly and positively influences the volatility of domestic wheat prices in Georgia and Mauritania: when the former increases 1 unit, the latter rise 0.1744 units and 0.0293 units, respectively. Estimation using the GARCH model is appropriate for Brazil, but results indicate no significant influence on the domestic price volatility in Brazil and its previous information (ARCH term) may be significantly influenced on it. Again, the estimated coefficients for π'_3 for wheat in Kyrgyzstan, Nepal, Pakistan and Peru are invalid because of the results of Q–Statistics tests.

In order to classify the results, Table 4 showed the summaries of GARCH model for equations (6) and (8). In the case of the influence of international grain prices on the volatility of domestic grain prices, there are 9 countries, in which their domestic price volatilities may be significantly influenced by international grain prices. However, the estimated positive coefficients in Chad, Sri Lanka and the Dominican Republic are larger in absolute values than the negative coefficients in Burundi, Tunisia, Mauritania and Philippines. This is the same for the effect of international grain price volatility on the volatility of domestic grain prices in 4 developing countries.

Regarding their situations of production, consumption, imports and exports in these developing countries (Ito, 2014), which would be significantly influenced by international grain prices or the volatility of international

Table 4. Results Summaries of GARCH model for equation (6) and (8)

Grains	Countries	$P_t^I \rightarrow V_{P_t^D}(\pi_3)$	Countries	$V_{P_t^I} \rightarrow V_{P_t^D}(\pi'_3)$
Rice	Burundi	–0.0079***	Cape Verde	–0.0070***
	Chad	0.0140***	Nicaragua	0.1372***
	Sri Lanka	0.0107***		
	Tunisia	–0.0041***		
Wheat	Brazil	–0.0089***	Georgia	0.1744**
	Mauritania	–0.0003***	Mauritania	0.0293***
Maize	The Dominican Republic	0.0282***		
	Niger	0.0053***		
	Philippines	–0.0027*		

Note: *, ** and *** indicate10%, 5% and 1% significance; table 4 is summary for table 2 and 3 as follows, this table only show the results which is statistically significant; π_3 indicates influence of international price (P_t^I) on domestic price volatilities ($V_{P_t^D}$); π_3 indicates influence of international price volatility ($V_{P_t^I}$) on domestic price volatilities ($V_{P_t^D}$)

grain prices, it was found that the grain consumption in these countries relies heavily on foreign import. For example, rice imports account for 58.5% of total consumption in Tunisia (1.68 million of 2.88 million tons consumed). Imports comprise 66.3% of Brazilian wheat consumption (7.13 million of 10.76 million tons consumed). Some of the 24 countries studied in this research are very closely linked with international grain markets. For some other countries, the trade is not much with international grain markets, but they still would be significantly influenced by international grain prices or the volatility of international grain prices. For example, Sri Lanka imports only 2.4% of rice consumed and the Philippines 2.44% of maize consumption, while the prices of those grains in these two countries are influenced by the international prices. The reason may be due to their trade policies or some other reasons in their own countries. This study can reflect the transmitted situations from international market to domestic markets in sampled developing countries from the perspective of price volatility.

CONCLUSION AND DISCUSSIONS

This study estimated whether and how the international grain prices and the volatility in international grain prices influence the volatility of domestic grain prices in 24 developing countries during the period from January 2005 to July 2013. Our conclusions are as follows:

First, there are some countries where their domestic grain prices volatility was influenced by international grain prices. International price affected the volatility of rice prices significantly and negatively in Burundi and Tunisia and positively in Chad and Sri Lanka. International wheat prices had significant negative effects on wheat prices in Brazil and Mauritania. International prices for maize exerted significant effects on domestic rice prices in the Dominican Republic, Niger and the Philippines. These countries would be significantly influenced by international grain prices because these countries have grain trade with international markets.

Second, the results of estimating whether and how volatility of international grain prices influences volatility of domestic grain prices show that the volatility of international rice price has significant positive influence on the volatility of rice prices in Nicaragua; however, it has significant negative effects in Cape Verde; the volatility of international wheat price exerts significant positive influence in Georgia and Mauritania.

Third, in above two cases, absolute value of influence (π_3 and π'_3) in these countries, whose effects are positive, are larger than other countries, whose effects are negative.

Finally, some countries were not significantly affected by international grain prices and the volatility of international grain prices. The reason may be that their domestic volatility of rice price in these countries may be significantly influenced by its previous information (ARCH term) or its previous month's rice price volatility or both of them. Those countries are pat to be self–sufficient in supply the grains. Trade policies, government subsidies or other reasons may be influencing domestic grain market.

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