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Market integration between surplus and deficit rice markets during global food crisis period[1]

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Applying the maximum-likelihood method of co-integration, this study analysed spatial market integration between an adjacent rice surplus market (India) and deficit markets (Bangladesh and Nepal). The main focus is on the government policies of these three rice-producing countries which have been imposed to reduce domestic price volatilities in rice markets during the recent 'global food crisis' in 2007–2008. The co-integration tests find that domestic rice prices of India, Bangladesh and Nepal are integrated both in short-run and long-run periods despite the imposition of export restriction policies by India. The reason that prices are transmitted so effectively is most likely to be the widespread informal cross-border trade through the porous borders among India, Bangladesh and Nepal.

Key words: global food crisis, market co-integration, price transmission, public policies, rice price.

1. Introduction

Foodgrain market co-integration in developing countries has increased in importance in the political debate over recent years because of price stabilisation and food security considerations. If markets for foodgrain commodities are not co-integrated, the correct price signals will not be transmitted among deficit and surplus markets, whereas when markets are integrated, price changes in one market will be transmitted to other markets and enhance market co-integration (Froot *et al.* 1995). However, a number of factors such as public policy interventions, noncompetitive market behaviour and informal cross-border trade can influence price transmission processes between integrated markets.

India, Bangladesh and Nepal are neighbouring rice-producing and rice-consuming countries in South Asia. Although Bangladesh and Nepal produce rice, both countries mostly depend on imports from India to fill the gap

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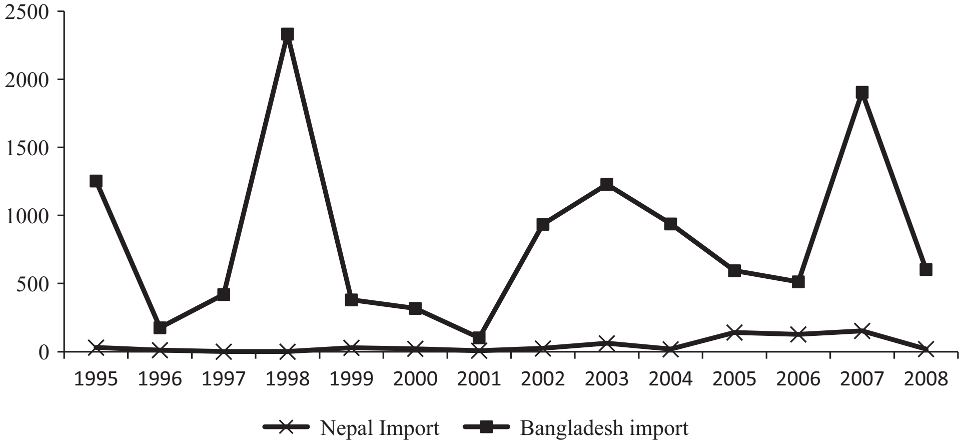

Figure 1 Rice imports from India to Bangladesh and Nepal (in thousand tonnes). Source: FAO, 2011.

between domestic demand and supply of rice. Since trade liberalisation in 1994, India has become the major source of rice imports for Bangladesh and Nepal (see Figure 1). During the devastating flood in 1997–1998, several hundreds of small importers in Bangladesh imported rice from India in small quantities which helped to stabilise rice prices by adding supply in Bangladesh (Ninno and Dorosh 2001). It was identified that if India had not been a source of rice for private importers during that period, prices could have increased by 40 to 60 per cent in Bangladesh (Dorosh 2001; Ninno *et al.* 2003). In 1998, the Bangladeshi government signed a trade agreement with Indian government to allow rice imports through nine land ports located in India and Bangladesh border areas (Chowdhury 2010). As a landlocked country, Nepal depends heavily on India for commodity trade as India is the only country that provides land transits to Nepal. Whenever Nepal faces any rice production shortfalls, large amounts of imports from India help to stabilise its domestic market price of rice (Sanogo and Maliki 2010).

However, based on the demand or supply shocks, governments of these three countries often impose different types of trade policies such as import tariffs, export taxes, export subsidies, quantitative restrictions and exports bans on rice to keep domestic prices stable (Dorosh 2009; Dawe *et al.* 2010). It has been claimed that any attempt to regulate the trade of rice may increase illegal or informal trade between the neighbouring countries (Taneja 2004). The longer delivery time through formal trade channels could also increase informal border trade when demand in one market is higher than that in others. Inefficient and corrupt trade institutions are likely to encourage informal trade at the borders between the countries (Pohit and Taneja 2003).

Thus, rice prices in Bangladesh are affected through informal trading over a porous border between India and Bangladesh (Murshid *et al.*, 2009). Similarly, despite an open border and a trade treaty, there is a large volume of rice traded informally due to the porous border and a fixed currency exchange rate between India and Nepal (Sanogo 2008).

During 2007 to 2008, the global foodgrain market was volatile due to a sudden change in demand and supply. India, one of the major global rice exporters, experienced relatively low domestic rice production mainly caused by adverse weather in the second half of 2007. In response, the Indian government cut-off their global rice exports to keep the domestic prices lower by ensuring enough supply in the domestic markets (Headey and Fan 2008; Dorosh 2009). At the same time, Bangladesh faced two consecutive floods and a devastating cyclone named 'Sidr' which caused significant damage to its rice production (Chowdhury 2010). However, as India was the largest source of rice imports for Bangladesh, it was unable to import rice at a regular import parity price due to India's trade restriction. As a consequence, the domestic market price of rice in Bangladesh increased to very high levels (Javier 2011). On the other hand, although Nepal did not experience any rice production shortfall during the global food crisis in 2007–2008, domestic rice prices in Nepal rose by 17.1 per cent due to the high export price of rice in India during that period (WFP, 2010).

A study conducted by Food and Agricultural Organization (FAO) in 2007 found that rice markets in the plain areas of Nepal were closely linked with the border markets of India, noting that the study was restricted to monthly price data from 2001 to 2004 (UNWFP-FAO, 2007). However, Murshid *et al.* (2009) tested spatial market co-integration between Dhaka and Kolkata by using the Johansen co-integration model under a dynamic vector autoregressive (VAR) framework and a vector error correction model (VECM) with wholesale rice prices from June 2005 to November 2008. The study found that Dhaka and Kolkata rice markets were less than perfectly co-integrated, implying neither of these markets dominates; instead, there is a feedback relationship between the Dhaka and Kolkata markets. The finding of the study was supported by Dorosh (2001), and Dorosh and Shahabuddin (2002).

Previous studies have involved limited geographic scopes and sampling periods, and results are not consistent between studies. There is limited empirical research on market co-integration that can inform the public debate about the likely impact of trade policy changes on rice markets between India, Bangladesh and Nepal. Although a sizeable number of studies have identified some causes and impacts of the global food crisis (Conceição and Mendoza 2009; Mitra and Josling 2009; Slayton 2009; Headey 2011; Bellemare 2015; Horwood 2015), only a few studies have analysed the price transmission between the global market and the domestic foodgrain markets of various countries (Headey and Fan 2008; Gilbert 2011; Rapsomanikis and Mugera 2011).

Hence, this study investigates the likely impact of changes in trade policies, in particular the export restriction policies on rice imposed by the Indian government during the recent global food crisis that can affect market co-integration mechanisms on the neighbouring net importing countries of Bangladesh and Nepal. The study helps to find whether restrictive trade policies among these countries were successful and efficient stabilising domestic prices. The study is organised as follows. Following introduction in Section 1, the econometric models and the data are presented under methodology in Section 2. Section 3 provides the results and discussions. The last section concludes and provides some policy recommendation.

2. Methodology

This study is based on the theory of the Law of One Price (LOP) proposed by Fackler and Goodwin (2001) and Sharma (2003). According to Fackler and Goodwin (2001), theoretically, in an undistorted world, the LOP is supposed to regulate prices of a commodity between spatially separated markets where prices move together, thereby offering full transmission of price signals and information. On the other hand, market distortions can be introduced by governments in the form of policies, either at the border, or as price support mechanisms, which weaken co-integration and a smooth price transmission between the spatially separated markets. Price transmission in less developed countries is less efficient than in developed countries because of market rigidities and protective policy instruments such as import tariffs, export/import quotas, export subsidies/taxes/restrictions and exchange rate policies (Sharma 2003; Abdulai 2007).

Implementation of protective policy instruments of a large exporting country would impede changes in international prices being fully transmitted to the domestic market in relative terms (Sharma 2003). Due to export restriction policies, no trade is supposed to occur between small importing countries that have limited access to other sources and large exporting markets. As a result, the domestic prices of both markets may become close to the autarky price level by eliminating opportunities for trade, resulting in the two prices moving independently of each other.

The main focus of the study was to look at the protective policy instruments, in particular the export restriction policies imposed by India on its rice market which could impede the price transmission from India to the domestic rice markets of Bangladesh and Nepal and could affect the domestic market's excess demand and supply schedules.

2.1 Econometric approaches

2.1.1 Multivariate co-integration model

In case of more than two variables, an appropriate way to test multiple co-integrating vectors is to use the maximum-likelihood co-integration method developed by Johansen (1988) and later expanded by Johansen and Juselius (1990). This method can solve the endogeneity problem of the error correction model by treating all the variables as explicitly endogenous, which means the estimation procedure of the model does not require the arbitrary choice of a variable for normalisation.

In a multivariate context, two or more nonstationary data series might be stationary when they share a common unit root and a common sequence of stochastic shocks. In that case, such variables can have long-run equilibrium and are said to be co-integrated. The number of co-integrating vectors and the stochastic trend are important indicators of the extent of the co-movement of prices and the strength of market integration in the multivariate model. The number of stochastic trends in Johansen and Juselius co-integration test can be determined by subtracting the number of co-integrating vectors from the dimension of the impact matrix, given by the number of price series (n) included in the VAR. If there are $n - 1$ co-integrating vectors and all the price series share a common stochastic trend, then the markets are co-integrated, suggesting that the relative LOP holds for the commodity markets (Sharma 2003). However, one co-integrating vector can satisfy that price series are co-integrated, while zero co-integrating vectors are said to be non-co-integration between the price series.

The Johansen and Juselius model is based on the maximum-likelihood estimation of the VECM, which is a slight modification of the Johansen likelihood co-integration analysis in a VAR framework. The Johansen and Juselius co-integration model begins with a VAR model.

A vector of price series at time t is related to the vector of prices at time $t - i$ which can be written as follows:

$$P_t = \pi_1 P_{t-1} + \cdots + \pi_k P_{t-k} + \varepsilon$$

represented by P is an n-vector of the price series; π is parameter with $(n \times n)$ matrix; k is lag length; ε is an n-vector of residuals and t is time trend.

The above equation can be reformulated into the following VECM form:

$$\Delta P_t = \Gamma \nabla P_{t-1} + \Pi P_{t-k}$$

where $\nabla P = [\Delta P_t, \cdots, P_{t-k+1}]$, $\Gamma = [(I + \pi_1), (I + \pi_1 + \pi_2), \cdots, (I + \pi_1 + \cdots + \pi_k)]$, and $\Pi = (I - \pi_1 - \pi_2 - \cdots - \pi_k)$.

In the equation, Δ is difference operator and Π is parameter with $(n \times n)$ matrix. Co-integration is present if the matrix Π has a rank (r) greater than zero ($r > 0$), and there is no co-integration if the rank is equal to zero ($r = 0$). The rank of Π determines the number of co-integrating vectors when stationary linear combination(s) of nonstationary time series exists.

There are three interesting cases that can be observed in the model: first, if the rank ($\Pi = r$) = n, then Π is invertible and all the price variables are stationary in levels, meaning no co-integration exists. Second, if the rank (Π =r) = 0, Π is a null matrix which means none of the linear combinations of price variable are stationary. Note that the second case can be estimated with the unrestricted VAR to identify the short-run dynamics. Third, if 0 <

rank ($\Pi = r$) < n, then there are r co-integrating relations or r stationary linear combination(s) among the elements of price variables.

The statistical procedure of the Johansen and Juselius (1990) maximum-likelihood model relies on the relationship between the rank of the matrix and its eigenvalues or characteristic roots. To determine the presence of co-integrating relationships between the price series, the trace test and the maximum eigenvalue test can be used.

In the case of the trace test, the null hypothesis of the co-integration rank is equal to r against a general alternative hypothesis of co-integrating vectors greater than r. A rejection of the null hypothesis implies no co-integrating vectors, implying the variables are not co-integrated. Using the estimates of the characteristic roots (the eigenvalues), the test for the number of characteristic roots that are insignificantly different from unity was conducted by the following statistics, known as trace statistics (λ-trace):

$$\lambda - \text{trace} = -T \sum_{i=r+1}^{n} ln(1 - \hat{\lambda}_i)$$

where $\hat{\lambda}_i$ is the estimated eigenvalues obtained from the estimated Π matrix and T is the number of observations.

The maximum eigenvalue test assumes the null hypothesis of the co-integration rank is equal to r against the alternative that the co-integration rank is equal to $r + 1$. Using the following estimates, the maximum eigenvalue statistics (λ-max) can be formed:

$$\lambda - \max = -Tln(1 - \hat{\lambda}_{r+1}).$$

2.1.2 Co-integration in the presence of structural breaks

Most of the co-integration approaches assume a constant market structure and behaviour throughout the entire sample period. However, allowing major policy changes or other kinds of shocks, which in general are known as ‘structural breaks’, in the co-integration approach may alter the degree of market co-integration. A structural break can be defined as an intermittent shock with a permanent effect on the time series data (Campos *et al.* 1996). Thus, the presence of structural breaks should be integrated. The unit root tests do not consider any structural breaks might lack the power to distinguish the order of co-integration between the null hypothesis of nonstationarity and the stationary alternative, leading to the incorrect interpretation of results.

Zivot and Andrews (1992) formulated a unit root test against a stationary alternative with a single unknown possible break point. The regression equations estimated by the Zivot and Andrews (Z-A) approach to test for a unit root follow three models, allowing for a change Equation (1) in the level of the series, Equation (2) in the trend and Equation (3) both in the intercept and in the trend. The equations for these three models can be written as follows:

$$y_t = \mu^A + \theta^A DU_t(\lambda) + \beta^A t + \rho^A y_{t-1} + \sum_{j=1}^{k} C_j^B \Delta y_{t-j} + \varepsilon_t \tag{1}$$

$$y_t = \mu^B + \beta^{BA} t + \gamma^B DT_t^*(\gamma) + \rho^B y_{t-1} + \sum_{j=1}^{k} C_j^A \Delta y_{t-j} + \varepsilon_t \tag{2}$$

$$y_t = \mu^c + \theta^c DU_t(\lambda) + \beta^c t + \gamma^c DT_t^*(\lambda) + \rho^c y_{t-1} + \sum_{j=1}^{k} C_j^c \Delta y_{t-j} + \varepsilon_t. \tag{3}$$

In the above equations, $DU_t(\lambda)$ is a dummy for a mean shift and $DU_t(\lambda) = 1$ if $t < T\lambda$, 0 otherwise; $DT_t^*(\lambda)$ is a dummy corresponding to a trend shift and $DT_t^*(\lambda) = t - T\lambda$, 0 otherwise; and k indicates the number of lags to be added to the regression to prevent autocorrelation.

2.2 Data

This study uses rice price data from Kolkata, Biratnagar and Dhaka. The rice markets are selected based on close economic interaction between the markets, which is due to geographical proximity, lower transaction costs and volume of trades. Biratnagar region, which contains Nepal's second largest city after Kathmandu, is selected as it is the major entry point for Indian rice to Nepal. Morang, which is the district headquarters of Biratnagar, is connected with the harbour of Kolkata by a train via Jogbani in India. Dhaka is selected based on a study by Dawson and Dey (2002) where the authors found LOP between the rice prices in Dhaka and each regional market in Bangladesh since trade liberalised in the early 1990s.

Although different varieties of rice are produced in the study areas, only coarse rice/nonbasmati/nonaromatic/parboiled rice is considered for the study. As coarse rice is the staple for the large part of the poorer segment of the population in the study areas, the price of coarse rice is considered as a key indicator for monitoring the national food security status.

Monthly average retail prices are collected for the study. As the data from the wholesale price of rice in Biratnagar were unavailable, the study uses the retail price data for all three markets to make the analyses consistent. Another reason for using the retail price data is to see the effect of price transmission from the consumers' aspect. However, the major downside of using retail prices is that they are not adjusted with inflation and are higher than the wholesale prices due to the addition transfer costs to the retail market.

The data periods cover from January 1999 to May 2013. The price data have been collected from several different sources such as published issues of food outlook of FAO of United Nations, Global Information on Early Warning System (GIEWS), Department of Agricultural Marketing (DAM) under the Ministry of Agriculture in Bangladesh, Food Policy Monitoring Unit (FPMU) under Ministry of Food and Disaster Management in Bangladesh, Department of Consumer Affairs, and Department of Food and Public Distribution under the Ministry of Consumer Affairs, Food, and Public Distribution in India, Agriculture Information and Communication Centre under the Ministry of Agriculture Development in Nepal and market watch of the World Food Program (WFP) of the United Nations.

All the price series in the study areas have been converted into USD. For conversion of the local currency, monthly average exchange rates were used. The data for the monthly exchange rates were collected from the central banks of India, Bangladesh and Nepal. All price series have been transformed in logarithmic values to capture the elasticities of the coefficients.

3. Results and discussion

To observe the price movement and the existence of trends on the prices, a line graph of all the price series is plotted. Figure 2 shows that all the prices seem to move together over time and display an upward drift during the global food crisis period in 2007–2008 and again in 2010–2011. The upward trend implies that the data series may attribute nonstationary feature. Although all the price series show trending behaviour, it is hard to tell from the visual inspection whether there were any deterministic or stochastic trends in the price series over the period.

Consequently, the principle of econometric analyses suggests testing unit roots of all the price variables individually. If none of the price series contain unit roots, then any shock to the series is temporary and has short-run consequences; otherwise, if there are unit roots, any shock to the series is permanent and thus will have a long-run co-integration effect.

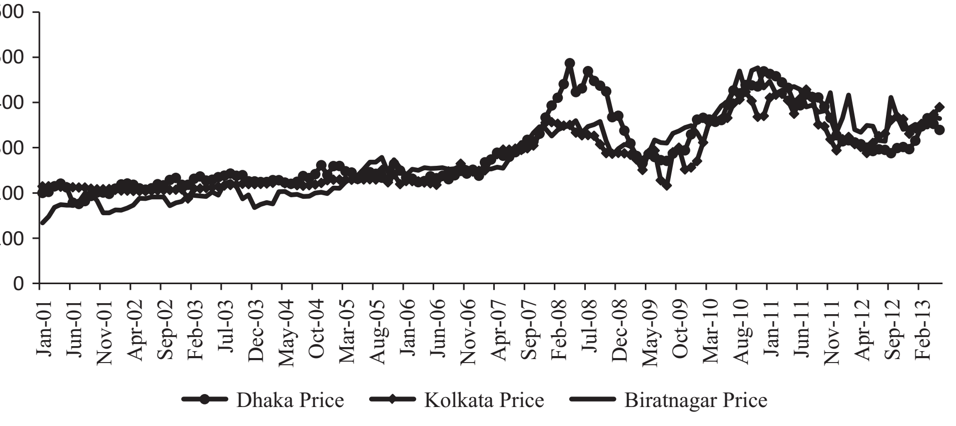

Figure 2 Trends of rice prices from January 2001 to May 2013 (USD/tonne). Sources: http://www.fao.org/giews/pricetool/; http://www.wfp.org/countries/food-security/food-prices; Department of Consumer Affairs, India; Department of Agricultural Marketing, Bangladesh; and http://www.wfp.org/content/nepal-market-watch-2011.

Table 1 Results of unit root tests

Price series	Level (with trend)				
	ADF	DF-GLS	PP	ERS	KPSS
lnP_{Dhaka}	−2.82	−1.73	−3.04	18.22	0.13**
lnP_{Kolkata}	−2.52	−1.35	−2.47	28.21	0.28***
$lnP_{\text{Biratnagar}}$	−2.86	−1.94	−2.83	14.43	0.18**
	First differences (without trend)				
lnP_{Dhaka}	−13.16***	−12.99***	−13.22***	0.29***	0.10
lnP_{Kolkata}	−14.43***	−2.38**	−14.40***	1.13***	0.22
$lnP_{\text{Biratnagar}}$	−13.75***	−12.58***	−13.79***	0.34***	0.05

Source: Author's calculations.
Note: ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

The stationarity of the price series is tested by using various unit root tests, such as Augmented Dickey-Fuller (ADF), Dickey and Fuller-Generalized Least Square (DF-GLS), Phillips and Perron (PP), Elliott, Rothenberg and Stock (ERS), and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) presented in Table 1. The results of all the unit root tests show that the null hypothesis of unit roots cannot be rejected at levels of the log prices and stationary after the log differences. The results confirm that the processes are I (1) (integrated of order 1, or stationary after first differencing).

It has been claimed that the standard unit root tests that do not consider any structural breaks have lower explanatory power compared to stationary alternatives with structural break having low power against the stationary alternatives with structural breaks (Campbell and Perron 1991; Dejong *et al.* 1992). As such the Z-A structural break procedure is applied to search for one break point endogenously to test for a unit root in each price variable. In the study, both the intercept and the trend in the Z-A structural break approach are included to detect the stationarity with one structural break point. Table 2 shows that the test statistics of all the price variables are much smaller than the critical value of 1 per cent level of significance. Therefore, the null hypothesis of nonstationary is accepted, implying the price variables in levels individually contain a unit root even when a break point is appropriately taken into account.

The Z-A unit root test also identifies that the Kolkata price series contains a unit root with a structural break point at November 2009, whereas the

Table 2 Zivot and Andrews unit root test with structural breaks

Price series	Break points	*t*-statistics	Critical value
lnP_{Dhaka}	August, 2007	−3.88	−5.57
lnP_{Kolkata}	November, 2009	−3.16	
$lnP_{\text{Biratnagar}}$	September, 2006	−3.29	

Source: Author's calculation.
Note: The critical value depicts significance at 1 per cent level.

Dhaka and Biratnagar price series have unit roots with structural break points at August 2007 and at September 2006, respectively.

The identification of break points in the tests has specific reasons within the context of each country. As discussed in earlier section, Bangladesh experienced severe production shocks due to floods from July to September 2007, and a cyclone in November 2007, which could have had a significant impact on the rice market; therefore, the test would have a valid reason to consider a structural break point in the Dhaka price during 2007.

In India, several policy measures were taken to stabilise the price of rice in the domestic market during 2007, with some of the policies continuing until 2011. In 2009, due to the emergence of inflationary pressure in the domestic market, India continued the export ban on nonbasmati rice which was first imposed in 2007. In August 2009, the state governments in India imposed stock limits on rice for consumers and distributed one million tonnes of rice in October 2009. The above policies during 2009 could have had a significant impact on the price of rice in Kolkata, and were captured as a structural break point by the Z-A unit root test.

In Nepal, there was a civil war between the monarchy and the Communist Party of Nepal (Maoist fighters) which started in 1996 and continued until 2006. According to the UNHR (2013), the level of political agitation in Nepal was extreme during 2006, and it is referred to as 'The 2006 Democracy Movement', or *Jana Andolan-II* (People's Movement-II), in the political history of Nepal which ended with the Comprehensive Peace Accord signed on 21 November 2006. Thus, it is most likely that Nepal had a structural break in 2006 which could have had a significant impact on their staple food market and is captured by the Z-A unit root test.

Since the unit root tests confirm that all the price variables are nonstationary at their levels and stationary at first differences, a co-integration analysis can be performed now. The Johansen and Juselius maximum-likelihood multivariate co-integration approach under a VAR framework will be used to investigate the long-run relationship among the rice prices.

As the results of the VAR model are sensitive to the choice of lag length, therefore, various information criteria such as likelihood ratio (LR), Akaike information criterion (AIC), Schwarz criterion (SC), final prediction error (FPE) and Hannan–Quinn (HQ) information criterion were used to detect the appropriate lag number.

The results in Table 3 show that the optimal lag order at period 1 is selected by all the information criteria. As such, lag 1 in the VAR model is used and tested for autocorrelation among the VAR residuals using the Lagrange multiplier model. The null hypothesis of no autocorrelation is rejected using lag order 1. Hence, the VAR (1) framework is chosen to estimate the long-run and short-run co-integrating relationships between the price series.

Table 3 Lag order selection using different information criteria

Lag order	LR	AIC	SC	FPE	HQ
0	–	−2.53	−2.47	1.60e-05	−2.50
1	958.21*	−8.38*	−8.15*	4.60e-08*	−8.29*
2	14.99	−8.36	−7.96	4.69e-08	−8.20
3	11.88	−8.33	−7.75	4.85e-08	−8.09
4	12.89	−8.29	−7.57	4.93e-08	−8.01
5	12.02	−8.28	−7.37	5.05e-08	−7.92
6	15.35	−8.21	−7.19	5.11e-08	−7.84
7	12.11	−8.24	−6.97	5.34e-08	−7.72
8	7.73	−8.18	−6.74	5.69e-08	−7.59

Source: Author's calculation.
Note: * indicates lag order selected by the information criterions.

The results of the Johansen and Juselius multivariate co-integration approach under a VAR (1) are presented in Table 4. Both the trace test and the maximum eigenvalue test in the Johansen and Juselius multivariate co-integration model identify one co-integrating vector. Out of the three price indices, there are two stochastic trends that exist in the price series. This indicates that markets are not fully integrated and there are exogenous influences that can affect the rice prices.

The long-run co-integrating equation of the price series can be found by analysing the normalised co-integrating coefficients. The long-run relationships normalised by the price changes in Dhaka can be presented as follows:

$$lnP_{\text{Dhaka}} = 6.12 - \underset{(-4.40)}{0.60} lnP_{\text{Biratnanar}} + \underset{(3.59)}{1.66} lnP_{\text{Kolkata}}$$

The t-values are shown in the parentheses. The adjustment coefficient of the co-integration equation for Kolkata is significant at 1 per cent level of significance, suggesting a long-run equilibrium relationship between the Kolkata and Dhaka rice markets. In other words, the Dhaka rice market is strongly co-integrated with the Kolkata rice market in the long run. The coefficient of the Kolkata price suggests that a 1 per cent increase in the Kolkata price would result in a 1.7 per cent increase in price in the Dhaka rice

Table 4 Multivariate co-integration rank test

Eigenvalue	Trace test			Maximum eigenvalue test		
	Null	λ-trace	Decision	Null	λ-max	Decision
0.18	$r = 0$	46.85**	Rejected	$r = 0$	34.11**	Rejected
0.07	$r <= 1$	12.75	Not rejected	$r = 1$	12.47	Not rejected
0.00	$r <= 2$	0.28	Not rejected	$r = 2$	0.28	Not rejected

Source: Author's calculation.
Note: ** indicates significance at 5 per cent level; the critical values for λ-trace and λ-max are determined by Osterwald-lenum (1992).

market. This result is expected as an increase in price in the Kolkata market increases the import price of rice in Bangladesh which raises the domestic market price in Dhaka. The adjustment coefficient of the Biratnagar price suggests that a 1 per cent increase in the Biratnagar price would result in a corresponding 0.6 per cent reduction in domestic rice prices in Bangladesh. Although the significance level confirms integration between the Biratnagar and Dhaka rice markets, the magnitude is far from unity, indicating that only a small proportion of Biratnagar price changes are eventually incorporated by the price in the Dhaka rice market.

However, in the short run, the existence of a long-run co-integration among the rice markets of Dhaka, Kolkata and Biratnagar can deviate from the long-run equilibrium path due to the exogenous shocks. In other words, the long-run relationship or equilibrium between each of the price variables in the multivariate model may not be balanced in the short run. The equilibrium can be reinstated only when an error correction process begins. Therefore, the short-run dynamics using a VEC model is tested to correct the disequilibrium in the short run.

The VECM represents the price deviation and explains the error correction process to confirm the existence or absence of a substantial relationship between the price series in the short run. The error correction term (ECT) can measure the speed of adjustment towards equilibrium since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. Table 5 shows the test results from the VECM.

The validation of the ECT_{t-1} estimates is obtained by examining likelihood ratio (LR) binding *p*-statistics associated with the fitted residuals which are presented in the parentheses of the ECT coefficients. The results show that the coefficients of the ECT of Kolkata and Biratnagar prices are significant; hence, all three markets are integrated in the short run. The value of the ECT equals −0.07 indicating that any shocks in the Dhaka price and the Kolkata price revert to equilibrium, meaning when there is a shock in Dhaka and Kolkata prices, the system only corrects approximately 7 per cent of the error in the first month, 7 per cent of the remaining error in the second

Table 5 Results of the VECM estimates

Exogenous variables	Endogenous variables		
	$\Delta lnP_{\text{Kolkata}}$	$\Delta lnP_{\text{Biratnagar}}$	$\Delta lnP_{\text{Dhaka}}$
ECT_{t-1}	−0.07***[0.00]	0.08* [0.07]	−0.05 [0.14]
$\Delta lnP_{\text{Kolkata-1}}$	−0.15** [−1.96]	0.14 [1.02]	0.27*** [2.70]
$\Delta lnP_{\text{Biratnagar-1}}$	0.03 [0.67]	−0.17** −2.11]	0.03 [−0.05]
$\Delta lnP_{\text{Dhaka-1}}$	0.09 [1.50]	−0.03 [−0.24]	−0.03 [−0.44]

Source: Author's calculation.
Note: *t*-statistics are in [ ], and p-values are in () brackets. The *t*-values of 1, 5 and 10 per cent significant levels are 2.58, 1.96 and 1.68, respectively; Δ denotes first differences of the price series; −1 is the lagged period.

month and again 7 per cent of the remaining error in the third month, and so forth until it reaches the long-run equilibrium. In other words, the negative value of the Kolkata price caused the Dhaka price to diverge in the short run and the ECT reflects the impact of market forces that push the integrated variables to return to their long-run relationship when they deviate from it. Consequently, a price shock that induces price deviations from the equilibrium level would induce the traders to respond to the shock in a way that would result in prices converging towards the equilibrium level. The ECT confirms that the speed of adjustments of Kolkata, Dhaka and Biratnagar rice markets towards equilibrium is very low.

The VECM reveals that the estimated short-run coefficient of the Kolkata price (0.27) in the previous month is significant at a 1 per cent level of significance on current price changes in Dhaka. Thus, a 1 per cent increase in the price of rice in the Kolkata market on the previous month results in a 0.27 per cent increase in prices in Dhaka. The coefficients of the Kolkata and Biratnagar prices in the previous month are significant on current price changes in their own domestic markets.

A Granger causality test is executed to detect the presence of a causality relationship among the price variables. The causality test establishes the appropriate direction of the price transmission and indicates the degree of integration between the markets. The causality based on a VECM of the three price series in their first differences is analysed with one optimal lag order. The results of the causality tests are validated from the *F*-statistics and are reported in Table 6.

It can be concluded from the causality test that the Kolkata price Granger causes the Dhaka price and a long-run unidirectional causality exists from the Kolkata price to the Dhaka price. The result is consistent with the notion that the price of rice in Kolkata plays an important role in the domestic price in the Dhaka rice market. Moreover, the unidirectional causality relationship informs a leader–follower relationship, in terms of price adjustments, where the Kolkata price acts as a leader and the Bangladesh price acts as a follower. As expected, the model fails to detect any significant causality between the Biratnagar and Dhaka prices. However, an expected unidirectional causality

Table 6 Results of the Granger causality tests

Endogenous variables	Exogenous variables	Decisions	Exogenous variables	Decisions
$\Delta lnP_{\text{Kolkata}}$	$\Delta lnP_{\text{Biratnagar}}$ 0.99 (0.32)	No causality	$\Delta lnP_{\text{Dhaka}}$ 1.74 (0.19)	No causality
$\Delta lnP_{\text{Biratnagar}}$	$\Delta lnP_{\text{Kolkata}}$ 1.99 (0.16)	No causality	$\Delta lnP_{\text{Dhaka}}$ 0.05 (0.82)	No causality
$\Delta lnP_{\text{Dhaka}}$	$\Delta lnP_{\text{Kolkata}}$ 7.17*** (0.01)	Causality	$\Delta lnP_{\text{Biratnagar}}$ 0.17 (0.68)	No causality

Source: Author's calculations.
Note: *** indicates significance at 1 per cent level; figures in parentheses are *f*-probabilities.

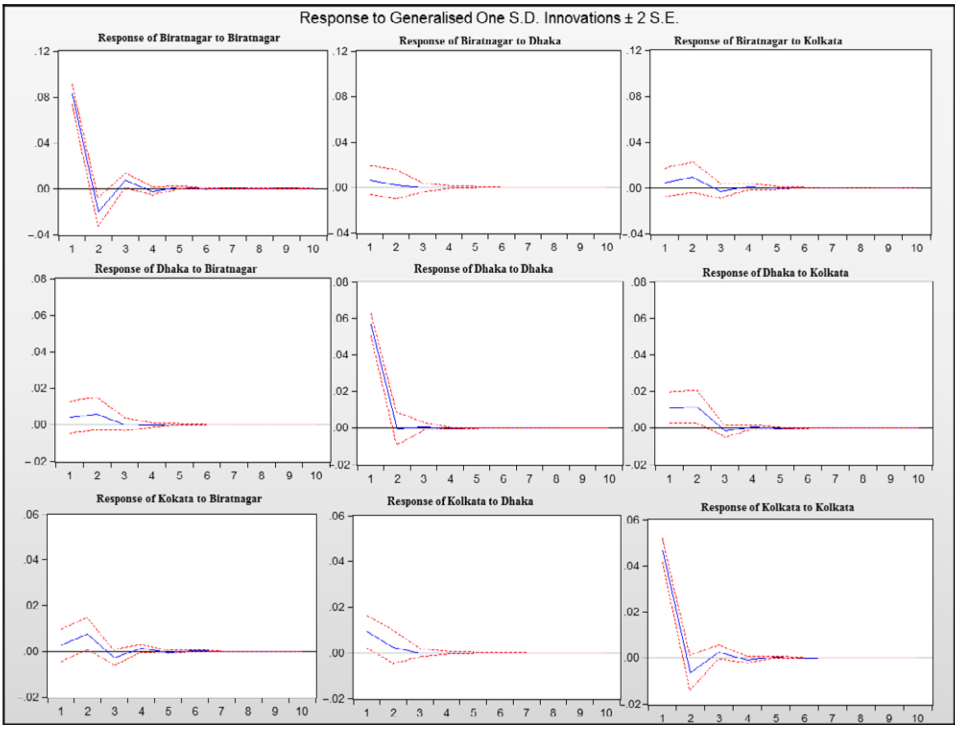

Figure 3 Responses to generalised one S.D. innovations ± 2. S.E. Source: Author's calculation.

from the Kolkata to Biratnagar prices is absent in the Granger causality model.

To further visualise, the dynamic price relationships between Kolkata, Dhaka and Biratnagar are estimated using the generalised impulse response functions (GIRFs) method in a VAR framework. A GIRF is preferred in this study as the function does not consider an ordering of the residuals. The GIRF can trace the response of a sudden change in one variable and its impact on another variable over time, and can assess how long the effects of the shocks will last.

Figure 3 shows that the horizontal axis indicates the number of months after a shock and the vertical axis represents the standardised responses to shocks to each variable. The results show that the responses to shocks within the same rice markets create initial positive impacts. A positive shock in the Kolkata markets generates a positive reaction in the Dhaka rice markets. These results are consistent with the Granger causality tests.

4. Conclusion

The study provides empirical analyses on price transmission and market co-integration among India, Nepal and Bangladesh, with a particular reference to the major changes in rice policies during the global food crisis in 2007–2008. The focus in this study is on the effect of rice trade restrictions imposed by the Indian government on market co-integration and price transmission among these three countries.

Theoretically, export restriction policies, especially bans on exports, are supposed to impede smooth price transmission between the integrated markets. However, the empirical results of this study confirm that despite export restriction policies imposed by India, the Indian, Nepalese and Bangladeshi rice markets were integrated both in the short run and in the long run, indicating that those policies were not able to completely eliminate the market linkages.

One of the reasons for smooth price transmission and market co-integration in these three neighbouring markets, despite the export restrictions of India during the global food crisis, could be the widely reported informal border trade through the porous borders. It is possible that a large volume of informal trade may occur between Bangladesh and India and India and Nepal through the border markets. Thus, when India imposes any administrative restrictions on rice exports, the cheaper rice in Indian domestic markets encourages Bangladeshi and Nepalese traders to import rice illegally through the border markets. In such circumstances, the large amount of informal rice import helps to reduce the domestic rice price both in Bangladesh and in Nepal.

However, restrictive trade policies among these countries are costly to police and largely ineffective in stabilising domestic prices; it encourages cross-border smuggling that imposes large social and economic costs. In the circumstances, there seems to be a strong case to promote market integration between surplus and deficit regions by eliminating policy distortions and taking steps to coordinate food policies on a regional basis, using already existing trade agreements and elevating the level of policy cooperation to embrace a broader vision of regional food security.

References

Abdulai, A. (2007). Spatial and vertical price transmission in food staples market chains in eastern and southern Africa: what is the evidence. Trade and markets division workshop on staple food trade and market policy options for promoting development in Eastern and Southern Africa. FAO, Rome, Italy.

Bellemare, M.F. (2015). Rising food prices, food price volatility, and social unrest, *American Journal of Agricultural Economics* 97, 1–21.

Campbell, J.Y. and Perron, P. (1991). *Pitfalls and opportunities: what macroeconomists should know about unit roots*, in NBER (ed.), *Macroeconomics*. MIT Press, USA.

Campos, J., Ericsson, N.R. and Hendry, D.F. (1996). Cointegration tests in the presence of structural breaks, *Journal of Econometrics* 70, 187–220.

Chowdhury, N. (2010). Price stabilization, market integration and consumer welfare in Bangladesh. National food policy capacity strengthening programme. FAO, Italy and Bangladesh Rice Foundation, Bangladesh.

Conceição, P. and Mendoza, R.U. (2009). Anatomy of the global food crisis, *Third World Quarterly* 30, 1159–1182.

Dawe, D., Block, S., Gulati, A., Huang, J. and Ito, S. (2010). *Domestic rice price, trade, and marketing policies. Rice in the global economy: strategic research and policy issues for food security*. International Rice Research Institute, Los Banos, Philippines, pp. 379–407.

Dawson, P.J. and Dey, P.K. (2002). Testing for the Law of One Price: rice market integration in Bangladesh, *Journal of International Development* 14, 473–484.

Dejong, D.N., Nankervis, J.C., Savin, N.E. and Whiteman, C.H. (1992). The power problems of unit root test in time series with autoregressive errors, *Journal of Econometrics* 53, 323–343.

Dorosh, P.A. (2001). Trade liberalization and national food security: rice trade between Bangladesh and India, *World Development* 29, 673–689.

Dorosh, P.A. and Shahabuddin, Q. (2002). *Rice price stabilization in Bangladesh: an analysis of policy option*. Discussion Paper, International Food Policy Research Institute, USA.

Dorosh, P.A. (2009). Price stabilization, international trade and national cereal stocks: world price shocks and policy response in South Asia, *Food Security* 1, 137–149.

Fackler, P.L. and Goodwin, B.K. (2001). Spatial price analysis, *Handbook of Agricultural Economics*. 1 (Part B). Volume 1, Chapter 17, Elsevier Science Direct, North Holland, 971–1024.

Froot, K.A., Kim, M. and Rogoff, K. (1995). *The law of one price over 700 years*. National Bureau of Economic Research, USA.

Gilbert, C.L. (2011). Grains price pass-through, 2005–09, in Prakash, A. (ed), *Safeguarding Food Security in Volatile Global Markets*. FAO, Rome, Italy, pp. 127–148.

Headey, D. (2011). Rethinking the global food crisis: the role of trade shocks, *Food Policy* 36, 136–146.

Headey, D. and Fan, S. (2008). Anatomy of a crisis: the causes and consequences of surging food prices, *Agricultural Economics* 39, 375–391.

Horwood, A. (2015). Food, markets and human rights: the role of speculation in food crises, Quarterly access, Australian Institute of International Affairs, Australia.

Javier, L.A. (2011). Rice imports by Bangladesh to double on ‘panic-buying’. bloomberg.com.

Johansen, S. (1988). Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control* 12, 231–254.

Johansen, S. and Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration- with applications to the demand for money, *Oxford Bulletin of Economics and Statistics* 52, 169–210.

Mitra, S. and Josling, T. (2009). Agricultural export restrictions: welfare implications and trade disciplines. Agricultural and Rural Development Policy Series. International Food & Agricultural Trade Policy Council.

Murshid, K. A. S., Yunus, M., ALI, S. M. Z., and Ahmed, N. (2009). Re-emergence of food insecurity in Bangladesh: instability in food production and prices, nature of food markets, impact and policy. policy resource program of Bangladesh Institute of Development Studies, Dhaka, Bangladesh.

Ninno, C.D. and Dorosh, P.A. (2001). Averting a food crisis: private imports and public targeted distribution in Bangladesh after the 1998 flood, *Agricultural Economics* 25, 337–346.

Ninno, C.D., Dorosh, P.A. and Smith, L.C. (2003). Public policy, markets and household coping strategies in Bangladesh: avoiding a food security crisis following the 1998 floods, *World Development* 31, 1221–1238.

Osterwald-lenum, M. (1992). A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test Statistics 1, *Oxford Bulletin of Economics and Statistics* 54, 461–472.

Pohit, S. and Taneja, N. (2003). India’s informal trade with Bangladesh and Nepal, *The World Economy* 26, 1187–1214.

Rapsomanikis, G. and Mugera, H. (2011). Price transmission and volatility spillovers in food markets of developing countries, in Piot-lepetit, R. and Barek, M. (eds), *Methods to Analyse Agricultural Commodity Price Volatility*. Springer, New York, USA.

Sanogo, I. (2008). Spatial integration of the rice market: empirical evidence from mid-west and far-west Nepal and the Nepalese-Indian border, *Asian Journal of Agriculture and Development* 4, 139–156.

Sanogo, I. and Maliki, A.M. (2010). Rice market integration and food security in Nepal: the role of cross-border trade with India, *Food Policy* 35, 312–322.

Sharma, R. (2003). The transmission of world price signals: the concept, issues, and some evidence from Asian cereal markets, in *Agricultural Trade and Poverty: Making Policy Analysis Count*. Organization for Economic Co-operation and Development, France, pp. 141–160.

Slayton, T. (2009). Rice crisis forensics: how Asian governments carelessly set the world rice market on fire. Center for Global Development. Working paper 163.

Taneja, N. (2004). Informal trade in the SAARC region: implications for FTAs, *Economic and Political Weekly* 39, 5367–5371.

UNHR (2013). The Nepal conflict report [Online]. United Nations Human Rights. http://www.ohchr.org/EN/Countries/AsiaRegion/Pages/NepalConflictReport.aspx 2013.

UNWFP-FAO (2007). Food and agricultural markets in Nepal. Nepal information platform. Food and Agriculture Organization of the United Nations, Italy.

WFP (2010). Crop and food security update. Joint report by Ministry of Agriculture and Cooperatives and World Food Program, Nepal.

Zivot, E. and Andrews, D.W.K. (1992). Further evidence on the great crash, the oil price shock and the unit root hypothesis, *Journal of Business and Economic Statistics* 10, 251–279.