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A. Amarender Reddy

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Centre for Studies in International Relations and Development (CSIRD)
167-B, S. P. Mukherjee Road, Kolkata 700026, India
Phone: (9133) 24630884, 22483769, Fax: (9133) 24630884
Email: csirdindia@yahoo.co.in, Website: www.csird.org.in

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Executive Summary

Asia is becoming a global hub for agricultural commodity trade. Rice is an important staple food for most of the Asian population. Most of the international rice trade takes place within Asia. Efficient and integrated rice markets in Asia is essential for improving the volume of rice trade as only less than 6 percent of the global production is traded internationally. This paper tests the extent cointegration among rice markets by using Johansen test, examined the causality by Granger causality tests and also captures the speed of adjustment to divinations in long run equilibrium in rice prices by using vector error correction model. The result reveals that international rice price indices (Thailand and US), farm harvest prices and also government support prices were cointegrated in the long run, however law of one price does not hold. Thai II (100) granger causes both Thai-A1-super and long grain No.2 (4 percent)-US international price indices. There are five cointegrating vectors out of nine countries in case of farm harvest prices (FHPs). Japan, Thailand, Bangladesh and Philippines FHPs are exogenous and influence other countries prices, thereby important sources of price formation in the Asian rice market. Short-run elasticities are quite significant for some countries (between India and Thailand, between Bangladesh and Pakistan). Long-run elasticities of adjustment are quite low (only about 6 to 8 percent of total deviation in long run equilibrium will be corrected in a year in different countries). In case of Government support prices, only four price series are integrated out of nine countries considered. Granger causality results suggest that, no single country is completely exogenous, and many countries GSP prices are inter-linked to some extent. Here also short-run elasticities are significant for many countries GSP prices (ranging from 0.21 between India and Korea to 0.84 between Thailand and India). Long-run elasticities (ECTs) are quite low and insignificant. Finally the paper concludes that Thailand, Bangladesh, Philippines and Japan are important sources of price formation in Asian markets.

1. Introduction

Many Asian countries have been pursuing agricultural market reforms in the recent past mainly due to the influence of World Trade Organization (WTO). These policies are mostly aimed at reducing market-distorting practices, increasing market efficiency, and market integration across the regions and countries. It has been argued that such market reforms are required for achieving efficient agricultural markets (Gulati *et al*, 1996). One of the indicators of efficient market is the market integration across the regions. Unless agricultural markets are not integrated, producers and consumers will not realize the gains from liberalization, the correct price signal will not be transmitted through the marketing channels, resulting which the farmers will not be able to specialize according to long-term competitive advantage and the gains from trade will not be realized in full (Ravallion, 1986). Spatial market integration refers to a situation in which prices of a commodity in spatially separated markets move together, thereby offer smooth transmission of price signals and information. Hence, spatial market performance may be evaluated in terms of the relationship between the prices of spatially separated markets, and spatial price behaviour in regional markets, which, in other words, is termed as a measure of overall market performance.

Rice is the second largest produced cereal in the world, after wheat. About half of the world population depends on rice for their staple food. In the 1960s the world rice production averaged at 264 MT and over the years it increased to 596 MT during 2001-2005. Asian

* The author is a Scientist (Agricultural Economics) at the Indian Institute of Pulses Research, (Indian Council of Agricultural Research), Kanpur 208024. Email: aareddy12@email.com.

countries accounted for about 90 percent or 500 MT during the whole period. The coefficient of variation of world rice production is significantly reduced during the same period from 11 percent to 2.5 percent. Asian rice price index has been raised from 100 in 1990 to 150 in 2003 (though real rice prices declined) and coefficient of variation of Asian rice prices is about 20 percent during 1990-2003 (Table 1). These indicate that even though rice production is stabilized at global level, price fluctuations are higher in recent years. Based on 1.8 percent growth in demand for rice in Asia (FAO, 2003), by 2025, Asia would need to produce about 840 MT to maintain prices at current levels Asian rice farmers are small and mainly produce rice for their family requirements. The marketable surplus is small and prices fluctuate widely due to thin market. Hence, maintaining self-sufficiency in production and stability in prices are important political objectives in most of the Asian countries. As a result domestic prices of rice in many Asian countries are generally controlled by government and has no correlation with international prices. The world rice market is highly sensitive to shortfalls in domestic production in any of these countries. International rice trade is increased from about 7 MT (2.6 percent of world production) during 1960s to 25 MT (6 percent of world production) in 2005 (Table 2). However international rice market is one of the smallest and volatile markets in the world, compared to other grain markets, such as wheat (110 million tons) and corn (80 million tons) during 2000-04 (FAOSTAT, 2005). With new food habits growing in developed countries and expansion of markets in developing countries, the scope for increasing rice trade in Asia is also expanding. Market liberalization has also been brightening the prospect for rice trade in the region.

Table 1: Trend of Rice Production of Major Rice Producing Countries in Asia

	Production (Million tons)										Price Index (1990)		
Country	1961-70		1971-80		1981-90		1991-2000		2001-05		1990 (100)		1990-2003
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	1991-93	2000-03	CV
Bangladesh	15.8	9.0	18.1	10.8	23.1	9.2	29.1	13.4	38.6	4.1	95.8	99.1	8.1
China	87.9	19.6	130.6	7.7	173.3	6.9	191	4.6	176.5	4.8	110.7	177.9	26.5
India	54.9	11.2	68.9	12.5	92.8	14.3	121.7	6.4	128.8	6.5	108.9	155.4	16.6
Japan	17.1	6.2	15.4	9.2	13.4	6.5	12.3	11.5	10.8	5.7	103.4	67.8	17.0
Korea	5.0	10.1	6.7	18.3	7.7	4.4	7.0	4.8	6.7	7.9	104.9	168.0	19.4
Pakistan	2.3	30.4	4.1	14.3	4.9	5.0	6.2	16.6	6.9	10.0	110.8	229.9	28.9
Philippines	4.4	14.5	6.3	17.6	8.6	9.2	10.5	11.5	13.8	5.8	104.8	175.3	20.6
Sri Lanka	1.1	22.2	1.6	21.2	2.4	8.9	2.6	10.9	2.9	7.7	108.3	174.7	21.6
Thailand	12.1	10.1	14.9	11.0	19.1	7.8	22.1	10.0	26.1	5.0	90.7	111.8	20.5
Asia	242.1	11.6	321.1	8.2	426.5	7.7	511.2	5.5	539.7	2.5	104.0	151.0	20.0
World	264.6	11.7	352.3	8.4	466.2	7.5	559.8	5.7	596.1	2.6			
Share of Asia in world (%)	91.5		91.1		91.5		91.3		90.5				

Source: Compiled from FAOSTAT (2005)

Even though Asia contributes about 90 percent of world rice production, its share in both exports and imports is more than 75 to 80 percent. Asian countries emerged as net exporters of rice in recent years with trade surplus of about 6 MT to 8 MT per annum (Table 2). And the contribution of world top ten exporters is higher (of 21 MT, about 16 MT is contributed by Asian countries) and contribution of top ten importers is just about 10 MT in 1999-2003 (Table 2). While rice exporting countries are concentrated in Asia, rice importing countries are scattered widely. This is another source of instability in world rice markets as only few countries control and meet world export demand. Sudden supply shocks in these few rice exporting Asian countries can destabilize world rice prices. Most of Asian countries consume whatever rice they produce (international trade is residual in nature, only 16 MT out of 500 MT of production) (Table 2). Domestic rice markets are, therefore, very segmented, and often one of the most protected. Most of the Asian countries have followed policy of self-sufficiency, which resulted in less dependence on international trade in agricultural sector. And most of the times rice trade among countries determined by inter-governmental contracts rather than market forces, which also has resulted in market segmentation and squeezed the opportunities for private sector. Taking into account the importance of Asian countries in world rice production, consumption and trade, there is a need for policies to improve Asian rice market integration, which increases efficiency of rice markets, and provide right price signals across Asian countries in post-WTO regime. With this objective this study examines whether Asian rice markets are integrated in the long run and law of one price hold for the region by using Johansen Cointegration test. The paper also examines whether price signals will transmit from rice exporters (surplus producers) to rice importers (deficit producers) or vice versa, or whether price information transmit from large players to small players in rice trade (through Granger casualty test). The study also estimates the short-run adjustment elasticity of prices between different countries and also tries to assess the speed of adjustments (long-run elasticity) to any deviations in long-run equilibrium price through error correction model.

Table 2: Top Ten Leading Rice Trading Countries

Country				**Exporters**			
	1950-64		1965-81		1985-98		1999-2002
Myanmar	1.52	USA	2.03	Thailand	5.12	Thailand	6.86
Thailand	1.38	Thailand	1.75	USA	2.55	USA	3.88
USA	0.80	China	1.62	Vietnam	1.60	Vietnam	2.69
China	0.69	Myanmar	0.59	India	1.42	India	2.36
Cambodia	0.47	Pakistan	0.58	Pakistan	1.29	Pakistan	1.87
Egypt	0.22	Italy	0.34	China	1.10	China	1.83
Italy	0.19	Egypt	0.32	Italy	0.61	Italy	0.67
Vietnam	0.16	Japan	0.30	Australia	0.47	Australia	0.64
Pakistan	0.12	Australia	0.18	Uruguay	0.39	Uruguay	0.51
Brazil	0.06	Korea	0.17	Myanmar	0.29	Myanmar	0.41
Total of top 10 countries	5.61		7.88		14.84		21.72
Total of Asian countries	4.22		3.39		10.82		16.02
Share of Asia among top ten countries (%)	75.2		43.0		72.9		73.8
				Importers			
Indonesia	0.70	Indonesia	1.02	Iran	0.77	Indonesia	2.03
Japan	0.66	Vietnam	0.62	Indonesia	0.75	Nigeria	1.30
India	0.58	South Korea	0.51	Brazil	0.68	Iran	1.17
Malaysia and Singapore	0.53	India	0.42	Saudi Arabia	0.47	Iraq	1.01
Sri Lanka	0.47	USA	0.40	China	0.47	Philippines	0.91
Hong Kong	0.31	Hong Kong	0.36	USSR	0.47	Saudi Arabia	0.88
Pakistan	0.25	Sri Lanka	0.36	Iraq	0.46	EU	0.81
Cuba	0.20	Bangladesh	0.31	Philippines	0.42	Bangladesh	0.71
West Germany	0.13	Malaysia	0.29	Malaysia	0.40	Senegal	0.70
Philippines	0.11	Singapore	0.24	Senegal	0.40	Japan	0.67
Total of top 10 countries	3.94		4.53		5.29		10.19
Total of Asian countries	3.81		4.13		4.14		8.50
Share of Asia among top ten countries (%)	96.7		91.2		78.3		83.4

Note: Figures are averages in million tons of milled rice
Source: FAOSTAT (2005)

2. World Rice Price Trends

In this section a brief review of rice price policies followed by Asian countries has been given. There is a decline in the level of rice prices adjusted for inflation (real prices) in the last 50 years. In 1950, the average world market price for top quality indica (e.g. Thai 100Bs, FOB Bangkok) was US$ 137 per ton in nominal terms. In 2004, the nominal price is about US$ 220 per ton, an increase of 61 percent. Yet, during those 53 years, the average price level, as measured by the United States CPI, has increased by 666 percent. The net result is that, after adjusting for inflation, world rice prices today are 77 percent lower. This is mainly due to wider adoption of high yielding varieties, which reduced cost of production in almost all countries (Dawe, 2004). The decline has been at least 50 percent in almost all-Asian countries except Indonesia, in real terms, indicating that the rice prices move in same direction in all Asian countries.

However, world rice markets are subjected to import tariffs and tariff rate quotas in key importing countries and price supports in key exporting countries. In 2000, the global trade weighted average tariff on all rice was 43.3 percent. Medium grain rice markets are far more distorted than long grain rice markets due to the TRQs and quotas in the medium grain rice-importing countries of Japan, South Korea, and Taiwan. Global trade weighted average rice tariffs in 2000 for medium and short grain rice markets were 217 percent compared to 21 percent for long grain markets (Wailes, 2004)

Price support for rice producers has been important in most of the countries. Much of the price support in Japan extends from the tariffs and TRQ levels. Since 1998, Japan's internal market intervention applies only to maintaining rice stocks for food security. Therefore, Japan's producer subsidy equivalents measure (PSE), which reflects domestic and border support, remains extremely high even though aggregate measure of Support reduced due to WTO commitment.

The greatest degree of protection in world rice trade is for medium/short grain. World export prices of medium/short grain rice are lower by approximately 100 percent as a result of protection by Japan, South Korea and Taiwan. Tariffs in major low quality rice importing nations such as Indonesia and Bangladesh are estimated to reduce world export prices by as much as 30 percent compared to prices under full liberalization. The major impact of protection in low quality rice markets falls on consumers in these low-income importing developing nations and producers in low quality rice exporting nations such as Vietnam, India, Pakistan, and Thailand.

Asian markets are still subjected to high protection until recently. One of the early starters of rice trade liberalization is Thailand, which reduced role of government-to-government contracts over the past 25 years (Slayton, 1999), and taxation of rice exports being effectively abandoned by 1976 (Sriprasert, 2003). Bangladesh liberalized its international rice trade in 1994, allowing the private sector to import. Pakistan fully privatized rice exports in 1996, removing the monopoly formerly enjoyed by the Rice Export Corporation. Sri Lanka has allowed private sector imports of rice recently (Slayton, 1999). Other Asian countries have liberalized much less. Exports from China are still only in the hands of state-owned companies. The government of India still makes the key decisions that determine the quantity of exports that occur (even if the private sector negotiates the sales and handles the actual exporting). The Philippine government still strictly controls the overall import volume, with the result that domestic wholesale prices are often double what they would be if unrestricted private sector imports were allowed. Farmers and other private sector importers are allowed to carry out some of the imports, but the government still has full authority over the quantity to be imported, which receives licenses, and the procedures that must be followed. Japan, Korea, and Taiwan have all increased their level of imports as part of the WTO negotiations, but protection in these countries is still extraordinarily high as the governments in those countries effectively control the quantity of imports through very high tariffs or quotas (Cramer *et al*, 1999).

3. Review of Literature

Several studies have found price transmission within the context of the Law of One Price (LOP) (Ardeni, 1989; Baffes, 1991) or within the context of market integration (Ravallion, 1986; Palaskas and Harriss 1993; Blauch 1997). The concept and the analytical techniques have also been used to evaluate policy reform, such as *ex post* assessment of market integration in the context of the implementation of the structural adjustment programs (Alexander and Wyeth, 1994; Dercon, 1995).

The large body of research on spatial market integration and price transmission has applied different quantitative techniques and highlighted several factors that impede the pass-through of price signals. Distortions introduced by governments in the form of policies, either at the border, or as price support mechanisms, weaken the link with the international markets. Agricultural policy instruments, such as import tariffs, quotas, export subsidies or taxes, intervention mechanisms, as well as exchange rate policies insulate the domestic markets and hinder the full transmission of international price signals by affecting the excess demand or supply schedules of domestic commodity markets (Sharma, 2002).

In theory, spatial price determination models suggest that, if two markets are linked by trade in a free market regime, excess demand or supply shocks in one market will have an equal impact on prices in both markets. The implementation of import tariffs, in general, will allow international price changes to be fully transmitted to domestic markets in relative terms. Thus, a proportional increase in the international price will result in an equal proportional increase in the domestic price, provided that tariff levels remain unchanged. However, if the tariff level is prohibitively high, changes in the international price would be only partly, if at all, transmitted to the domestic market, as domestic prices may be close to the autarky price level, thus eliminating opportunities for spatial arbitrage and resulting in the two prices moving independently of each other, as if an import ban exists. Policy instruments such as quotas may result in international price changes not being at all points of time proportionately transmitted to domestic prices, as changes in the domestic price level will depend on two different tariff rates that are applied according to whether the volume of imports falls within or outside the quota level. In the event of imports being equal to the quota level, changes in the international price may not affect the domestic price level at all, provided these changes are relatively small, as compared to the difference between the within the quota and the out-of-the-quota tariff levels. The implementation of price support policies, such as intervention mechanisms and floor prices, may result in the international and the domestic price being completely unrelated or being related in a non-linear manner, depending on the level of the intervention or floor price relative to the international price. Changes in the international price will have no effect on the domestic price level when the international price stays on a level lower than that to which the floor-price has been set. However, any changes in the international price above the floor-price level will be transmitted to the domestic market. Thus floor price policies may result in the domestic price being completely unrelated to the international market below a certain threshold determined by the floor price, or in the two prices being related in a non-linear manner with increases in the international price being fully transmitted to the domestic level, whilst decreases are slowly and incompletely passed through.

Apart from policies, domestic markets can also be partly insulated by large marketing margins that arise due to high transfer costs. Especially in the Asian countries, poor infrastructure, transport and communication services give rise to large marketing margins due to high costs of delivering the locally produced commodity to the border for export or the imported commodity to the domestic market for consumption. High transfer costs and marketing margins hinder the transmission of price signals, as they may prohibit arbitrage (Badiane and Shively, 1998).

Non-competitive behaviour, such as that considered in pricing-to-market models, government-to-government contracts (Krugman, 1986) could hinder market integration. Pricing-to-market models postulate that firms may absorb part of exchange rate movements by altering export prices measured in home currency in order to retain their market share. Alternatively, oligopolistic behaviour and collusion among domestic traders may retain price differences between international and domestic prices in levels higher than that those determined by transfer costs.

Most of the studies utilize time series econometric analysis techniques that test for the co-movement of prices. The development of these techniques, which include co integration and error correction models, has become the standard tool for analyzing spatial market relationships, replacing earlier empirical tools, such as the bivariate correlation coefficient and regressions.

Market integration is formally testable, if one adheres to the definition implied by the standard spatial equilibrium model. However, the extent of price transmission is an inherently ambiguous concept. Cointegration and error correction models provide an analytical tool that can focus beyond the case of market integration or complete price transmission, in testing notions such as completeness and speed of the relationship between prices. For example, discontinuities in trade, within a time series-modeling framework, correspond to slow speed of convergence to a long run relationship.

4. Data and Methodology

The data structure considered here for cointegration analysis is as follows.

- Government-to-government contract prices for countries Myanmar SMS 42, Thailand White Rice 35, Thailand White Rice 10, China PR 35 for the period 1961 to1985.
- International private trade prices for Thailand White Rice 25 Super, Thailand Cargo Rice 100, Thailand Broken 100 and Pakistan Basmati for the period 1961 to 1991.
- World Price index for low and high quality rice from 1982 to 2000.
- World price indices for 2nd grade 100(Thai), A1 super (Thai) and long grain No.2 (4 percent) (USA) from 1983 to 2000.
- Farm harvest prices (FHP) for Bangladesh, China, Japan, Korea, Pakistan, Philippines, SriLanka, and Thailand from 1966 to 2002.
- Government support prices (GSP) for Bangladesh, China, Japan, Korea, Pakistan, Philippines, SriLanka, and Thailand from 1961to1998.

The data used in the cointegration exercise consists of yearly prices of various rice markets for the period 1961 to 2002. The data relating to the average prices quoted in nine different countries Bangladesh, China, India, Japan, Korea, Pakistan, Philippines, Sri Lanka, Thailand and United States are compiled from IRRI/FAO web site. All prices are converted into US$ before analysis. For conversion of local currency into US$, three year moving average of exchange rate has been considered to minimize effect of exchange rate fluctuation. Mostly government support price is announced by government agency at the beginning of the crop year and remains constant for the whole period. The farm harvest pries are the prices remained at the harvest period**.** The monthly price data is not consistent across countries and not available for most of the countries.

We try to explore here the causality relationships between different Asian price indices. Granger definition of causality is the most widely accepted definition of causality. According to Granger (1969), Y is said to "Granger-cause" X if and only if X is better predicted by using the past values of Y than by not doing so with the past values of X being used in either case. In short, if a scalar Y can help to forecast another scalar X, then we say that Y Granger-causes X. If Y causes X and X does not cause Y, it is said that unidirectional causality exists from Y to X. If Y does not cause X and X does not cause Y, then X and Y are statistically independent. If Y causes X and X causes Y, it is said that feedback exists between X and Y. Essentially, Granger's definition of causality is framed in terms of predictability.

To implement the Granger test [originally developed by Granger (1969)], we assume a particular autoregressive lag length *k (or p)* and estimate Equation (1) and (2) by maximum likelihood method.

$$X_t = \lambda_1 + \sum_{i=1}^{k} a_{1i} X_{t-i} + \sum_{j=1}^{k} b_{1j} Y_{t-j} + \mu_{1t} \qquad (1)$$

$$Y_t = \lambda_2 + \sum_{i=1}^{p} a_{2i} X_{t-i} + \sum_{j=1}^{p} b_{2j} Y_{t-j} + \mu_{2t} \qquad (2)$$

F test is carried out for the null hypothesis of no Granger causality $H_0 : b_{i1} = b_{i2} = \cdots = b_{ik} = 0, i = 1,2.$ where *F* statistic is the Wald statistic for the null hypothesis. If the *F* statistic is greater than a certain critical value for an *F* distribution, then we reject the null hypothesis that *Y* does not Granger-cause *X* (equation (1)), which means Y Granger-causes X in the long run. The above two variable case has been extended by Granger (1981) and Engle and Granger (1987) as below.

A time series with stable mean value and standard deviation is called a stationary series. If 'd' differences have to be made to produce a stationary process, then it can be defined as integrated of order 'd'. Granger (1981) proposed the concept of cointegration, and Engle and Granger (1987) made further improvement. If several variables are all I(d) series, their linear combination may be cointegrated, that is, their linear combination may be stationary. Although the variables may drift away from equilibrium for a while, economic forces may be expected to act so as to restore equilibrium, thus, they tend to move together in the long run irrespective of short run dynamics. The definition of the Granger causality is based on the hypothesis that *X* and *Y* are stationary or I(0) time series. However, it is now widely recognized that many macro-economic series appear to contain a (or at least a) unit root in their autoregressive representations, and there are plenty of empirical evidences to indicate that macro-economic series often appear to be I(1). So we cannot apply the fundamental Granger method for variables of I(1).

The classical approach to deal with integrated variables is to difference them to make them stationary. In the absence of cointegration, the direction of causality can be decided upon via standard *F*-tests in the first differenced VAR. the VAR in the first difference can be written as follows:

$$\Delta X_t = \lambda_1 + \sum_{i=1}^{k} a_{1i} \Delta X_{t-i} + \sum_{j=1}^{k} b_{1j} \Delta Y_{t-j} + \mu_{1t} \qquad (3)$$

$$\Delta Y_t = \lambda_2 + \sum_{i=1}^{p} a_{2i} \Delta X_{t-i} + \sum_{j=1}^{p} b_{2j} \Delta Y_{t-j} + \mu_{2t} \qquad (4)$$

However these granger causality tests can only tell about long run causality among variables. According to Engle and Granger (1987), the test must be carried out with error-correction models (ECM) to know about dynamics of adjustment process. The VECM tells more about short-term adjustments and also speed of adjustment to long run equilibrium if there is any disequilibrium in the preceding period. The error correction representations are as follows.

$$\Delta X_t = \lambda_1 + \sum_{i=1}^{k} \alpha_{1i} \Delta X_{t-i} + \sum_{j=1}^{k} \beta_{1j} \Delta Y_{t-j} + \phi_1 ecm_{1t-1} + \mu_{1t}, \; ecm_{1t-1} = (X - \gamma Y)_{t-1} \quad (5)$$

$$\Delta Y_t = \lambda_2 + \sum_{i=1}^{k} \alpha_{2i} \Delta X_{t-i} + \sum_{j=1}^{k} \beta_{2j} \Delta Y_{t-j} + \phi_2 ecm_{2t-1} + \mu_{2t}, \; ecm_{2t-1} = (Y - \delta X)_{t-1} \quad (6)$$

Where ecm_{it-1} (i=1, 2) is error-correction (EC) term(s). ϕ_1 and ϕ_2 are called coefficients of adjustment and one of them must not be equal to zero according to Engle and Granger (1987). In equations (5) and (6), all series are I(0) processes.

An ECM representation is really a restricted VAR with co-integration specification. So it is designed for the non-stationary series known to be co-integrated. The parameters in the ECM have clear interpretations. In Equation (5), the coefficient of *Y* in the EC term (ecm_{1t-1}) is the long-run elasticity of *X* with respect to *Y*. Conversely, in Equation (6), the coefficient of *X* in the EC term (ecm_{2t-1}) is the long-run elasticity of *Y* with respect to *X*. β_{1j} and α_{2i} clearly reflect the immediate response of *X* to changes in *Y* and the immediate response of *Y* to changes in *X* respectively. They are therefore the short-run elasticities (Thomas, 1997). In Equation (5), if the parameter ϕ_1, is nearer to –1 the faster adjustment of *X* to the previous period's deviation from long-run equilibrium. At the opposite extreme, very small values of ϕ_1 imply that *X* is unresponsive to the last period's equilibrium error. The same condition exists in equation (6). Since the ECTs ϕ_1 and ϕ_2 cannot at the same time equal to zero as the result of the presence of the cointegrating relationship, there must exist one direction of long-term causality between Y and X. Standard t test can be used to test the significance of ϕ_1 and ϕ_2.

Now by re-parameterisation equation (6) can be written in the form of vector autoregressive in difference and error correction components for 'n' variables as follow

$$\Delta Z_t = C + \Gamma_1 \Delta Z_{t-1} + ... + \Gamma_{k-t} \Delta Z_{t-k+1} + \Pi Z_{t-k} + e_t \quad (7)$$

where as; Z_t = [$BANG_t$, $CHIN_t$, $INDI_t$, $JAPA_t$, $KORE_t$ $PAKI_t$,$PHIL_t$, $SRIL_t$, THAI], and ΔZ_t = [$\Delta BANG_t$, $\Delta CHIN_t$, $\Delta INDI_t$, $\Delta JAPA_t$, $\Delta KORE_t$, $\Delta PAKI_t$, $\Delta PHIL_t$, $\Delta SRIL_t$, $\Delta THAI_t$ $]^{/}$. While $\Gamma_j \Delta Z_{t-j}$ and ΠZ_{t-p} are the vector autoregressive (VAR) components in first difference and error-correction components respectively. C is a ($n \times 1$) vector of constants, while e_t is a ($n \times 1$) vector of white noise error terms. Γ_j is a ($n \times n$) matrix that stands for the short term adjustment coefficients among variables with k-1 number of lags, Π is a ($n \times n$) matrix of parameters. As $\Pi = \alpha\beta^{/}$, where α is an ($n \times r$) matrix which represents the speed of adjustment coefficient of the error correction mechanism, while β is an ($n \times r$) matrix of cointegrating vectors such that the term $\beta^{/} X_{t-k}$ in equation (7) represents up to r [If 0< rank(Π) = $r < p$, we can see that there are r cointegrating relations among the elements of $\mathbf{Y}_t$ which will be determined by λ –trace and λ –max statistics (Johansen and Juselius, 1990)].

5. Results

We apply the Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1981) to find stationary of price series (results were presented in Appendix 1). Akaic Information Criteria has been used to test lag length of the price series. AIC is a statistic that decides the number of lags required for describing time series adequately. In an autoregressive scheme the model that minimizes AIC will be selected. According to AIC, lag length of one period is sufficient for all time series. The null hypothesis of non-stationary cannot be rejected for the prices in levels based on ADF test but can be rejected for all the prices in first differences for world price indices of Thailand and United States, and also for FHP price series and GSP price series of all countries. These prices are therefore non-stationary in their levels but stationary in first differences. This implies that the above price series contain unit root and integrated at order one, which is inline with many studies on time series properties of prices. While government-to-government price series and private trade price series and world price indices for low and high quality rice exhibited non-stationary of different degrees, hence, it may be concluded that they are not integrated and removed from further analysis.

5.1 International Price Indices

For the International price series of THAI 2^{nd} grade 100 (THAI-II), THAI-A1 super (THAI-A1) and long grain no. 2 of United States (US) Johansen cointegration, Granger causality and error correction model test results were presented in Tables 3.1, 3.2 and 3.3 respectively. In all markets we select the lag length in the underlying VECM by means of the AIC.

The Johansen cointegration test indicates that out of three price indices there is only one cointegrating vector (Table 3.1), hence one can conclude that even though international price indices are cointegrated, law of one price (LOP) does not hold in the long run. The number of stochastic trends is determined by subtracting the number of cointegrating vector from the dimension of the impact matrix, given by the number of price series (n) included in the VAR. The presence of one cointegrating vector and two stochastic trends signifies that the prices are not pair-wise cointegrated. If there are ‘zero’ cointegrating vectors, prices are said to be not cointegrated in the long run; on the other extreme, if there are n-1 cointegrating vectors, all the prices said to be contain the same stochastic trend and therefore, are pair-wise cointegrated and LOP applicable (Sharma, 2002). In the case of international rice price indices, only one out of three price series are cointegrated and hence international price series (Thai and US) are integrated to the market process and that there is Granger causality in at least one direction. The Granger causality tests indicate that the THAI-II Granger causes THAI-A1 and also US price in the long run (Table 3.2). The error correction terms indicates that the correction to any deviation in long run equilibrium price is slow as error correction terms turned out to be either positive or insignificant (Table 3.3). ECTs also known as long run elasticities, represents “percent of correction to any deviation in long run equilibrium price in a single period”; in other words, it also represents how fast the deviations in the long run equilibrium are corrected. The international rice markets were thin and segmented and hence adjustment process to a disturbance in long run equilibrium is slow. But in the short run, a 1 percent increase in THAI-II in period ‘t-1’ leads to 0.8 percent increase in THAI-A1 price in period ‘t’, and it also leads to 0.75 percent increase in US price in period ‘t’. Indicating THAI-II price is having influence on both THAI-A1 and US prices in the short-run.

The results are in line with the common perception that the Thailand rice price is an indicator of international rice price, as Thailand is located in center of Asia and it contributes more than 70 to 90 percent of world rice exports.

Table 3.1: Johansen Cointegration Test results for International Price Indices (THAI and US)

NULL:	λ –trace	Crit 90%	Crit 95%	Crit 99%
r = 0	39.14***	27.06	29.79	35.46
r <= 1	4.19	13.42	15.49	19.93
r <= 2	0.58	2.70	3.84	6.63
NULL:	λ-max	Crit 90%	Crit 95%	Crit 99%
r = 0	34.98***	18.89	21.13	25.86
r = 1	3.65	12.29	14.26	18.52
r = 2	0.54	2.70	3.84	6.63

Note: * Indicates significant at 5% level

Table 3.2: Results of Granger Casualty Tests for International Price Indices (THAI and US)

	THAI-II	THAI-A1	US
Variable	$Ch\hat{i}^2$ (prob.)	$Ch\hat{i}^2$ (prob.)	$Ch\hat{i}^2$ (prob.)
THAI-II	0.273 (0.76)	3.095* (0.10)	8.778* (0.01)
THAI -A1	0.117 (0.89)	1.442 (0.29)	0.809 (0.48)
US	0.316 (0.73)	1.572 (0.27)	6.009* (0.03)

Note: Figures in parenthesis are f-probabilities

Table 3.3: Error Correction Model for International Price Indices (THAI and US)

	Δ Thai-II	Δ Thai-A1	Δ US
Constant	0.723 (1.1)	-0.543 (-0.7)	-1.300* (-1.9)
Δ Thai-II$_{-1}$	0.871 (1.8)	0.809* (2.0)	0.512 (1.1)
Δ Thai-II$_{-2}$	0.430 (0.7)	-0.350 (-0.4)	0.800 (1.3)
Δ Thai-A1$_{-1}$	-0.245 (-0.8)	-0.447 (-1.2)	0.047 (0.2)
Δ Thai-A1$_{-2}$	-0.229 (-0.7)	-0.283 (-0.7)	-0.137 (-0.4)
Δ US$_{-1}$	-0.088 (-0.4)	0.046 (0.2)	0.754* (3.1)
Δ US$_{-2}$	-0.319 (-1.3)	-0.503 (-1.7)	-0.341 (1.6)
ECT_{-1}	-0.038 (-1.1)	0.028 (0.7)	0.065* (1.9)
R squire	0.53	0.50	0.80

Note: * Indicates significant at 5% level

5.2 Farm Harvest Prices (FHPs)

Farm Harvest Prices in each country reflects prices prevailing at the time of peak harvest season. It generally reflects the cost of production to farmers (including subsidies and taxes) and farm harvest price is subjected to less market distorting practices (tariff, non-tariff barriers) compared to other GSP price export price *etc,*. Given the subsidies and taxes are more stable over a period, change in farm harvest prices is a proxy for changes in cost of production of the country. The cointegration among FHPs of the selected countries in general indicates that production technology in all countries is cointegrated in the long run. The results of the Johansen cointegration tests, granger causality tests and error correction models were reported in Tables 4.1, 4.2 and 4.3 respectively for FHP prices. According to λ-trace statistics there are more than five cointegrating price series and according to λ-max tests only five cointegrating price series out of nine FHP price series included in analysis. Considering that λ-max is more accurate in measuring number of cointegrating vectors, there will be only five FHP price series are cointegrated out of nine in the long run. The presence of four (9-5) stochastic trends implies the absence of pair-wise cointegration of prices, suggesting that the LOP does not hold even though FHPs are cointegrated in the long run, which indicates that rice production technology among Asian countries are cointegrated in the long run.

Table 4.1: Results of Johansen MLE Estimates for FHPs of Asian Countries

NULL:	λ-trace	Crit 90%	Crit 95%	Crit 99%
r = 0	534.0***	190.9	197.4	210.0
r <= 1	315.7***	153.6	159.5	171.1
r <= 2	203.8***	120.4	125.6	136.0
r <= 3	142.8***	91.1	95.8	105.0
r <= 4	97.7***	65.8	69.8	77.8
r <= 5	55.1***	44.5	47.9	54.7
r <= 6	30.3	27.1	29.8	35.5
r <= 7	17.0	13.4	15.5	19.9
r <= 8	5.5	2.7	3.8	6.6
NULL:	λ-max	Crit 90%	Crit 95%	Crit 99%
r = 0	218.3***	55.2	58.4	65.0
r = 1	111.9***	49.3	52.4	58.7
r = 2	60.9***	43.3	46.2	52.3
r = 3	45.1***	37.3	40.1	45.9
r = 4	42.6***	31.2	33.9	39.4
r = 5	24.8	25.1	27.6	32.7
r = 6	13.2	18.9	21.1	25.9
r = 7	11.6	12.3	14.3	18.5
r = 8	5.5	2.7	3.8	6.6

Note: ***,**,* Indicates significant at 1%, 5% and 10% level respectively

On the whole, our results of cointegration tests for FHP prices for Asian regional markets are spatially linked in the long run, even though the Asian rice markets are geographically dispersed, and rice production is subjected to many tariff and non-tariff barriers and subsidies across countries. Spatial cointegration of FHP prices also indicate that the prices as well as to some extent cost of production are linked together and hence all countries are in the same economic market and also production technologies across countries to some extent related to each other in the long run. Cost of production, which ultimately reflects farm harvest prices with some exceptions like subsidies, direct and indirect taxes.

The Granger causality tests indicate that the FHP prices of Thailand (large and frequent exporter; which practiced liberalization policies early) Japan, Bangladesh and Philippines (frequent importers) are exogenous to all markets and also influence other countries FHP prices. Hence these countries are important source of price formation in the Asian rice markets. Pakistani FHP price Granger causes Sri Lankan price, Pakistani and Korean FHP prices Granger cause Indian FHP price, whereas Thailand and Indian prices Granger cause Korean price, and Japanese and Thailand price Granger cause

Pakistani price. There is two-way Granger causality between Pakistan and Indian FHP prices, and also between Indian and Korean farm harvest prices. Here price leadership of Thailand and Japan may be due to early adoption in rice production technology and also due to dominance in either exports or imports in rice markets.

Table 4.2: Results of Granger Causality Tests for FHPs of Asian Countries

	BANG	CHIN	INDI	JAPA	KORE	PAKI	PHIL	SRIL	THAI
Variable	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*	$\hat{Chi}^2$ *(prob.)*
BANG	2.87 (0.11)	1.26 (0.28)	0.02 (0.88)	0.43 (0.52)	0.03 (0.86)	1.16 (0.30)	0.06 (0.81)	0.13 (0.72)	0.01 (0.98)
CHIN	0.19 (0.67)	0.64 (0.44)	2.38 (0.15)	1.37 (0.26)	0.90 (0.36)	0.24 (0.63)	0.00 (0.95)	2.06 (0.17)	0.85 (0.37)
INDI	0.86 (0.37)	0.01 (0.94)	67.00* (0.00)	0.11 (0.75)	5.35* (0.04)	3.98 (0.07)	1.87 (0.20)	1.33 (0.27)	0.03 (0.95)
JAPA	0.11 (0.74)	0.54 (0.47)	1.62 (0.22)	0.00 (0.99)	1.29 (0.28)	6.47* (0.02)	1.49 (0.24)	0.23 (0.64)	0.01 (0.94)
KORE	0.01 (0.93)	0.41 (0.53)	10.45* (0.01)	0.03 (0.86)	3.71 (0.08)	0.04 (0.85)	2.75 (0.12)	1.92 (0.19)	0.61 (0.45)
PAKI	0.32 (0.58)	3.59 (0.08)	24.68* (0.00)	0.00 (1.00)	0.95 (0.35)	6.13* (0.03)	0.03 (0.86)	7.46* (0.02)	0.02 (0.89)
PHIL	0.36 (0.56)	0.52 (0.49)	0.04 (0.97)	0.02 (0.90)	1.76 (0.21)	2.12 (0.17)	5.86* (0.03)	0.18 (0.68)	0.18 (0.68)
SRIL	0.04 (0.84)	3.64 (0.08)	0.04 (0.85)	0.02 (0.89)	2.42 (0.14)	0.00 (0.99)	0.01 (0.93)	0.05 (0.83)	0.08 (0.78)
THAI	1.47 (0.25)	0.88 (0.36)	1.23 (0.29)	1.71 (0.21)	6.10* (0.03)	4.58* (0.05)	0.18 (0.68)	0.02 (0.89)	0.17 (0.69)

Note: * Indicates significant at 5% level

Table 4.3: Error Correction Model for FHPs of Asian Countries (US$/t)

	Δ BANG	Δ CHIN	Δ INDI	Δ JAPA	Δ KORE	Δ PAKI	Δ PHIL	Δ SRIL	Δ THAI
Constant	6.870 (1.52)	-2.488 (-0.98)	-1.432 (-1.43)	0.829 (0.32)	2.500 (1.29)	4.221* (2.07)	6.610 (1.93)	4.200 (1.33)	-1.318 (-0.27)
Δ BANG$_{-1}$	0.373 (1.50)	0.027 (0.19)	-0.005 (-0.06)	-0.084 (-0.58)	-0.126 (-1.18)	-0.261* (-2.32)	0.057 (0.30)	0.072 (0.41)	0.053 (0.20)
Δ CHIN$_{-1}$	-0.360 (0.35)	0.796 (1.36)	-0.327 (-1.09)	-0.489 (-0.81)	-0.381 (-0.86)	-0.838 (-1.79)	-0.610 (-0.78)	0.352 (0.48)	0.059 (0.05)
Δ INDI$_{-1}$	-0.497 (-0.55)	-0.409 (-0.80)	-0.331 (1.26)	-0.004 (-0.01)	0.142 (0.37)	0.566 (1.39)	0.272 (0.40)	-0.354 (-0.56)	-0.567 (-0.59)
Δ JAPA$_{-1}$	-0.128 (-0.24)	-0.017 (-0.06)	-0.258 (-1.64)	-0.057 (-0.18)	-0.183 (-0.79)	0.305 (1.25)	-0.482 (-1.18)	0.050 (0.13)	0.075 (0.13)
Δ KORE$_{-1}$	0.092 (0.09)	-0.580 (-0.99)	-0.161 (-0.54)	0.064 (0.11)	-0.039 (-0.09)	0.615 (1.32)	-0.242 (-0.31)	-0.044 (-0.06)	-0.089 (-0.08)
Δ PAKI$_{-1}$	0.526 (0.50)	0.521 (0.88)	0.079 (0.26)	0.081 (0.13)	-0.088 (-0.20)	-0.452 (-0.96)	0.251 (0.32)	1.048 (1.43)	1.120 (1.01)
Δ PHIL$_{-1}$	0.087 (0.22)	0.167 (0.74)	-0.197 (-1.70)	0.220 (0.95)	0.278 (1.63)	-0.307 (-1.71)	0.650* (2.15)	0.049 (0.17)	0.223 (0.53)
Δ SRIL$_{-1}$	0.088 (0.14)	-0.729* (-2.05)	0.027 (0.15)	-0.024 (-0.06)	-0.162 (-0.60)	0.471 (1.66)	-0.030 (-0.06)	-0.033 (0.08)	-0.644 (-0.96)
Δ THAI$_{-1}$	0.265 (0.67)	0.293 (1.30)	0.695* (6.00)	0.279 (1.20)	0.038 (0.22)	0.031 (0.17)	-0.225 (-0.75)	-0.200 (-.79)	0.783 (1.84)
ECT_{-1}	-0.021 (-0.60)	-0.021 (-1.06)	-0.017 (-1.66)	-0.004 (-0.20)	-0.034* (-2.34)	0.017 (1.11)	-0.076* (-2.92)	-0.061* (-2.53)	-0.082* (-2.24)
R squire	0.79	0.64	0.91	0.47	0.67	0.79	0.71	0.75	0.53

Note: * Indicates significant at 5% level

Short-run elasticities of ECM in Table 4.3 indicates that a one percent increase in Srilankan FHP price in ‘t-1’ period leads to a reduction of 0.75 percent of Chinese FHP price in period ‘t’, in the same way a percent increase in Thailand FHP price in period ‘t-1’ leads to an increase of 0.69 percent of Indian FHP price in period ‘t’ . A percent increase in Bangladesh price in period ‘t-1’ leads to a reduction of about 0.26 percent in Pakistan price in period ‘t’. Except these above significant relationships, many error correction terms are insignificant in ECM, which indicates there are very few cause and effect relationships in the short-run in Asian FHP prices as expected.

The results of error correction model (long-run adjustment elasticities) suggests that about 3.4 percent of total deviation in long run equilibrium can be adjusted within one year in Korea, the same figures are 7.6 percent for Philippines, 6.1 percent for Sri Lanka and 8.2 percent for Thailand (Table 4.3). On the other hand for Bangladesh, India and Pakistan the ECTs are turned out to be either positive or insignificant, indicating that the adjustment to any disturbance in long-run equilibrium is very slow. Interestingly frequent players in international markets (either as importer or exporter) Korea, Philippines, Sri Lanka and Thailand deviations in long run equilibrium will be corrected faster than less frequent and more restrictive players such as India and Pakistan.

Overall the FHP prices of Bangladesh, Japan, Philippines and Thailand are exogenous and important sources of price formation. Many short-run elasticities are insignificant in error correction model and only few are significant. ECTs indicate that disturbances to long run equilibrium can be corrected up to 6 to 8 percent a year through short-run adjustment. Thailand and Japan play dominant roles in influencing farm harvest prices as they are leaders in rice production technology and also important players in international markets (either as exporter or as importer).

5.3 Government Support Prices (GSP)

Generally governments announce GSP prices at the beginning of a crop season. In fixation of support prices, respective governments take into consideration many factors such as remuneration to farmers, cost of production, international prices, input/output prices, prices of competing crops, affordability to consumers as it is major staple food for majority of poor Asian countries. Out of nine Asian countries considered in this study, five GSP price series are cointegrated, according to λ –trace statistics, and four price series (at 90 percent level of significance) are cointegrated, according to λ –max statistics. Considering the superiority of λ -max statistics, one can conclude that only four price series are cointegrated among nine price series of government support price (Table 5.1). The Granger causality test indicates that Japanese price Granger causes Bangladeshi and Philippine prices, whereas Bangladeshi price granger causes Sri Lankan price (Table 5.2). While Chinese price is influenced by Sri Lankan price, Japanese price is influenced by Chinese price, Indian GSP price is influenced by Japan, Korea and Sri Lankan GSP price in the long run. Similarly Korean GSP price is influenced by China and Philippines GSP price. Thailand GSP price is influenced by Japan and Korean GSP price series in the long run.

Unlike farm harvest prices, there is no exogenous series among GSP prices in Asian countries. That is the GSP price series are interdependent on each other countries support prices. According granger causality tests Indian, Korea and Thailand GSP price series are mostly dependent on many other markets. Major source of GSP price formation are Bangladesh, Sri Lanka, China, Japan and Philippines (in case of FHPs Thailand, Japan, Philippines and Bangladesh) even though they are partly endogenous as at least one other price series are influencing every countries GSP price series.

Unlike Thailand's FHP, which was exogenous to all markets, here Thailand's GSP price was influenced by Japan and Korean prices (Table 5.2).

Table 5.1: Results of Johansen MLE Estimates for GSPs of Different Countries

NULL:	λ-trace	Crit 90%	Crit 95%	Crit 99%
r = 0	310.1***	190.9	197.4	210.0
r <= 1	231.2***	153.6	159.5	171.1
r <= 2	171.9***	120.4	125.6	136.0
r <= 3	124.5***	91.1	95.8	105.0
r <= 4	85.1***	65.8	69.8	77.8
r <= 5	45.4*	44.5	47.9	54.7
r <= 6	29.1	27.1	29.8	35.5
r <= 7	12.7	13.4	15.5	19.9
r <= 8	5.6	2.7	3.8	6.6
NULL:	λ-max	Crit 90%	Crit 95%	Crit 99%
r = 0	78.9***	55.2	58.4	65.0
r = 1	59.3***	49.3	52.4	58.7
r = 2	47.4**	43.3	46.2	52.3
r = 3	39.4*	37.3	40.1	45.9
r = 4	30.7	31.2	33.9	39.4
r = 5	25.3	25.1	27.6	32.7
r = 6	16.5	18.9	21.1	25.9
r = 7	7.0	12.3	14.3	18.5
r = 8	5.6	2.7	3.8	6.6

Note: ***, ** and * Indicates significant at 1%, 5% and 10% level respectively.

Table 5.2: Results of Granger Causality Tests for GSPs of Different Countries

	BANG	CHIN	INDI	JAPA	KORE	PAKI	PHIL	SRIL	THAI
Variable	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)	$\hat{Chi}^2$ (prob.)
BANG	0.487 (0.49)	0.475 (0.50)	3.966 (0.06)	0.671 (0.42)	0.027 (0.87)	7.838* (0.01)	0.001 (0.98)	4.155* (0.05)	2.945 (0.10)
CHIN	2.171 (0.15)	0.811 (0.38)	3.697 (0.07)	5.662* (0.03)	9.531* (0.01)	0.110 (0.74)	2.705 (0.11)	1.050 (0.32)	0.849 (0.37)
INDI	1.206 (0.28)	0.891 (0.35)	1.797 (0.19)	2.134 (0.16)	3.707 (0.07)	0.843 (0.37)	0.312 (0.58)	0.286 (0.60)	2.188 (0.15)
JAPA	6.596* (0.02)	1.271 (0.27)	7.296* (0.01)	1.021 (0.32)	0.405 (0.53)	0.058 (0.81)	5.868* (0.02)	0.319 (0.58)	7.540* (0.01)
KORE	1.203 (0.28)	0.471 (0.50)	13.961* (0.00)	0.359 (0.55)	0.217 (0.65)	3.130 (0.09)	0.158 (0.69)	0.130 (0.72)	4.553* (0.04)
PAKI	2.203 (0.15)	0.000 (0.99)	0.271 (0.61)	2.759 (0.11)	3.890 (0.06)	2.098 (0.16)	0.078 (0.78)	2.043 (0.17)	0.010 (0.92)
PHIL	1.072 (0.31)	0.825 (0.37)	4.203 (0.05)	0.602 (0.45)	4.435* (0.05)	0.467 (0.50)	0.018 (0.90)	0.841 (0.37)	1.275 (0.27)
SRIL	0.428 (0.52)	5.776* (0.02)	5.844* (0.02)	0.247 (0.62)	2.987 (0.10)	0.743 (0.40)	1.081 (0.31)	1.941 (0.18)	0.347 (0.56)
THAI	1.224 (0.28)	1.299 (0.27)	0.294 (0.59)	0.052 (0.82)	2.998 (0.10)	0.731 (0.40)	0.303 (0.59)	0.970 (0.33)	1.239 (0.28)

Note: * Indicates significant at 5% level

Table 5.3: Error Correction Model for GSPs of Different Countries (US$/t)

	ΔBANG	ΔCHIN	ΔINDI	ΔJAPA	ΔKORE	ΔPAKI	ΔPHIL	ΔSRIL	ΔTHAI
constant	-2.443 (-1.63)	0.168 (0.17)	0.561 (0.92)	-0.326 (-0.30)	0.937 (0.98)	0.023 (0.02)	-0.093 (-0.08)	4.293* (3.73)	-0.835 (-0.59)
$\Delta BANG_{-1}$	0.092 (0.38)	-0.147 (0.90)	0.169 (1.72)	-0.132 (-0.74)	-0.123 (-0.79)	0.518* (2.77)	0.026 (0.14)	-0.070 (-0.38)	-0.311 (-1.360
$\Delta CHIN_{-1}$	-0.046 (-0.15)	0.273 (1.34)	0.048 (0.39)	-0.378 (-1.70)	0.109 (0.56)	0.356 (1.52)	0.229 (0.98)	0.448 (1.93)	-0.114 (-0.40)
$\Delta INDI_{-1}$	0.438 (1.18)	0.296 (1.09)	-0.030 (-0.19)	0.389 (1.31)	0.323 (1.24)	0.054 (0.17)	-0.142 (-0.46)	0.161 (0.52)	0.545* (2.21)
$\Delta JAPA_{-1}$	0.727 (1.75)	0.182 (0.65)	0.541* (3.20)	0.070 (0.23)	-0.225 (-0.84)	-0.248 (-0.77)	0.632* (1.97)	0.308 (0.96)	0.608* (2.30)
$\Delta KORE_{-1}$	0.212 (0.80)	0.193 (1.09)	0.219* (2.05)	0.025 (0.13)	0.371* (2.19)	-0.040 (-0.20)	-0.190 (-0.94)	0.124 (0.61)	0.374 (1.50)
$\Delta PAKI_{-1}$	0.439* (2.10)	0.033 (0.24)	0.177* (2.07)	-0.216 (-1.40)	-0.043 (-0.32)	-0.070 (-0.43)	-0.007 (-0.04)	-0.225 (-1.39)	-0.149 (-0.75)
$\Delta PHIL_{-1}$	0.180 (0.88)	0.122 (0.89)	0.183 (2.21)	0.103 (0.68)	0.277* (2.11)	0.090 (0.57)	-0.017 (-0.11)	0.195 (1.24)	0.212 (1.10)
$\Delta SRIL_{-1}$	-0.212 (-0.89)	0.214 (2.58)	-0.144 (-1.48)	0.019 (0.11)	-0.199 (-1.30)	-0.216 (-1.17)	0.212 (1.16)	0.428* (2.33)	0.043 (0.19)
$\Delta THAI_{-1}$	0.170 (0.64)	0.119 (0.67)	0.001 (0.01)	-0.002 (-0.01)	-0.175 (-1.03)	-0.404 (-1.97)	0.187 (0.92)	0.512* (2.51)	0.004 (0.02)
ECT_{-1}	-0.016 (0.65)	-0.005 (-0.29)	-0.029* (-2.96)	0.020 (1.14)	-0.027 (-1.78)	-0.010 (-0.53)	-0.014 (-0.74)	-0.073* (-3.94)	-0.029 (1.26)
R-squire	0.40	0.49	0.63	0.38	0.69	0.60	0.34	0.60	0.47

Note: * Indicates significant at 5% level

The ECM indicates that short-run adjustment elasticities are quite significant for many countries GSP prices unlike FHP price series (Table 5.3), which is inline with the results of granger causality tests. A one percent change in Pakistan GSP price in period ‘t-1’ increases Bangladesh GSP price by 0.43 percent in period ‘t’. Short-run adjustment elasticity of Chinese price with respect to lagged Sri Lankan price was 0.21 percent. A one- percent increase in Japanese price increases Indian price by 0.51 percent, and also a one- percent change in Korean price increases Indian price by 0.21 percent. Short-run adjustment elasticity of Indian price with respect to Pakistan price is 0.17 percent. A one percent change in Philippines price induces 0.27 percent change in Korean price. And a one percent change in Bangladesh price induces 0.52 percent change in Pakistan price. A one percent change in Japanese price induces 0.63 percent change in Philippines price. A one percent change in Thailand GSP price induces 0.51 percent change in Srilankan GSP price. A one percent change in Indian price induces 0.54 percent change in Thailand price and a percent change in Japanese price induces 0.61 percent change in Thailand price.

However, among GSP series the ECTs are not significant for many countries indicating long-run adjustment elasticities are either positive or insignificant. The figures indicates that only 2.9 percent of total deviation from long run equilibrium will be corrected in a year among Indian GSP prices, and only 7 percent of total deviation from long-run equilibrium will be corrected in a year in case of Sri Lankan GSP price series. And for all other countries ECTs are not significant. When compared to FHP, among GSP short-run correction towards long-run equilibrium is slower in all countries.

6. Conclusion and Policy Recommendation

The paper studied the cointegration among Asian rice markets by using Johansen test ,examined causality by Granger causality tests and also estimated the speed of adjustment from short run deviations from long run equilibrium in prices among rice markets by using vector error correction model. The causality tests are also performed to find cointegration among international prices of high and low quality rice. The result reveals that international rice price indices (Thai and US), farm harvest prices and also government support prices were cointegrated in the long run, however law of one price does not hold. In the case of international rice price indices, only one out of three price series are cointegrated and hence international price series (Thai and US) are integrated to the market process and that there is Granger causality in at least one direction. The Granger causality tests indicate that the THAI-II Granger causes THAI-A1 and also US price in the long run. As Thailand contributes majority of international trade in rice, and it is the center of rice trade in Asian region, which alone contributes to about 70-90 percent of world rice trade every year.

Results for farm harvest prices indicates that Japan, Thailand, Bangladesh and Philippines FHP price series are exogenous to all markets and influence many other markets, thereby important sources of price formation in the Asian rice market in respect of farm harvest prices.

According to Johansen test, out of nine farm harvest price series only five cointegrating price series exist. On the whole, our results show that farm harvest prices of Asian countries are spatially linked in the long run. The Granger causality tests indicate that, Thailand (large and frequent exporter), Japan (early adopters of high yielding rice technology), Bangladesh and Philippines (frequent importers) farm harvest prices are exogenous and influence many other countries farm harvest prices, hence important source of price formation in the Asian farm harvest prices. Pakistani price Granger causes Sri Lankan price, Pakistani and Korean prices Granger cause Indian price, whereas Thailand and Indian prices Granger cause Korean price, and Japanese and Thailand price Granger cause Pakistani price.

However, in case of government support prices, only four price series are cointegrated among nine price series. Granger causality tests indicate that there is no exogenous independent price series exists in case of GSP prices. Japanese GSP price Granger causes Bangladeshi and Philippine prices. Bangladeshi price granger causes Sri Lankan price. While Chinese price is influenced by Sri Lankan price, Japanese price is influenced by Chinese price. Many countries influence some countries GSP prices. For example, Indian GSP price is influenced by Japan, Korea and Sri Lankan GSP price. Similarly, Korean GSP price is influenced by China and Philippines GSP price. Thailand GSP price is influenced by Japan and Korean GSP price series. Major sources of GSP price formation are Bangladesh, Sri Lanka, China, Japan and Philippines (in case of FHPs Thailand, Japan, Philippines and Bangladesh) even though they are partly endogenous as at least one other price series are influencing every countries GSP price series. Unlike Thailand's FHP, which was exogenous to all markets, here Thailand's GSP price was influenced by Japan and Korean prices

The ECM indicates that short-run adjustment elasticities are quite significant for many countries GSP prices unlike FHP price series, which is inline with the results of granger causality tests. A one percent change in Pakistan GSP price in period 't-1' increases Bangladesh GSP price by 0.43 percent in period 't'. A one- percent increase in Japanese price increases Indian price by 0.51 percent, and also a one- percent change in Korean price increases Indian price by 0.21 percent. Short-run adjustment elasticity of Indian price with respect to Pakistan price is 0.17 percent. A one percent change in Philippines price induces 0.27 percent change in Korean price. There is two-way granger causality between Pakistan and Bangladesh. A one percent change in Japanese price induces 0.63 percent change in Philippines price. A one percent change in Thailand GSP price induces 0.51 percent change in Sri Lankan GSP price. A one percent change in Indian price induces 0.54 percent change in Thailand price and a percent change in Japanese price induces 0.61 percent change in Thailand price.

However, among GSP series the error correction terms are not significant for many countries indicating long-run adjustment elasticities are insignificant. The figures indicates that only 2.9 percent of total deviation from long run equilibrium will be corrected in a year among Indian GSP prices, and only 7 percent of total deviation from long-run equilibrium will be corrected in a year in case of Sri Lankan GSP price series. And for all other countries ECTs are not significant. When compared to FHP, among GSP short-run correction towards long-run equilibrium is slower in all countries.

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Appendix I: Results of the ADF Test for the Order of Integration

	Level (t)	First-Difference (t)		Level (t)	First-Difference (t)
World Price series					
2nd grade 100(Thai)	-1.78	-4.51*			
A1 super (Thai)	-1.47	-4.92*			
long grain No.2 (4%)(USA)	-2.62	-3.74*			
Govt.-Govt. Contract			Private trade		
Myanmar sms42	-2.48	-4.95*	Thailand white Rice25super	-2.85	-4.86*
Thailand white rice35	-2.59	-4.59*	Thailand Cargo rice 100	-2.38	-4.13*
Thailand white rice10	-1.62	-3.12*	Thailand Broken 100	-3.20	-5.90*
China pr35	-1.25	-4.57*	Pakistan Basmati	-3.13	-6.78*
GSPs			FHPs		
Bangladesh	-2.72	-5.71*	Bangladesh	-3.53	-5.28*
China	-2.39	-3.88*	China	-2.61	-3.98*
India	-1.70	-3.57*	India	-1.86	-4.37*
Japan	-3.45	-3.53*	Japan	-2.28	-3.53*
Korea	-2.54	-3.37*	Korea	-3.48	-2.72*
Pakistan	-2.38	-4.40*	Pakistan	-1.82	-4.46*
Philippines	-3.27	-4.68*	Philippines	-2.39	-4.48*
Sri Lanka	-2.75	-3.72*	Sri Lanka	-3.12	-3.94*
Thailand	-2.18	-3.54*	Thailand	-3.04	-3.57*

Note: *Indicates significance at 5% level