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Impact of Wheat and Rice Export Ban on Indian Market Integration

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1. Introduction

In response to the dramatic increase in world grain prices in 2007 and 2008, many governments restricted exports to ensure sufficient domestic food supplies (Abbott, 2009; Abbott, 2010). In 2007, India, one of the world's largest grain exporters, banned exports of wheat and some varieties of rice, lifting the ban only four years later in September 2011 (Chand, 2009 and Chand et al, 2010). While a few papers explore the effect of export bans on world commodity prices (Gotz, Glauben and Brummer 2010; Abbott 2010; Liefert et al 2012; Martin and Anderson 2012; Welton 2011; Djuric 2009 and 2011) in this paper, we empirically estimate how the Indian export ban affected the domestic market. Specifically, we ask if and how the ban affected price differences among producing, consuming and exporting regions, and whether it increased domestic price volatility. Understanding the spatial effects of an export ban can better inform countries of the true costs and benefits of this form of blunt trade instrument on their own markets.

Countries impose export bans to insulate the domestic market from international price volatility and ensure the commodity is available in the domestic market at a lower than world price. Along with exacerbating the increase in world prices, export bans may have unintended consequences for the domestic market, such as increasing domestic price volatility due to the inability of the world market to mitigate against short run supply shocks and exacerbate existing market inefficiencies (Welton, 2011). Further, if commodities cannot move freely within the country, export restrictions may increase price differentials within the country. Export restrictions can also directly increase the cost of domestic trade (Porteous, 2012), which could further exacerbate regional differences in prices. Indian agriculture is highly regulated by production and consumption subsidies, minimum export prices and domestic trade restrictions (Mallory and Baylis 2013). Given the already limited efficiency of domestic agricultural markets within India, the export ban might have further exacerbated market distortions (Kubo, 2011). In this paper, we ask two research questions: What effect did the Indian export ban have on the integration of domestic markets with the world market? What effect did the export ban have on the integration within the domestic market?

Several authors find that market liberalization generally increases domestic market integration (Goleti and Babu, 1994 for Malawi; Dercon, 1995 for Ethiopia; Alexander and Wyeth 1994 for Indonesia). Welton (2011) explicitly considers the effect of an export ban on domestic prices and price volatility in the case of Russia. Using a detailed description of the ban and following market changes, Welton (2011) finds that while the traders stored grain in expectation of the lifting of the ban, limiting the ban's immediate effect on domestic grain prices. Eventually, a supply response led to a sharp fall in domestic price and widening of the price gap between domestic and world market, prompting the government to end the ban. Thus, the Russian export ban led to short run price increases in both the domestic market and world market, and did not successfully isolate the domestic price from the world price (Welton, 2011). Few studies analyze the Indian export ban, and those that do have largely been descriptive and do not use extensive data (Woolverton and Kiawu, 2009; Dorosh, 2008; Slayton, 2009, Abbott, 2010; Martin and Anderson, 2011; Liefert, Westcott and Wainio, 2011; Clarkson and Kulkarmi, 2012). One exception is Acharya et al. (2012) who use farmgate and retail prices for several markets in India to analyze the extent of price transmission for rice and wheat from world markets and consider the effect of the ban on domestic market integration. They find that while domestic prices did increase during the global food crisis, the increase was considerably less than the increase in the world prices.

Our work differs from Acharya et al (2012) in several ways. First, because we analyze the effect of the export ban not just on the integration of the Indian market with the international market but integration among domestic markets. In particular, we differentiate not only producing states and consuming states but also the major port areas, which we expect are the regions most likely affected by an export ban. Given other authors have found little market integration within India, we want to include and test for those markets most likely to be integrated with world prices (Mallory and Baylis 2012; Sekhar, 2012). Second, unlike Acharya et al (2012) we incorporate tests for nonlinearity during the export ban period. If the export ban was indeed effective, the trajectory of domestic prices in India should be different than the trajectory of world prices, and the nonlinearity tests allow us to test for this break. We also consider other possible sources of nonlinearity such as rainfall shocks, gasoline prices and other government intervention variables such as minimum support prices (MSP) and centrally issued prices (CIP). To our knowledge, ours is one of the first papers to econometrically explore the domestic market effect of an export ban.

We begin by modifying a simple model of spatial price transmission from Fackler and Goodwin's (2001), and deriving several testable hypotheses about the effect of the ban. Next, using data on markets from major producing states, urban retail centers, major ports and rainfall-induced supply shocks, we empirically evaluate whether the export ban affected price transmission between the domestic markets and global market. We use a linear vector error correction models as a baseline analysis of spatial market relationships. We extend the linear framework by testing for nonlinearity arising from a regime shift caused by the ban because we hypothesize that our price data may exhibit discrete jump or structural change in levels from the changes in Indian trade policy.

We find that none of the market pairs were fully integrated in the linear VECM results. However, Gregory-Hansen statistic show there are significant thresholds for the following market pairs: wheat producing states and wheat consuming states, rice producing states and rice consuming states and rice exporting states and the world market. This implies that for these market pairs with significant breaks, the rank of cointegration may differ across thresholds. We find that wheat producing and consuming states are fully integrated after the ban and that rice exporting states and world market are fully integrated prior to ban.

2. Overview of India's Food Policy and Export Market

India faces long-run problems of domestic malnutrition and household food insecurity. In 2011, India has 224.6 million inhabitants who are undernourished (FAO-SOFI, 2011) and has one of the highest rates of child stunting in the world (Cagliarni and Rush, 2011). Concerns with food insecurity have led the Indian government to be heavily involved in domestic agricultural markets.

India's government food policy consists of two pillars: (1) government procurement of staple crops from farmers and (2) public distribution of these crops (Dorosh, 2009). The government directly purchases unmilled rice or wheat from farmers or traders at organized wholesale markets called *mandis*. The Food Corporation of India (FCI) and the procurement arms of state governments in theory will purchase an infinite amount of paddy or wheat at the minimum support price (MSP), as long as the grain satisfies a minimum standard called "fair average quality (FAQ)". The MSP is set by the government each year based on recommendations by the Commission on Agricultural Costs and Prices (CACP) based on a cost-plus basis using cost-of-cultivation estimates obtained through farm surveys. The government then distributes grain through the Public Distribution System (PDS) selling the milled grain at government run Fair Price Shops at Central Issued Prices (CIP). The government withholds some stocks of grain from the market as a buffer for food security.

In early 2000, agricultural policy was liberalized in India, including reforms in 2002 that improved mobility of grains across state lines. However, the trend toward liberalization reversed when global prices rose. The domestic wheat stock on July 1, 2006 was only 8.2 million tons, less than half of the 17 million ton norm. In that same month, the Indian government increased the level of grain procurement and distributed higher quantities of subsidized rice and wheat to the Fair Price Shops (Chand et al, 2010). To further enhance domestic supply in September 2006, the government reduced the import tariff on wheat to zero and the private sector was encouraged to import wheat. In February 2007, the government began to actively import and placed an export ban on wheat, and from February through June 2007, actively imported wheat (Acharya et al, 2012). [See figure 1 for timeline of wheat policy.] The government also increased the MSP for wheat. These efforts only increased the wheat stock slightly so that by July 1, 2007 wheat stocks were still 4.2 million tons below the July 1 norm (Dorosh, 2009).

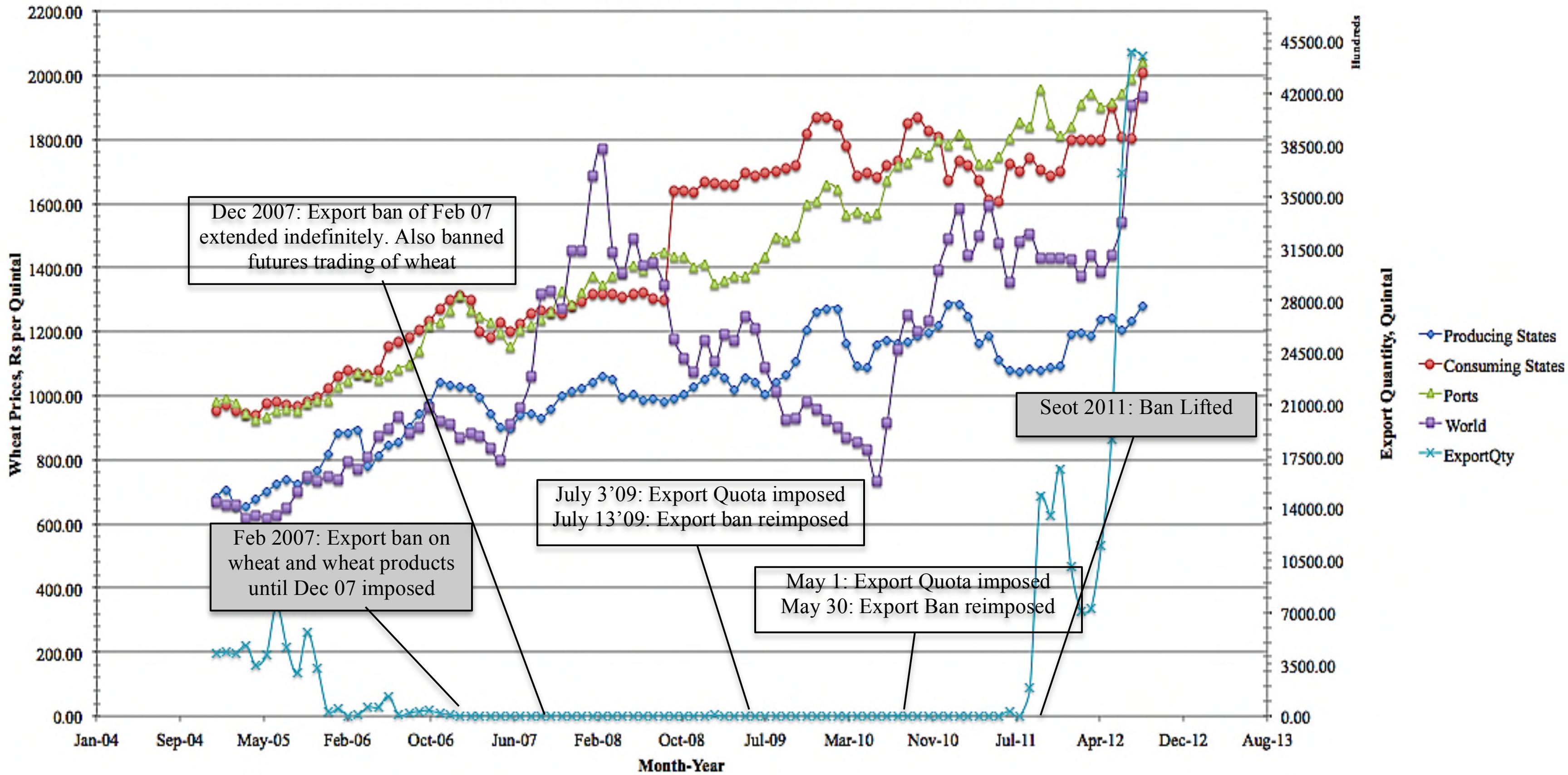
With wheat stocks low and international wheat and rice prices high, the government then raised the MSP, increasing rice procurement during the monsoon (kharif) season of 2007. India also placed an export ban on non-basmati (ordinary) rice on October 9, 2007 [see figure 2 for rice policy timeline]. Though the ban was lifted on October 31, 2007, it was replaced with a minimum export price[1] (MEP) of $425 per ton (Sharma, 2011). The MEP was subsequently raised and the export ban on non-basmati rice was reinstated on April 1, 2008 (Dorosh, 2009). In addition, on March 8, 2008, the month prior to the reinstatement of the non-basmati export ban, basmati rice's MEP was raised to $950/ton. Several adjustments were made and the high MEP for basmati rice continued as well (Sharma, 2011).

Due to the export ban and government's active procurement, government's rice stocks grew dramatically, and by mid-2009 they were more than twice as large as the norm (Kubo, 2012). Literature suggests that the mistake was from setting the MSP too high (Clarkson and Kulkarmi, 2012). In July 2010 newspapers reported large amounts of rice and wheat rotting in FCIs storage facilities (Kubo, 2012). Despite these high stocks, the *non-basmati* rice export ban and wheat ban were not lifted until July 19, 2011 (Director General of Foreign trade, India government 2012[2]).

[1] Under a MEP, no export is allowed below the set minimum price. The MEP is often used together with an export tax. A low MEP may have little effect on domestic supplies in an implementing country and a very high MEP may result in an export ban. Some countries prefer an MEP to an outright export ban for revenue reasons when world prices are surging as well as to prevent under invoicing (Dorosh, 2009).

[2] http://www.aec-fncci.org/index.php?page=news&NewsID=110; http://timesofindia.indiatimes.com/business/india-business/Govt-lifts-ban-on-wheat-exports-Sharad-Pawar/articleshow/9246520.cms

Figure 1. Average Wheat Prices in Selected Markets and Export Quantity



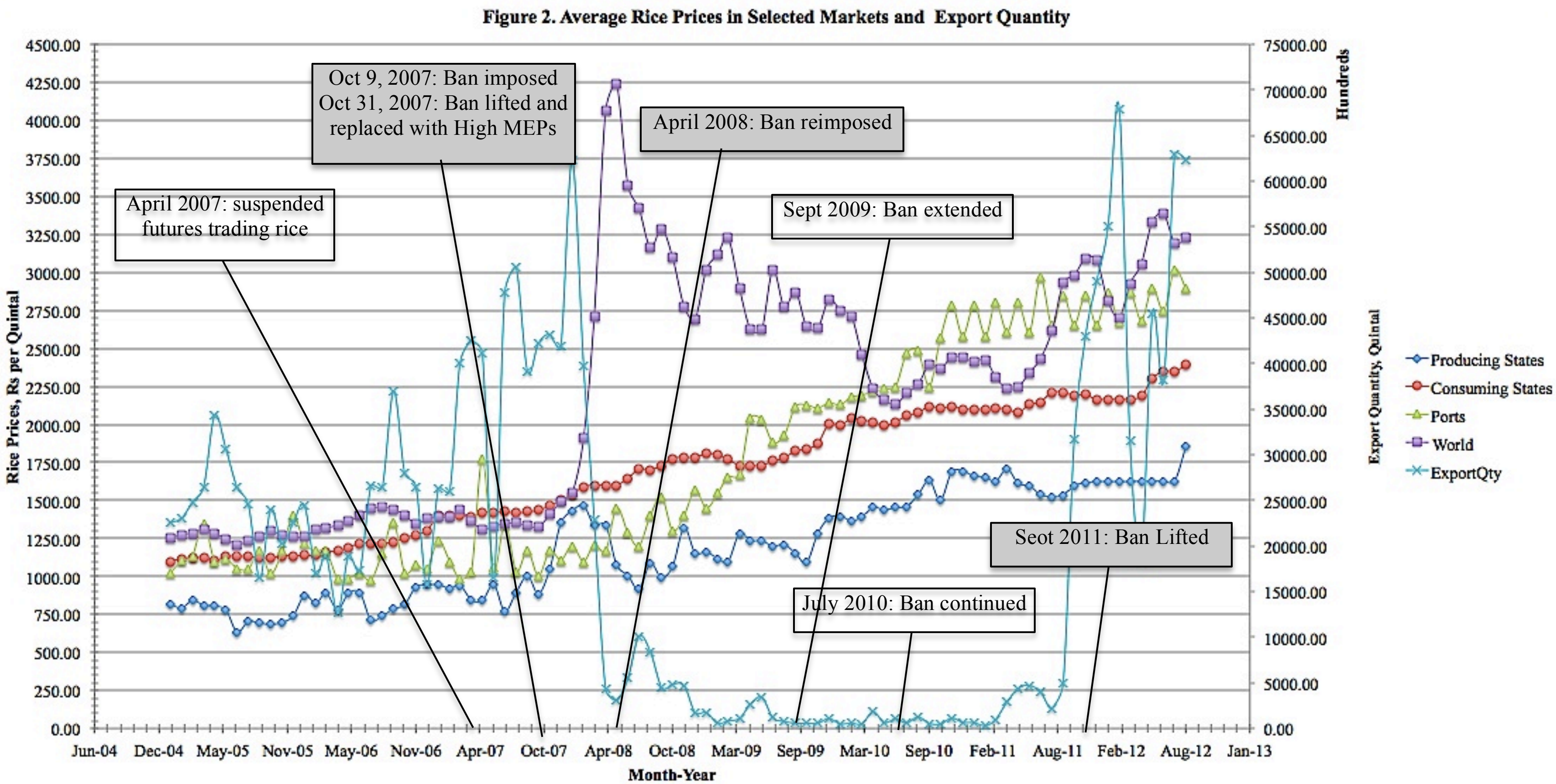


Figure 2. Average Rice Prices in Selected Markets and Export Quantity
Oct 9, 2007: Ban imposed
Oct 31, 2007: Ban lifted and replaced with High MEPs
April 2008: Ban reimposed
April 2007: suspended futures trading rice
Sept 2009: Ban extended
Seot 2011: Ban Lifted
July 2010: Ban continued
Rice Prices, Rs per Quintal
Export Quantity, Quintal
Hundreds
Month-Year
Producing States
Consuming States
Ports
World
ExportQty

3. Data

We analyze domestic impacts of the export ban by using monthly data for major markets in producing states, major retail centers in consuming states and markets in major ports cities for rice and wheat as summarized in Table 1. To capture crucial supply, consumption, and export regions, we select three primary wholesale market centers that supply 35-40% of the rice and wheat to major urban centers in India (Patna, Rewari and Unnao for Wheat; Patna, Fatehabad and Bahraich for Rice) (India Stat 2013 http://www.indiastat.com). We also choose three major urban centers in India (Delhi, Mumbai and Kolkata) to take into account the effect of the ban on end consumers. Last, we choose three major ports based on the 2005 India port report (Kandla, Visakhapatnam and Tuticorin) (I-maritime Research). We use local prices from January 2005 to August 2012 from AgMarkNet[3], FAO-GIEWS[4] and Indiastat website. For the missing price data, we follow the multiple imputation procedure using the Amelia R Package[5] as in Mallory and Baylis (2012). To minimize the problem of missing observsations, we select those markets with less than 20% missing data.

In addition to monthly crop prices, we include monthly rainfall data from the Indian Department of Meteorology and Datanet India to account for domestic weather related supply shocks effects on market integration.

[3] AgMarkNet is the website of the Indian Ministry of Agriculture http://agmarknet.nic.in/
[4] GIEWS is FAO's Global Information and Early Warning System on Food and Agriculture
[5] http://cran.r-project.org/web/packages/Amelia/citation.html

Table 1. Selected Markets for Rice and Wheat

Commodity	Primary Wholesale Markets	Retail Markets	Major Ports
Rice	Patna, Bihar[2] Fatehabad, Haryana[1] Bahraich, Uttar Pradesh[1]	Delhi, Delhi[2] Kolkata, West Bengal[2] Mumbai, Maharashtra[3]	Kandla, Gujarat[3] Visakhapatnam, Andrha Pradesh[3] Tuticorin, Tamil Nadu[3]
Wheat	Patna, Bihar[2] Rewari, Haryana[1] Unnao, West Bengal[1]	Delhi, Delhi[2] Kolkata, West Bengal[2] Mumbai, Maharashtra[3]	Kandla, Gujarat[3] Visakhapatnam, Andrha Pradesh[3] Tuticorin, Tamil Nadu[3]
Source: 1-Agmarknet; 2-FAO-GIEWS; 3- Indiastat			

To analyze price transmission from international to domestic markets, we use the monthly world price for rice (Thai rice 5% broken) and wheat (US HRW wheat) as available from Indexmundi.com. Using the prevailing Indian Rupee-US $ exchange rate from the Reserve Bank of India[6], all domestic prices were converted to Indian Rupee per quintal equivalents. The monthly nominal price series were logarithmically transformed.

Our econometric analysis for assessing the transmission of international prices to primary wholesale and retail markets also includes domestic policy variables: the minimum support prices and central issue prices from Food Corporation of India. We also include gasoline prices from the Indiastat website as a proxy for transportation cost. Finally, we include monthly rainfall data from the Indian Department of Meteorology and Datanet India to use the induced supply shocks to further test market integration. Table 2 below summarizes the variables used, summary statistics and data sources. Figures 3-8 depict domestic price movements vis-à-vis world price.

[6] http://dbie.rbi.org.in/DBIE/dbie.rbi?site=statistics

Table 2. Summary Statistics of Variables Used, Units and Sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Rice Retail Prices							
Delhi	92	1890.772	431.673	1229	2523	Rs/Quintal	FAO-GIEWS
Mumbai	92	1688.337	414.674	1150	2790	Rs/Quintal	FAO-GIEWS
Kolkata	92	1483.696	393.9156	850	2132	Rs/Quintal	FAO-GIEWS
Rice Wholesale Prices							
Patna	92	1386.37	494.709	900	2325	Rs/Quintal	FAO-GIEWS
Fatehabad	92	1390.756	473.5935	444	2315	Rs/Quintal	Agmarknet
Bahraich	92	797.7242	191.502	546.4	1127.26	Rs/Quintal	Agmarknet
Kandla	92	1891.304	772.3252	1000	3800	Rs/Quintal	Indiastat
Visakhapatnam	92	1904.583	1141.434	610	3400	Rs/Quintal	Indiastat
Tuticorin	92	1524.978	386.7791	1000	2550	Rs/Quintal	Indiastat
Wheat Retail Prices							
Delhi	92	1276.424	221.8543	807	1668	Rs/Quintal	FAO-GIEWS
Mumbai	92	1661.891	365.5652	1058	2590	Rs/Quintal	FAO-GIEWS
Kolkata	92	1434.304	452.5714	900	2100	Rs/Quintal	FAO-GIEWS
Wheat Wholesale Prices							
Patna	92	1062.935	177.5559	600	1397	Rs/Quintal	FAO-GIEWS
Rewari	92	1004.589	170.7755	620	1348	Rs/Quintal	
Unnao	92	993.4925	161.743	620	1260	Rs/Quintal	
Kandla	92	1035.054	244.3003	705	1650	Rs/Quintal	Indiastat
Visakhapatnam	92	1597.446	368.9974	1020	2350	Rs/Quintal	Indiastat
Tuticorin	92	1645.717	383.6943	958	2328	Rs/Quintal	Indiastat
World Prices							
Rice	92	2208.245	801.2239	1210.03	4239.16	Rs/Quintal	Indexmundi
Wheat	92	1121.708	324.0183	615.12	1934.12	Rs/Quintal	Indexmundi
Value of Exports							
Basmati Rice	92	724.6368	493.504	149.17	2013.83	Rs Crore	Database of Indian economy
Non-basmati Rice	92	374.2757	460.9202	7.23	2011.31	Rs Crore	Database of Indian economy
Wheat	92	44.55891	144.3151	0	861.23	Rs Crore	Database of Indian economy

Table 2 cont'd. Summary Statistics of Variables Used, Units and Sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Rainfall							
Delhi	92	39.58804	54.41828	0	198.1	Mm	India Dept of Meteorology
Mumbai	92	88.54565	107.9151	0	368.5	Mm	India Dept of Meteorology
Kolkata	92	214.0022	219.8375	0	750.8	Mm	India Dept of Meteorology
Patna	92	91.04457	123.438	0	512.9	Mm	India Dept of Meteorology
Fatehabad	92	39.61522	54.39892	0	198.1	Mm	India Dept of Meteorology
Bahraich	92	64.32663	93.21009	0	334.5	Mm	India Dept of Meteorology
Kandla	92	97.70435	160.2373	0	614.7	Mm	India Dept of Meteorology
Visakhapatnam	92	92.52065	85.35325	0	386.7	Mm	India Dept of Meteorology
Tuticorin	92	85.42935	81.31208	0	347.8	Mm	India Dept of Meteorology
Rewari	92	39.61522	54.39892	0	198.1	Mm	India Dept of Meteorology
Unnao	92	64.32663	93.21009	0	334.5	Mm	India Dept of Meteorology
Domestic Policies							
MSP* Rice	92	765	197.4007	560	1080	Rs/Quintal	Food Corporation of India
CIP* Rice	92	517.0543	69.49568	415	635	Rs/Quintal	Food Corporation of India
MSP Wheat	92	864.7826	213.9091	630	1170	Rs/Quintal	Food Corporation of India
CIP Wheat	92	469.5835	31.22253	415	503.64	Rs/Quintal	Food Corporation of India
Transportation Cost							
Gasoline Prices	92	68.6197	29.61	132.47	23.792	$/Barrell	Indiastat

* MSP stands for Minimum Support Price and CIP stands for Central Issued Price.

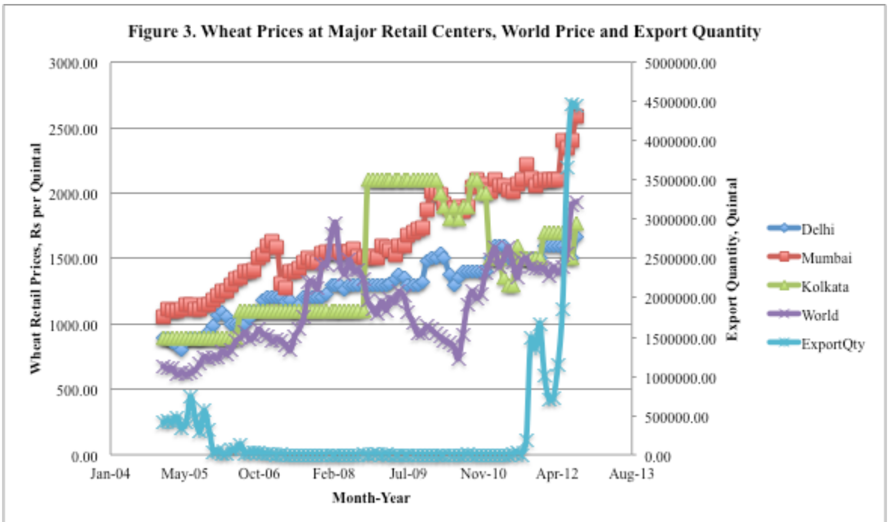


Figure 3. Wheat Prices at Major Retail Centers, World Price and Export Quantity
Wheat Retail Prices, Rs per Quintal
Export Quantity, Quintal
Month-Year
Delhi
Mumbai
Kolkata
World
ExportQty

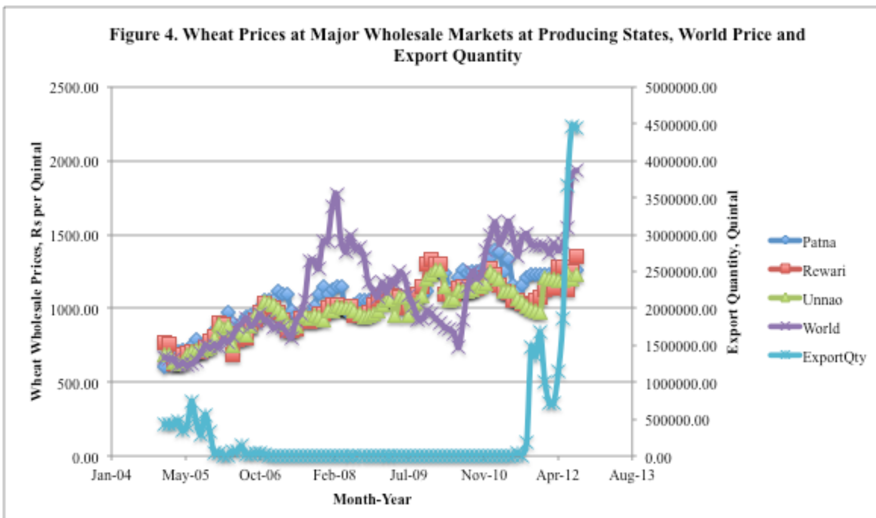


Figure 4. Wheat Prices at Major Wholesale Markets at Producing States, World Price and Export Quantity
Wheat Wholesale Prices, Rs per Quintal
Export Quantity, Quintal
Month-Year
Patna
Rewari
Unnao
World
ExportQty

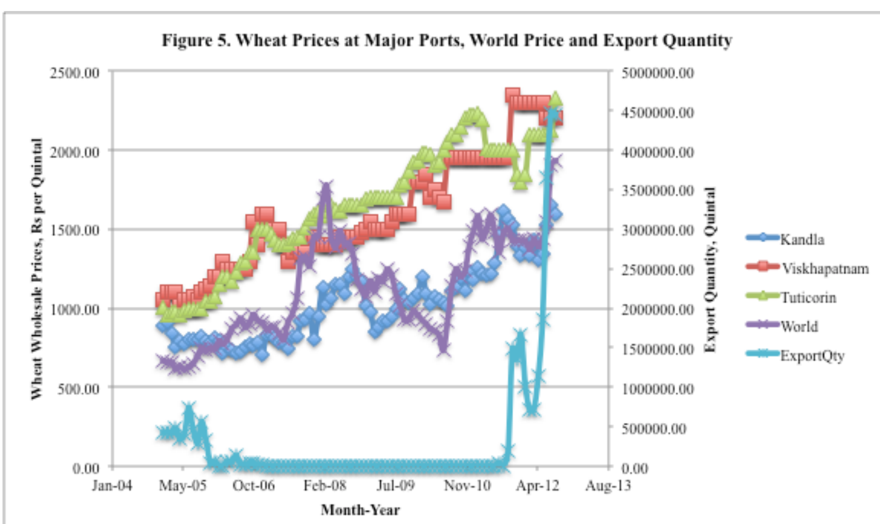


Figure 5. Wheat Prices at Major Ports, World Price and Export Quantity
Wheat Wholesale Prices, Rs per Quintal
Export Quantity, Quintal
Month-Year
Kandla
Viskhapatnam
Tuticorin
World
ExportQty

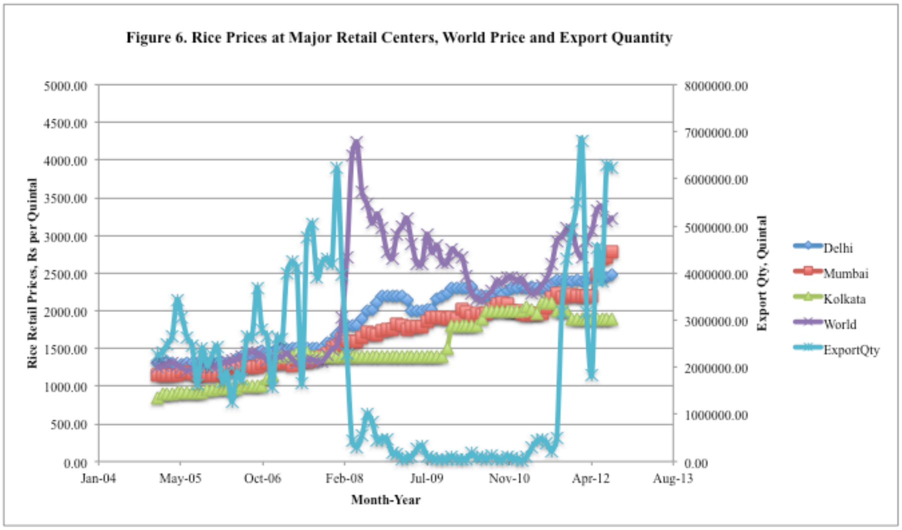


Figure 6. Rice Prices at Major Retail Centers, World Price and Export Quantity
Rice Retail Prices, Rs per Quintal
Export Qty, Quintal
Month-Year
Delhi
Mumbai
Kolkata
World
ExportQty

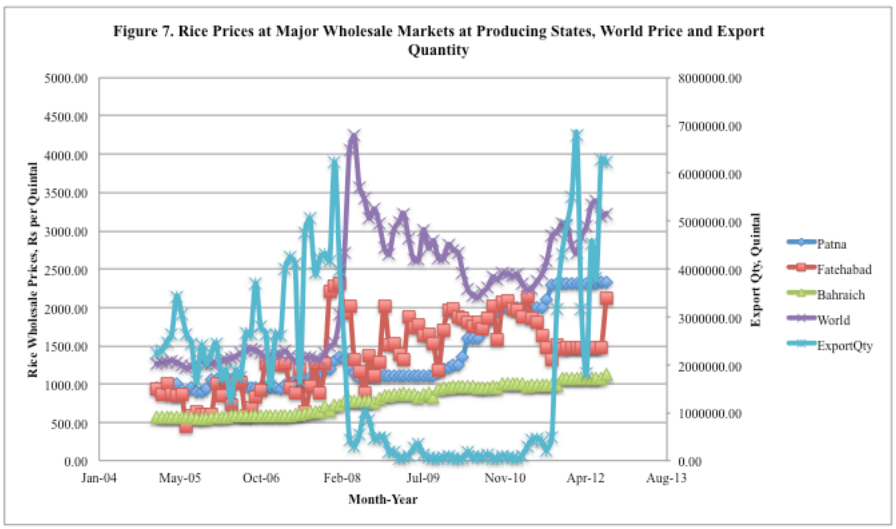


Figure 7. Rice Prices at Major Wholesale Markets at Producing States, World Price and Export Quantity
Rice Wholesale Prices, Rs per Quintal
Export Qty, Quintal
Month-Year
Patna
Fatehabad
Bahraich
World
ExportQty

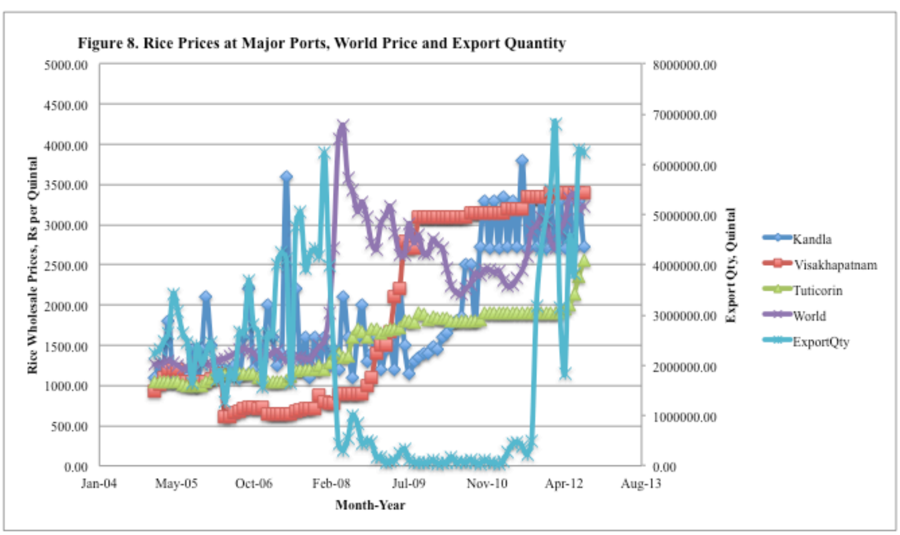
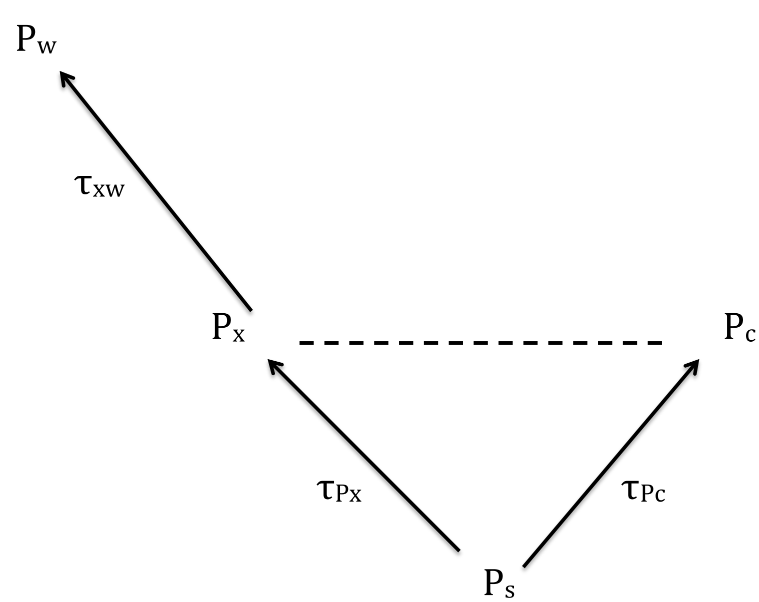


Figure 8. Rice Prices at Major Ports, World Price and Export Quantity
Rice Wholesale Prices, Rs per Quintal
Export Qty, Quintal
Month-Year
Kandla
Visakhapatnam
Tuticorin
World
ExportQty

4. Conceptual Model for Empirical Strategy and Hypotheses

We develop a simple theoretical model to predict the effect of an export ban on price transmission. We begin by dividing India's grain market landscape into three regions: a supply region *(S)* with local price P_s, a domestic consumption region *(C)* with local price P_c, and an export region (X) with local price $P_{x.}$ The export region can be thought of as the area around the major ports. From the export market, grains are sold into the world market (W), where they receive price P_w. The cost to move grain domestically, from the supply region to either the consumption or export region, is τ_d. The cost of exporting grain from the port to the world market is τ_w, where τ_w includes the monetary value of any export restrictions. This market landscape is illustrated below:

Figure 9. India's Market Landscape



A farmer can chose to sell to the domestic market or to the world market, where she will receive P_c less per unit domestic transaction costs τ_d, or world price P_w less per unit transaction costs $\tau_d + \tau_w$, Te farmer will chose quantities to sell to each market to maximize their expected profit:

$$\Pi(q_{ct}, q_{wt}) = \sum \{\delta^t \lfloor P_{c,t+k} q_{ct} + P_{w,t+j} q_{wt} - C(Q_t) - \tau_d q_{ct} - (\tau_d + \tau_w) q_{wt} \rfloor\} \qquad (1)$$

Where q_{ct} is the quantity sold in the domestic market and q_{wt} is the quantity sold in the world market at time t; $P_{i,t+k}$ is the price received upon delivery in market i, k periods after t; $C(.)$ is the cost function; Q_t is the total traded quantity where $Q_t = q_{ct} + q_{wt}$; and δ is the real discount.

Taking first order conditions, we observe that the farmer will chose the quantities to sell by equalizing the marginal profit in each market. Specifically, they will set the expected difference in discounted prices net of transaction costs to zero:

$$E_t = \{\delta^k P_{c,t+k} - \delta^j P_{w,t+j} + \tau_w\} = 0 \qquad (2)$$

Assuming no delivery lags (i.e. *k=j=0*), the above relation implies that the difference in the domestic and world price is simply the cost of exporting:

$$P_{dt} - P_{wt} = \tau_w \qquad (3)$$

Significant anecdotal evidence indicates that the Indian national border was porous even during the export ban, and export bans were never completely enforced over time (Kubo, 2011; Dorosh, 2009). We follow Porteous's (2012) framework and model the export ban and minimum export prices as an increase in the trade costs, τ_w. From this result, we obtain our first hypothesis: The export ban increases the difference between the world and the domestic price.

Given that prices include a stochastic component, this increased price wedge may lead to a decrease in integration between domestic and world markets.

Next, we explore how the ban might differentially affect prices within India. Assume that grain movement takes time, and that at the moment of the export ban, some grain is sitting at port. The value of this grain is determined by the world price less the cost of exporting, $P_w - \tau_w$, and therefore decreases with the imposition of the export ban. Moving this grain to the domestic consumption region is not costless, and a trader will only ship the grain today if the expected price in the domestic market is more than the domestic cost of moving grain higher than the expected discounted future world price less future export cost. Thus, the grain will only move if:

$$E(P_{c,t} - \tau_d) \geq E\delta^k(P_{w,t+k} - \tau_{w,t+k}) \quad (3)$$

Thus, as is the case of the Russian export ban on wheat, a trader may have the incentive to store the grain at the port instead of moving it to the domestic market if they expect the export costs to decrease. At a minimum, the price in the consuming trigon has to be τ_d higher than the price at the port, P_x to induce the movement of grain from port. Thus, if grain movement takes time and prices are uncertain, the export ban may make domestic market prices more 'sticky'. Therefore, we expect the primary effect of the export ban to be reflected in prices at the port, where Px should drop by the change in τ_w. We also expect that the export ban will increase the supply in the domestic market, driving down Pc, but perhaps not to the same degree as it affects prices in the export market, Px. Thus, our second hypothesis is that the export ban reduces market integration between domestic consumption and port prices.

After the imposition of the export ban, farmers will be less likely to ship grain to the ports with the increase in trade costs, making the domestic market their primary sales outlet. Thus, our third hypothesis is that the export ban may increase the market integration between the supply and consuming region. Finally, given the loss of the export market, we hypothesize that domestic production shocks will have a larger effect on prices in the supply and domestic consumption regions after the export ban.

Following Baulch (1997) and Barret and Li (2002), we recognize that there may be different possible trading regimes and or discontinuity based on relative magnitude of actual observed price difference and unobserved trade costs.

$$P_{dt} - P_{wt} = \tau_w + \varepsilon \begin{cases} \text{Case 1: } P_{dt} - P_{wt} = \tau_w + \varepsilon \text{ Competitive Trade Equilibrium} \\ \text{Case 2: } P_{dt} - P_{wt} < \tau_w + \varepsilon \text{ Segmented Equilibrium} \\ \text{Case 3: } P_{dt} - P_{wt} > \tau_w + \varepsilon \text{ Disequilibrium} \end{cases} \quad (4)$$

In case 1, markets are in a competitive tradeable equilibrium with no arbitrage opportunities. In other words, the grain is tradeable from *w* to *d* and ΔP_{dwt} increases one for one with an increase in trade costs. In case 2, markets are in segmented equilibrium. Trade does not occur because the price difference between the markets is smaller and the trade costs are larger. In this case, local prices are determined by local supply and demand, and price differences are unaffected by changes in trade costs. In case 3, markets are in disequilibrium following a shock in which the realized price difference is greater than the expected price difference. In this case, there are foregone arbitrage opportunities from *i* to *j*. For cases 1 and 2, the relationship between the trade costs and price differences is straight-forward. In Case 1, traders transport the grains according to expected price differences, but production shocks may cause those price differences to be larger or smaller; that is the error term maybe greater than or less than zero ($\varepsilon > 0$ or $\varepsilon < 0$). In case 2, traders may make a small profit or loss.

5. Methods

Market integration is concerned about linkages among markets. To study the interdependence of prices between any pair of markets *i* and *j*, literature suggests testing if there is any relation among the prices series in the two markets (Palaskas and Harris, 1991; Goodwin and Schroeder, 1991; Ardeni, 1989).

Mathematically,

$$P_{it} = \varphi + \delta P_{jt} + e_t \qquad (5)$$

where P_{it} denotes the price of crop of interest at time *t* and at location *i* of a certain given quality, φ and δ are parameters to be estimated and e_t is an error term. Prices are generally nonstationary and equation (5) has interest only if the error term e_t is stationary.

Thus, we first need to test for stationarity of the variables series. Stationarity implies that price changes in regional market *i* do not drift apart in the long run from market *j*. When this occurs the two series are said to be cointegrated. Cointegrated means that there exists a linear combination of the non stationary series that is itself is stationary or in other words the series share a common form of non-stationarity and cannot drift apart indefinitely (Greb et al, 2012).

5.1 Test for Stationarity

Since equation (5) is only relevant when error term is stationary, we first test the stationarity properties of the data. We use the Augmented Dickey-Fuller test as it is widely used test for the unit root of the series. The ADF is generated from the following regression:

$$\Delta P_t = \varphi + \delta_1 \Delta P_{t-1} + \delta_2 \Delta P_{t-2} + \ldots + \delta_k \Delta P_{t-k} + e_t \qquad (6)$$

where the vector P represents the price series in different markets in India; t is the time index; $\Delta P_t = P_t - P_{t-1}$ and k is the lag order chosen such that $k / t^{1/3} \to 0$ as $t \to \infty$ and regression residuals behave as a white noise series. φ is the deterministic part which can either be 0, a constant or a constant plus a linear time trend. The null hypothesis of ADF test is that the process has a unit root (nonstationary). A nonstationary time series is said to be integrated to order 1 denoted by *I(1)*.

5.2 Linear Cointegration Analysis

If the series of interest is stationary, equation (5) is relevant and the cointegration framework can be represented by linear Vector Autoregression Regression (VAR). For a market pair i and j,

$$\begin{Bmatrix} P_{it} = \varphi_1 + \delta_{ii}^{i} P_{it-1} + \delta_{ij}^{i} P_{jt-1} + \delta_{ii}^{j} P_{it-2} + \delta_{ij}^{j} P_{jt-2} + e_{it} \\ P_{jt} = \varphi_2 + \delta_{ji}^{i} P_{it-1} + \delta_{jj}^{i} P_{jt-1} + \delta_{ji}^{j} P_{it-2} + \delta_{jj}^{j} P_{jt-2} + e_{jt} \end{Bmatrix} \qquad (7)$$

In matrix form,

$$\begin{pmatrix} P_{it} \\ P_{jt} \end{pmatrix} = \begin{pmatrix} \varphi_1 \\ \varphi_2 \end{pmatrix} + \begin{pmatrix} \delta_{ii}^i & \delta_{ij}^i \\ \delta_{ji}^i & \delta_{jj}^i \end{pmatrix} \begin{pmatrix} P_{it-1} \\ P_{jt-1} \end{pmatrix} + \begin{pmatrix} \delta_{ii}^j & \delta_{ij}^j \\ \delta_{ji}^j & \delta_{jj}^j \end{pmatrix} \begin{pmatrix} P_{it-2} \\ P_{jt-2} \end{pmatrix} + \begin{pmatrix} e_{it} \\ e_{jt} \end{pmatrix} \qquad (8)$$

In a multivariate series, consider a vector of *n* time-ordered variables P_t

$$P_t = \varphi + \delta_1 P_{t-1} + \delta_2 P_{t-2} + \ldots + \delta_n P_{t-n} + e_t \qquad (9)$$

where each of the δ_n is an *nxn* coefficient matrices, φ is a constant term, and e_t are *(nx1)* identically and independently distributed with zero means and contemporaneous covariance matrix Ω.

However, since price data are often non-stationary, regression can lead to spurious results. Vector Error Correction Model (VECM) is a reparametarized VAR which relates current level of set of time series to lagged values of those series. The VECM form for any pair *i* and *j*,

$$\left\{ \begin{array}{l} \Delta P_t^i = \varphi_1 + \alpha_1 \left(P_{t-1}^i - \beta_1 P_{t-1}^j \right) + \delta_1 \Delta P_{t-1}^j + \rho_1 \Delta P_{t-1}^i + e_{1t} \\ \Delta P_t^j = \varphi_2 + \alpha_2 \left(P_{t-1}^i - \beta_1 P_{t-1}^j \right) + \delta_2 \Delta P_{t-1}^j + \rho_2 \Delta P_{t-1}^i + e_{2t} \end{array} \right\} \qquad (10)$$

In matrix form,

$$\begin{bmatrix} \Delta P_t^i \\ \Delta P_t^j \end{bmatrix} = \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} 1 & \beta_1 \end{bmatrix} \begin{bmatrix} P_{t-1}^i \\ P_{t-1}^j \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{1i} & \rho_{1i} \\ \delta_{2i} & \rho_{2i} \end{bmatrix} \begin{bmatrix} \Delta P_{t-1}^i \\ \Delta P_{t-1}^j \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \qquad (11)$$

A multivariate VECM can be represented as

$$\Delta P_{i,t} = \mu + \Pi P_{t-k} + \sum_{i=1}^{k} \Gamma_i \Delta P_{t-i} + u_t \qquad (12)$$

where Δ is the difference operator, $\Pi = I - \pi_1 - \pi_2 - ... - \pi_p$ and $\Gamma_i = (I + \pi_1 + \pi_2 + ...\pi_i)$ and k is chosen such that u_t is a multivariate normal white noise process with mean 0 and a finite covariance matrix.

The advantage of VECM or VAR is it separates long run cointegrating relationship between any 2 pairs of 2 prices as captured by the error term $\left(P_{t-1}^{i} - \beta_1 P_{t-1}^{j}\right)$ for any pair *ij*. This is the error term from short run dynamics that ensure that any deviations from long run equilibrium are corrected and thus only temporary.

In the bivariate VECM (equation 10), the parameter β may be interpreted as the matrix of cointegrating vectors representing how the price reacts to changes in the other prices in the long run and α represents the adjustment parameter. If the two series are cointegrated, one must be (+) and other should be (-) or they have offsetting effects until driving the prices back to equilibrium. The speed with which the market returns to the equilibrium depends on the proximity of α_i to one.

We use the Johansen test to test the null hypothesis that there are at most *r* cointegration vectors in the system. The Johansen test involves the use of the trace test statistic and maximum eigenvalue test.

$$\begin{aligned} \lambda_{Trace} &= -T \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right) \\ \lambda_{Max} &= -T \ln\left(1 - \hat{\lambda}_{r+1}\right) \end{aligned} \qquad (13)$$

The alternative hypothesis in the trace test is that there exist more than *r* cointegration vectors while in the maximum eigenvalue test there are exactly *r+1* cointegration vectors. Each follows a non-standard distribution.

Critical values are provided by Osterwald-Lenum(1992). Johansen's multivariate test procedure also allows hypothesis test on the matrix of cointegrating vectors and matrix of adjustment parameters. Asche, Bremmes and Wessells (1999) suggests that perfect integration exists and the Law of One Price holds if the following condition is satisfied:

$$\beta = \begin{bmatrix} 1 & 1 & \dots & 1 \\ -1 & 0 & \dots & 0 \\ 0 & -1 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & -1 \end{bmatrix} \qquad (14)$$

where β is an $n \times n$ matrix, n is the number of markets and r is the number of cointegrating vectors. A test statistic is provided by Johansen, which is Chi-square distributed under the null hypothesis. On the other hand, a weak exogeneity test on the factor loading matrix α is:

$$H_0 = \alpha_{i1} = \alpha_{i2} = \dots = \alpha_{in} = 0 \qquad (15)$$

where α_{ij} is the element in the *ith* row and *jth* column. And to test whether the *ith* price series is weakly exogenous, we only need to test whether all of the parameters in the *ith* row of the α matrix are zeroes. A Chi-sq test statistic is used to test this hypothesis as well.

We recognize the following limitations of the linear VECM approach (Greb et al, 2012): (a) The system is assumed to be linear in all parameters (i.e. assumed to be constant over entire sampling period; (b) The system is linear in a sense that dependent variable reacts linearly to the independent variable. Thus, these limitations make this approach restrictive.

Furthermore, trade changes such as an export ban can switch, say, one country from being a net export to being net import position, , causing a non-linear break in the price series or or segmenting the equilibrium as explained by Barret and Li (2002). Spatial equilibrium theory (Takayama and Judge, 1971) predicts that short-run price adjustment due to arbitrage will take place only if the difference between the prices exceeds a threshold that is determined by the trade costs. Changes in trade costs is comprised of transportation, transactions cost, minimum export prices and other export restriction policies (Barret and Li, 2002). If the difference between prices is less than that of the threshold, then there is no incentive for traders to engage in arbitrage and prices can move independently. In such cases price transmission will be characterized by different regimes.

5.3 Non-Linear Cointegration Analysis

Because we hypothesize that our price data may exhibit occasional episodes of discrete jumps based on changed in policies (i.e. export bans), and to deal with shortcomings of a simple VECM we propose an additional method of analyses.

Since we do not have information on transportation costs and we can only utilize our price series data, we use the Threshold Vector Autoregression (TVAR) or Threshold Vector Error Correction Model (TVECM). TVAR/TVECM models use time series properties and the assumption of a fixed but unknown trade cost to test whether the market falls into a segmented equilibrium. The models also estimate an adjustment parameter for the speed with which the markets returns to a no-arbitrage equilibrium. Regime dependent price transmission can be described as a piecewise linear model in which each regime is characterized by a standard VAR/VECM as in equations (7) and (10). Some trigger or transition mechanism determines when model jumps from 1 regime to another. This trigger can be exogenous (example: coinciding with policy changes) or endogenous (example: determined whether the distance between 2 prices exceeds a certain threshold) (Goodwin and Piggott, 2001).

To illustrate, we allow for at least one possible source of nonlinearity. For the TVECM, we modify a basic VECM (equation 10) to include a structural break. We determine pre and post break parameters using Gregory and Hansen (1996) test, and we perform VECM for each pair. The resulting specification is as follows:

$$\begin{bmatrix} \Delta P_t^i \\ \Delta P_t^j \end{bmatrix} = \begin{cases} \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} 1 & \beta_1 \end{bmatrix} \begin{bmatrix} P_{t-1}^i \\ P_{t-1}^j \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{1i} & \rho_{1i} \\ \delta_{2i} & \rho_{2i} \end{bmatrix} \begin{bmatrix} \Delta P_{t-1}^i \\ \Delta P_{t-1}^j \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} & \text{pre-break} \\ \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} 1 & \beta_1 \end{bmatrix} \begin{bmatrix} P_{t-1}^i \\ P_{t-1}^j \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \delta_{1i} & \rho_{1i} \\ \delta_{2i} & \rho_{2i} \end{bmatrix} \begin{bmatrix} \Delta P_{t-1}^i \\ \Delta P_{t-1}^j \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} & \text{post break} \end{cases} \quad (16)$$

Note that equation (16) mirrors equation (4) in our conceptual framework. We consider testing for thresholds on time (pre and post ban), value of exports (if the market was really porous during the ban period) and weather shocks.

To check whether the break is a plausible cut-off, we apply the Gregory and Hansen (1996) test of the null of no cointegration against the alternative of cointegration with a possible regime shift. The Gregory-Hansen approach is an extension of similar tests for unit root tests with structural breaks (Zivot and Andrews, 1992) which accommodates for a possible endogenous break in an underlying cointegrating relatiohship. The four models of Gregory and Hansen

(1996a and 1996b) with assumptions about structural breaks and their specifications with two variables, for simplicity, are as follows:

Cointegration with Level Shift:	$\Delta P_t^i = \varphi_1 + \varphi_2 X_{tk} + \delta_1 \Delta P_t^j + e_t$	(17)
Cointegration with Regime Shift:	$\Delta P_t^i = \varphi_1 + \varphi_2 X_{tk} + \delta_1 \Delta P_t^j + \delta_2 \Delta P_t^j X_{tk} + e_t$	(18)
Cointegration with Level Shift and Trend:	$\Delta P_t^i = \varphi_1 + \varphi_2 X_{tk} + \beta_{1t} + \delta_1 \Delta P_t^j + e_t$	(19)
Cointegration with Regime Shift and Trend:	$\Delta P_t^i = \varphi_1 + \varphi_2 X_{tk} + \beta_{1t} + \delta_1 \Delta P_t^j + \delta_2 \Delta P_t^j X_{tk} + e_t$	(20)

where X is a dummy variable such that:

$$X_{tk} = \begin{cases} 0 & t \le k \text{ (k is the breaking point)} \\ 1 & t > k \end{cases} \qquad (21)$$

Gregory and Hansen (1996b) construct three statistics for those test: ADF*, Z_α^* and Z_t^*. They are corresponding to the traditional ADF test and Phillips type test of unit root residuals. The null hypothesis of no cointegration with structural breaks is tested against the alternative of cointegration by Gregory and Hansen approach. The single break in these models is endogenously determined. Gregory and Hansen have tabulated critical values by modifying the Mackinon(1991) procedure. The null hypothesis is rejected if the statistic ADF*, Z_α^* and Z_t^* is smaller than the corresponding critical value. Alternatively, these can be written as:

$$ADF^* = \inf_{\tau \in T} ADF(\tau) \qquad (22)$$

$$Z_\alpha^* = \inf_{\tau \in T} Z_\alpha(\tau) \qquad (23)$$

$$Z_t^* = \inf_{\tau \in T} Z_t(\tau) \qquad (24)$$

6. Estimation Results

We employ a four-step procedure in our empirical analysis. First, we test for the presence of unit roots to see if price series are integrated of order one. Then we estimate linear multivariate regressions using logarithmic transformations of monthly domestic prices to test whether prices in these markets are cointegrated by Johansens test using Stata and Eviews.

Third, we test for cointegration with regime using Gregory-Hansen test and whether the breaks are plausible. We compare the computed breaks as to when the export bans were instituted. Finally, given the estimated cointegrated matrix, we estimate threshold Vector Error Correction Model.

6.1 Test for Non Stationarity

We first test for the order of integration. We apply a number of tests, namely Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979) and the $Zt - Z\rho$ tests by Phillips and Perron (1988).[7] Table 3 presents the summary for the unit root tests. The unit root statistics for all variables and both their levels and differences are presented in Appendix Table 2 (one that includes constant and trend, one includes constant but no trend and one that excludes both constant and trend). We perform the test for variables in levels, logarithmic transformation of the variables and variables in differences. The ADF test is performed by including up to 10 lagged terms of the differenced terms in the regression and we use the Akaike Information Criteria (AIC) to choose the appropriate lag length by trading off parsimony against reduction in the sum

[7] ADF is the most commonly used test, but sometimes behaves poorly in the presence of serial correlation. Dickey and Fuller correct for serial correlation by including lagged differenced terms in the regression, however, the size and power of the ADF has been found to be sensitive to the number of these terms. The Phillips and Perron tests are non parametric tests of the null of the unit root and are considered more powerful, as they use consistent estimators of the variance (Rapomanikis et al, 2003).

of squares and a lag length where autocorrelation is not present. The ADF test statistics presented in Table 3 correspond to the regression that has the maximized AIC.

On the basis of both ADF and Phillips and Perron tests, both with and without deterministic trend, we conclude that there is insufficient evidence to reject the null hypothesis of non stationarity for all price series. Moreover, when applied to the differenced series, both tests reject the null, indicating that all price series are I(1).

Table 3. Stationarity Summary for Logarithmic Transformation of Variables used in the Study

Market	Wheat	Rice
Delhi Retail Price	U	U
Mumbai Retail Price	U	U
Kolkata Retail Price	U	U
Patna Wholesale Price	U	U
Fatehabad Wholesale Price	--	U
Bahraich Wholesale Price	--	U
Kandla Wholesale Price	U	U
Visakhapatnam Wholesale Price	U	U
Tuticorin Wholesale Price	U	U
Rewari Wholesale Price	U	--
Unnao Wholesale Price	U	--
World Price	U	U
MSP	U	U
CIP	U	U
Value of Exports	U	U
Delhi Rainfall	S	S
Mumbai Rainfall	S	S
Kolkata Rainfall	S	S
Patna Rainfall	S	S
Fatehabad Rainfall	--	S
Bahraich Rainfall	--	S
Kandla Rainfall	S	S
Visakhapatnam Rainfall	S	S
Tuticorin Rainfall	S	S
Rewari Rainfall	S	--
Unnao Rainfall	S	--

U indicates unit root, S is stationary, -- indicates no data

6.2 Linear VECM Results

Following Rapsomanikis et al (2003), we proceed with the following sequence of tests: First, test for cointegration using Johansen approach and then formulate an ECM to assess the dynamics and speed of adjustment. Table 4 presents the lag order selection summary for each market pair. More details are in Appendix tables 3-8.

Table 4. Lag Order Selection based on AIC

Crop	Market Pair	Number of Lags
Wheat	Producing and Consuming States	1
	Producing and Exporting States	2
	Exporting States and the World	1
Rice	Producing and Consuming States	2
	Producing and Exporting States	1
	Exporting States and the World	2

6.2.1 Wheat Producing States and Consuming States

There are six variables and rank (5) specified to estimate the equilibrium relationships. We have 90 observations for each variable. Each of the six equations has its own R-squared, with the Kolkata equation being the lowest at 11% and Patna, Delhi and Unnao being the highest of more than 40%. The speeds of adjustment ranges from 0.01 to as high as 0.70. The speeds of adjustment and ECM coefficients are presented in Table 5.

The multivariate cointegration test results indicate that there are three cointegration vectors among six price series and hence there exists three common stochastic trend in the system. Thus, producing states and consuming states in India are not fully integrated.

Looking at our estimated short-run adjustment parameters, we find that Patna prices are linked directly to Rewari prices, both of which are producing states. But there is no direct link in other markets. Looking at the consuming states, we find that Delhi significantly affects prices in Rewari which makes sense as they share borders. Mumbai also affects the prices in Rewari.

In general, we see that the prices in producing regions are integrated in the long run. In the short-run, prices in producing regions are affected by the closest consuming region (i.e. the case of Haryana and Delhi). Among the consuming markets, Delhi seems to be dominant market among in the short-run affecting other consuming markets' prices.

6.2.2 Wheat Producing States and Exporting States

There are six variables and rank (5) specified to estimate the equilibrium relationships. We have 90 observations for each variable. Each of the six equations has its own R-squared. With the Kandla equation being the lowest at 14% and Unnao being the highest with 48%. The speeds of adjustment and equilibrium relationships are presented in Table 6.

The multivariate cointegration test results indicate that there are two cointegration vectors among six price series and hence there exists four common stochastic trend in the system. Thus, producing states and exporting states in India are not fully integrated.

Looking at our estimated short-run adjustment parameters, we see there is no direct link among markets. Kandla and Tuticorin, both of which are exporting states, affect the prices in Unnao. Similar to previous result, Rewari affects the prices in Patna. We do not find long run cointegration only short run effects from exporting regions prices to producing states.

6.2.3 Wheat Exporting States and World Market

There are four variables and rank (3) specified to estimate the equilibrium relationships.

As with rice, we have 90 observations for each variable. Each of the four equations has its own R-squared, with the World equation being the lowest at 13% and Visakhapatnam and Tuticorin being the highest at around 23%. The speeds of adjustment and equilibrium relationships are presented in Table 7.

The multivariate cointegration test results indicate that there is one cointegration vector among four price series and hence there exists three common stochastic trend in the system. Thus, exporting states of India are not fully integrated with the world market.

Looking at our estimated short-run adjustment parameters, we find that Tuticorin affects the prices in Visakhapatnam markets and World affect the prices in Tuticorin. We do not find long run cointegrating relationship.

6.2.4 Rice Producing States and Consuming States

There are six variables and rank (5) specified to estimate the equilibrium relationships. 90 observations for each variable. Each of the six equations has its own R-squared. With the Kolkata equation being the lowest at 16% and all producing regions fatehabad, Bahraich and Patna are high at around 35%. The speeds of adjustment and equilibrium relationships are presented in Table 8.

The multivariate cointegration test results indicate that there is one cointegration vector among six price series and hence there exists five common stochastic trend in the system. Thus, producing states and consuming states in India are not fully integrated.

Looking at our estimated short-run adjustment parameters, we find that Patna affects the prices in other producing regions (i.e. Bahraich and Fatehabad). On the other hand, Delhi prices affect prices in producing markets. We do not find long run cointegrating relationship.

6.2.5 Rice Producing States and Exporting States

There are six variables and rank (5) specified to estimate the equilibrium relationships. 90 observations for each variable. Each of the six equations has its own R-squared. With the Patna equation being the lowest at 25% and Kandla is the highest at 51%. The speeds of adjustment and equilibrium relationships are presented in Table 9.

The multivariate cointegration test results indicate that there are two cointegration vector among six price series and hence there exists four common stochastic trend in the system. Thus, producing states and exporting states in India are not fully integrated.

The estimated short-run adjustment parameters show that producing regions affect each other markets' prices and seems to be unaffected at all by the prices in the exporting regions. We find no long run cointegration.

6.2.6 Rice Exporting States and World Market

There are four variables and rank (3) specified to estimate the equilibrium relationships. 90 observations for each variable. R-squared ranged from 14% (Visakhapatnam) to 41% (Kandla). The speeds of adjustment and equilibrium relationships are presented in Table 10.

The multivariate cointegration test results indicate that there are two cointegration vector among four price series and hence there exists two common stochastic trend in the system. Thus, exporting states of India is not fully integrated with the world market.

The short-run adjustment parameter estimates show that only Tuticorin is affected by prices in the world market and in turn Tuticorin affects prices in other exporting regions.

Table 5. Market integration tests for Wheat Producing States and Consuming States

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	129.0114	ns
1	2	81.1001	ns
2	3	46.1272	**
3	4	21.3882	ns
4	5	5.3585	ns
5	6	0.7012	na

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	38.4636	ns
2	30.8642	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Rewari	12.894	***
Unnao	10.888	***
Patna	9.819	***
Delhi	0.05	ns
Mumbai	233.477	***
Kolkata	3358.701	***
All	3669.828	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters						
	D_wheatrewari_w	**D_wheatunnao_w**	**D_wheatpatna_w**	**D_wheatdelhi_r**	**D_wheatmumbai_r**	**D_wheatkolkata_r**
L._ce1	-0.564***	0.458***	0.0316	0.231*	-0.166	-0.18
	(0.215)	(0.177)	(0.148)	(0.121)	(0.159)	(0.362)
L._ce2	0.192	-0.750***	0.183	-0.185	0.11	-0.057
	(0.203)	(0.167)	(0.140)	(0.115)	(0.150)	(0.341)
L._ce3	0.200*	0.308***	-0.401***	0.0973	-0.00581	-0.0749
	(0.119)	(0.098)	(0.082)	(0.067)	(0.088)	(0.201)
L._ce4	-0.206	-0.236**	-0.0854	-0.288***	0.116	0.502**
	(0.139)	(0.114)	(0.095)	(0.078)	(0.102)	(0.233)
L._ce5	0.168**	0.112*	0.203***	0.133***	-0.0732	-0.131
	(0.081)	(0.066)	(0.055)	(0.046)	(0.060)	(0.136)

Continued Table 5. Market integration tests for Wheat Producing States and Consuming States

Linear VECM Test for Cointegrating Relationship

Beta Coefficients	**D_wheatrewari_w**	**D_wheatunnao_w**	**D_wheatpatna_w**	**D_wheatdelhi_r**	**D_wheatmumbai_r**	**D_wheatkolkata_r**
LD.wheatrewari_w	0.335**	0.141	0.258**	0.154	0.251**	0.416
	(0.166)	(0.137)	(0.114)	(0.094)	(0.123)	(0.280)
LD.wheatunnao_w	-0.0765	0.0345	-0.14	0.0641	-0.0389	0.0136
	(0.169)	(0.139)	(0.116)	(0.095)	(0.125)	(0.284)
LD.wheatpatna_w	-0.244*	-0.269**	0.0622	-0.0375	0.0044	-0.096
	(0.136)	(0.112)	(0.093)	(0.077)	(0.100)	(0.228)
LD.wheatdelhi_r	0.131	0.0797	0.332**	0.111	-0.0761	-0.366
	(0.236)	(0.194)	(0.162)	(0.133)	(0.175)	(0.397)
LD.wheatmumbai_r	-0.0208	0.264*	-0.171	-0.166*	0.117	0.0427
	(0.169)	(0.139)	(0.117)	(0.096)	(0.125)	(0.285)
LD.wheatkolkata_r	-0.0279	-0.00157	0.00385	0.0171	-0.0492	-0.0545
	(0.072)	(0.059)	(0.049)	(0.040)	(0.053)	(0.120)
Constant	-0.000279	-0.000242	0.000204	0.00287*	0.00366*	0.000614
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)

Table 6. Market integration tests for Wheat Producing States and Exporting States

Johansen test for cointegration
No. of cointegrating vectors

Null	Alternative	Trace Statistic	Significance
0	1	130.2151	ns
1	2	61.6692	*
2	3	36.6632	ns
3	4	18.0671	ns
4	5	7.8183	ns
5	6	0.1981	ns

Lagrangre Multiplier Test Autcorrelation
Ho: No autocorrelation at lag order

1	51.4236	**
2	27.1837	ns

Test for Normality
Jarque-Berra
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed

Rewari	8.886	***
Unnao	16.145	***
Patna	14.289	***
Kandla	3.02	ns
Visakhapatnam	93.425	***
Tuticorin	s8.462	***
All	144.047	***

Test for Stability
Eigenvalue Stability Condition

The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_lnwheatrewari_w	D_lnwheatunnao_w	D_lnwheatpatna_w	D_lnwheatkandla_w	D_lnwheatvisakhap	D_lnwheattuticorin_
L._ce1	-0.289	0.683***	-0.0548	-0.179	-0.142	-0.0702
	(0.196)	(0.154)	(0.135)	(0.255)	(0.155)	(0.097)
L._ce2	-0.153	-1.095***	0.195	0.105	0.125	0.195*
	(0.236)	(0.184)	(0.162)	(0.306)	(0.186)	(0.116)
L._ce3	-0.000497	0.196*	-0.422***	-0.119	-0.046	-0.0846
	(0.134)	(0.104)	(0.092)	(0.173)	(0.105)	(0.066)
L._ce4	-0.0383	-0.102**	-0.0151	-0.167**	0.0676	0.0126
	(0.055)	(0.043)	(0.038)	(0.071)	(0.043)	(0.027)
L._ce5	0.0506	0.146***	0.0587	0.0771	-0.127**	0.0438
	(0.071)	(0.055)	(0.049)	(0.092)	(0.056)	(0.035)

Continued Table 6. Market integration tests for Wheat Producing States and Exporting States

Linear VECM Test for Cointegrating Relationship						
Beta Coefficients	D_lnwheatrewari_w	D_lnwheatunnao_w	D_lnwheatpatna_w	D_lnwheatkandla_w	D_lnwheatvisakhap	D_lnwheattuticorin_
LD.lnwheatrewari_w	0.223	0.0923	0.314***	4.33E-05	0.0948	0.226***
	(0.165)	(0.129)	(0.113)	(0.214)	(0.130)	(0.081)
LD.lnwheatunnao_w	0.0657	0.117	-0.0272	-0.00162	0.106	-0.0227
	(0.167)	(0.131)	(0.115)	(0.217)	(0.132)	(0.082)
LD.lnwheatpatna_w	-0.192	-0.245**	0.167	-0.0591	0.176	0.075
	(0.153)	(0.119)	(0.105)	(0.198)	(0.120)	(0.075)
LD.lnwheatkandla_w	0.0971	0.162**	0.0724	-0.0728	-0.0394	0.0235
	(0.092)	(0.072)	(0.063)	(0.119)	(0.072)	(0.045)
LD.lnwheatvisakhapatnam_	-0.0731	-0.138	0.0336	0.00272	-0.222**	-0.0191
	(0.133)	(0.104)	(0.091)	(0.172)	(0.105)	(0.066)
LD.lnwheattuticorin_w	0.335	0.416**	-0.0721	-0.0923	0.278	0.0423
	(0.233)	(0.182)	(0.160)	(0.302)	(0.184)	(0.115)
Constant	-0.000243	0.000841	-0.000757	0.000753	0.00217	0.00348**
	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)	(0.001)

Table 7. Market integration tests for Wheat Exporting States and the World

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	31.2	*
1	2	14.6501	ns
2	3	5.1128	ns
3	4	0.304	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	9.8398	ns
2	8.5623	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Kandla	1.321	ns
Visakhapatnam	111.114	***
Tuticorin	44.908	***
World	4.312	ns
All	161.555	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters	D_lnwheatkandla_w	_lnwheatvisakhapatnam_	D_lnwheattuticorin_w	D_lnwheatworld
L._ce1	-0.203***	0.0939**	0.0113	-0.0546
	(0.063)	(0.040)	(0.027)	(0.071)
L._ce2	0.0951	-0.133**	0.0408	0.0731
	(0.083)	(0.053)	(0.036)	(0.095)
L._ce3	0.031	0.0731	-0.0595*	0.0507
	(0.078)	(0.049)	(0.033)	(0.088)

Linear VECM Test for Cointegrating Relationship				
Beta Coefficients	D_lnwheatkandla_w	_lnwheatvisakhapatnam_	D_lnwheattuticorin_w	D_lnwheatworld
LD.lnwheatkandla_w	-0.0627	-0.0365	0.0324	0.157
	(0.109)	(0.069)	(0.047)	(0.124)
LD.lnwheatvisakhapa	-0.0409	-0.184*	0.0372	-0.0785
	(0.159)	(0.101)	(0.068)	(0.181)
LD.lnwheattuticorin_	-0.0703	0.480***	0.232**	0.171
	(0.249)	(0.158)	(0.106)	(0.283)
LD.lnwheatworld	-0.0278	0.0282	0.0944**	0.183
	(0.099)	(0.063)	(0.042)	(0.112)
Constant	0.00111	0.00226	0.00381**	0.000531
	(0.004)	(0.002)	(0.002)	(0.004)

Table 8. Market integration tests for Rice Producing States and Consuming States

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	76.0858	*
1	2	45.0232	ns
2	3	26.606	ns
3	4	12.0856	ns
4	5	3.9389	ns
5	6	0.134	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	45.8249	ns
2	52.0203	**

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Fatehabad	6.099	**
Bahraich	42.061	***
Patna	45.182	***
Delhi	11.791	***
Mumbai	56.453	***
Kolkata	628.795	***
All	790.381	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
L._ce1	-0.386***	0.0149	-0.0451**	0.00486	-0.00321	0.0165
	(0.107)	(0.014)	(0.018)	(0.012)	(0.014)	(0.019)
L._ce2	0.202	-0.336***	0.223*	0.0694	0.0955	-0.075
	(0.705)	(0.090)	(0.121)	(0.078)	(0.091)	(0.123)
L._ce3	-0.166	0.0227	-0.109***	-0.0433**	0.00091	-0.00503
	(0.190)	(0.024)	(0.033)	(0.021)	(0.025)	(0.033)
L._ce4	-0.106	0.131	-0.209*	-0.237***	-0.0512	0.0372
	(0.695)	(0.089)	(0.119)	(0.076)	(0.090)	(0.122)
L._ce5	0.393	0.193***	0.00374	0.163**	-0.0646	0.0739
	(0.582)	(0.074)	(0.100)	(0.064)	(0.076)	(0.102)

Continued Table 8. Market integration tests for Rice Producing States and Consuming States

Linear VECM Test for Cointegrating Relationship

Beta Coefficient	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
LD.lnricefatehaba	-0.138	-0.0175	0.0103	0.0027	-0.00384	0.00949
	(0.110)	(0.014)	(0.019)	(0.012)	(0.014)	(0.019)
LD.lnricebahraich	1.553*	-0.267***	-0.306**	-0.0289	-0.0446	0.0515
	(0.805)	(0.103)	(0.138)	(0.089)	(0.104)	(0.141)
LD.lnricepatna_w	1.653***	0.0601	0.314***	-0.0792	-0.0395	0.0525
	(0.590)	(0.075)	(0.101)	(0.065)	(0.077)	(0.103)
LD.lnricedelhi_r	-0.533	0.116	0.325*	0.275**	0.173	-0.0655
	(1.048)	(0.134)	(0.180)	(0.115)	(0.136)	(0.184)
LD.lnricemumbai_	-0.0942	-0.163	0.148	-0.099	0.19	-0.188
	(1.008)	(0.129)	(0.173)	(0.111)	(0.131)	(0.177)
LD.lnricekolkata_	0.392	-0.0394	-0.0609	-0.0183	-0.0377	0.15
	(0.637)	(0.081)	(0.109)	(0.070)	(0.083)	(0.112)
Constant	5.65E-05	0.000951	0.000198	-0.000355	0.00460**	0.002
	(0.015)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)

Table 9. Market integration tests for Rice Producing States and Exporting States

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	95.6598	ns
1	2	59.475	*
2	3	36.3838	ns
3	4	18.7779	ns
4	5	6.6802	ns
5	6	0.0518	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	39.1479	ns
2	36.4746	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Fatehabad	11.841	**
Bahraich	29.188	***
Patna	29.96	***
Kandla	52.654	***
Visakhapatnar	1919.01	***
Tuticorin	23.46	***
All	2066.115	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w
L._ce1	-0.383***	0.0114	-0.00611	-0.0927	-0.0587	-0.0196
	(0.097)	(0.013)	(0.019)	(0.115)	(0.044)	(0.016)
L._ce2	0.304	-0.163**	0.115	0.169	0.624**	0.301***
	(0.579)	(0.079)	(0.111)	(0.687)	(0.261)	(0.095)
L._ce3	-0.147	0.0495*	-0.0733*	0.910***	-0.220**	-0.0586*
	(0.209)	(0.028)	(0.040)	(0.248)	(0.094)	(0.034)
L._ce4	0.0942	-0.0154	0.0198	-0.855***	0.069	0.0332
	(0.136)	(0.019)	(0.026)	(0.161)	(0.061)	(0.022)
L._ce5	-0.144*	-0.0161	0.0192	-0.0514	-0.0713**	-0.0117
	(0.076)	(0.010)	(0.015)	(0.090)	(0.034)	(0.012)

Continued Table 9. Market integration tests for Rice Producing States and Exporting States

Linear VECM Test for Cointegrating Relationship

Beta Coefficient	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w
LD.lnricefatehaba	-0.129	-0.0315**	-0.00627	0.0804	0.00731	0.0165
	(0.107)	(0.015)	(0.021)	(0.127)	(0.048)	(0.018)
LD.lnricebahraich	1.121	-0.268**	-0.226	-1.294	0.33	0.00823
	(0.847)	(0.115)	(0.162)	(1.004)	(0.382)	(0.138)
LD.lnricepatna_w	1.946***	0.124	0.339***	-0.0385	0.108	0.0329
	(0.570)	(0.077)	(0.109)	(0.676)	(0.257)	(0.093)
LD.lnricekandla_	0.00677	-0.0101	-0.00788	-0.139	-0.00481	-0.0171
	(0.098)	(0.013)	(0.019)	(0.116)	(0.044)	(0.016)
LD.lnricevisakhap	-0.0597	0.0503	-0.0322	0.0861	0.0886	-0.0501
	(0.255)	(0.035)	(0.049)	(0.302)	(0.115)	(0.042)
LD.lnricetuticorin	0.206	0.00353	0.0165	-0.498	0.189	0.353***
	(0.712)	(0.096)	(0.136)	(0.843)	(0.321)	(0.116)
Constant	3.81E-05	0.00408***	0.00311	3.98E-05	-0.000525	0.00205
	(0.010)	(0.001)	(0.002)	(0.012)	(0.005)	(0.002)

Table 10. Market integration tests for Rice Exporting States and the World

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	50.6358	ns
1	2	18.1448	*
2	3	6.8838	ns
3	4	0.0214	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	14.3768	ns
2	28.6746	**

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Kandla	55.835	***
Visakhapatnai	3191.511	***
Tuticorin	9.986	***
World	13.402	***
All	3270.735	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters				
	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
L._ce1	-0.321***	-0.01	0.0325**	-0.0027
	(0.104)	(0.038)	(0.013)	(0.028)
L._ce2	0.0653	-0.0704**	0.00598	-0.0394
	(0.094)	(0.035)	(0.012)	(0.026)
L._ce3	0.261	0.171	-0.122***	0.260**
	(0.385)	(0.142)	(0.047)	(0.105)

Linear VECM Test for Cointegrating Relationship				
Beta Coefficient	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
LD.lnricekandla_	-0.417***	0.0481	-0.0166	0.0224
	(0.102)	(0.037)	(0.013)	(0.028)
LD.lnricevisakhaj	-0.126	0.0789	-0.0624*	-0.00499
	(0.292)	(0.108)	(0.036)	(0.080)
LD.lnricetuticorin	-0.134	-0.0413	0.294***	0.278
	(0.866)	(0.319)	(0.107)	(0.236)
LD.lnriceworld	0.223	-0.0501	-0.118***	0.562***
	(0.342)	(0.126)	(0.042)	(0.093)
Constant	0.000409	-0.000194	0.00412***	0.00165
	(0.013)	(0.005)	(0.002)	(0.003)

Figure 10. Wheat Market Linear VECM Summary of Results

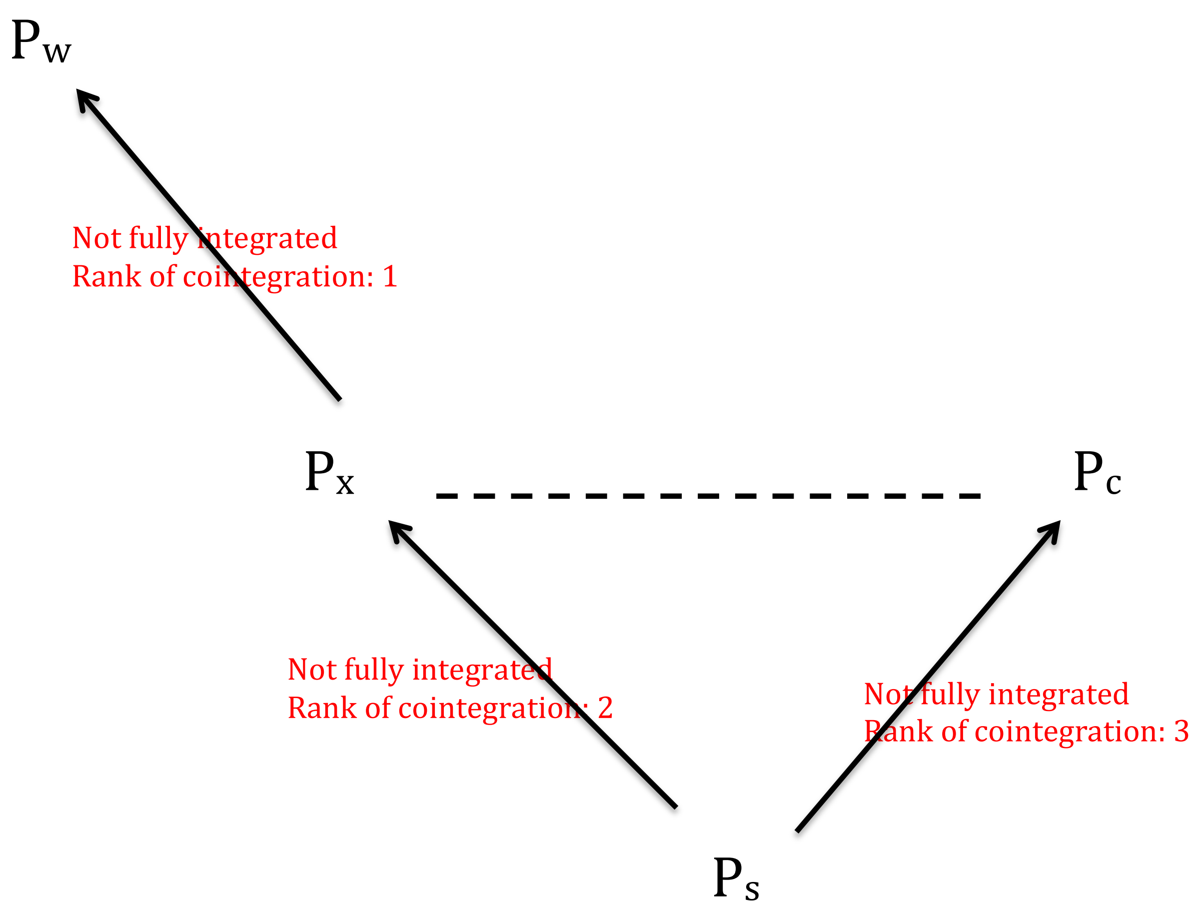
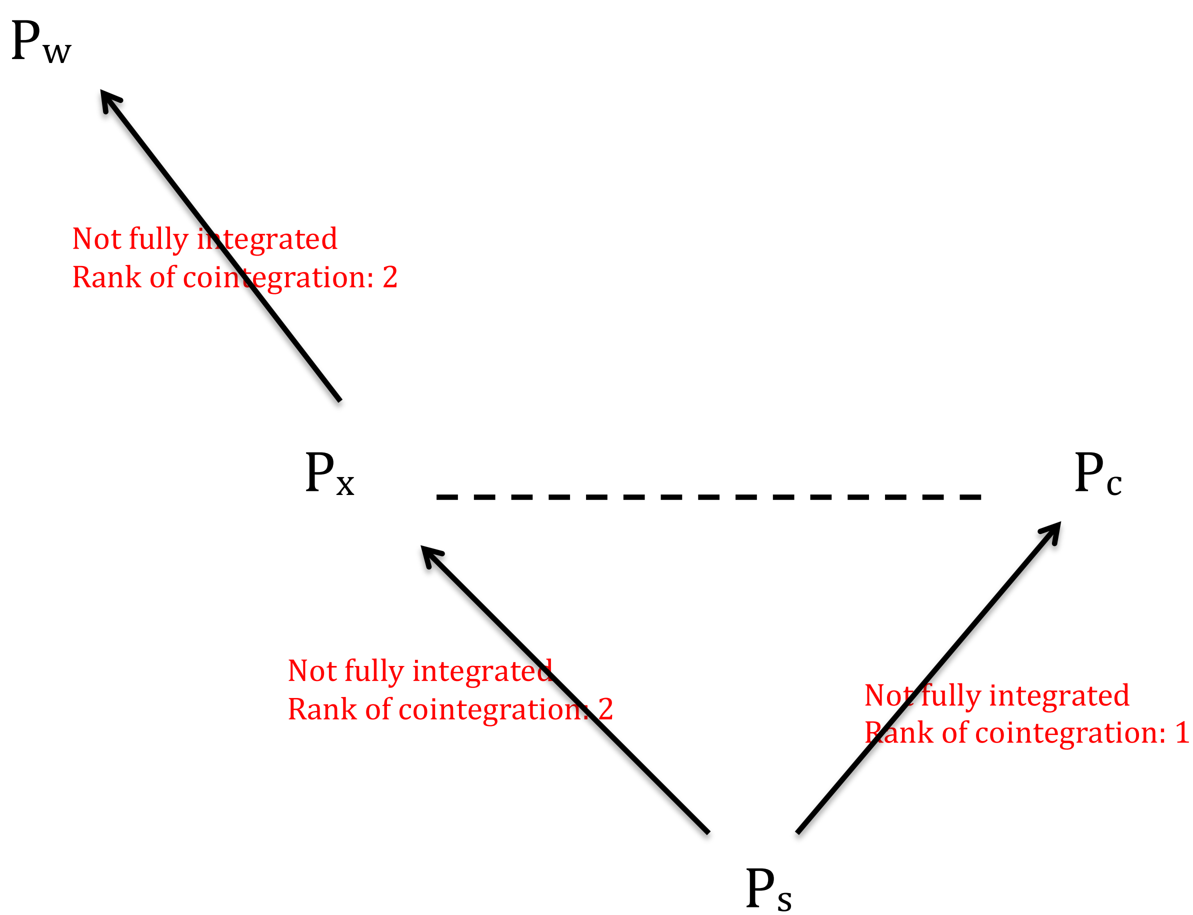


Figure 11. Rice Market Linear VECM Summary of Results



6.3 Non-Linear VECM

In the previous sections, we hypothesized that our price data may exhibit a structural change arising from the export ban. Regime shifts such as these induce substantial nonlinearities in the stochastic process and the relationships may change depending on the level of one or more variables.

Before proceeding to estimating Threshold Vector Error Correction Model (TVECM), we first find the plausible endogenous breaks in the price series using Gregory-Hansen test. We find that for wheat, we only reject the null of no cointegration with regime shifts for the wheat producing states and consuming states. And the plausible cut off is month-year 75 or March 2011. For rice, we find that we reject the null of no cointegration with regime shifts for two market pairs: producing and consuming region and exporting regions and the world with the plausible cut offs at month-year 34 or October 2007 and 68 or August 2010, respectively. The results summarizing market pairs significant regimes are presented in Table 11.

Table 11. Tests for Cointegration with Structural Breaks

	Model	Break Date	GH Test Statistic: ADF	GH Test Statistic: Zt	GH Test Statistic: Za
Wheat Producing and Consuming States	Change in Level	75	-5.84***	-6.07***	-48.65*
	Change in Regime	75	-6.31**	-6.00**	-68.94*
	Change in Level and Trend	75	-6.13**	-6.35**	-54.22*
	Change in Regime and Trend	75	-6.52**	-6.66**	-58.19*
Wheat Producing and Exporting States	Change in Level	63	-6.29***	-5.98*	-50.66
	Change in Regime	65	-6.54**	-6.44**	-55.68
	Change in Level and Trend	65	-6.32**	-6.07**	-51.85
	Change in Regime and Trend	64	-6.06	-6.34	-54.36
Wheat Exporting States and the World	Change in Level	38	-4.62	-4.73	-35.86
	Change in Regime	38	-5.10	-5.14	-39.76
	Change in Level and Trend	56	-4.91	-4.96	-36.2
	Change in Regime and Trend	38	-4.73	-4.91	-36.61
Rice Producing and Consuming States	Change in Level	34	-5.75**	-5.78**	-51.13*
	Change in Regime	34	-5.16*	-6.18**	-55.69*
	Change in Level and Trend	34	-5.81**	-5.84**	-5.43*
	Change in Regime and Trend	34	-7.04***	-7.08***	-67.19*
Rice Producing and Exporting States	Change in Level	78	-5.45*	-5.48*	-47.02
	Change in Regime	39	-5.18	-6.41*	-58.13
	Change in Level and Trend	78	-5.43	-5.46	-47.24
	Change in Regime and Trend	39	-6.98**	-6.94**	-64.16
Rice Exporting States and the World	Change in Level	68	-10.78***	-10.84***	-103.68***
	Change in Regime	68	-6.39**	-10.89**	-104.03***
	Change in Level and Trend	68	-11.88***	-11.94***	-112.34***
	Change in Regime and Trend	68	-12.04***	-12.10***	-113.59***

Reject Ho: no cointegration if all the GH test statistics are significant.

We align the date of cutoffs with the export bans (Figures 12 and 13 for rice and wheat, respectively), supply shock or rainfall (Figure 14), government's MSP and CIP (Figures 15 and 16 for rice and wheat, respectively) and transportation costs (Figure 17). We find that the cutoff date for wheat cointegration between producing and consuming regions was when the ban ended. While for the case of rice, the timing of the regime change was more vague. The regime change that occured at month 34 between producing and consuming is likely caused by a decline in CIP and the "dip" in rainfall. The regime change happening at month 68 between exporting regions and the world would have been rise in MSP and peak in the rainfall. The petroleum prices seem to have not caused any of the breaks

Figure 12. Wheat Export Quantity over time with cutoff at month-year 75 (March 2011)

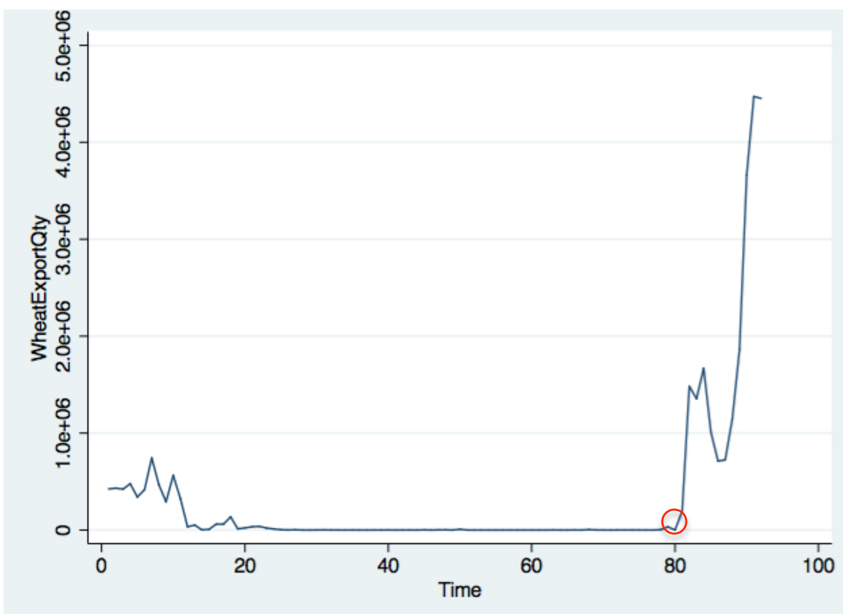


Figure 13. Rice Export Quantity over time with cutoffs at month-year 34 (October 2007) and month year 68 (August 2010)

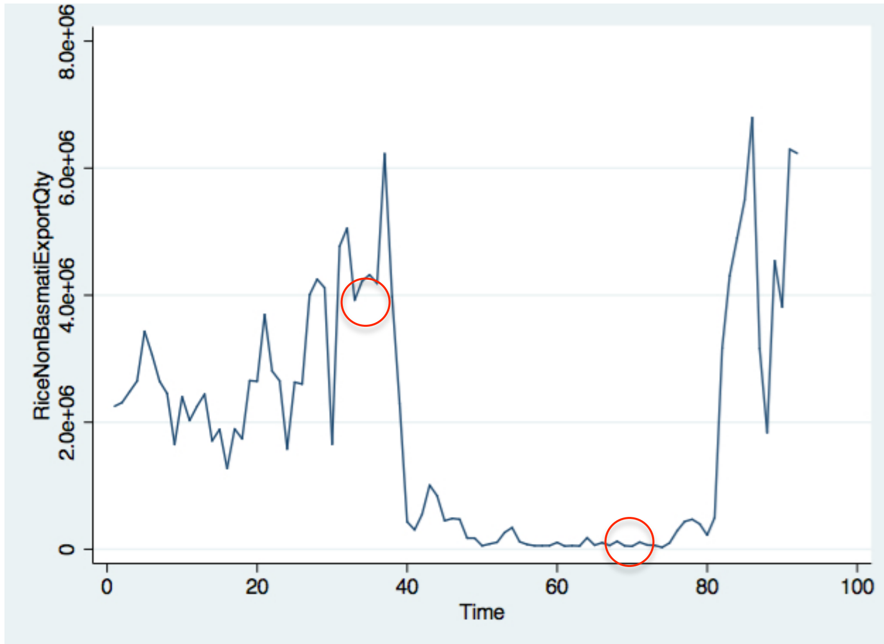


Figure 14. Average Rainfall (in mm) with cutoffs at month-year 75 (March 2011), month-year 34 (October 2007) and month year 68 (August 2010)

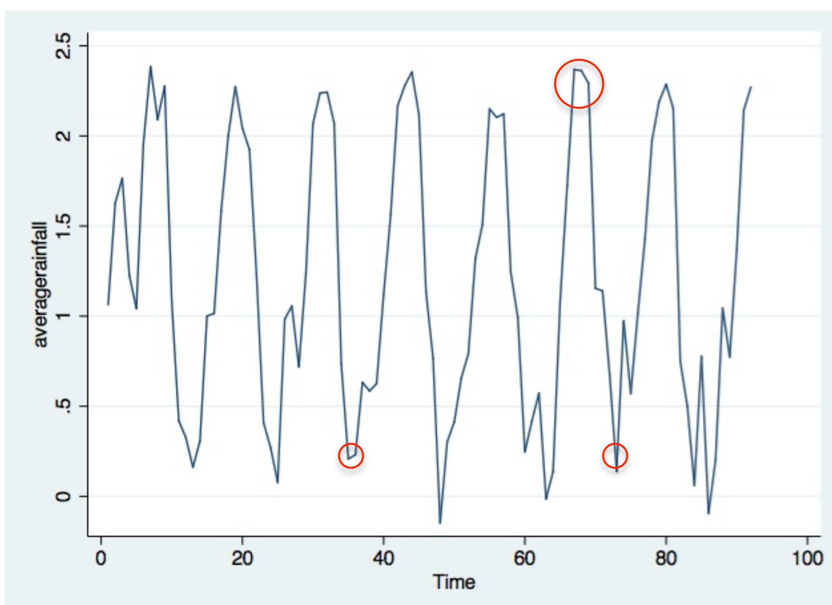


Figure 15. Wheat Minimum Support Prices and Central Issue Prices with cutoff at month-year 75 (March 2011)

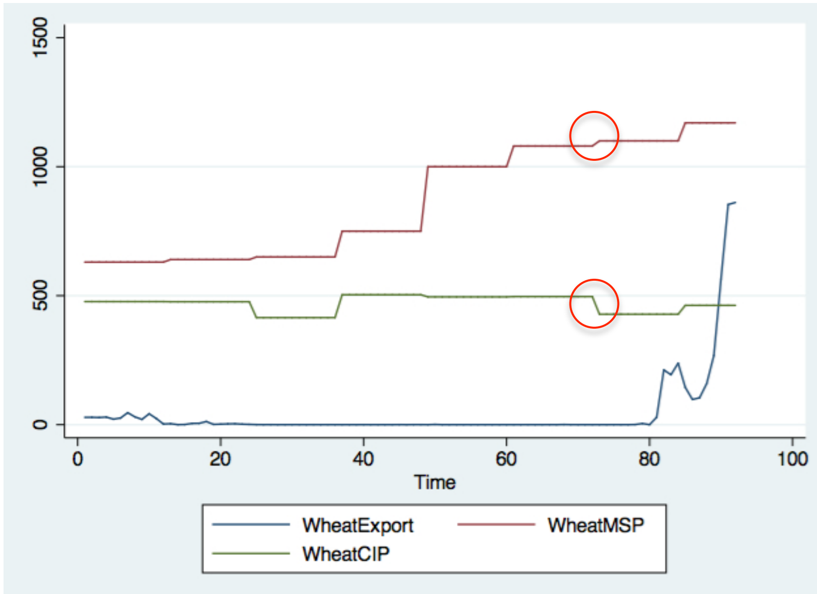


Figure 16. Wheat Minimum Support Prices and Central Issue Prices with cutoffs at month-year 34 (October 2007) and month year 68 (August 2010)

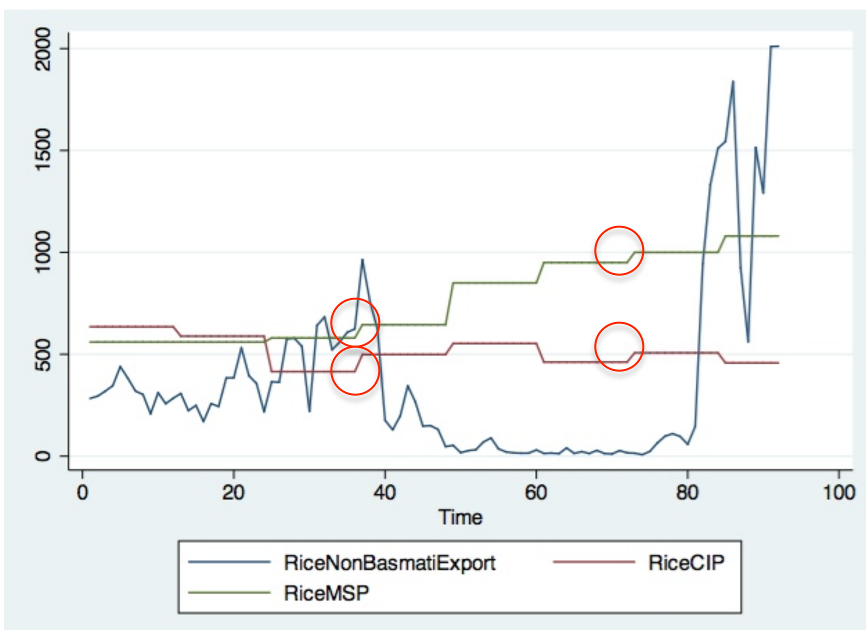
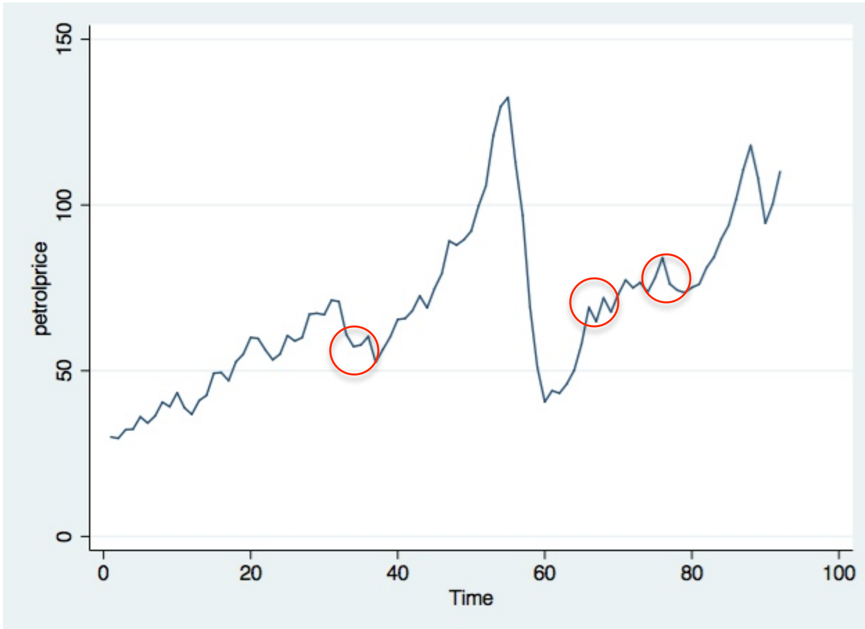


Figure 17. Petroleum Price Averages with cutoffs at month-year 75 (March 2011), month-year 34 (October 2007) and month year 68 (August 2010)



We then run separate VECMs before and after the cutoffs for market pairs with significant cutoffs.

6.3.1 Wheat Producing States and Consuming States with cut off at time 75

Prior to March 2011 (i.e. time 75), we find that producing and consuming states are not fully integrated. Multivariate cointegration results indicate that there are three cointegration vectors among six price series, and hence there exists 3 common stochastic trend in the system. However, after the export ban was lifted, we find that producing and consuming states are fully integrated. Results are presented in Tables 12a and 12b, for pre-break and post-break, respectively. And summarized into a diagram in Figures 18a and 18b.

Table 12a. Market integration tests for Wheat Producing States and Consuming States, time < 75

Lag Order Selection based on AIC		
0	-24.3481	ns
1	-31.4904	*
2	-31.17	ns

Johansen test for cointegration No. of cointegrating vectors Null	Alternative	Trace Statistic	Significance
0	1	121.6544	ns
1	2	81.7108	ns
2	3	44.439	**
3	4	24.8827	ns
4	5	7.1274	ns
5	6	1.1208	ns

Lagrangre Multiplier Test Autcorrelation Ho: No autocorrelation at lag order		
1	20.5356	ns
2	35.5334	ns

Test for Normality Jarque-Berra Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Rewari	30.351	***
Unnao	28.717'	***
Patna	22.66	***
Delhi	0.466	ns
Mumbai	405.32	***
Kolkata	1677.503	***
All	2165.017	***

Test for Stability Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_wheatrewari_w	D_wheatunnao_w	D_wheatpatna_w	D_wheatdelhi_r	D_wheatmumbai_r	D_wheatkolkata_r
L._ce1	-0.458*	0.440**	-0.046	0.356**	-0.118	-0.461
	(0.251)	(0.203)	(0.164)	(0.148)	(0.179)	(0.436)
L._ce2	-0.0501	-0.741***	0.176	-0.23	0.0968	-0.365
	(0.268)	(0.217)	(0.175)	(0.158)	(0.192)	(0.466)
L._ce3	0.287**	0.309***	-0.477***	0.163**	0.171*	-0.146
	(0.141)	(0.114)	(0.092)	(0.083)	(0.101)	(0.246)
L._ce4	-0.124	-0.243	0.0726	-0.359***	-0.00766	1.095***
	(0.194)	(0.157)	(0.127)	(0.114)	(0.139)	(0.337)
L._ce5	0.165	0.13	0.303***	0.0417	-0.231**	0.0553
	(0.129)	(0.105)	(0.085)	(0.076)	(0.092)	(0.224)

Continued Table 12a. Market integration tests for Wheat Producing States and Consuming States, time < 75

Linear VECM Test for Cointegrating Relationship						
Beta Coefficients	**D_wheatrewari_w**	**D_wheatunnao_w**	**D_wheatpatna_w**	**D_wheatdelhi_r**	**D_wheatmumbai_r**	**D_wheatkolkata_r**
LD.wheatrewari_w	0.32	0.24	0.370***	0.0617	0.114	0.515
	(0.201)	(0.163)	(0.132)	(0.119)	(0.144)	(0.350)
LD.wheatunnao_w	-0.129	-0.171	-0.0496	0.105	0.00337	0.162
	(0.220)	(0.179)	(0.144)	(0.130)	(0.158)	(0.383)
LD.wheatpatna_w	-0.269*	-0.278**	0.189*	-0.0867	-0.0524	0.155
	(0.156)	(0.127)	(0.102)	(0.092)	(0.112)	(0.272)
LD.wheatdelhi_r	0.268	0.23	0.0516	0.103	0.0537	-0.388
	(0.262)	(0.212)	(0.171)	(0.154)	(0.187)	(0.456)
LD.wheatmumbai_r	0.18	0.279*	-0.242*	-0.0776	0.302**	0.0219
	(0.191)	(0.154)	(0.125)	(0.112)	(0.136)	(0.332)
LD.wheatkolkata_r	-0.00455	0.00626	0.0319	0.00406	-0.0652	-0.0551
	(0.075)	(0.061)	(0.049)	(0.044)	(0.054)	(0.130)
Constant	0.000247	-0.00106	0.000994	0.00347	0.00172	0.000876
	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)	(0.006)

Table 12b. Market integration tests for Wheat Producing States and Consuming States, time > 75

Lag Order Selection based on AIC		
0	-24.3481	ns
1	-31.4904	*
2	-31.17	ns

Johansen test for cointegration
No. of cointegrating vectors

Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	23.76	ns
1	2	25.41	ns
2	3	29.68	ns
3	4	47.21	ns
4	5	68.52	ns
5	6	94.15	**

Lagrangre Multiplier Test Autcorrelation
Ho: No autocorrelation at lag order

1	25.2539	ns
2	32.5776	ns

Test for Normality
Jarque-Berra
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed

Rewari	13.884	***
Unnao	2.93	ns
Patna	3.931	ns
Delhi	1.7	ns
Mumbai	7.819	**
Kolkata	10.596	***
All	40.859	***

Test for Stability
Eigenvalue Stability Condition

The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_wheatrewari_w	D_wheatunnao_w	D_wheatpatna_w	D_wheatdelhi_r	D_wheatmumbai_r	D_wheatkolkata_r
L._ce1	0.927	-0.0378	-0.203	-0.0241	1.035***	-0.212
	(1.803)	(2.094)	(0.588)	(0.768)	(0.398)	(1.370)
L._ce2	1.228	-0.659	-0.563	0.778	-0.591*	1.815
	(1.561)	(1.813)	(0.509)	(0.665)	(0.344)	(1.186)
L._ce3	2.345	1.368	-1.651*	1.505	-2.081***	3.435
	(2.904)	(3.373)	(0.947)	(1.237)	(0.641)	(2.207)
L._ce4	-6.573	-1.425	3.097	-4.212	1.358	-9.814*
	(7.838)	(9.105)	(2.555)	(3.339)	(1.730)	(5.958)
L._ce5	-0.934	-0.505	1.120*	-0.676	0.255	-2.098
	(1.995)	(2.318)	(0.651)	(0.850)	(0.440)	(1.517)

Continued Table 12b. Market integration tests for Wheat Producing States and Consuming States, time > 75

Linear VECM Test for Cointegrating Relationship

Beta Coefficients	**D_wheatrewari_w**	**D_wheatunnao_w**	**D_wheatpatna_w**	**D_wheatdelhi_r**	**D_wheatmumbai_r**	**D_wheatkolkata_r**
LD.wheatrewari_w	-1.406	0.257	0.408	0.0693	0.255	0.101
	(2.102)	(2.442)	(0.685)	(0.895)	(0.464)	(1.598)
LD.wheatunnao_w	-1.404	0.535	0.095	-0.487	0.568	-0.62
	(1.947)	(2.262)	(0.635)	(0.829)	(0.430)	(1.480)
LD.wheatpatna_w	0.0437	-1.295	0.173	-0.463	0.474**	-2.003**
	(1.053)	(1.224)	(0.343)	(0.449)	(0.232)	(0.801)
LD.wheatdelhi_r	6.733	-1.693	-0.66	2.117	-1.425	4.146
	(8.605)	(9.996)	(2.805)	(3.665)	(1.899)	(6.541)
LD.wheatmumbai_r	-0.923	1.005	-0.713**	0.446	-0.999***	1.598**
	(0.867)	(1.007)	(0.283)	(0.369)	(0.191)	(0.659)
LD.wheatkolkata_r	-0.281	-0.316	0.00506	-0.286	-0.105	-1.108***
	(0.434)	(0.504)	(0.141)	(0.185)	(0.096)	(0.330)
Constant	0.000642	0.00012	0.000822	-0.00296	-0.000264	0.00105
	(0.010)	(0.012)	(0.003)	(0.004)	(0.002)	(0.008)

Figure 18a. Wheat Market Non-Linear VECM Results (Pre-break, time<75)

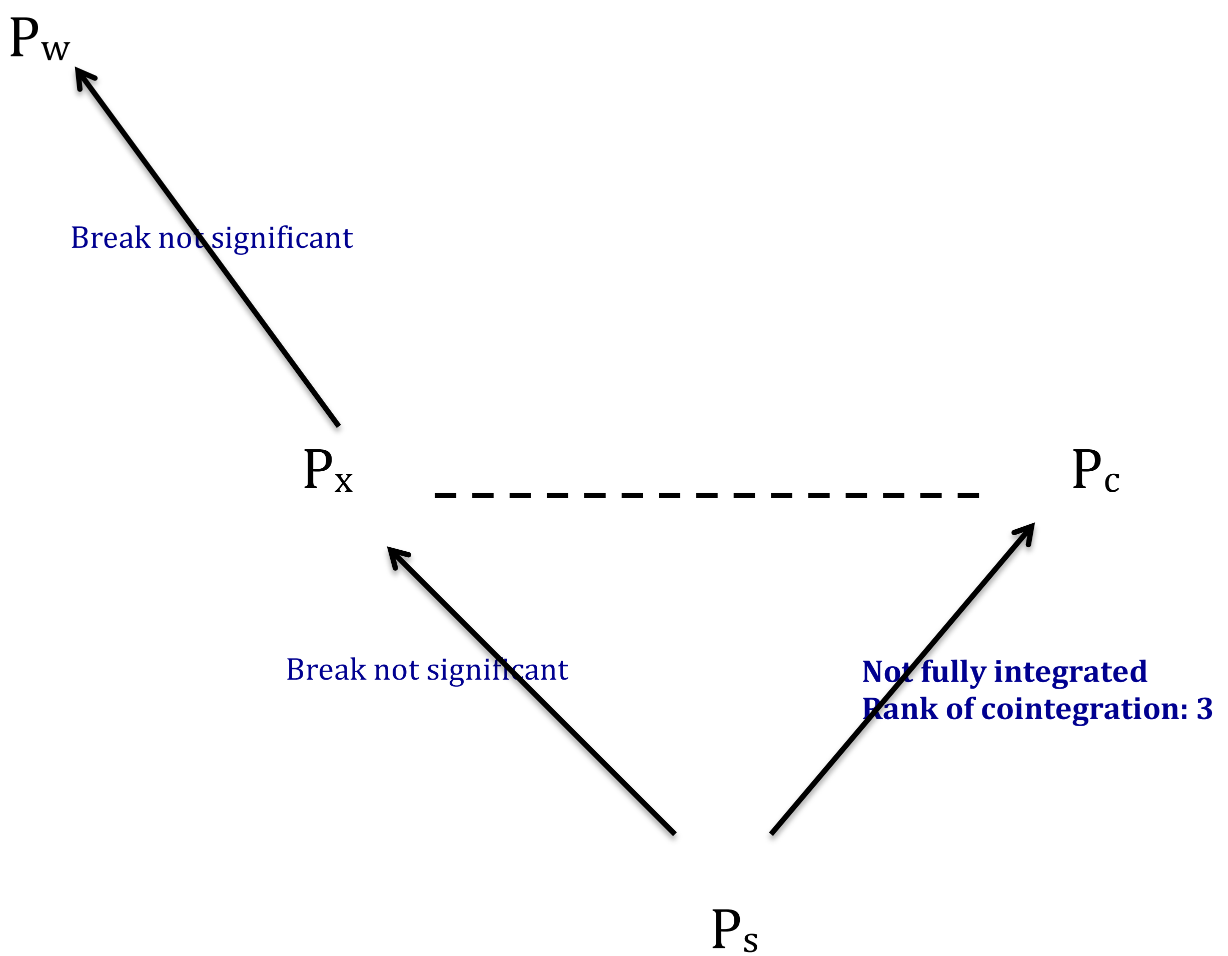
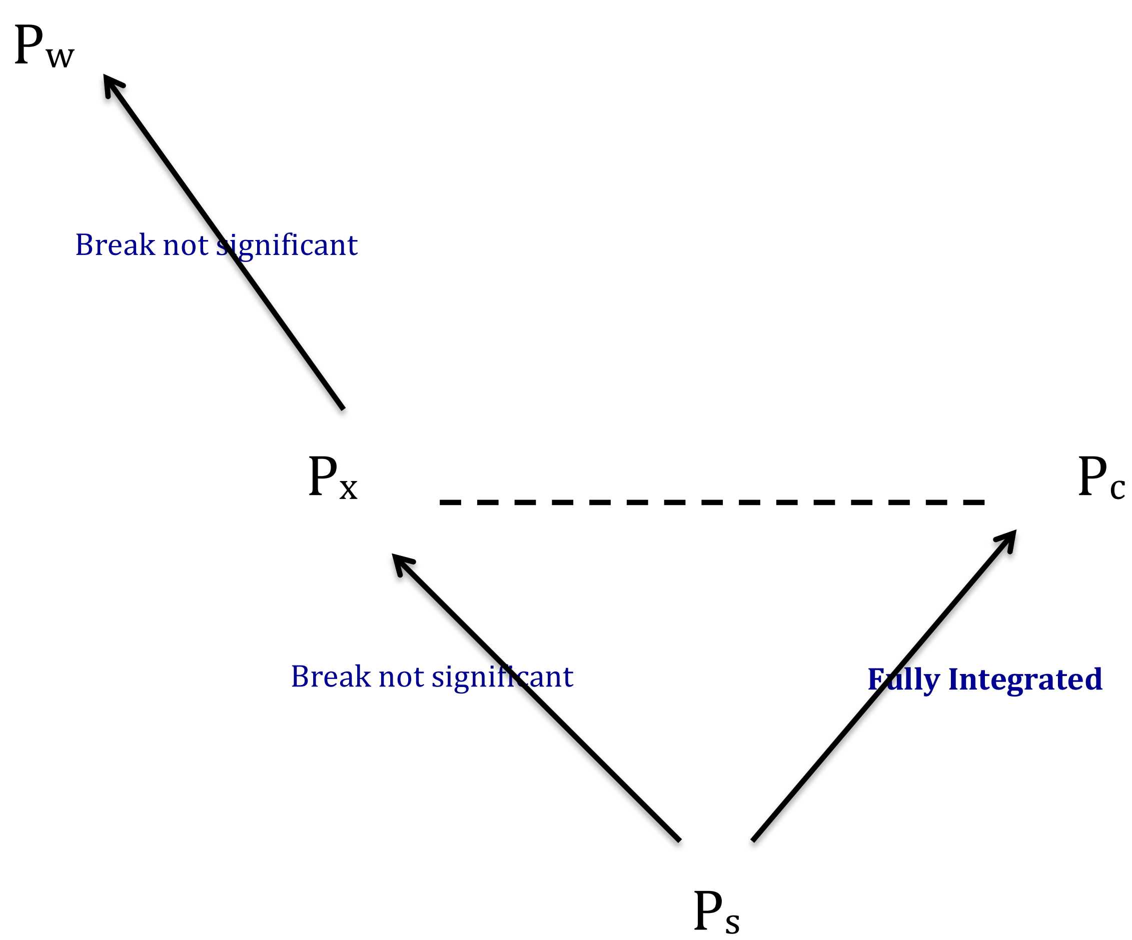


Figure 18b. Wheat Market Non-Linear VECM Results (Post-break, time>75)



6.3.2 Rice Producing and Consuming States with cut off at time 34

Prior to October 2007, we find that producing and consuming states are not fully integrated. Appendix table 1 reports that the ban was lifted and replace with a high MEP by the end of October. Multivariate cointegration results indicate that there are three cointegration vectors among six price series, and hence there exists 3 common stochastic trend in the system. And on October 2007, we find that producing and consuming states are less integrated with a cointegration rank of two. Results are presented in Tables 13a and 13b, for pre-break and post-break, respectively. And summarized into a diagram in Figures 19a and 19b.

6.3.3 Rice Exporting States and World Market with cut off at time 68

Prior to August 2010, we find that exporting states and the world market are fully integrated. However, after August 2010, we find that that exporting states and the world market are not fully integrated with a cointegration rank of two out of four price series. Hence there exists two common stochastic trend in the system. Results are presented in Tables 14a and 14b, for pre-break and post-break, respectively. And summarized into a diagram in Figures 19a and 19b.

Table 13a. Market integration tests for Rice Producing States and Consuming States, time < 34

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	112.3906	ns
1	2	64.5128	*
2	3	41.6224	ns
3	4	22.5538	ns
4	5	9.6088	ns
5	6	0.6753	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	27.0684	**
2	44.9872	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Fatehabad	1.34	ns
Bahraich	3.711	ns
Patna	1.286	ns
Delhi	24.246	***
Mumbai	0.474	ns
Kolkata	40.653	***
All	71.71	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
L._ce1	-0.489*	-0.0135	0.0258	0.000685	0.0156	0.0878**
	(0.288)	(0.012)	(0.045)	(0.021)	(0.020)	(0.042)
L._ce2	3.353	-0.265	0.817	-0.318	0.231	-0.365
	(4.293)	(0.180)	(0.671)	(0.312)	(0.301)	(0.633)
L._ce3	-0.595	0.0852	-0.548**	0.00866	0.0896	-0.231
	(1.589)	(0.067)	(0.248)	(0.115)	(0.111)	(0.234)
L._ce4	4.568	0.115	0.116	-0.825***	0.207	-0.0932
	(3.237)	(0.135)	(0.506)	(0.235)	(0.227)	(0.477)
L._ce5	-2.911	-0.114	-0.87	1.007***	-0.342	0.843
	(3.831)	(0.160)	(0.599)	(0.278)	(0.268)	(0.565)

Continued Table 13a. Market integration tests for Rice Producing States and Consuming States, time < 34

Linear VECM Test for Cointegrating Relationship

Beta Coefficient	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
LD.lnricefatehaba	-0.249	0.00648	-0.0291	0.00953	-0.00925	-0.0212
	(0.227)	(0.009)	(0.036)	(0.017)	(0.016)	(0.033)
LD.lnricebahraich	1.67	0.361	0.57	0.525	-0.0939	0.942
	(6.247)	(0.261)	(0.976)	(0.454)	(0.438)	(0.921)
LD.lnricepatna_w	2.221	-0.111	0.19	-0.0252	-0.0962	0.235
	(1.679)	(0.070)	(0.262)	(0.122)	(0.118)	(0.247)
LD.lnricedelhi_r	-4.014	-0.0396	0.444	0.15	-0.0648	0.108
	(2.700)	(0.113)	(0.422)	(0.196)	(0.189)	(0.398)
LD.lnricemumbai_	2.56	0.16	0.362	-0.726***	-0.205	-0.607
	(3.736)	(0.156)	(0.584)	(0.271)	(0.262)	(0.551)
LD.lnricekolkata_	1.453	-0.00598	-0.228	0.043	-0.0363	-0.126
	(1.335)	(0.056)	(0.209)	(0.097)	(0.094)	(0.197)
Constant	0.000111	0.00290**	0.000606	0.0017	0.00258	0.000413
	(0.030)	(0.001)	(0.005)	(0.002)	(0.002)	(0.004)

Table 13b. Market integration tests for Rice Producing States and Consuming States, time > 34

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	98.0805	ns
1	2	55.9372	*
2	3	30.1073	ns
3	4	16.0237	ns
4	5	3.5726	ns
5	6	0.0339	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	53.3253	**
2	44.1933	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Fatehabad	0.498	ns
Bahraich	2.572	ns
Patna	105.814	***
Delhi	15.218	***
Mumbai	15.83	***
Kolkata	108.219	***
All	248.151	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters						
	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
L._ce1	-0.442***	0.0306	-0.0443	-0.0416**	-0.00982	-0.0128
	(0.159)	(0.024)	(0.030)	(0.021)	(0.031)	(0.034)
L._ce2	-0.609	-0.538***	0.106	0.057	0.141	0.271
	(0.848)	(0.129)	(0.158)	(0.111)	(0.163)	(0.179)
L._ce3	0.0505	0.0604*	-0.190***	-0.0512	0.0411	-0.00755
	(0.240)	(0.037)	(0.045)	(0.032)	(0.046)	(0.051)
L._ce4	-0.0169	0.242**	-0.220*	-0.315***	-0.0195	-0.0992
	(0.684)	(0.104)	(0.127)	(0.090)	(0.132)	(0.144)
L._ce5	0.458	0.243***	0.129	0.124*	-0.13	-0.0809
	(0.506)	(0.077)	(0.094)	(0.066)	(0.097)	(0.107)

Continued Table 13b. Market integration tests for Rice Producing States and Consuming States, time > 34

Linear VECM Test for Cointegrating Relationship

Beta Coefficient	D_lnricefatehabad_w	D_lnricebahraich_w	D_lnricepatna_w	D_lnricedelhi_r	D_lnricemumbai_r	D_lnricekolkata_r
LD.lnricefatehaba	-0.0755	-0.0034	0.0491*	0.0351*	-0.0143	0.0227
	(0.145)	(0.022)	(0.027)	(0.019)	(0.028)	(0.031)
LD.lnricebahraich	1.021	-0.159	-0.12	0.00882	-0.16	-0.0544
	(0.740)	(0.112)	(0.138)	(0.097)	(0.142)	(0.156)
LD.lnricepatna_w	1.314**	-0.0107	0.340***	-0.117	0.00432	0.129
	(0.628)	(0.095)	(0.117)	(0.082)	(0.121)	(0.132)
LD.lnricedelhi_r	-1.403	0.151	0.272	0.362**	0.132	0.00696
	(1.073)	(0.163)	(0.200)	(0.141)	(0.206)	(0.226)
LD.lnricemumbai_	-0.582	-0.282**	0.149	-0.117	0.311*	-0.0688
	(0.864)	(0.131)	(0.161)	(0.113)	(0.166)	(0.182)
LD.lnricekolkata_	0.923	0.122	-0.203	-0.0747	0.0689	0.139
	(0.814)	(0.123)	(0.151)	(0.107)	(0.156)	(0.172)
Constant	-0.000154	0.00249	0.00181	-5.36E-05	0.00506*	0.00128
	(0.014)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)

Table 14a. Market integration tests for Rice Exporting States and the World, time < 68

Johansen test for cointegration
No. of cointegrating vectors

Null	Alternative	Trace Statistic	Significance
0	1	59.6895	ns
1	2	23.6303	*
2	3	7.0177	ns
3	4	0.8226	ns

Lagrangre Multiplier Test Autcorrelation
Ho: No autocorrelation at lag order

1	6.371	ns
2	14.7994	na

Test for Normality
Jarque-Berra
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed

Kandla	38.827	***
Visakhapatnar	1129.58	***
Tuticorin	7.217	***
World	3.674	ns
All	1177.298	***

Test for Stability
Eigenvalue Stability Condition

The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters

	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
L._ce1	-0.933***	0.0308	0.0587**	-0.00444
	(0.200)	(0.086)	(0.026)	(0.060)
L._ce2	-0.0411	-0.0614*	0.0158	-0.0287
	(0.079)	(0.034)	(0.010)	(0.024)
L._ce3	0.251	0.173	-0.140**	0.273**
	(0.421)	(0.181)	(0.055)	(0.126)

Linear VECM Test for Cointegrating Relationship

Beta Coefficient	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
LD.lnricekandla_	-0.0737	0.0354	-0.0344*	0.0294
	(0.140)	(0.060)	(0.018)	(0.042)
LD.lnricevisakhap	0.12	0.0557	-0.0675*	-0.0287
	(0.298)	(0.128)	(0.039)	(0.089)
LD.lnricetuticorin	-0.0679	0.0609	0.185	0.388
	(0.954)	(0.410)	(0.124)	(0.284)
LD.lnriceworld	-0.117	-0.0362	-0.108**	0.582***
	(0.377)	(0.162)	(0.049)	(0.112)
Constant	0.000222	7.91E-06	0.00365*	0.00167
	(0.015)	(0.006)	(0.002)	(0.005)

Table 14b. Market integration tests for Rice Exporting States and the World, time > 68

Johansen test for cointegration			
No. of cointegrating vectors			
Null	**Alternative**	**Trace Statistic**	**Significance**
0	1	50.2617	ns
1	2	27.8318	*
2	3	13.4177	ns
3	4	0.4044	ns

Lagrangre Multiplier Test Autcorrelation		
Ho: No autocorrelation at lag order		
1	30.1822	**
2	10.921	ns

Test for Normality		
Jarque-Berra		
Null hypothesis: Skewness and Kurtosis is zero; all disturbances are normally distributed		
Kandla	6.739	**
Visakhapatnam	63.871	***
Tuticorin	0.844	ns
World	0.771	ns
All	72.225	***

Test for Stability
Eigenvalue Stability Condition
The VECM specification imposes one unit modulus.

Linear VECM Results Adjustment Parameters				
	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
L._ce1	-0.875***	0.0386	-0.122***	0.0125
	(0.267)	(0.031)	(0.041)	(0.105)
L._ce2	0.447	-0.0947	-0.000459	2.200***
	(1.581)	(0.183)	(0.241)	(0.626)
L._ce3	-0.633	-0.0364	0.320***	-0.0996
	(0.744)	(0.086)	(0.113)	(0.294)

Linear VECM Test for Cointegrating Relationship				
Beta Coefficient	D_lnricekandla_w	_lnricevisakhapatnam_	D_lnricetuticorin_w	D_lnriceworld
LD.lnricekandla_w	-0.396**	-0.0083	0.0724***	0.018
	(0.169)	(0.020)	(0.026)	(0.067)
LD.lnricevisakhap	-1.014	-0.0616	0.136	-0.0198
	(2.509)	(0.290)	(0.382)	(0.993)
LD.lnricetuticorin	1.186	-0.0261	0.221	0.775
	(1.891)	(0.219)	(0.288)	(0.749)
LD.lnriceworld	-0.297	-0.0109	0.0813	0.554***
	(0.438)	(0.051)	(0.067)	(0.173)
Constant	5.33E-05	0.00251*	0.000422	9.74E-05
	(0.012)	(0.001)	(0.002)	(0.005)

Figure 19a. Rice Market Non-Linear VECM Summary of Results (Pre-break)

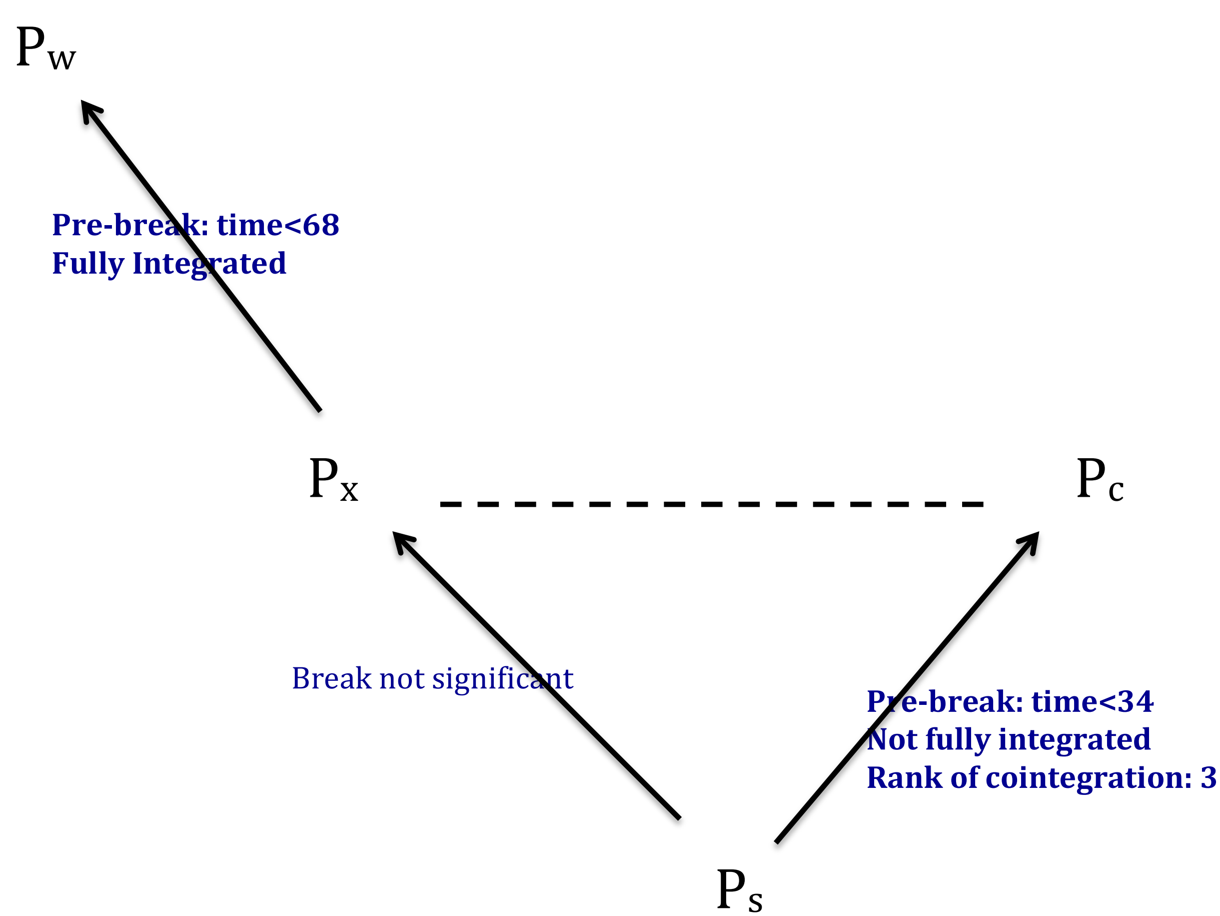
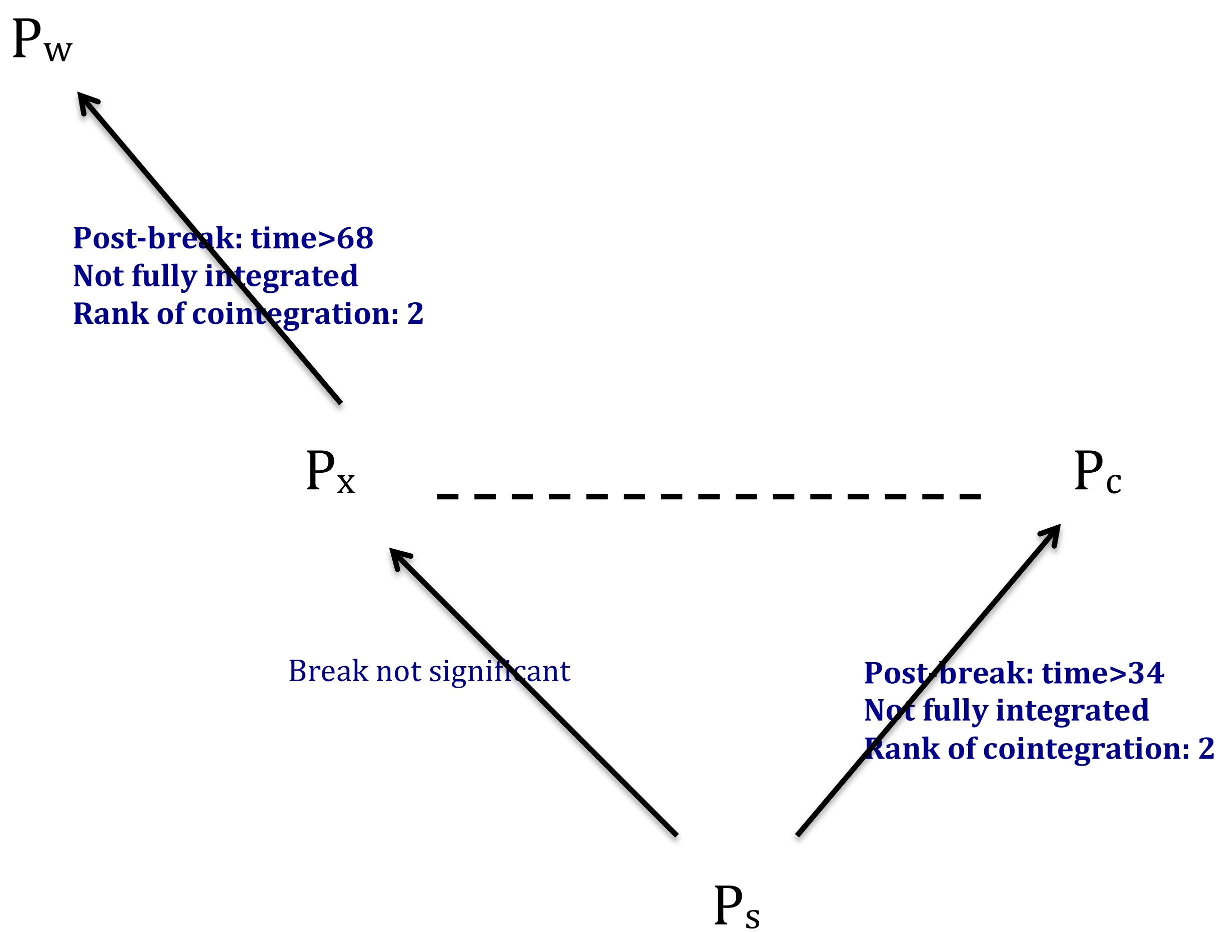


Figure 19b. Rice Market Non-Linear VECM Summary of Results (Post-break)



7. Conclusion

During the global food crisis of 2007/2008, the Indian government intended to reduce the domestic impact of rapidly increasing world prices on the world and regional markets by implementing export ban on wheat and non-basmati rice in combination with domestic price policies and food grain procurement and distribution. By introducing these policy measures, the government was aiming to influence supply and demand of wheat and rice on the domestic market.

We find that none of the market pairs were fully integrated in the linear VECM results. However, Gregory-Hansen statistic show there are significant thresholds for the following market pairs: wheat producing states and wheat consuming states, rice producing states and rice consuming states and rice exporting states and the world market. This implies that for these market pairs with significant breaks, the rank of cointegration may differ across thresholds. We find that wheat producing and consuming states are fully integrated after the ban and that rice exporting states and world market are fully integrated prior to ban.

Since the decisions to use these blunt instruments are taken by domestic governments worldwide, we believe that studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

8. References

Abdulai, A. 2000. "Spatial Price Transmission and Assymetry in the Ghanian Maize Market", *Journal of Development Economics,* 63: 327-349.

Abbott, P. 2009. "Development Dimensions of High Food Prices." OECD.

Abbott, P. 2010. "Stabilization Policies in Developing Countries after the 2007-08 Food Crisis." OECD.

Acharya, S.S., R. Chand, P.S. Birthal, S. Kumar and D.S. Negi. 2012. "Market Integration and Price Transmission in India: A Case of Rice and Wheat with Special Reference to World Food Crisis of 2007/08". FAO, Rome, Italy.

Alexander, C. and J. Wyeth. 1994. "Cointegration and Market Integration: An Application to the Indonesian Rice Market". *The Journal of Development Studies, 30(2): 303-334.*

Anselin, L. 1988. "Spatial Econometrics: Methods and Models". Dordrecht, Kluwer.

Ardeni, P.G. 1989. "Does Law of One Price Really Hold for Commodity Prices?". *American Journal of Agricultural Economics*. 71(3):661-669.

Arellano, M. & Bond, S. 1991. "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations". *Review of Economic Studies*, 58: 277-297.

Asche, F., H. Bremmes, and C.R. Wessels. 1999. "Product Aggregation, Market Integration, and Relationships Between Prices: An Application to World Salmon Markets". *American Journal of Agricultural Economics*, 81:568-581.

Badinger, H, Muller, W and Tondl, G. 2002. "Regional Convergence in European Union: a spatial dynamic panel analysis". IEF Working Paper No. 47. Research Institute for Europe.

Baffes J. and Ajwad, M. 2001. "Identifying Price Linkages: A Review of the Literature and an Application to the Indonesian Rice Market". *Journal of Development Studies*, 30:303-328.

Balke, Nathan S. 2000. "Credit and economic activity: credit regimes and nonlinear propagation of shocks". *The Review of Economics and Statistics,* 82 (2): 344-349.

Baltagi, B. H. 2005. *Econometric Analysis of Panel Data*. 3rd ed. Chichester, John Wiley.

Baltagi, B. H., Bresson, G. & Pirotte, A. 2005. "Panel Unit Root Tests and Spatial Dependence". Mimeo Syracuse University and University of Paris II.

Barrett, C.B. 2005. "Spatial Market Integration". 2nd ed. London: Palgrave Macmillan.

Barrett, C.B. and J.R. Li. 2002. “Distinguishing Between Equilibrium and Integration in Spatial Price Analysis”. *American Journal of Agricultural Economics, 84(2): 292-307.*

Baulch, B. “Testing For Food Market Integration Revisited”. *Journal of Development Studies*, 33:512–34.

Beenstock, M. and Felsenstein, D. 2007. “Spatial Vector Autoregressions”. *Journal of Spatial Economic Analysis,* 2(2):167–196.

Bernanke, B.S. and I. Mihov. 1998. “Measuring monetary policy”. *The Quarterly Journal of Economics,* 113 (3): 869-902.

Burgess, R. and D. Donaldson. 2012. “Can Openness to Trade Reduce Income Volatility? Evidence from Colonial India’s Famine Era”.. *American Economic Review*, 100:449-453.

Cagliarni, A and A. Rush. 2011. “Economic Development and Agriculture in India”. Reserve Bank of Australia

Chand, R. 2009. “Global Food and Financial Crises: Experiences and Perspectives from India, Chapter 8 in Agricultural Reforms and Trade Liberalization in China and Selected Asian Countries: Lessons of Three Decades, Policy Assistance Series 6, FAO-RAP”. Publication No. 2009/15, pp. 151-61.

Chand, R., S.S. Raju and L.M. Pandet. 2010. “Effect of Global Recession on Indian Agriculture”. *Indian Journal of Agricultural Economics,* 65(3): 487-496.

Clarckson, N. and K. Kulkarni. 2012. “Effects of India’s Trade Policy on Rice Production and Exports”. University of Denver, CO.

Clements, M. P., and G.E. Mizon. 1991. “Empirical analysis of macroeconomic time series. VAR and structural models”. *European Economic Review*, 35: 887–932.

Damodaran, H. 2000. “No move to Discontinue Paddy Purchase”. The Hindu Business Line., Aug2.

Davies, R. B. 1977. “Hypothesis testing when a nuisance parameter is present only under the alternative”. *Biometrika,* 64 (2): 247-254.

Del Ninno, C., P.A. Dorosh, and K. Subbarao. 2007. “Food aid, domestic policy and food security: contracting experiences from South Asia and Sub-Saharan Africa”. *Food Policy*, 32(3): 413-435.

Dercon, S. 1995. “On Market Integration and Liberalization: Method and Application to Ethiopia”. *Journal of Development Studies,* 32(1): 112-143.

Dickey, D.A. and W. Fuller. 1979. "Distribution of the Etsimators for Autoregressive Time Series with a Unit Root". *Journal of American Statistical Association*, 74(366a): 427-431.

Djuric, I., Glauben, T., and Götz, L. 2009. "The Influences of Export Controls on Wheat Markets in Serbia During the Food Crisis 2007-2008". Paper presented at the 113 EAAE Seminar: "The Role of Knowledge, Innovation and Human Capital in Multifunctional Agriculture and Territorial Rural Development". Belgrade - Serbia.

Djuric, I., L.Gotz and T. Glauben. 2011. "Influences of the Governmental Market Intervention on Wheat Markets in Serbia during the Food Crisis 2007/2008". Paper prepared for presentation at the EAAE 2011 Congress.

Dollive, K. 2008. "The Impact of Export Restraints on Rising World Grain Prices". US International Trade Commission Office.

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.

Engle R.F. and C.W.J. Granger. 1987. "Co-Integration and Error Correction: Representation Estimation and Testing". *Econometrica*. 55:251-276.

Fackler P. and B. Goodwin. 2001. "Spatial Price Analysis". *Handbook of Agricultural Economics*, 1(2):979-997.

FAO. 2011. "The State of Food Insecurity in the World: How does International Price Volatility Affect Domestic Economies and Food Security?". FAO, Rome, Italy. (www.fao.org/docrep/014/i2330e/i2330e.pdf)

Kubo, K. 2011. "India: The Burden of domestic Food Policy". Chiba, IDE-JETRO.

Galvão, A.B.C. 2003. "Multivariate threshold models: TVARs and TVECMs". *Brazilian Review of Econometrics,* 23 (1): 143-171.

Galvão, A.B.C. 2006. "Structural break threshold VARs for predicting US recessions using the spread". *Journal of Applied Econometrics,* 21 (4): 463-487.

Galvão, A.B.C., and M. Marcellino. 2010. "Endogenous monetary policy regimes and the great moderation". EUI Working Paper ECO 2010/22. Florence, Italy: European University Institute Department of Economics.

Gardner, B.L. 1975. "The Farm-Retail Price Spread in a Competitive Food Industry". *American Journal of Agricultural Economics*, pp. 400-409.

Getis, A., and Griffith, D.A. 2002. "Comparative Spatial Filtering in Regression Analysis". *Geographical Analysis*, 34(2): 130-140.

Getis, A., and J.K. Ord. 1992. "The Analysis of Spatial Association by Use of Distance Statistics". *Geographical Analysis*, 24:189-206.

Goletti, F. and S. Babu. 1994. "Market Liberalization and Integration of Maize Markets in Malawi. *Journal of Agricultural Economics, 11(1):311-324.*

Gonzales-Rivera, G. and S.M. Helfand. 2001. "Economic Development and the Determinants of Spatial Integration in Agricultural Markets". Working Paper 01-28, Department of Economics, University of California, Riverside.

Gonzalo, Jesús, and Jean-Yves Pitarakis. 2002. "Estimation and model selection based inference in single and multiple threshold models". *Journal of Econometrics,* 110 (2): 319-352.

Goodwin, B. and N. Piggot. 2001. "Spatial Market Integration in the Presence of Threshold Effects". *American Journal of Agricultural Economics.*

Goodwin, B.K., and T.C. Schroeder. 1991. "Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets". *American Journal of Agricultural Economics,* 73: 452-464.

Gotz, L., T. Glauben and B. Brummer. 2010. "Impacts of Export Controls on Wheat Markets During the Food Crisis 2007/08 in Russia and Ukraine". Selected paper for Agricultural and Applied Economics Association, Denver, CO.

Granger, C.W.J. 1969. "Investigating Causal Relations by Econometric Models and Crossspectral Methods". *Econometrica,* 37: 428-438.

Granger, C.W.J. 1988. "Causality, Cointegration and Control". *Journal of Economic Dynamics and Control*, 12:551-559.

Hansen, B.E. and B. Seo. 2002. "Testing for two-regime threshold cointegration in vector error-correction models". *Journal of Econometrics,* 110 (2): 293-318.

Hahn, J. and G. Kuersteiner. 2002. "Discontinuous of weak instrument limiting distributions". *Economic Letters Elsevier,* 75(3): 325-331.

Hsiao, C. 1986. "Analysis of Panel Data". Cambridge, Cambridge University Press.

Ihle, R. and S.V. Cramon-Taubadel. 2008. "A Comparison of Threshold Cointegration and Markov-Switching Vector Error Correction Models in Price Transmission Analysis". Proceedings of NCCC-134 Conference on Applied Commodity Price Analysus, Forecasting and Market Risk Management, St. Louis, MO.

Ihle, R., S.V. Cramon-Taubadel, and S. Zorya. 2009. "Markov-switching estimation of spatial maize price transmission processes between Tanzania and Kenya". *American Journal of Agricultural Economics,* 91 (5): 1432-1439.

Johansen, S. 1988. “Statistical Analysis of Co-integrating Vectors.” *Journal of Economic Dynamics and Control,* 12:231-254.

Kubo, K. 2011. “India: The Burden of domestic Food Policy”. Chiba, Institute of Developing Economies – Japan External Trade Organization.

Kiviet, J.F. 1995. “On bias, inconsistency, and efficiency of various estimators in dynamic panel data models”. *Journal of Econometrics,* 68(1):53-78.

Korinek, J. and J. Kim. 2010. “Export Restrictions on Strategic Ra Materials and Their Impact on Trade and Global Supply.” *OECD Trade Policy Series.*

Lee, L.F. 2004. “Asymptotic distributions of quasi-maximum likelihood estimators for spatial autoregressive models”. *Econometrica*, 72: 1899-1925.

Liefert, W.M., P. Westcott, and J. Wainio. 2011. “Alternative Policies to Agricultural Export Bans that are Less Market-Distorting”. *American Journal of Agricultural Economics 94(2):435-441.*

Lo, M.C. and E. Zivot. 2001. “Threshold cointegration and nonlinear adjustment to the law of one price”. *Macroeconomic Dynamics,* 5 (4): 533-576.

Madariaga, N., S. Montout, and P. Ollivaud. 2005. “Regional convergence and agglomeration in Argentina: a spatial panel data approach”. Universite Paris. http://halshs.archives-ouvertes.fr/halshs-00193304/

Mallory, M. and K. Baylis. 2012. “The Food Corporation of India and the Public Distribution System: Impacts on Market Integration in Wheat, Rice, Pearl Millet, and Corn.” Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management.

Marcellino, M. and G.E. Mizon. 2000a. “Modelling shifts in the wage-price and unemployment inflation relationships in Italy, Poland, and the UK”. *Economic Modelling*, 17: 387–413.

Marcellino, M. and G.E. Mizon. 2000b. “Small system modelling of real wages, inflation, unemployment and output per capita in Italy 1970-1994”. Economics Department, Southampton University.

Martin, W. and K. Anderson. 2011. “Export Restrictions and Price Insulation During Commodity Price Booms.” *American Journal of Agricultural Economics, 94(2):422-427.*

Mason, N. 2011. “The Effects of the Food Reserve Agency on Maize Market Prices in Zambia”. MSU Department of Agricultural Economics Dissertation.

McNew, K. 1996. “Spatial Market Integration: Definition, Theory, and Evidence.” *Agricultural Resource Economics Review,* 25:1–11.

McNew, K., and P.L. Fackler. 1997. "Testing Mar- ket Equilibrium: Is Cointegration Informative?". *Journal of Agricultural Resource Economics,* 22:191–207.

Mitra, S. and T. Josling. 2009. "Agricultural Export Restrictions: Welfare Implications and Trade Disciplines". International Food and Agricultural Policy Council Policy Series.

Mitchell, D. 2008. "A Note on Rising Food Prices". The World Bank Policy Research Working Paper 4682.

Mundlak, Y. 1992. "Agricultural Productivity and Economic Policies: Concepts and Measurements". OECD Development Centre Working Paper 75, OECD Publishing.

Obstfeld, M. and A.M. Taylor. 1997. "Nonlinear Aspects of Goods-Market Arbitrage and Adjustment: Heckscher's Commodity Points Revisited." *Journal of the Japanese and International Economies* 11: 441-479.

Osterwald-Lenum, M. 1992. "A Note with Quantiles of the Assymptotic Distribution of Maximum Likelihood Cointegration Rank Test Statistics". *Oxford Bulletin of Economics and Statistics.* 54(2): 461-472.

Palaskas, T.B. and B. Harris. 1991. "Testing Market integration: New Approaches with Cases Material". Oxford Applied Discussion Papers Series, 126.

Phillips, P.C.B. and P. Perron. 1988. "Testing for a Unit Root in Time Series Regression". *Biometrica, 75:335-346.*

Porteous, O.C. 2012. "Empirical Effects of Short-Term Export Bans: The Case of African Maize." Working Paper, Dept of Agricultural Economics, University of California, Berkeley.

Quiroz, J. and Soto, R. 1996. "International Price Signals in Agricultural Markets: Do Governments Care?". Unpublished Mimeo, GERENS and ILADES/Georgetown University.

Rapsomanikis, G., D. Hallam, P. Comforti and R. Sharma. 2006. "Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and Applications". Commodities and Trade Division, FAO, Rome, pp.1‐20.

Report on Wheat. *National Multi-Commodity Exchange of India.* 2009. Available at http://www.nmce.com/files/study/wheat.pdf.

Saxegaard, M.. 2006. "Excess liquidity and effectiveness of monetary policy: evidence from sub-Saharan Africa". Working Paper No. 06/115. Washington, DC: International Monetary Fund, Africa Department. http://www.imf.org/external/pubs/ft/wp/2006/wp06115.pdf

Sekhar, C.S.C. 2012. "Agricultural Market integration in India: An Analysis of Select Commodities." *Food Policy 37: 309-322.*

Sexton, R.J., Kling, C.L., and H.F. Carman. 1991. "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to US Celery." *American Journal of Agricultural Economics*, 73(3): 568-580.

Sharma, R. 2011. "Food Export Restrictions Review of the 2007-2010 Experience and Considerations for Disciplining Restrictive Measures". Food Commodity and Trade Policy Research Working Paper No.32.

Slayton, T. 2009. "Rice Crisis Forensics: How Asian Governments Carelessly Set the World Rice Market on Fire". Center for Global Development.

Stock, J.H. and M.W. Watson. 1988. "Variable Trends in Economic Time Series". *Journal of Economic Perspectives, 2(3):147-174.*

Welton, G. 2011. "The Impact of Russia's 2010 Grain Export Ban". Oxfam.org.

Woolverton, A.E. and J. Kiawu. 2009. "Policy Responses to high Food Prices: Domestic Incentives and Global Implications". Presentation at the AAEA 2009 Meeting, Milwaukee, Wisconsin.

Zoellick, R.B. 2008. Speech to Rome World Food Security Summit, June 6.

Appendix Table 1. Timeline of Export Restriction Measures for Rice and Wheat in India

Non-basmati rice	• April 2007- Futures trading on rice was suspended • October 9, 2007 – Ban exports • October 31, 2007 – Ban lifted and replaced with MEP of US$425/t fob • December 2007 – MEP raised to $US500/t • March 5, 2008 – MEP raised to $US650/t and import duty was reduced to zero • March 27, 2008 – MEP to US$1000/t • **April 1, 2008 – Ban Exports** • September 2009 – Ban extended • Feb 2010 – Ban continued except for 3 premium varieties with US$800/t MEP and quota of 150,000t for MY 2010/11 • July 2010 – Decided to continue the ban • **September 2011 – Ban lifted**
Basmati rice	• March 8, 2008 – MEP increased to $US950/t at the same time import duty was reduced to zero • March 17, 2008: basmati rice exports were restricted only to two ports, Mundra and Pipavav • March 27, 2008 – MEP raised to $US1100/t • April 1, 2008 – MEP raised to US$1200/t • April 29, 2009 – Export tax of Rs.8000/t (approx. US$200) • January 20, 2009- Tax removed and MEP reduced to US$1100/t • September 2009 – MEP reduced to US$900/t • Feb 2010 – MEP of US$900/t
Wheat	• September 2006: Import tariff was reduced to zero and private sector allowed to import to increase supply in open market • December 2006- duty free imports • **February 2007 – export ban** on wheat and wheat products until end of December 2007. Also banned futures trading in wheat. • October 2007- Feb 2007 ban extended indefinitely • July 3, 2009 – Export quota of 3 million tons through STEs • July 13, 2009 – July 3 quota withdrawn and full export ban re-imposed • May 2010- Export quota of 650,000 t for one year • **September 2011– Ban lifted**

Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.071**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.464**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.158**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
wheatdelhi_r	-3.100	-0.957	2.623	-22.497**	-3.512**	-1.342	-0.783	0.551	1.913
wheatmumbai_r	-2.332	0.448	2.414	-17.341	-2.558	0.683	0.414	0.918	2.691
wheatkolkata_r	-1.835	-1.549	0.236	-8.387	-2.032	-4.456	-1.589	0.168	0.201
wheatpatna_w	-2.863	-2.194	1.321	-18.559*	-3.433*	-5.723	-2.460	0.454	1.170
wheatrewari_w	-2.900	-1.284	1.310	-20.759**	-3.269*	-3.735	-1.200	0.477	0.963
wheatunnao_w	-3.232*	-1.835	1.161	-20.207*	-3.335*	-4.836	-1.698	0.421	0.961
wheatkandla_w	-2.556	-0.130	1.403	-18.117*	-3.139	-4.836	-1.698	0.635	1.117
wheatvisakhapatnam_w	-2.391	-0.512	2.032	-19.963*	-3.299*	-0.843	-0.311	0.641	1.857
wheattuticorin_w	-2.525	-0.829	2.056	-12.094	-2.467	-0.765	-0.547	0.727	2.273
ricedelhi_r	-2.189	-0.773	1.796	-9.765	-2.212	-0.673	-0.573	0.564	2.151
ricemumbai_r	-1.522	1.479	2.927	-6.923	-1.202	2.131	1.677	1.037	3.429
ricekolkat~r	-2.015	-1.203	1.170	-8.485	-1.896	-1.741	-1.235	0.547	1.477
ricepatna_w	-1.654	-0.170	1.484	-3.949	-1.503	0.646	0.491	0.960	2.224
ricefateha~w	-3.319*	-1.922	0.085	-30.631***	-4.177***	-13.204*	-2.853*	-0.124	-0.086
ricebahrai~w	-2.501	0.164	2.749	-13.915	-2.941	0.318	0.345	0.694	3.268
ricekandla_w	-1.689	-0.562	0.982	-80.496***	-7.167***	-26.638***	-3.930***	-0.396	-0.256
ricevisakh~w	-2.602	-0.651	0.360	-4.408	-1.654	-0.324	-0.252	0.878	1.309
ricetutico~w	-2.275	0.685	1.601	-9.721	-1.764	1.513	0.864	1.020	2.457
wheatworld	-2.512	-1.418	0.745	-9.594	-2.007	-2.996	-0.911	0.848	0.967
riceworld	-2.530	-1.625	0.256	-10.754	-2.326	-4.870	-1.542	0.253	0.239

Continued Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.071**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.464**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.158**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
rain_delhi	-5.519***	-5.567***	-2.489**	-42.012***	-5.139***	-42.036***	-5.187***	-29.709***	-3.964***
rain_mumbai	-6.386***	-6.112***	-3.019***	-33.644***	-4.438***	-32.510***	-4.367***	-19.051***	-3.151***
rain_kolkata	-7.448***	-7.494***	-2.384**	-30.612***	-4.151***	-30.590***	-4.172***	-16.065***	-2.853***
rain_patna	-6.476***	-6.510***	-2.819***	-29.648***	-4.155***	-29.569***	-4.173***	-20.359***	-3.264***
rain_rewari	-5.284***	-5.330***	-2.405**	-40.631***	-5.030***	-40.651***	-5.078***	-28.562***	-3.873***
rain_unnao	-6.624***	-6.674***	-2.883***	-29.774***	-4.124***	-29.566***	-4.133***	-21.433***	-3.283***
rain_kandla	-5.696***	-5.522***	-3.573***	-38.043***	-4.994***	-36.664***	-4.879***	-27.689***	-4.011***
rain_visakhapatnam	-5.499***	-5.430***	-1.893*	-36.077***	-4.655***	-36.019***	-4.681***	-15.704***	-2.830***
rain_tuticorin	-5.393***	-5.334***	-1.797*	-44.857***	-5.777***	-44.974***	-5.810***	-23.305***	-3.676***
rain_fatehabad	-5.284***	-5.330***	-2.405**	-40.631***	-5.030***	-40.651***	-5.078***	-28.562***	-3.873***
rain_bahraich	-6.624***	-6.674***	-2.883***	-29.774***	-4.124***	-29.566***	-4.133***	-21.433***	-3.283***
wheatexport_value	4.972	5.396	5.713	15.105	4.009	17.655	5.065	18.290	5.579
ricenonbasmatiexport_value	0.442	0.542	1.150	-2.922	-0.671	-1.801	-0.411	1.614	0.523
ricemsp	-2.360	0.201	2.285	-9.777	-2.530	0.136	0.122	0.651	2.364
ricecip	-2.364	-2.295*	-1.008	-9.646	-2.263	-7.254	-2.089	-0.453	-1.025
wheatmsp	-2.120	-0.244	1.918	-9.636	-2.831	-0.313	-0.252	0.575	1.991
wheatcip	-2.360	-2.368	-0.242	-10.831	-2.344	-10.747	-2.346	-0.071	-0.249
petroleum price	-2.875	-1.782	0.498	-14.151	-2.652	-7.373	-1.892	0.280	0.218

Continued Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.071**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.464**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.158**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
lnwheatdelhi_r	-2.594	-1.588	2.748	-15.143	-2.846	-1.788	-1.112	0.086	2.082
lnwheatmumbai_r	-2.708	-0.331	2.568	-19.676	-3.149	-0.742	-0.487	0.102	2.748
lnwheatkolkata_r	-1.830	-1.523	0.790	-8.360	-2.021	-3.918	-1.512	0.086	0.789
lnwheatpatna_w	-3.043	-2.730*	1.678	-17.051	-3.693**	-6.845	-3.207**	0.102	1.737
lnwheatrewari_w	-2.864	-1.610	1.537	-19.312*	-3.187*	-3.806	-1.302	0.080	1.112
lnwheatunnao_w	-3.050	-2.168	1.505	-16.250	-3.003	-4.637	-1.791	0.081	1.287
lnwheatkandla_w	-2.730	-0.333	1.456	-20.730**	-3.520**	-1.328	-0.508	0.085	1.077
lnwheatvisakhapatnam_w	-2.840	-1.084	2.284	-23.591**	-3.594**	-1.584	-1.002	0.099	2.135
lnwheattuticorin_w	-2.311	-1.595	2.275	-7.234	-1.927	-1.315	-1.088	0.112	2.667
lnricedelhi_r	-1.802	-1.035	1.993	-6.873	-1.759	-0.864	-0.787	0.085	2.448
lnricemumbai_r	-2.055	0.709	3.015	-11.204	-2.152	0.880	0.874	0.121	3.613
lnricekolkat~r	-1.898	-1.446	1.558	-7.705	-1.803	-2.174	-1.599	0.107	2.022
lnricepatna_w	-1.906	-0.482	1.677	-5.790	-1.809	0.101	0.068	0.125	1.946
lnricefateha~w	-3.501**	-1.917	0.502	-34.963***	-4.258***	-13.362*	-2.638*	0.093	0.436
lnricebahrai~w	-1.998	-0.356	2.588	-10.718	-2.475	-0.094	-0.102	0.105	3.213
lnricekandla_w	-1.808	-0.663	1.267	-84.993***	-7.468***	-27.960***	-4.046***	0.109	0.706
lnricevisakh~w	-2.352	-0.462	0.804	-4.454	-1.615	-0.706	-0.470	0.171	1.283
lnricetutico~w	-2.548	0.081	1.804	-9.785	-2.138	0.376	0.254	0.122	2.383
lnwheatworld	-2.700	-1.839	1.126	-9.231	-2.095	-3.504	-1.200	0.146	1.217
lnriceworld	-2.497	-1.569	0.831	-9.101	-2.126	-3.587	-1.365	0.115	0.893

Continued Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.071**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.464**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.158**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
lnrain_delhi	-5.781***	-5.627***	-2.031**	-47.688***	-5.635***	-47.380***	-5.655***	-21.199***	-3.390***
lnrain_mumbai	-6.914***	-6.942***	-2.087**	-33.582***	-4.345***	-33.674***	-4.356***	-13.612***	-2.576**
lnrain_kolkata	-7.844***	-7.904***	-1.101	-30.830***	-4.105***	-30.831***	-4.125***	-4.569	-1.433
lnrain_patna	-8.021***	-8.084***	-1.976**	-30.850***	-4.105***	-30.835***	-4.121***	-11.793**	-2.392**
lnrain_rewari	-5.314***	-5.177***	-1.923**	-43.427***	-5.306***	-43.129***	-5.332***	-18.923***	-3.180***
lnrain_unnao	-6.050***	-6.094***	-1.845*	-31.649***	-4.254***	-31.635***	-4.277***	-13.223**	-2.547**
lnrain_kandla	-7.116***	-7.149***	-3.715***	-39.361***	-4.890***	-38.915***	-4.875***	-26.924***	-3.807***
lnrain_visakhapatnam	-5.703***	-5.723***	-1.189	-34.892***	-4.571***	-34.832***	-4.603***	-5.671	-1.664*
lnrain_tuticorin	-5.054***	-4.986***	-0.804	-35.777***	-4.793***	-35.703***	-4.823***	-3.224	-1.278
lnrain_fatehabad	-5.314***	-5.177***	-1.923**	-43.427***	-5.306***	-43.129***	-5.332***	-18.923***	-3.180***
lnrain_bahraich	-6.050***	-6.094***	-1.845*	-31.649***	-4.254***	-31.635***	-4.277***	-13.223**	-2.547**
lnwheatexport_value	-0.978	-1.058	-1.113	-23.771**	-3.571**	-24.267***	-3.596***	-24.201***	-3.617***
lnricenonbasmatiexport_value	-0.163	-0.813	0.180	-2.530	-0.785	-3.693	-1.156	0.132	0.161
lnricemsp	-2.270	-0.082	2.241	-10.104	-2.502	-0.129	-0.111	0.099	2.300
lnricecip	-2.394	-2.321	-0.721	-10.025	-2.300	-7.827	-2.133	-0.056	-0.742
lnwheatmsp	-1.957	-0.423	2.004	-9.277	-2.272	-0.498	-0.404	0.091	2.060
lnwheatcip	-2.380	-2.390	-0.125	-10.964	-2.360	-10.884	-2.363	-0.006	-0.129
lnpetroleum price	-3.227*	-2.225	0.910	-13.394	-2.684	-7.112	-2.083	0.260	0.896

Continued Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.071**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.464**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.158**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
dlnwheatdelhi_r	-5.102***	-4.992***	-4.039***	-49.422***	-6.532***	-49.722***	-6.622***	-52.214***	-6.465***
dlnwheatmumbai_r	-4.412***	-4.471***	-3.474***	-67.408***	-8.245***	-67.378***	-8.298***	-69.823***	-7.882***
dlnwheatkolkata_r	-4.213***	-4.197***	-4.098***	-90.070***	-9.422***	-90.241***	-9.468***	-90.869***	-9.450***
dlnwheatpatna_w	-5.425***	-5.161***	-4.763***	-69.032***	-9.126***	-69.401***	-9.049**	-70.223***	-8.859***
dlnwheatrewari_w	-5.008***	-5.011***	-4.667***	-70.812***	-8.501***	-70.611***	-8.560***	-71.971***	-8.491***
dlnwheatunnao_w	-5.175***	-5.095***	-4.746***	-81.023***	-9.814***	-81.650***	-9.832***	83.506***	-9.674***
dlnwheatkandla_w	-4.434***	-4.366***	-4.107***	-92.583***	-10.786***	-92.419***	-10.689***	93.556***	-10.594***
dlnwheatvisakhapatnam_w	-5.431***	-5.465***	-4.493***	-105.801***	-12.007***	-105.793***	-12.079***	-110.497***	-11.467***
dlnwheattuticorin_w	-3.627**	-3.537***	-2.678***	-65.952***	-7.415***	-66.938***	-7.441***	-68.629***	-6.982***
dlnricedelhi_r	-4.495***	-4.445***	-3.585***	-80.654***	-7.978***	-80.757***	-8.012***	-79.263***	-7.591***
dlnricemumbai_r	-3.587**	-3.512**	-2.062**	-70.135***	-7.961***	-69.737***	-7.881***	-69.315***	-7.172***
dlnricekolkat~r	-3.470**	-3.345**	-2.968***	-75.920***	-7.982***	-75.730***	-7.970***	-74.845***	-7.730***
dlnricepatna_w	-3.305*	-3.326**	-2.860***	-60.421***	-6.729***	-60.312***	-6.716***	-58.774***	-6.494***
dlnricefateha~w	-6.624***	-6.854***	-6.490***	-105.640***	-12.924***	-105.634***	-13.009***	-105.893***	-13.030***
dlnricebahrai~w	-4.060**	-4.088***	-2.931***	-129.915***	-13.115***	-129.907***	-13.174***	-140.571***	-11.903***
dlnricekandla_w	-4.305***	-4.342***	-4.173***	-123.015***	-25.590***	-123.073***	-25.686***	-123.477***	-25.200***
dlnricevisakh~w	-2.760	-2.757*	-2.626***	-83.632***	-8.602***	-84.412***	-8.620***	-84.147***	-8.528***
dlnricetutico~w	-3.049	-3.071**	-2.223**	-70.206***	-7.250***	-69.227***	-7.194***	-67.746***	-6.849***
dlnwheatworld	3.018	-3.052**	-2.840***	-74.081***	-7.882***	-73.889***	-7.923***	-73.890***	-7.835***
dlnriceworld	-3.940**	-3.956***	-3.810***	-38.665***	-5.147***	-38.664***	-5.181***	-38.474***	-5.173***

Continued Appendix Table 2. Unit root tests for all variables used in the Study

	Augmented Dickey-Fuller Test			Phillips-Perron Test					
	including constant and trend	including constant but no trend	excluding both constant and trend	including constant and trend		including constant but no trend		excluding both constant and trend	
				Z(rho)	Z(t)	Z(rho)	Z(t)	Z(rho)	Z(t)
1% critical value	**-4.062**	**-3.53**	**-2.606**	**-27.094**	**-4.06**	**-19.638**	**-3.523**	**-13.228**	**-2.604**
5% critical value	**-3.46**	**-2.901**	**-1.95**	**-20.538**	**-3.459**	**-13.628**	**-2.897**	**-7.864**	**-1.95**
10% critical value	**-3.156**	**-2.586**	**-1.61**	**-17.374**	**-3.155**	**-10.946**	**-2.584**	**-5.582**	**-1.61**
dlnrain_delhi	-5.182***	-5.216***	-5.250***	-109.108***	-14.152***	-109.077***	-14.204***	-89.960***	-9.945***
dlnrain_mumbai	-6.495***	-6.505***	-6.541***	-89.658***	-9.848***	-89.959***	-9.885***	-89.960***	-9.945***
dlnrain_kolkata	-6.578***	-6.605***	-6.647***	-78.590***	-8.507***	-78.616***	-8.559***	-78.563***	-8.607***
dlnrain_patna	-6.767***	-6.794***	-6.837***	-66.805***	-7.900***	-66.802***	-7.948***	-66.793***	-7.998***
lnrain_rewari	-4.931***	-4.963***	-4.996***	-97.799***	-12.937***	-97.768***	-12.987***	-97.749***	-13.072***
dlnrain_unnao	-5.590***	-5.615***	-5.650***	-74.574***	-9.222***	-74.472***	-9.273***	-74.445***	-9.333***
dlnrain_kandla	-5.397***	-5.404***	-5.435***	-83.481***	-10.594***	-83.851***	-10.625***	-83.872***	-10.669***
dlnrain_visakhapatnam	-5.334***	-5.369***	-5.403***	-88.607***	-10.746***	-88.645***	-10.802***	-88.631***	-10.871***
dlnrain_tuticorin	-5.646***	-5.691***	-5.727***	-72.781***	-10.458***	-88.645***	-10.802***	-72.771***	-10.614***
dlnrain_fatehabad	-4.931***	-4.963***	-4.996***	-97.799***	-12.937***	-97.768***	-12.987***	-97.749***	-13.072***
dlnrain_bahraich	-5.590***	-5.615***	-5.650***	-74.574***	-9.222***	-74.472***	-9.273***	-74.445***	-9.333***
dlnwheatexport_value	-4.431***	-3.849***	-3.860***	-112.127***	-20.099***	-114.227***	-18.664***	-114.276***	-18.748***
dlnricenonbasmatiexport_value	-4.176***	-3.857***	-3.855***	-87.005***	-10.712***	-88.659***	-10.503***	-88.724***	-10.543***
dlnricemsp	-4.391***	-4.386***	-3.629***	-85.872***	-9.880***	-86.159***	-9.900***	-90.000***	-9.434***
dlnricecip	-3.690**	-3.679***	-3.629**	-89.477***	-9.393***	-89.638***	-9.431***	-90.000***	-9.434***
dlnwheatmsp	-4.209***	-4.241***	-3.629***	-86.806***	-9.753***	-86.843***	-9.806***	-90.000***	-9.434***
dlnwheatcip	-3.584**	-3.607***	-3.629***	-89.991***	-9.329***	-89.992***	-9.382***	-90.000***	-9.434***

Ho: unit root is present

Ha: no unit root present or reject Ho: I(0) stationary implies can do VAR levels

Right of critical value on the number line, significant, reject Ho.

Note: Shocks to a stationary series are temporary; thus, the series reverts to its long run means. For non stationary series, shocks resul in permanent moved away from the long run mean of series. Stationary series have a finite variance but not for non stationary. If you accept the null hypothesis, i.e. significant, you conclude that there is unit root. Thus you should first difference the series before procedding with analysis. If you reject the null hypothesis of a unit root, and conclude that the approval series is stationary or I(0); we can do VAR in levels

Appendix Table 3. Lag Order Selection for Wheat Producing and Consuming States

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1464.32				8.50E-25	-32.7264	-32.6362*	-32.5027*
1	1534.63	140.62	64	0	7.4e-25*	-32.8682*	-32.0567	-30.8549
2	1592.22	115.18*	64	0	8.80E-25	-32.7241	-31.1913	-28.9212

Appendix Table 4. Lag Order Selection for Wheat Producing and Exporting States

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1107.45				1.20E-17	-24.7741	-24.7177*	-24.6343*
1	1140.93	66.968	25	0	9.9e-18*	-24.9647	-24.6266	-24.1259
2	1166.16	50.456*	25	0.002	9.90E-18	-24.9699*	-24.35	-23.4319

Appendix Table 5. Lag Order Selection for Wheat Exporting States and World

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	844.914				7.30E-14	-18.8969	-18.8519*	-18.7851*
1	861.03	32.232*	16	0.009	7.3e-14*	-18.8996*	-18.6741	-18.3403
2	870.243	18.426	16	0.3	8.50E-14	-18.747	-18.3413	-17.7404

Appendix Table 6. Lag Order Selection for Rice Producing and Consuming States

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1181.72				1.40E-19	-26.4206	-26.353	-2.63E+01
1	1428.87	494.3	36	0	1.2e-21*	-31.1656*	-30.6922*	-29.9912*
2	1457.94	58.136*	36	0.011	1.40E-21	-31.0098	-30.1307	-28.8288

Appendix Table 7. Lag Order Selection for Rice Producing and Exporting States

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	871.481				1.40E-16	-19.449	-19.3814	-1.93E+01
1	1124.59	506.23*	36	0	1.1e-18*	-24.328*	-23.8546*	-23.1535*
2	1145.33	41.48	36	0.244	1.60E-18	-23.985	-23.1059	-21.804

Appendix Table 8. Lag Order Selection for Rice Exporting States and World

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	621.568				1.10E-11	-13.8779	-13.8328	-1.38E+01
1	671.618	100.1	16	0	5.10E-12	-14.6431	-14.4177*	-14.0839*
2	694.651	46.066*	16	0	4.4e-12*	-14.8011*	-14.3954	-13.7945