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Effects of Export Restrictions on Domestic Market Efficiency: The case of India's Export Ban on Rice and Wheat

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Abstract: The use of export restrictions has substantially increased in recent years. While a number of papers show how these restrictions have increased world commodity prices, in this paper, we empirically estimate how one country's export restrictions affected the efficiency of their domestic market. We use a threshold cointegration model to estimate the integration between selected wheat and rice markets in India before and during the export bans and test whether those bans exacerbated the price effects of domestic production shocks. We find that before the ban, the majority of port markets for rice and wheat are integrated with the world market, while only one pair was afterward. We also find evidence that the ban reduced market integration between producing and consuming regions in India. Further, we find that the ban increased domestic price volatility resulting from domestic supply shocks. Thus, we show that export bans can have domestic costs by reducing domestic market efficiency and increasing domestic price volatility.

Keywords: Export ban, India, International rice and wheat markets, Threshold cointegration.

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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 number of authors explore the effect of export bans on world commodity prices,[1] we empirically estimate how the Indian export ban affected not only the integration between the domestic and world market but the integration within the domestic market itself. Understanding how an export ban affects the efficiency of its own domestic can better inform a country of the true costs and benefits of this blunt trade instrument.

While efforts to improve trade liberalization have substantially reduced import barriers, concern is now turning to the increased use of export restrictions which remain relatively unregulated under the WTO. Over half of the 128 countries subject to the WTO review process used export taxes between 2003 and 2009 and more have used non-tax export restrictions, both for agriculture and other products (Anania 2013). Countries impose export bans to insulate the domestic price from international price volatility and ensure availability in the domestic market at a lower than world price. Between 2007 and 2011, at least 32 countries restricted exports of agricultural products, particularly grains, including Argentina, Cambodia, China, Egypt, Kazakhstan, Pakistan, Russia, Ukraine and Vietnam (Sharma 2011). These export restrictions further increased international rice prices by an estimated 40 percent, and wheat prices by another 29 percent (Martin and Anderson 2012; Anderson 2012). Along with exacerbating the increase in world prices, export bans may have unintended consequences for the domestic market, such as

[1] For example, see Gotz, Glauben and Brummer 2010; Abbott 2010; Liefert Wescott and Wainio 2012; Martin and Anderson 2012; Welton 2011; Djuric Glauben and Goetz 2009 and Djuric Goetc and Glauben 2011; and Von Grebmer et al 2011.

increasing domestic price volatility due to the inability of the world market to mitigate against short run supply shocks and intensifying existing market inefficiencies (Anania, 2013; Welton, 2011). If commodities cannot move freely within the country, export restrictions may increase price differentials and reduce domestic market integration (Porteous, 2012).

For domestic producers to benefit from international trade, markets need to be both open and spatially integrated (Gonzales-Rivera and Helfand, 2001; Asche, Bremnes and Wessells, 1999; Sexton, King and Carmen, 1991; Ravallion, 1986). In a spatially integrated market, prices are determined simultaneously across locations, and large price spreads induce product movement from one location to another (Liu, 2003). In the absence of spatial market integration, price information may be conveyed inaccurately, distorting decisions of economic agents, which could lead to inefficient product movement. Spatial market integration is particularly important for agriculture because areas of production and consumption are generally separated, thus product movement is necessary. Further, most agricultural products are either bulky or perishable, implying product movement is also costly. Thus, spatial market integration is vital for agricultural markets to operate efficiently.

India is a large producer of both rice and wheat, and therefore its export ban was expected to affect markets both inside and outside of the country (Kubo 2011). India is the second largest producer of rice in the world accounting for 20% of world supply and the third largest producer of wheat accounting for 12% of world supply (Cagliarni and Rush, 2011). In terms of consumption, rice is the staple for the eastern and southern parts of the country while wheat is the staple for the northern parts of the country (Cagliarni and Rush, 2011). Because of the important role of these grains in local consumption and household food security, the Indian government has traditionally intervened when domestic markets face large price increases.

Even before the price pressure from global markets, Indian agriculture was highly regulated by production and consumption subsidies, minimum export prices and domestic trade restrictions (Acharya et al., 2002; Kubo, 2011). According to Kubo (2011), given the already limited efficiency of domestic agricultural markets within India, the export ban might have further exacerbated market distortions.

One might expect the impact of the Indian export ban might differ between the two crops. Prior to the 2007 export ban for wheat, the level of wheat exports was already quite low due to India's stagnant wheat yield and declining planted acres from 1996 to 2006. As a result, the Indian government actively imported wheat to slow the rising domestic prices in the wake of a production shortfall and reputed widespread hoarding by traders (Western Australia Trade Office). The government even reduced the import tariff on wheat to zero to encourage the private sector to import wheat. Figure 1 presents imports and exports vis-à-vis wheat production from 1996-2013. One can observe a reversal of trade flows for wheat prior to the ban, raising the question of whether the ban was, in fact, binding. Conversely, rice was actively being exported right up to the moment of the ban.

While many authors have found that market liberalization generally increases market integration (Goleti and Babu, 1994 for Malawi; Dercon, 1995 for Ethiopia; Alexander and Wyeth 1994 for Indonesia), fewer studies consider the domestic market effect of export bans. Welton (2011) explicitly considers the effect of an export ban on domestic prices and price volatility in the case of Russia. Welton (2011) finds that 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 widened the price gap between domestic and world markets, 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 in the short run (Welton, 2011).

Few studies analyze the Indian export ban, and those that do are largely descriptive (Woolverton and Kiawu, 2009; Dorosh, 2009; Slayton, 2009, Abbott, 2010; Martin and Anderson, 2012; Liefert, Westcott and Wainio, 2012; Clarkson and Kulkarmi, 2011). 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. That said, the paper only uses a special reference to the world food crisis of 2007/08 and does not estimate the effect of the ban per se. 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.

In this paper, we ask three research questions: (1) What effect did the Indian export ban have on the integration of domestic markets with the world market? (2) What effect did the export ban have on the integration within the domestic market? (3) Did the export ban worsen the price effects of domestic supply shocks? We see several contributions of our paper. First, 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. Not only do we differentiate between producing states and consuming states, we also consider the major port areas, which we expect to be most affected by an export ban. Given that other authors have found little market integration within India (Mallory and Baylis 2013; Sekhar, 2012), we want to test for integration in those markets most likely to be integrated with world prices. Second, we test for the effects of domestic supply shocks on domestic prices during the export ban period. To our knowledge, this paper is one of the first to econometrically explore the domestic market effect of an export ban.

We begin with a simple model of spatial price transmission modified from Fackler and Goodwin (2001), and derive several testable hypotheses about the effect of the ban. We use a linear vector error correction model as a baseline analysis of spatial market relationships. Then we extend the linear framework by testing for thresholds. Last, we use changes in the timing and amount of rainfall to test the effect of domestic production shocks on domestic prices before and after the ban. As expected, we find that while a majority of port markets for rice and wheat are integrated with the world market before the ban, the majority are no longer integrated with the world market during the export ban. Moreover, price thresholds between port markets and the world market increase during the export ban, implying that transaction costs rose between the two markets when exports were restricted. Second, for rice, the number of port markets that are integrated with domestic consuming markets drops during the export ban. We find the opposite effect for wheat, where a greater number of domestic consuming and port markets are integrated during export restrictions. A plausible reason for this counterintuitive finding is that India actively imported wheat from 1996-2006, linking port and consumer markets. Third, contrary to our expectation, fewer producing and consuming market pairs are integrated during the export ban than before, and more producing and port markets pairs are integrated for both crops. Price thresholds between producing and consuming regions for wheat thresholds switch signs. Thus, a plausible cause for the unanticipated result in wheat is that production even in the supply regions was sufficiently low that they needed to import grains. On the other hand, the decrease in integration between consumer and producer markets and increase in integration between port and producer markets in rice can possibly be explained by active storage. Last, we find evidence that the ban worsened the effect of domestic production shocks.

India's Food Policy and Export Restrictions

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*. In theory, the Food Corporation of India (FCI) and the procurement arms of state governments 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 Ministry of Agriculture 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 reported 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 placed an export ban on wheat (Acharya et al, 2012). [See Figure 2 for the timeline of the wheat policy.] The government also increased the MSP for wheat and began to actively import 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).

India also placed an export ban on non-basmati (ordinary) rice on October 9, 2007 [see Figure 3 for rice policy timeline]. Though the ban was lifted on October 31, 2007, it was replaced with a minimum export price[2] (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, the month prior to the reinstatement of the non-basmati export ban, on March 8, 2008 the government raised the MEP for basmati rice to $950/ton. Several adjustments were made and the restrictive 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, 2011). In July 2010 newspapers reported large amounts of rice and wheat rotting in FCIs storage facilities (Kubo, 2011). 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[3]). Because the export ban imposition was not continuous, in this paper, we focus on the export restrictions period (ER), which started on February 2007 for wheat and October 2007 for rice. As a control, we examine domestic market integration during the open trading period (OT) prior the imposition of the ban. .

[2] 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).

[3] 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

Data

We analyze the domestic impact of the export ban by using weekly data for major markets in producing states, major retail centers in consuming states and markets in major ports cities for rice and wheat, summarized in Table 1a. 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 (Punjab, Uttar Pradesh and Haryana for Wheat; West Bengal, Andrha Pradesh and Uttar Pradesh for Rice). Density maps for major producing states are presented in Appendix Figure 1. We also choose major urban centers for each crop (Delhi, Mumbai and Kolkata for rice and Delhi, Mumbai and Patna for wheat) to take into account the effect of the ban on end consumers. Last, we choose three major ports listed on the 2005 India port report (I-maritime Research). A map of the major ports is presented in Appendix Figure 2. We use weekly prices from the closest markets to these ports.

We use local prices from January 2003 to December 2013 from AgMarkNet,[4] and the Department of Agriculture website.[5] For missing price data, we follow the multiple imputation procedure using the Amelia R Package[6] as in Mallory and Baylis (2013). The percent of missing observations are summarized in Table 1b.

[4] AgMarkNet is the website of the Indian Ministry of Agriculture, http://agmarknet.nic.in/

[5] Retail Price Info System, Directorate of Economics and Statistics, http://rpms.dacnet.nic.in/

[6] http://cran.r-project.org/web/packages/Amelia/citation.html. Amelia performs multiple imputation as a general purpose approach to data with missing values. Multiple imputation has been shown to reduce bias and increase efficiency compared to listwise deletion and mean imputation. List-wise deletion requires one to delete an entire row of data even if only one data point is missing and thus could discard much valuable data. On the other hand, linearly interpolating or using mean conditional distribution can reduce the variance of the resulting sample thereby affecting inference (Friedman, 1962; King at al., 2001). Multiple imputation generates m completed datasets making random draws from the conditional distribution over the missing data. It also allows for smooth time trends and correlations across time and space (Honaker and King, 2010). The m completed datasets are the same for the observed data points, but the missing data are replaced by draws from the posterior density and hence incorporate the relevant level of uncertainty associated with those data points. Detailed graphs for observed and imputed values from Amelia are presented in Appendix Figure 3.

To analyze price transmission from international to domestic markets, we use the weekly world price for rice (Thai rice 5% broken[7]) and wheat (US, No. 2 HRW wheat) from FAO Economic and Social Division.[8] Using the prevailing Indian Rupee-ME $ exchange rate from the Oanda weekly average exchange rates[9], world prices were converted to Indian Rupee per kilo equivalents. The weekly nominal price series were logarithmically transformed.

We include rainfall data from the Indian Department of Meteorology for years 2005-2013 and Central Statistical Organization for years 2003 and 2004 to accommodate induced supply shocks in our analysis. Table 2 below summarizes the variables used, summary statistics and data sources. Figures 4-9 depict monthly domestic price movements for the selected markets in Table 1 vis-à-vis world price and export quantities.

Conceptual Model

We use 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 port 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.

[7] Thai rice positively correlates with Vietnam rice prices. Overall sample correlation is 95.41% and correlation during the export restriction period is 90.86%.
[8] Food and Agriculture Organization (FAO). 2013. Economic and Social Development Statistics Division, http://www.fao.org/es/esc/prices
[9] Oanda Average Exchange Rates, http//www.oanda.com/currency/average

We follow Porteous (2012) and model export ban as an increase in trade cost. Our focus is on price differences rather than prices themselves in analyzing the mechanics of how these policies actually affect agricultural markets while avoiding potential endogeneity issues. Drawing on the spatial price analysis literature, we develop a theoretical model to show how export bans affect the total trade costs (unobservables) and how total trade costs determine price differences (observables) across different markets. We argue that the timing of the export ban is plausibly exogenous to price differences. The Indian grain market landscape is illustrated in Figure 10.

A trader in a producing region can chose to sell to the domestic market or to the port market, where he will receive P_c less per unit domestic transaction costs τ_d, or P_x less per unit transaction costs τ_d, respectively. The trader in a producing region will chose quantities to sell to each market to maximize their profit:

$$\Pi(q_{ct}, q_{xt}) = P_{c,t+k} q_{ct} + P_{x,t+j} q_{xt} - \tau_d q_{ct} - \tau_d q_{xt} \quad (1)$$

where q_{ct} is the quantity sold in the domestic market and q_{xt} is the quantity sold in the port market at time t and $P_{i,t+k}$ is the price received upon delivery in market i, k periods after t.

On the other hand, a trader in an port region can chose to sell to the domestic market or to the world market, where he will receive P_x less per unit domestic transaction costs τ_d, or P_w less per unit transaction costs $\tau_d + \tau_w$, respectively. The trader in a port region will chose quantities to sell to each market to maximize their expected profit:

$$\Pi(q_{ct}, q_{wt}) = P_{c,t+k} q_{ct} + P_{w,t+j} q_{wt} - \tau_d q_{ct} - (\tau_d + \tau_w) q_{wt} \quad (2)$$

where q_{ct} is the quantity sold in the port market and q_{wt} is the quantity sold in the world market at time t and $P_{i,t+k}$ is the price received upon delivery in market i, k periods after t.

Taking first order conditions, the trader will chose the quantities to sell by equalizing the marginal profit in each market. In general, for any market pair, *a* and *b*, they will set the expected difference in discounted prices net of transaction costs to zero:

$$E_t = \{P_{a,t+k} - P_{b,t+j} + \tau_{a \to b}\} = 0 \tag{3}$$

where $\tau_{a \to b}$ is the total trade cost of moving the good from market *a* to *b*. The above relation implies that the difference in the prices for two markets is simply the cost of transporting the good (Fackler and Goodwin, 2001). The relationship in equation (3) relates to the Law of One Price model, which postulates that allowing for transporting cost τ, transporting commodity between two markets, the relationship between the prices is as follows:

$$P_{bt} = P_{at} + \tau \tag{4}$$

Following Baulch (1997) and Barrett and Li (2002), we recognize that there may be different possible trading regimes and/or discontinuities based on relative magnitude of actual observed price difference, unobserved trade costs and domestic shocks. For any two market pairs, *a* and *b,* trading regimes are illustrated in equation (5).

$$P_{bt} - P_{at} = \tau + \varepsilon \begin{cases} \text{Case 1: } P_{bt} - P_{at} = \tau + \varepsilon & \textbf{Perfect Integration} \\ \text{Case 2: } P_{bt} - P_{at} < \tau + \varepsilon & \textbf{No incentive to trade} \\ \text{Case 3: } P_{bt} - P_{at} > \tau + \varepsilon & \textbf{Incentive to trade} \end{cases} \tag{5}$$

In case 1, markets exhibit perfect market integration. In other words, the grain is tradable between two markets and the price differential increases one for one with an increase in trade costs.

In case 2, there is no incentive to trade because the price difference between the markets is smaller than the trade costs. In this case, prices are determined by local supply and demand, and price differences are unaffected by changes in trade costs. In case 3, the price difference is greater than the trade cost, thus it signals positive marginal profits to spatial arbitrage. For cases 1 and 3, the relationship between the trade costs and price differences is straightforward. 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 $(\varepsilon > 0 \text{ or } \varepsilon < 0)$. In case 2, when there is no incentive to trade, price movements between markets and within the transaction cost may be unrelated. In other words, the markets will not be integrated.

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). Therefore, we expect the primary effect of the export ban to be reflected in prices at the port, where P_x should drop by the change in τ_w. Thus, the export ban increases the price difference between the world and the domestic markets. Given that prices include a stochastic component, this increased price wedge may lead to lack of market integration between world market and port markets. From this discussion, we obtain our first hypothesis.

Hypothesis 1: *Fewer world and domestic market pairs exhibit integration during the export ban. Further, if the market pair exhibits threshold integration before and after the ban, the threshold will be larger when export ban is in place than when it is not in place.*

Next, we explore how the ban might differentially affect prices within India. Assume that grain movement takes time, and that at the moment the export ban was imposed, some grain is sitting at port. The value of this stored grain is determined by the world price less the cost of exporting, $P_w - \tau_w$, and therefore the value of stored grain 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 less the domestic cost of moving grain is higher than the discounted expected future world price less future export cost. Thus, the grain will only move if:

$$E\left(P_{c,t} - \tau_d\right) \geq \delta^k E\left(P_{w,t+k} - \tau_{w,t+k}\right) \tag{6}$$

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 ban to be lifted in the near future. At a minimum, the price in the consuming region has to be τ_d higher than the discounted expected price at the port, $\delta^k E(P_x)$ 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'. Moreover, if τ_d is low enough to cause an influx of supply in the domestic consuming market, we expect it to drive down P_c, but perhaps not to the same degree as it affects prices in the port market, P_x. Thus, the export ban increases the price difference between the port markets and domestic consuming markets, which will result in their lack of market integration.

Hypothesis 2: *Fewer port markets and domestic consuming market pairs will be integrated during the export ban. Further, if the market pair exhibits threshold integration before and after the ban, the threshold will be larger after the export ban is put in place.*

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.

Hypothesis 3: *When the export ban is in place, more producing and consuming market pairs will be integrated, and less producing markets and port markets will be integrated. For market pairs which exhibit threshold integration before and after the ban, the threshold between producing and consuming market pairs will be smaller and the threshold between producing and port markets will be larger after the export ban is in place.*

Last, production shocks will affect Ps, but if excess production can no longer be exported, one might anticipate that the resulting price shocks are larger after the export ban.

Hypothesis 4: *When the export ban is in place, more domestic producing and consuming markets will have significant domestic production shocks coefficients than when it is not in place.*

The amount of rainfall is significantly correlated with agricultural production in India (Cagliarni and Rush, 2011) as seen in Figure 11. Gulati et al. (2013) and Bhattacharya and Kar (2011), both emphasize domestic supply shocks through droughts and deficient rainfalls as one of the most important variables affecting food price inflation in India. Thus, we use rainfall as our measure of production shock.

Methods

The estimation strategy can be summarized as follows: First, because the paper aims to test for impacts of the export ban and the export ban was not continuous, we divide the data into the OT and ER periods. We call it export restrictions period to take into account other trade policy changes during the export ban period (i.e. wheat export quotas for month of July 2009 and rice minimum export prices for months of November 2008-March 2009). On the other hand, the open trade period covers the weeks prior to the imposition of the ban.[10] However, for wheat, since

[10] The post-ban period is too small to allow empirical analysis.

exports are significantly reduced even before the export ban was in place, we redefine export restrictions period as "effective" export restrictions period. So that open trade period for wheat includes weeks in between January 2003 to July 2005 and export restrictions period includes weeks in between August 2005 to August 2011. On the other hand, open trade period for rice includes weeks in between January 2003 to September 2007 and export restrictions period includes weeks in between October 2007 to August 2011. These cutoffs are based on timeline of export restrictions based on several publications and compilation of news articles (Appendix 1) and what we deem is the "effective" export restrictions period for wheat (Figure 1 and Appendix Table 3).

We next generate all possible market pairs for each crop (producing and consuming market pairs, producing and port market pairs, port and consuming market pairs, and port and world market pairs). The pairing results into 30 market pairs per crop. Then we perform both the linear and threshold cointegration tests for each market pair and report the number of market pairs that were cointegrated to synthesize the results from over 100 cointegration tests. In addition, we compare the thresholds estimates for market pairs which exhibit thresholds in both periods.

Finally, we compare the coefficients' significance of domestic production shock effects for ER and OT periods. Similar to integration results, we synthesize the result by reporting the number of producing and consuming markets with significant domestic supply shock effects.

Domestic Market Integration

We test our first, second and third hypotheses using a market integration framework. To determine whether the market price series are stationary, standard Augmented Dickey-Fuller (ADF) unit root tests are used. We test for linear cointegration between markets price pairs using the Johansen cointegration model. The tests were carried out for all possible market pairs.

Let $p_t = (p_1, p_2)'$ be a two-dimensional vector of price series for a price pair p_1 and p_2 The linear Vector Error Correction Model (VECM) of order l+1 can be written as follows:

$$\Delta p_t = \mu + \alpha w_{t-1} + \sum_{i=1}^{l} \Gamma_i \Delta p_{t-i} + u_t \qquad (8)$$

where $E_{t-1}(u_t) = 0$. The long run relationship is defined as

$$w_t = (1 - \beta) p_t = p_1 - \beta p_2 \qquad (9)$$

which is stationary as discussed by Engle and Granger (1987). The term w_{t-1} represents the error correction term obtained from the estimated long-term relationship between the two price series. If β = 1, the long run relationship implies a one-to-one responses between the two price series. We use the Johansen test to test the null hypothesis that there are at most *r* cointegration vectors in the system.

The concept of threshold cointegration was introduced by Balke and Fomby (1997) as a way of combining cointegration and non-linearity. In this paper, we use Hansen and Seo's (2002) bivariate two-regime, threshold vector error-correction model (TVECM) to test for non-linear cointegration among all market pairs. The two-regime TVECM allows one to characterize an environment in which trade between spatially separated markets only occurs when relative prices exceed some level of transaction costs. As in equation (5), trading regimes occur based on the relative magnitude of actual observed price differences and unobserved trade costs.

The representation of the VECM with a two-regime threshold is given as:

$$\Delta p_t = \begin{cases} \mu_1 + \alpha_1 w_{t-1} + \sum_{i=1}^{l} \Gamma_{1i} \Delta p_{t-i} + u_t & \text{if} \quad \mathrm{w}_{t-1} \le \hat{\tau} \\ \mu_2 + \alpha_2 w_{t-1} + \sum_{i=1}^{l} \Gamma_{2i} \Delta p_{t-i} + u_t & \text{if} \quad \mathrm{w}_{t-1} > \hat{\tau} \end{cases} \qquad (10)$$

The coefficients α_1 and α_2 relates to the dynamics in the regimes. Values of the error correction term w_{t-1} could either be above or below the threshold parameter, $\hat{\tau}$. Except for the cointegrating parameter β, the system allows all coefficients including w_{t-1} to switch between the regimes.

Threshold effect exists if $0 < P\left(w_{t-1} \le |\tau|\right) \le 1$, otherwise a linear cointegration model is more fitting. This constraint is imposed assuming that $\pi_0 < P\left(w_{t-1(\beta)} \le |\tau|\right) \le (1 - \pi_0)$ by setting $\pi_0 > 0$ as a trimming parameter equal to 0.05 in the empirical estimation. This value follows Hansen and Seo (2002) which implies that each regime is restricted to contain at least 5% of the observations. Assuming the errors, u_t, are iid Gaussian, the model is estimated by maximum likelihood.

A grid search algorithm is used to obtain MLE estimates of β **and** τ (Hansen and Seo, 2002). The grid search requires a region over which to search. Thus, two confidence intervals, $[\tau_L, \tau_U]$ and $[\beta_L, \beta_U]$, are constructed for τ **and** β respectively. Notation *L* and *U* represent lower and upper values. The grid search procedure over (τ, β) examines all pairs (τ, β) on the grids $[\tau_L, \tau_U]$ and $[\beta_L, \beta_U]$ subject to constraint $\pi_0 \le P\left(w_{t-1} \le \tau\right) \le 1 - \pi_0$. In the empirical application the grid search procedure is carried out with 300 grid points as in Hansen and Seo (2002).

Once β and τ have been estimated, we proceed to test for the presence of threshold cointegration using the Lagrange multiplier (supLM) test provided by Hansen and Seo (2002) where the null hypothesis of linear cointegration is tested against the alternative of threshold cointegration. We also use the Sup-Wald test by Seo (2006), where the null hypothesis of no cointegration is tested against threshold cointegration using a bootstraped distribution.

Domestic Production Shocks

Similar to Loening at al. (2009), we use a high-frequency rainfall data transformation as a direct proxy for agricultural supply. Food crop agriculture in India is overwhelmingly rainfed so that conditional on planting decisions, yield variation is high and dependent on rainfall variation. .

To test our fourth hypothesis (i.e. domestic production supply shocks have more effect on prices in the production and domestic consumption regions during export restrictions period), we model rainfall variable as an exogenous variable in a Vector Autoregression (VAR) of all domestic prices.

The choice between VECM and VAR lies in the research question we hope to answer. The foremost advantage of VECM is that it has nice interpretation with long term and short term equations. Thus, VECM is mostly used for cointegration analysis. On the other hand, VAR is commonly used for analyzing the dynamic impact of random disturbances on the system of variables (Enders, 2010). Thus, while we use VECM to test my first three hypotheses, we use VAR to test my fourth hypothesis.[11]

[11] In Dave Giles blog on how to effectively randomize the choice of a VAR or VECM model, he finds that the practice of pretesting for cointegration can result in severe overrejections of the noncausal null, whereas overfitting results in better control of the Type I error probability with often little loss in power." (Clarke & Mirza, 2006, p.207.) Thus, he suggests in some cases, VAR is preferred over VECM in testing for causality.

Diagnostic Tests

We first test for the order of integration. We apply a number of tests, namely the Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979) and the $Zt - Z\rho$ tests by Phillips and Perron (1988).[12] Table 3 presents the summary results of the unit root tests. The unit root statistics for all variables and both their levels and differences are presented in Appendix Table 2 (one test includes a constant and trend, one includes a constant but no trend and one 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 lags of the differenced terms in the regression and we the Akaike Information Criteria (AIC) to choose the appropriate lag length. 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, both tests reject the null, indicating that all the price series have unit roots.

Knowing that the variables are integrated to the same order, we can proceed with Johansen's cointegration tests to find cointegrating vectors that posit non-spurious long-run relationships among variables. Lag order for the test for each market pair were chosen by Akaike Information Criteria. But we also perform Lagrange multiplier test for autocorrelation and chose the lag that was sufficient to eliminate autocorrelation in the residuals. Results are presented in Tables 4a and 4b.

[12] 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).

Results

We summarize the results of Johansen's cointegration tests as the number of market pairs that are cointegrated for each pair type and crop in Table 5a and then list the integrated market pairs in Table 5b. More detailed results are in Appendix Table 4. For example, in Table 5a, the first row of the second column means 0 of the 9 possible market pairs for producing and consuming regions are cointegrated during the export restrictions period.

Finding linear cointegration is supportive of the law of one price model, as in equation 4. On the other hand, finding threshold cointegration as opposed to linear cointegration is supportive of the segmented equilibrium model, as in equation 5. Lo and Zivot (2001) and Taylor (2001) suggest that linear modeling may induce misleading conclusions regarding cointegration if the data generating mechanism is not linear. Thus, we test for both linear and non-linear cointegration for both regimes and make cointegration conclusions based on the preferred model using the Hansen and Seo test (2002) and the Seo test (2006).

Results from the cointegration tests show that fewer port markets are integrated with the world market during the export restriction period than the open trade period (Table 5a's first row for each crop). This finding is consistent with the Hypothesis 1, i.e. that the export ban is likely to result in less integration between port markets and world markets.

Hypothesis 2 posits that the export ban results in a lack of market integration between the port markets and the domestic consuming markets. We find that the hypothesis holds for rice but not wheat (table 5a).

Faced with an export ban a rice trader has two choices: (1) store grain stocks that are already at the port in anticipation of the ban being lifted which leads to leads to less integration or

(2) move the grain back to the interior to sell to domestic markets, which could still manifest in integrated markets but with relative prices favoring grain flow in the other direction. If grain movement takes time and prices are uncertain, the export ban may make domestic market prices more ‘sticky’. Thus, the export ban could possibly increase the price difference between the port markets and domestic consuming markets, which will result in their lack of market integration.

A plausible reason for the contrary effect on wheat (more producing and port market pairs exhibit integration) is that grain movement flowed in the opposite direction with India’s active wheat importation. From 1996-2006, India’s wheat yield remained stagnant and planted acres steadily declined (www.indexmundi.com). As a result, wheat production lagged behind consumption from 2001-2006, resulting in beginning stocks dropping from a record 23.0 metric million tons in 2002/2003, to a 40 year low of 2.0 MMT by 2006 (Western Australia Trade Office).[13] In February 2006, the Indian government announced a decision to import wheat to arrest rising domestic prices in the wake of a production shortfall and widespread hoarding by traders (Western Australia Trade Office). Examining the relative prices show that wheat prices in the main Indian consuming regions are higher than the wheat world prices during the export restriction period. On average, wheat world price during export restrictions period is 11.70 Rs/kilo while average prices in Delhi, Mumbai and Patna are 14.82, 19.12 and 15.57, respectively.

Finally, we find that fewer producing and consuming market pairs and more producing and port market pairs are integrated during the export restrictions period (see the first two rows of Table 5). This result is contrary to our third hypothesis

[13] Western Australia Trade Office. January 2012. India Wheat Market Report. http://www.dsd.wa.gov.au/documents/India_Wheat_Market_Report_January_2012.pdf

A plausible explanation for the counterintuitive finding in rice is that since rice is a storable grain and the export ban was not instituted continuously, traders may have continued to move rice to the port despite the ban being in place in anticipation of port markets opening up. Examining the price differences between rice world market and rice consuming markets during the export restrictions period reveal a substantial difference in favor of the world prices. Thus, storage is a plausible story for rice. However, because wheat is being imported during the export restrictions period, wheat warrants more discussion by examining thresholds and relative prices.

Threshold Cointegration Results

To further assess our hypotheses, we analyze the threshold cointegration results by comparing the estimated threshold parameters before and after the ban. The estimated beta from the cointegrating vector, estimated thresholds, and proportion of weeks when there is incentive to trade consistent with the conceptual model and equation 5 are presented in Table 6. The proportion of weeks in which there is incentive to trade was determined by counting the proportion of observations for which $\beta * P_{bt} - P_{at} > \tau$, where b is the destination market and a is origin market.

For instance, in Table 6a's first row, for a rice producing and consuming market pair, Burdwan and Delhi, the estimated beta from the cointegrating vector is 1.27 during the export restrictions period. There is no estimated threshold and thus no estimated proportion of weeks when there is incentive to trade during the export restrictions period since a linear model was preferred in this case.

During the open trade period, the beta from Burdwan and Delhi's estimated cointegrating vector is 0.89 with a threshold of -1.70. The proportion of weeks in which there is incentive to trade was determined by counting the proportion of observations for which ($0.89 \times P_{Delhi}$-$P_{Burdwan}$>-1.70), or 93%. The highlighted market pairs in Table 6 are those for which the threshold model is preferred to the linear model in both the ER and OT periods.

The sign on the threshold parameter provides some intuition as to the direction of trade flows between markets, particularly when the sign reverses between the open trade period and the export restriction period. In table 6, say for Ludhiana and Delhi for wheat, during the export restrictions period, the estimated threshold is -1.64 and the estimated cointegrating relationship is $w_t = P_{delhi} - 0.66 \times P_{ludhiana}$. The sign of the threshold has switched from positive in the open trade regime to negative in the export restriction regime, suggesting that the incentive for grain to flow from Ludhiana to Delhi in the open trade period was reversed in the export restriction period. Here, 92% of the total observations occur when 0.66 times the market price in Ludhiana is more than 1.64 above the price in Delhi. In these cases, there are incentives for grain to flow are from Delhi to Ludhiana, (column 5 of table 6b). Conversely, 8% of the total observations occur when 0.66 times the market price in Ludhiana is more than 1.64 below the price in Delhi. This is the case where incentives are for grain to flow from Ludhiana to Delhi.

Hypothesis 1 states that for port and world market pairs where the threshold model was preferred to the linear model, the threshold would be larger in the export restriction regime than in the open trade regime. We find evidence in support of this hypothesis for one of the market pairs. The other market pairs either did not favor a threshold specification in one of the periods, or the estimated threshold was larger in the open trade regime. The evidence for the wheat market pair, Kachch and World is in table 4.6b. The threshold during the export restrictions period was larger than the threshold during the open trade period, which implies that the transaction cost between the two markets is higher during the export restrictions period. Consistent with increased transactions costs, we find that the proportion of weeks in which the relative prices indicate a possible incentive to trade between Kachch and world market is also higher in the open trade period than export restrictions period.

Hypothesis 2 could not be explored via the threshold models because none of the port and consuming market pairs for either crop exhibited thresholds both before and after the ban.

Hypothesis 3 states that for market pairs which exhibit threshold integration before and after the ban, the threshold between producing and consuming market pairs will be smaller during the ban and the threshold between producing and port markets will be larger during the ban than when it is not in place. As expected, in the case of rice, thresholds increased between producing and port markets during the export restriction period. While in the case of wheat, thresholds decreased between producing and consuming market pairs during the export restriction regime. Note also that the threshold sign for wheat during the export restrictions regime is negative.

The negative sign on the wheat threshold indicates that production may have been sufficiently low that even producing regions needed to import grains. This importation into producing regions could have plausibly led to more price integration between port and producing regions.

Robustness Tests

One might be concerned that the results of number of significant market pairs are driven by the nature of the imputed data. As a robustness check we look at market pairs with fewer missing observations as in Table 1b, and find that thresholds exist in those pairs in much more frequency. For instance, during the ER period for rice, there were three market pairs which exhibit threshold integration, namely Mumbai-Burdwan, Mangalore-Bijnaur, Vadodara-Bijnaur. In all the three market pairs in the ER period for rice, the percentage of missing data range from 2.48% to 16.83%. For wheat during the ER period, with the exception of Kachch-World market pair, the market pairs exhibiting thresholds are those pairs with less imputation. We find the same story for both crops during the OT period. Thus we observe similar results even when we restrict our sample to those pairs with less imputation.

Another concern is the fact that our port markets are themselves consumer markets. While we find that some of the counterintuitive results come from those pseudo port markets (proxy cities) that happen to have large domestic populations and therefore can be thought of as consuming markets (i.e. Mysore-World during OT period and Kachch-World during ER period), results from the other market pairs were consistent with our earlier findings.

Results of Domestic Production Shocks

Increased price differences might be worsened due to the inability of the world market to mitigate against domestic supply shocks. We test for the impacts of short run supply shocks on the market prices and find that domestic supply shock effects in prices are mostly felt in producing and consuming states during ER period as compared to OT. A summary of results is reported in Table 7. We find that the results for both crops are consistent with the hypothesis.

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 increase the supply of wheat and rice on the domestic market.

We find evidence that the export bans did reduce the connection between the domestic and world market. Countries normally impose export bans to insulate the domestic market from international price volatility and ensure availability in the domestic market at a lower than world price. While one might anticipate that the export ban would create stronger market ties within India, we find the converse to hold. Domestic producer and consumer markets were less integrated for both rice and wheat during the export ban. This result indicates that the ban may have exacerbated existing market rigidities within India. Plausible explanations include active role of storage in the case of rice, the export ban not being instituted continuously coupled with domestic production shocks. For wheat, India actually imported grain during this period, increasing the integration between ports and consumer markets, but decoupling producing and consuming regions. Finally, we find that the export ban may have exacerbated the price volatility for both rice and wheat arising from domestic supply shocks. Thus, the export ban in India, similar to the Russian export ban on wheat, may have had unintended consequences of increasing domestic price volatility.

Since the decisions to use these blunt instruments are taken by domestic governments worldwide, we believe that it is useful to know if and how government market interventions affect market integration and thus the efficiency of domestic markets. Moreover, studying the domestic effect of these policies has the potential to affect the use of these policies by other countries in the future.

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Tables

Table 1a Selected Markets for Rice and Wheat

Commodity	Primary Wholesale/Producing Markets	Primary Retail/Consuming Markets	Major Ports
Rice	Burdwan, West Bengal[1] West Godavari, Andrha Pradesh[1] Bijnaur, Uttar Pradesh[1]	Delhi, Delhi[2] Kolkata, West Bengal[2] Mumbai, Maharashtra[2]	Managalore, Karnataka[1] Ernakulam, Kerala[1] Vadodara, Gujarat[1]
Wheat	Unnao, Uttar Pradesh[1] Ludhiana, Punjab[1] Gurgaon, Haryana[1]	Delhi, Delhi[2] Patna, Bihar[2] Mumbai, Maharashtra[2]	Kachch, Gujarat[1] Mysore, Karnataka[1] Malda, West Bengal[1]
Source: 1-Agmarknet; 2-Department of Agriculture			

Table 1b Percentage of Missing Observations for Selected Markets

Market Type	Market	% Missing Obs (OT Period)	% Missing Obs (ER Period)
Rice Producing Markets	Burdwan, West Bengal	4.91%	4.95%
	West Godavari, Andrha Pradesh	47.68%	17.52%
	Bijnaur, Uttar Pradesh	21.68%	2.97%
Rice Consuming Markets	Delhi, Delhi	27.50%	20.69%
	Kolkata, West Bengal	11.61%	12.87%
	Mumbai, Maharashtra	17.50%	16.83%
Rice Major Ports	Mangalore, Karnataka	19.20%	4.95%
	Ernakulam, Kerala	5.80%	11.39%
	Vadodara, Gujarat	20.98%	2.48%
Wheat Producing Markets	Unnao, Uttar Pradesh	4.63%	0.91%
	Ludhiana, Punjab	25.93%	12.27%
	Gurgaon, Haryana	29.72%	24.09%
Wheat Consuming Markets	Delhi, Delhi	1.39%	1.36%
	Patna, Bihar	12.96%	0.91%
	Mumbai, Maharashtra	19.81%	16.82%
Wheat Major Ports	Kachch, Gujarat	5.09%	30.45%
	Mysore, Karnataka	6.94%	9.55%
	Malda, West Bengal	17.13%	35.45%

Table 2 Summary Statistics of Variables Used, Units and Sources

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Rice Producing Market, Wholesale Prices							
Bijnaur, Uttar Pradesh	528	13.51	3.49	8.00	20.89	Rs/kg	Ag Marketing Information Network
Burdwan, West Bengal	528	14.29	3.70	9.47	25.50	Rs/kg	Ag Marketing Information Network
West Godavari, Andrha Pradesh	528	19.33	8.72	3.76	41.00	Rs/kg	Ag Marketing Information Network
Wheat Producing Markets, Wholesale Prices							
Unnao, Uttar Pradesh	528	9.80	2.49	5.52	15.85	Rs/kg	Ag Marketing Information Network
Ludhiana, Punjab	528	9.89	2.70	5.72	17.00	Rs/kg	Ag Marketing Information Network
Gurgaon, Haryana	528	10.19	2.40	5.98	18.14	Rs/kg	Ag Marketing Information Network
Rice Major Ports, Wholesale Prices							
Vadodara, Gujarat	528	16.93	5.57	4.34	26.82	Rs/kg	Ag Marketing Information Network
Mangalore, Karnataka	528	16.71	5.97	9.44	78.22	Rs/kg	Ag Marketing Information Network
Ernakulam, Kerala	528	18.88	7.05	0.36	73.36	Rs/kg	Ag Marketing Information Network
Wheat Major Ports, Wholesale Prices							
Kachch, Gujarat	528	10.99	3.17	6.06	19.51	Rs/kg	Ag Marketing Information Network
Mysore, Karnataka	528	15.30	4.74	7.52	26.13	Rs/kg	Ag Marketing Information Network
Malda, West Bengal	528	9.91	2.63	4.00	17.10	Rs/kg	Ag Marketing Information Network
Rice Consuming Markets, Retail Prices							
Delhi, Delhi	528	17.62	5.55	0.00	26.00	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Mumbai, Maharashtra	528	18.90	6.41	7.35	34.50	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Kolkata, West Bengal	528	16.05	5.40	2.88	28.55	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics

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

Variable	Obs	Mean	Std. Dev.	Min	Max	Units	Source
Wheat Consuming Markets, Retail Prices							
Delhi, Delhi	528	14.61	4.79	0.00	24.57	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Mumbai, Maharashtra	528	20.38	7.33	11.40	37.58	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
Patna, Bihar	528	14.47	4.19	0.00	23.00	Rs/kg	Retail Price Info System, Directorate of Econ and Statistics
World Prices							
Rice World Price	528	16.60	7.79	6.65	34.06	Rs/kg	FAO Economic and Social Development Statistics Division
Wheat World Price	528	11.89	4.36	5.83	21.14	Rs/kg	FAO Economic and Social Development Statistics Division
Other Data							
Rainfall	528	115.63	112.20	2.13	382.10	mm	Meteorological Department, Govt. of India
Non-Basmati Rice Exports	528	456.31	507.00	7.23	2027.94	Rs Crore	Database on Indian Economy - Reserve Bank of India
Wheat Exports	528	171.18	337.37	0.00	1432.53	Rs Crore	Database on Indian Economy - Reserve Bank of India
Minimum Support Prices	528	8.40	2.27	5.60	11.10	Rs/kg	Ministry of Consumer Affairs, Food and Public Distribution, Govt of India
Central Issued Prices	528	8.30	0.00	8.30	8.30	Rs/kg	Ministry of Consumer Affairs, Food and Public Distribution, Govt of India

Table 3 Stationarity Summary for Logarithmic Transformation of Variables

Market	Wheat	Rice
Rice Producing Markets		
Bijnaur, Uttar Pradesh	U	U
Burdwan, West Bengal	U	U
West Godavari, Andrha Pradesh	U	U
Wheat Producing Markets		
Unnao Uttar Pradesh	U	U
Ludhiana, Punjab	U	U
Gurgaon, Haryana	U	U
Rice Major Port Markets		
Mangalore, Karnataka	U	U
Ernakulam, Kerala	U	U
Vadodara, Gujarat	U	U
Wheat Major Port Markets		
Kachch, Gujarat	U	U
Mysore, Karnataka	U	U
Malda, West Bengal	U	U
Rice Consuming Markets		
Delhi, Delhi	U	U
Mumbai, Maharashtra	U	U
Kolkata, West Bengal	U	U
Wheat Consuming Markets		
Delhi, Delhi	U	U
Mumbai, Maharashtra	U	U
Patna, Bihar	U	U
World Prices		
Rice World Pirce	U	U
Wheat World Price	U	U
Exogenous Supply Shock		
Rainfall	S	S

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

Note: Data are used are all logarithmic transformations, ran adf with lags; but no trend and with constant because that is how I am running the vars/vecm

Table 4a Lag order Selection for each Rice Market Pair for different periods based on AIC and LM test for Autocorrelation

Pair Type	Market Pair	Export restrictions Period		Open Trade Period	
		Lags based on AIC	Lags based on LM test for Autocorr	Lags based on AIC	Lags based on LM test for Autocorr
Producing and Consuming	Burdwan and Delhi	2	2	4	5
	Burdwan and Kolkata	5	8	4	4
	Burdwan and Mumbai	1	1	4	5
	Bijnaur and Delhi	2	3	5	6
	Bijnaur and Kolkata	3	3	4	5
	Bijnaur and Mumbai	1	1	5	5
	West Godavari and Delhi	2	3	5	6
	West Godavari and Kolkata	5	6	5	6
	West Godavari and Mumbai	4	4	5	5
Producing and Port	Burdwan and Mangalore	0	3	3	4
	Burdwan and Ernakulam	5	6	5	7
	Burdwan and Vadodara	1	1	1	4
	Bijnaur and Mangalore	0	2	5	6
	Bijnaur and Ernakulam	3	5	4	5
	Bijnaur and Vadodara	1	1	4	4
	West Godavari and Mangalore	4	4	5	6
	West Godavari and Ernakulam	5	5	5	6
	West Godavari and Vadodara	1	1	5	6
Port and Consuming	Mangalore and Delhi	2	4	5	6
	Mangalore and Kolkata	3	3	4	5
	Mangalore and Mumbai	2	3	5	6
	Ernakulam and Delhi	3	4	4	5
	Ernakulam and Kolkata	5	6	4	5
	Ernakulam and Mumbai	3	4	4	5
	Vadodara and Delhi	2	3	4	5
	Vadodara and Kolkata	5	6	3	4
	Vadodara and Mumbai	1	1	4	5
Port and World	Mangalore and World	5	6	5	6
	Ernakulam and World	5	6	5	6
	Vadodara and World	1	1	5	6

Table 4b Lag order Selection for each Wheat Market Pair for different periods based on AIC and LM test for Autocorrelation

Pair Type	Market Pair	Export restrictions Period		Open Trade Period	
		Lags based on AIC	Lags based on LM test for Autocorr	Lags based on AIC	Lags based on LM test for Autocorr
Producing and Consuming	Unnao and Delhi	1	1	4	4
	Unnao and Patna	1	1	4	4
	Unnao and Mumbai	1	1	4	4
	Ludhiana and Delhi	4	6	4	5
	Ludhiana and Patna	5	5	4	5
	Ludhiana and Mumbai	4	6	4	5
	Gurgaon and Delhi	2	4	5	5
	Gurgaon and Patna	2	4	4	4
	Gurgaon and Mumbai	2	5	4	5
Producing and Port	Unnao and Kachch	3	4	2	3
	Unnao and Mysore	5	8	4	5
	Unnao and Malda	1	1	5	5
	Ludhiana and Kachch	5	5	5	6
	Ludhiana and Mysore	5	6	5	6
	Ludhiana and Malda	4	6	4	4
	Gurgaon and Kachch	2	4	5	5
	Gurgaon and Mysore	3	4	4	4
	Gurgaon and Malda	2	4	5	5
Port and Consuming	Kachch and Delhi	3	3	5	6
	Kachch and Patna	3	3	4	5
	Kachch and Mumbai	4	5	4	4
	Mysore and Delhi	3	5	5	6
	Mysore and Patna	3	3	5	6
	Mysore and Mumbai	5	6	4	5
	Malda and Delhi	1	1	4	4
	Malda and Patna	1	1	4	4
	Malda and Mumbai	1	1	3	4
Port and World	Kachch and World	2	3	2	2
	Mysore and World	5	6	5	5
	Malda and World	1	1	3	3

Table 5a Number of Integrated Market Pairs by Pair Type and Crop

Pair Type Rice	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	0/9	5/9
Producing and Port Markets	3/9	2/9
Port and Consuming Markets	0/9	2/9
Port and World Markets	1/3	3/3

Pair Type Wheat	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	2/9	3/9
Producing and Port Markets	4/9	1/9
Port and Consuming Markets	5/9	3/9
Port and World Markets	1/3	2/3

Note: ER stands for export restrictions regime and OT stands for open trade regime.

Table 5b List of Integrated Market Pairs by Pair Type and Crop

Pair Type Rice	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	none	Burdwan and Delhi, Burdwan and Kolkata, Bijnaur and Mumbai, West Godavari and Delhi, West Godavari and Mumbai
Producing and Port Markets	Bijnaur and Mangalore, Bijnaur and Vadodara, West Godavari and Ernakulam	Bijanur and Mangalore, Bijnaur and Ernakulam
Port and Consuming Markets	none	Mangalore and Delhi, Mangalore and Mumbai
Port and World Markets	Vadodara and World	Mangalore and World, Ernakulam and World, Vadodara and World

Pair Type Wheat	Linear and Threshold Coint With ER	Linear and Threshold Coint OT
Producing and Consuming Markets	Ludhiana and Patna, Ludhiana and Mumbai	Ludhiana and Delhi, Ludhiana and Mumbai, Gurgaon and Delhi
Producing and Port Markets	Unnao and Malda, Ludhiana and Mysore, Ludhiana and Malda, Gurgaon and Kachch	Gurgaon and Kachch
Port and Consuming Markets	Kachch and Patna, Mysore and Delhi, Mysore and Patna, Mysore and Mumbai, Malda and Mumbai	Kachch and Delhi, Mysore and Delhi, Malda and Delhi
Port and World Markets	Kachch and World	Kachch and World, Malda and World

Note: ER stands for export restrictions regime and OT stands for open trade regime.

Table 6 Proportion of Weeks where the estimated difference is more than the Threshold (i.e. Incentive to Trade)

Crop	Pair Type	Market Pair	Export Restrictions Period Estimated Cointegrated Vector, Beta	Export Restrictions Period Estimated Thresholds, Tau	Export Restrictions Period % Weeks when there is incentive to trade	Open Trade Period Estimated Cointegrated Vector, Beta	Open Trade Period Estimated Thresholds, Tau	Open Trade Period % Weeks when there is incentive to trade
Rice	Consuming-Producing	Delhi-Burdwan	1.27	-		0.89	-1.70	93%
		Kolkata-Burdwan	0.65	-		0.52	-	
		Mumbai-Burdwan	0.64	3.47	10%	0.51	-	
		Delhi-Bijnaur	0.23	-		0.82	-1.31	93%
		Kolkata-Bijnaur	0.24	-		0.89	-1.94	93%
		Mumbai-Bijnaur	0.15	-		0.79	0.73	19%
		Delhi-West Godavari	0.79	-		0.98	-0.03	59%
		Kolkata-West Godavari	0.82	-		2.30	-	
		Mumbai-West Godavari	0.56	-		1.79	-	
Rice	Port-Producing	Mangalore-Burdwan	1.35	-		0.93	0.13	28%
		Ernakulam-Burdwan	1.06	-		2.95	-	
		Vadodara-Burdwan	-2.06	-		0.31	-	
		Mangalore-Bijnaur	0.82	1.15	7%	0.85	-0.93	75%
		Ernakulam-Bijnaur	0.54	-		0.76	-1.76	93%
		Vadodara-Bijnaur	0.73	3.25	1%	0.86	1.75	8%
		Mangalore-West Godavari	1.43	-		4.82	-	
		Ernakulam-West Godavari	1.31	-		-2.78	-	
		Vadodara-West Godavari	-0.68	-		1.02	1.38	15%
Rice	Consuming-Port	Delhi-Managalore	-4.17	-		0.95	-1.88	93%
		Kolkata-Mangalore	0.45	-		1.04	-1.95	91%
		Mumbai-Mangalore	3.90	-		0.53	-	
		Delhi-Ernakulam	0.01	-		0.17	-	
		Kolkata-Ernakulam	0.59	-		0.32	-	
		Mumbai-Ernakulam	0.09	-		-0.09	-	
		Delhi-Vadodara	-0.11	-		0.93	0.24	48%
		Kolkata-Vadodara	-0.63	-		1.74	-	
		Mumbai-Vadodara	0.34	-		0.89	1.05	27%
Rice	World-Port	World-Mangalore	4.52	-		1.24	-2.93	91%
		World-Ernakulam	5.89	-		1.36	-5.43	93%
		World-Vadodara	-0.23	-		1.19	1.71	23%

Continued Table 6 Proportion of Weeks where the estimated difference is more than the Threshold (i.e. Incentive to Trade)

Crop	Pair Type	Market Pair	Export Restrictions Period Estimated Cointegrated Vector, Beta	Export Restrictions Period Estimated Thresholds, Tau	Export Restrictions Period % Weeks when there is incentive to trade	Open Trade Period Estimated Cointegrated Vector, Beta	Open Trade Period Estimated Thresholds, Tau	Open Trade Period % Weeks when there is incentive to trade
Wheat	Consuming-Producing	Delhi-Unnao	0.66	-0.30	9%	0.98	-	
		Patna-Unnao	0.45	-		0.86	-	
		Mumbai-Unnao	0.17	-		0.72	-	
		Delhi-Ludhiana	0.66	-1.64	92%	0.76	0.21	89%
		Patna-Ludhiana	0.68	-1.60	98%	0.74	0.03	79%
		Mumbai-Ludhiana	0.49	-1.60	91%	0.51	0.16	31%
		Delhi-Gurgaon	0.43	-		0.91	-	
		Patna-Gurgaon	0.36	-		0.71	-	
		Mumbai-Gurgaon	0.12	-		0.85	-	
Wheat	Port-Producing	Kachch-Unnao	0.82	-		0.70	-	
		Mysore-Unnao	0.43	-		0.72	-	
		Malda-Unnao	0.99	0.96	0%	0.62	-	
		Kachch-Ludhiana	1.31	-		0.92	-0.08	62%
		Mysore-Ludhiana	0.68	-		0.73	-0.47	93%
		Malda-Ludhiana	2.47	-		0.96	0.35	31%
		Kachch-Gurgaon	0.91	-1.17	90%	0.80	-	
		Mysore-Gurgaon	0.47	-		0.81	-	
		Malda-Gurgaon	1.12	-		1.05	0.31	42%
Wheat	Consuming-Port	Delhi-Kachch	0.48	-		0.85	0.64	72%
		Patna-Kachch	0.45	-		1.02	-	
		Mumbai-Kachch	0.16	-		0.87	-	
		Delhi-Mysore	1.04	-2.40	95%	1.49	-	
		Patna-Mysore	1.04	-2.49	98%	1.17	-	
		Mumbai-Mysore	0.38	-		1.24	-	
		Delhi-Malda	0.31	-		0.81	-0.31	95%
		Patna-Malda	0.32	-		0.74	0.32	56%
		Mumbai-Malda	0.12	-		0.99	-	
Wheat	World-Port	World-Kachch	0.90	4.98	0%	1.04	1.05	45%
		World-Mysore	1.12	-		-2.88	-	
		World-Malda	0.10	-		0.97	0.29	57%

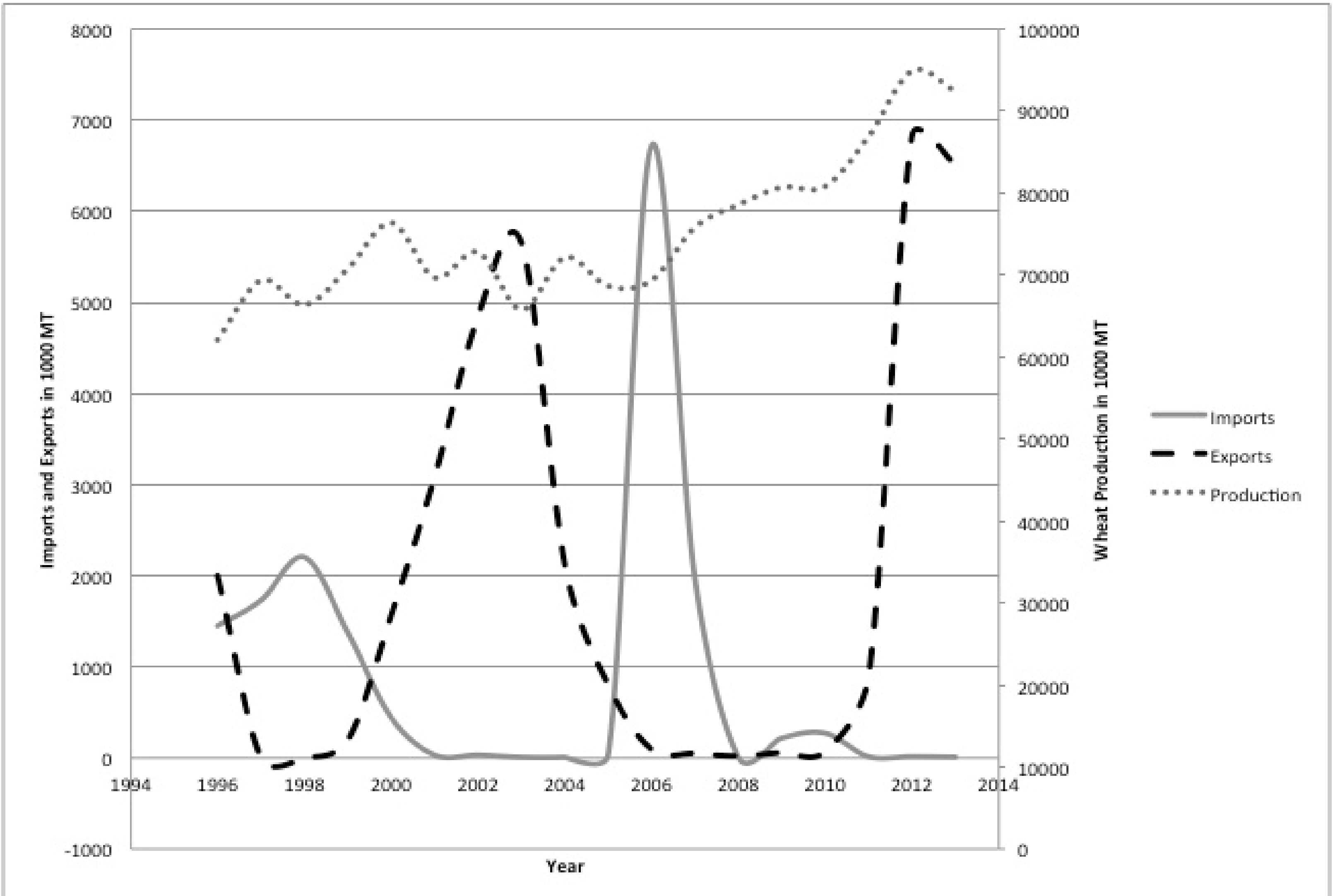
Table 7a Multivariate VAR Significance Results for the Domestic Production Shock Effects (ER Period)

	RICE			WHEAT		
	Producing	Consuming	Ports	Producing	Consuming	Ports
Rainfall	2/3	3/3	0/3	2/3	2/3	1/3

Table 7b Multivariate VAR Significance Results for the Domestic Production Shock Effects (OT Period)

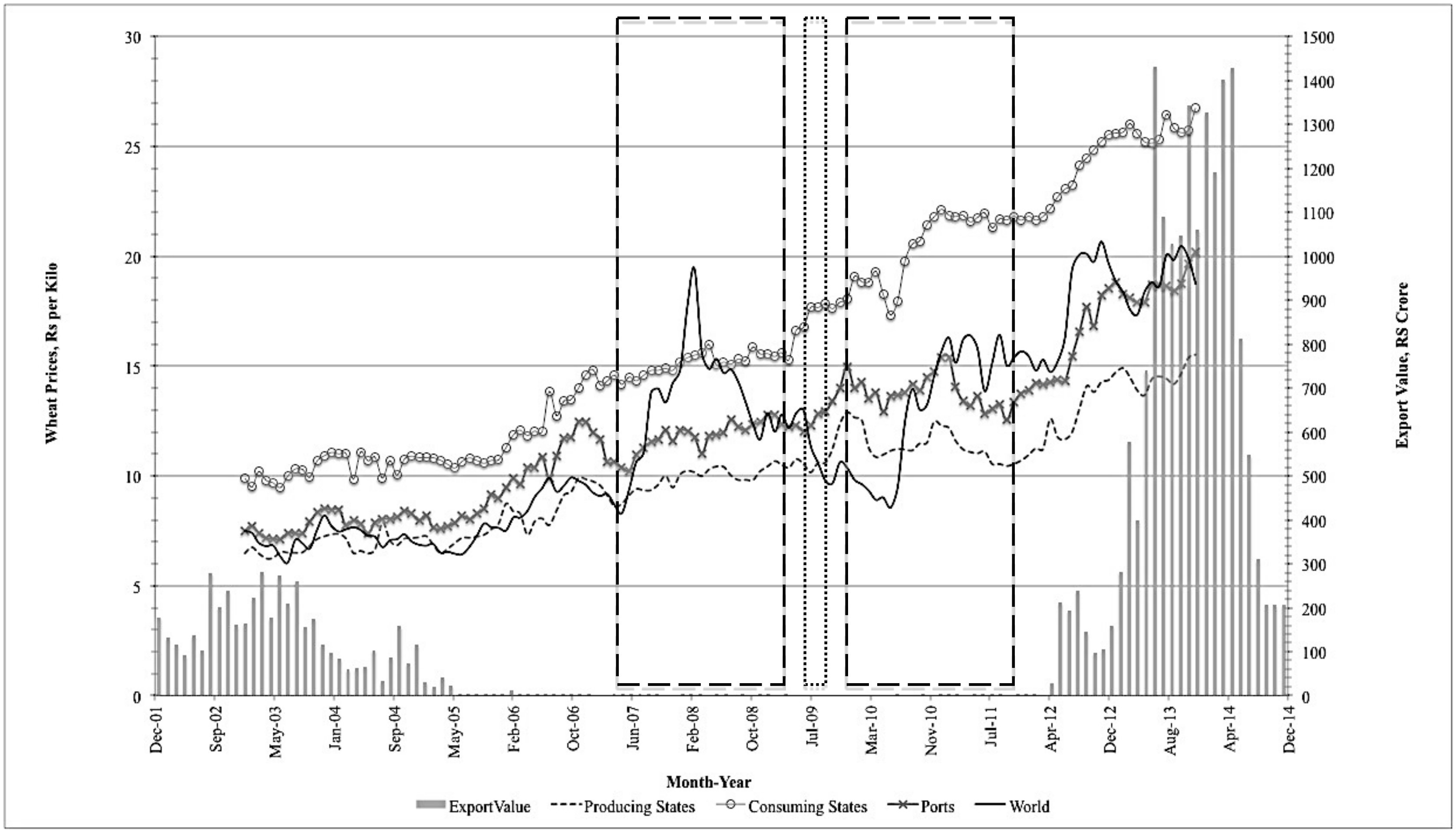
	RICE			WHEAT		
	Producing	Consuming	Ports	Producing	Consuming	Ports
Rainfall	0/3	1/3	0/3	0/3	1/3	0/3

Figure 1. India's Wheat Exports, Imports and Production, 1996-2013



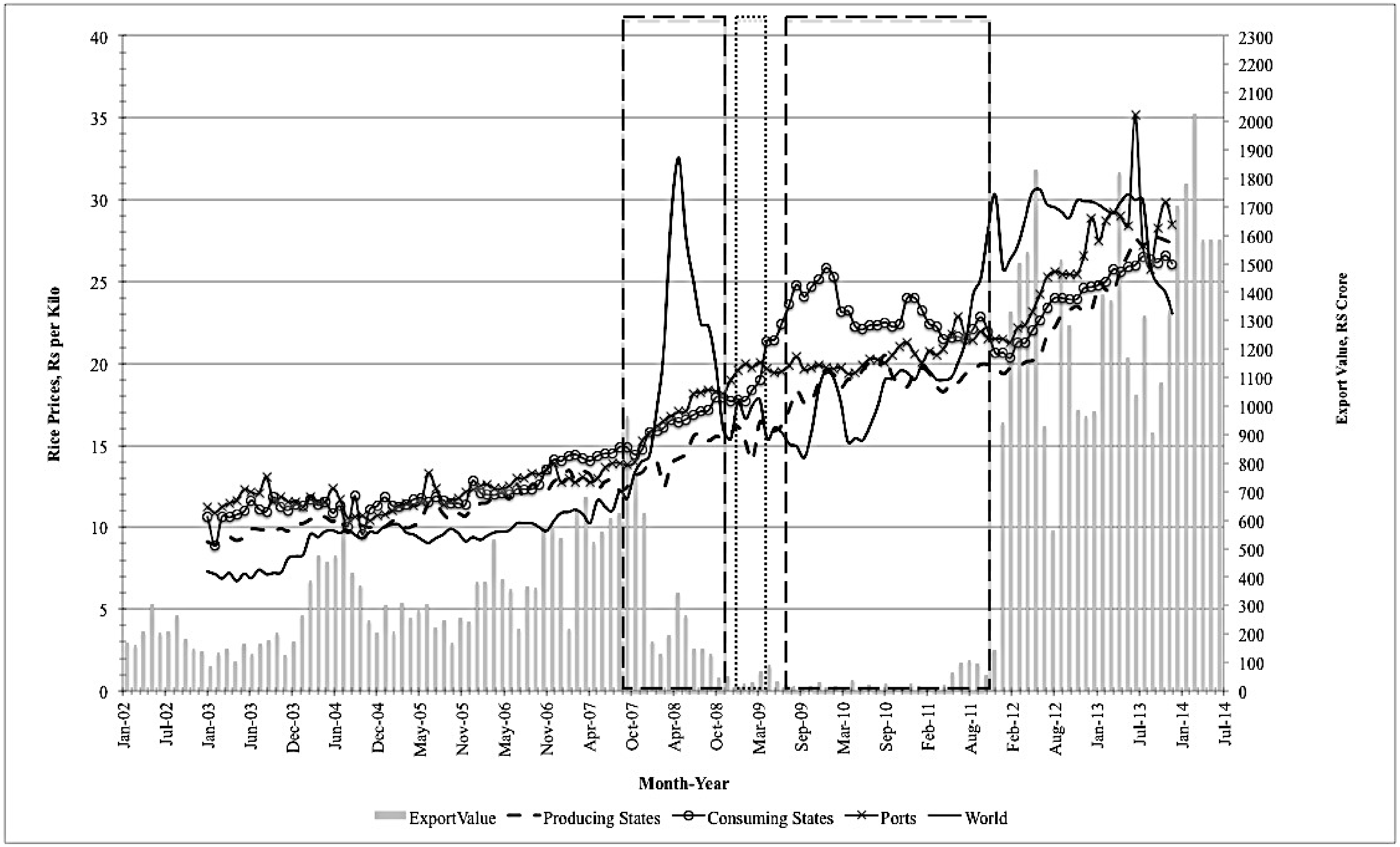
Source: http://www.indexmundi.co

Figure 2 Average Wheat Prices in Selected Markets and Export Quantity



Export ban   Export Quota   Note: whenever the "restricted trade" regime does not prevail, the "open trade" regime applies

Figure 3 Average Rice Prices in Selected Markets and Export Quantity



Export ban Minimum Export Prices Note: whenever the "restricted trade" regime does not prevail, the "open trade" regime applies.

Figure 4 Wheat Markets from Major Producing States

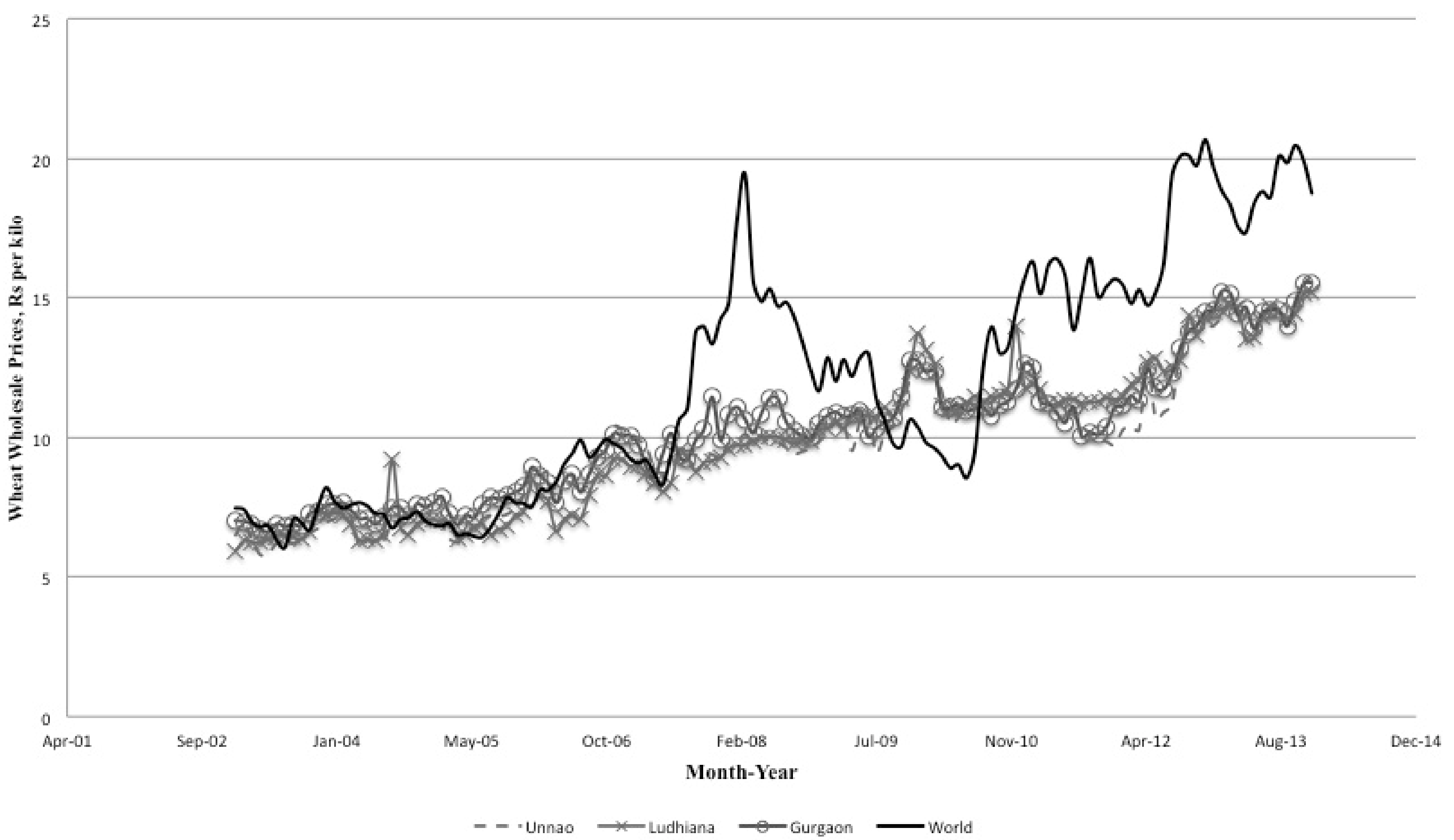


Figure 5 Wheat Markets from Major Consuming States

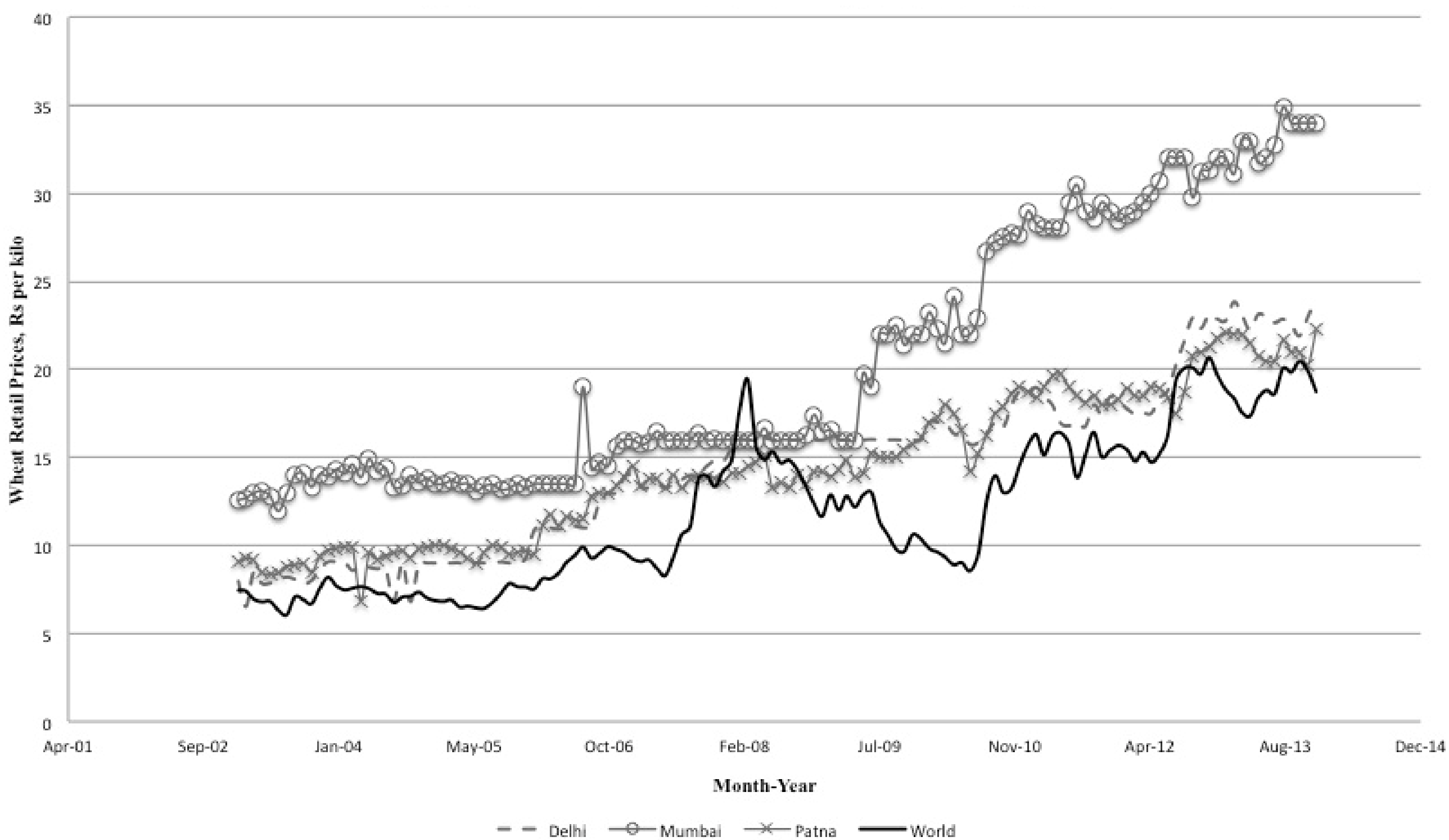


Figure 6 Wheat Markets from Major Ports

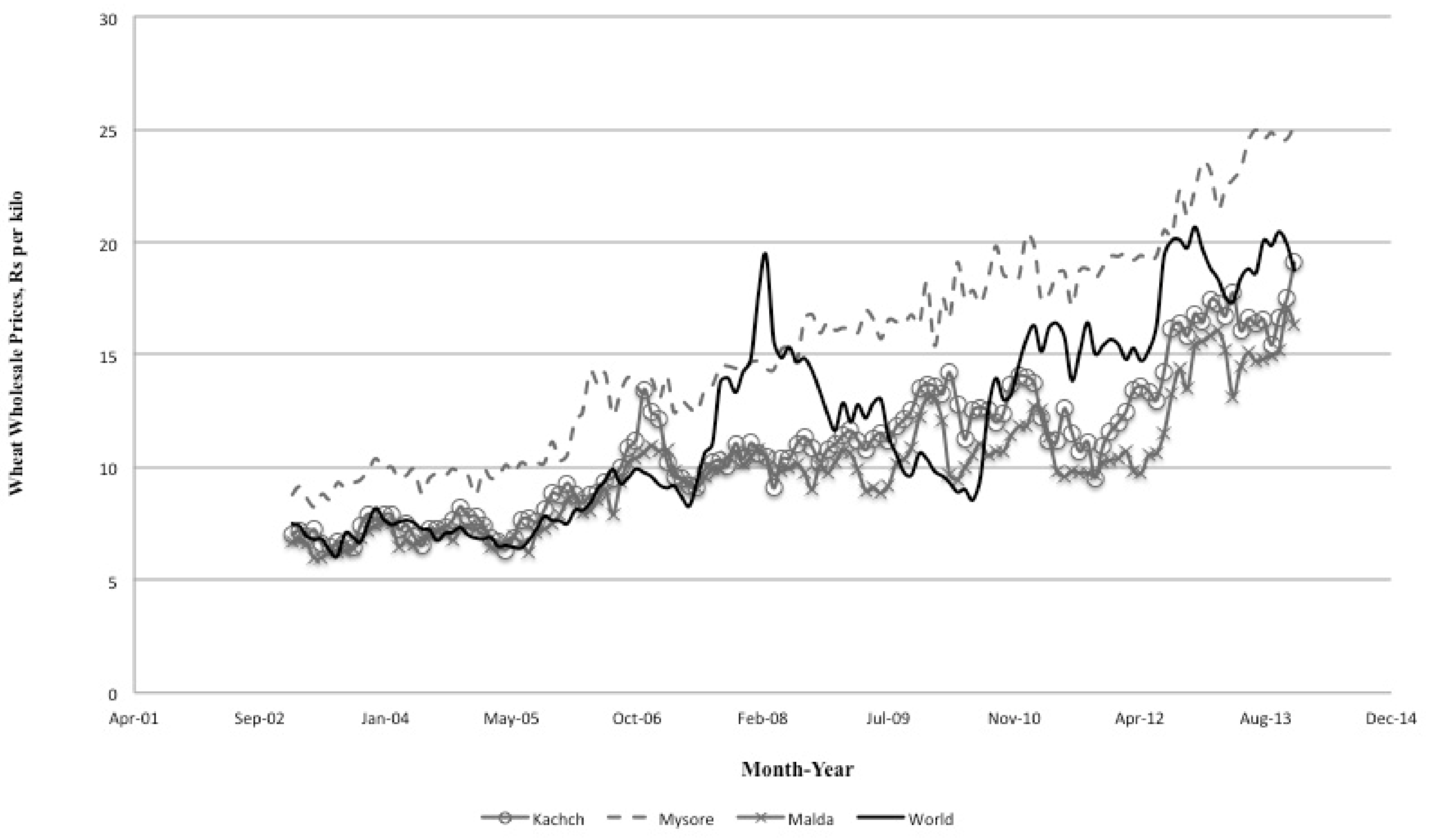


Figure 7 Rice Markets from Major Producing States

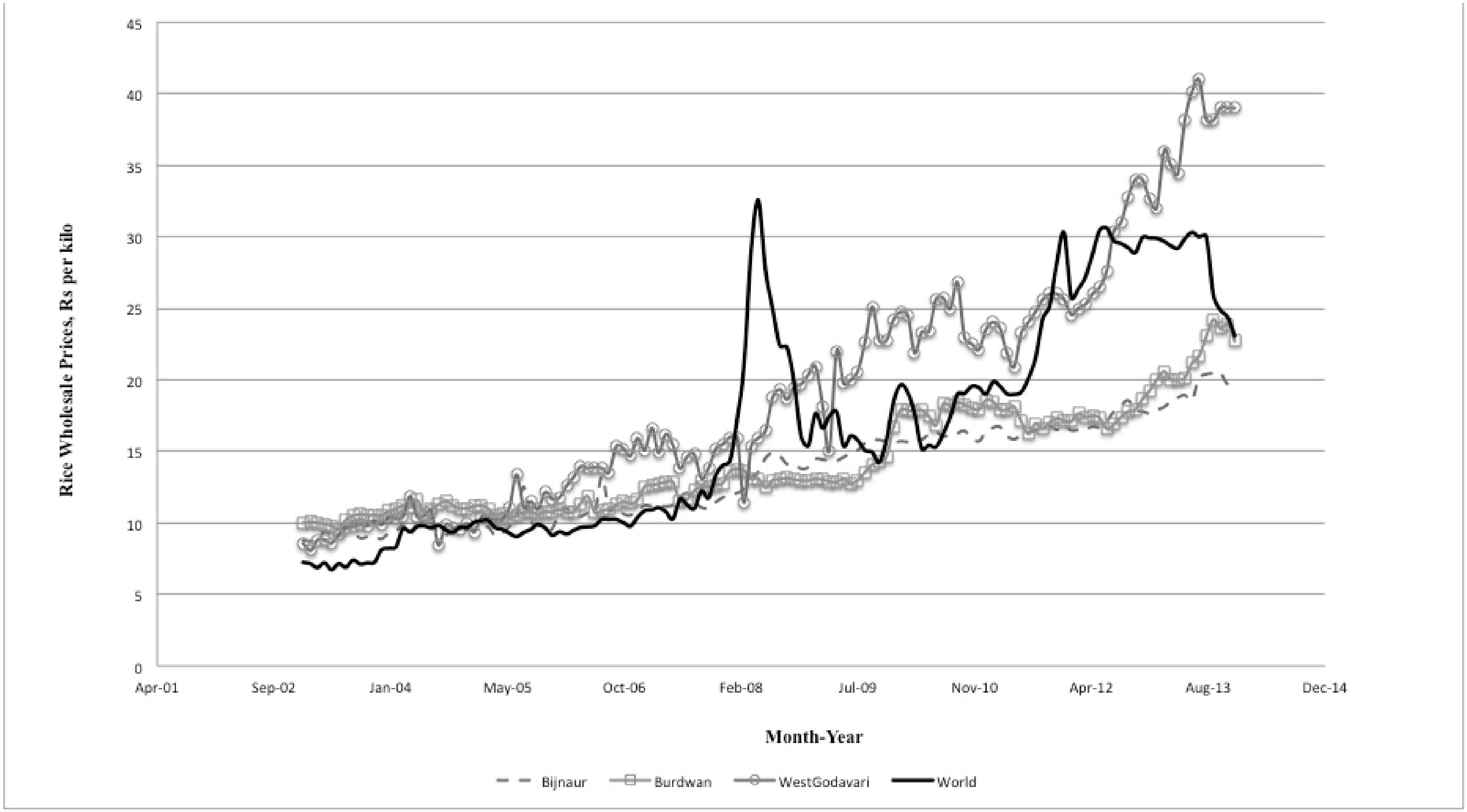


Figure 8 Rice Markets from Major Consuming States

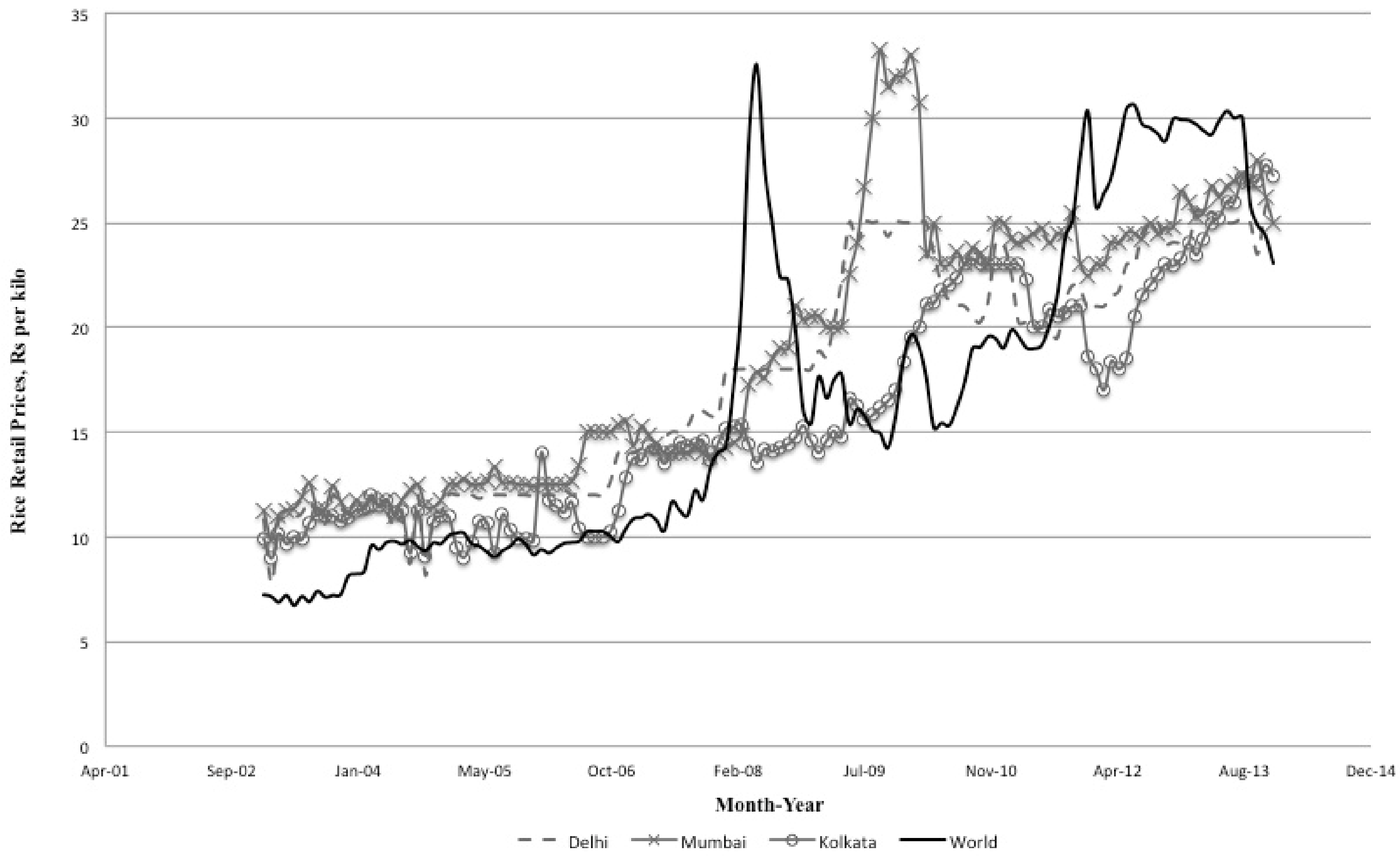


Figure 9 Rice Markets from Major Ports

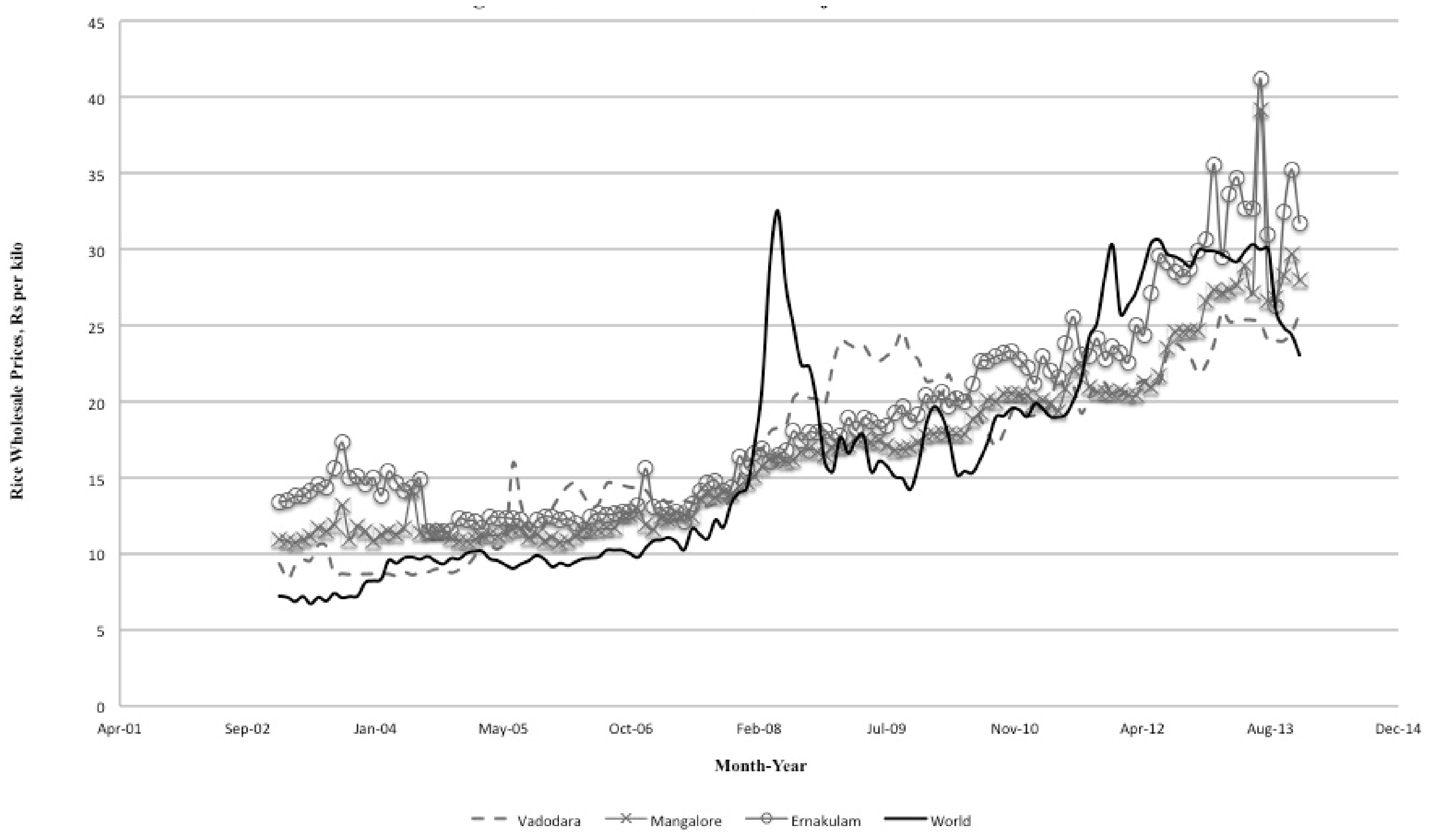


Figure 10 India's Market Landscape

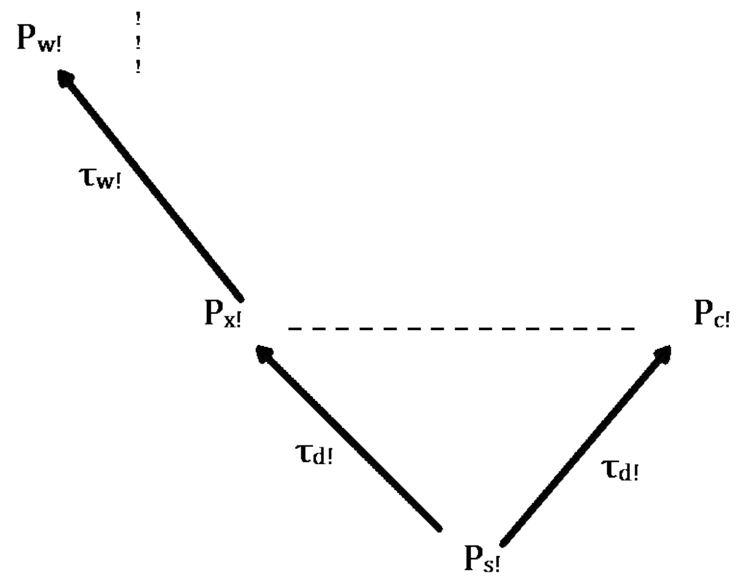
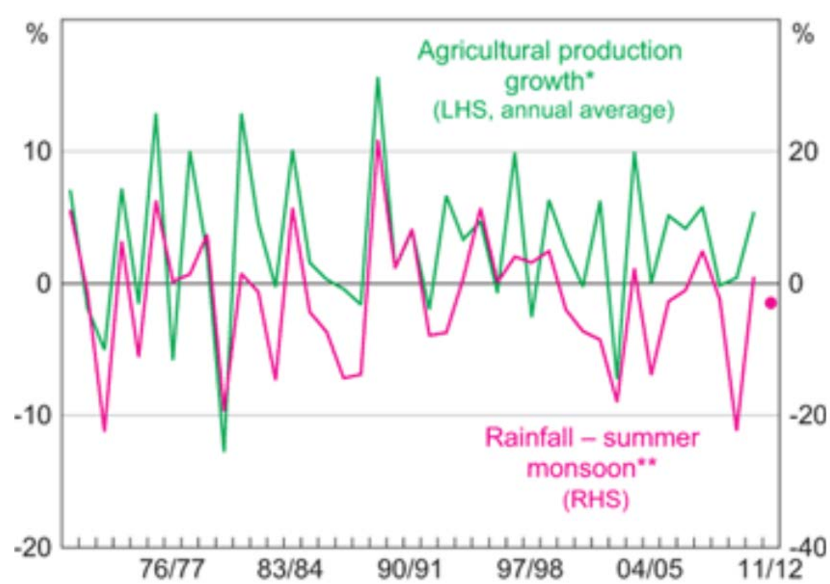


Figure 11 Percentage Changes in Agricultural Production and Rainfall



Source: Cagliarni and Rush (2011)

Appendix

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 ME$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 ME$1000/t • **April 1, 2008 – Ban Exports** • September 2009 – Ban extended • Feb 2010 – Ban continued except for 3 premium varieties with ME$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 ME$1200/t • April 29, 2009 – Export tax of Rs.8000/t (approx. ME$200) • January 20, 2009- Tax removed and MEP reduced to ME$1100/t • September 2009 – MEP reduced to ME$900/t • Feb 2010 – MEP of ME$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- 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 (Levels, Logs, Differences in Levels, Differences in Logs)

	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	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
bijnaur_rice	-4.239***	-0.433	1.639	-287.179***	-13.416***	-6.326	-1.749	0.596	0.804
burdwan_rice	-2.259	0.054	1.788	-12.339	-2.450	0.093	0.050	0.812	1.747
westgodavari_rice	-2.896	0.056	1.639	-68.333***	-6.108***	-2.364	-0.846	1.084	1.023
unnao_wheat	-3.161*	-0.296	1.358	-25.409**	-3.432**	-1.765	-0.650	0.812	1.222
ludhiana_wheat	-4.435**	-0.777	1.173	-233.244***	-11.930***	-9.021	-2.083	0.512	0.546
gurgaon_wheat	-3.158*	-0.397	1.353	-84.717***	-6.853***	-5.105	-1.426	0.654	0.899
vadodara_rice	-2.689	-0.850	1.122	-24.435**	-3.563**	-2.909	-1.171	0.664	0.875
mangalore_rice	-3.907**	-0.895	0.741	-412.083***	-16.498***	-49.927***	-5.242***	0.975	-0.484
ernakulam_rice	-3.675**	-1.127	0.421	-279.252***	-13.157***	-43.807***	-4.886***	-1.075	-0.517
kachch_wheat	-3.177*	-0.476	1.137	-148.935***	-9.277***	-12.142	-2.365	0.555	0.499
mysore_wheat	-4.772***	-0.409	1.504	-429.575***	-17.001***	-11.486	-2.392	0.528	0.509
malda_wheat	-3.274*	-0.946	0.762	-29.474**	-3.809**	-4.747	-1.301	0.641	0.711
rice world	-3.439**	-1.489	0.125	-19.423*	-3.163*	-3.395	-1.245	0.433	0.378
wheat world	-2.908	-1.153	0.460	-19.050*	-3.167*	-3.602	-1.242	0.345	0.350
delhi_rice	-2.727	-0.837	1.138	-89.615***	-7.202***	-5.398	-1.581	0.386	0.436
mumbai_rice	-2.211	-1.275	0.575	-21.292*	-3.319*	-3.823	-1.413	0.257	0.308
kolkata_rice	-2.473	-0.101	1.609	-49.719***	-5.291***	-2.189	-0.794	0.742	0.927
delhi_wheat	-3.035	-0.009	2.098	-156.335***	-9.605***	-2.670	-0.992	0.830	1.134
mumbai_wheat	-2.278	0.019	1.850	-23.734**	-3.642**	-0.821	-0.403	0.838	1.272
patna_wheat	-4.501***	-0.557	1.367	-156.547***	-9.633***	-3.380	-1.182	0.625	0.860
rainfall	-6.773***	-6.783***	-4.359***	-45.218***	-4.803***	-45.303	-4.814	-20.977***	-3.255***

Continued Appendix Table 2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	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	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
ln bijnaur_rice	-4.410***	-0.804	1.711	-272.320***	-13.030***	-6.038	-1.838	0.311	1.109
ln burdwan_rice	-2.782	-0.318	1.802	-18.930*	-3.117*	-0.597	-0.318	0.293	1.689
ln westgodavari_rice	-4.966***	-0.706	1.495	-337.464***	-14.714***	-8.251	-2.149	0.458	0.942
ln unnao_wheat	-3.494**	-0.672	1.279	-27.847**	-3.720**	-2.727	-1.045	0.371	1.258
ln ludhiana_wheat	-4.548***	-1.060	1.313	-207.880***	-11.206***	-7.456	-1.996	0.347	0.893
ln gurgaon_wheat	-3.551**	-0.724	1.332	-89.844***	-7.112***	-5.467	-1.620	0.329	1.061
ln vadodara_rice	-2.634	-1.119	1.191	-36.269***	-4.413***	-4.407	-1.604	0.330	0.981
ln mangalore_rice	-3.087	-0.233	1.849	-195.449***	-10.873***	-5.449	-1.561	0.308	0.970
ln ernakulam_rice	-5.357***	-2.174	0.297	-476.095***	-18.280***	-157.177***	-9.636***	-0.162	-0.157
ln kachch_wheat	-3.630**	-0.864	1.097	-140.609***	-9.042***	-10.916	-2.363	0.358	0.791
ln mysore_wheat	-5.107***	-0.912	1.477	-464.692***	-17.826***	-13.041*	-2.678*	0.322	0.799
ln malda_wheat	-3.477**	-1.091	0.872	-51.144***	-5.237***	-7.102	-1.805	0.329	0.790
ln rice world	-2.739	-1.320	1.026	-21.678***	-3.334***	-2.779	-1.254	0.412	1.097
ln wheat world	-2.822	-1.117	0.785	-17.729	-3.062	-2.983	-1.138	0.271	0.691
ln delhi_rice	-5.284***	-2.009	0.429	-486.061***	-18.604***	-99.190***	-7.581***	-0.142	-0.154
ln mumbai_rice	-2.130	-1.310	1.166	-33.780***	-4.242***	-3.580	-1.383	0.208	0.724
ln kolkata_rice	-3.840**	-0.978	1.066	-259.831***	-12.678***	-15.763**	-2.829**	0.213	0.422
ln delhi_wheat	-5.506***	-1.549	0.691	-531.129***	-19.818***	-68.283***	-6.257***	0.041	0.050
ln mumbai_wheat	2.717	-0.442	1.753	-39.041***	-4.675***	-1.665	-0.757	0.302	1.245
ln patna_wheat	-5.839***	-1.366	0.840	-426.356***	-17.272***	-27.773***	-3.906***	0.181	0.323
ln rainfall	-5.853***	-5.861	-1.549	-41.364***	-4.634***	-41.536***	-4.654***	-2.716	-1.142

Continued Appendix Table 2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	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	-3.96	-3.43	-2.58	-29.5	-3.96	-20.7	-3.43	-13.8	-2.58
5% critical value	-3.41	-2.86	-1.95	-21.8	-3.41	-14.1	-2.86	-8.1	-1.95
10% critical value	-3.12	-2.57	-1.62	-18.3	-3.12	-11.3	-2.57	-5.7	-1.62
d bijnaur_rice	-14.581***	-14.580***	-14.403***	-614.050***	-50.467***	-614.137***	-50.489***	-615.085***	-50.119***
d burdwan_rice	-9.509***	-9.460***	-9.260***	-488.318***	-23.732***	-489.214***	-23.705***	-492.193***	-23.565***
d westgodavari_rice	-12.018***	-12.002***	-11.801***	-668.597***	-42.737***	-669.206***	-42.661***	-671.131***	-42.300***
d unnao_wheat	-10.195***	-10.160***	-10.045***	-403.865***	-18.888***	-404.173***	-18.897***	-404.450***	-18.850***
d ludhiana_wheat	-12.684***	-12.685***	-12.589***	-606.560***	-44.640***	-606.621***	-44.675***	-607.446***	-44.471***
d gurgaon_wheat	-11.469***	-11.463***	-11.342***	-574.424***	-38.021***	-574.697***	-38.016***	-575.825***	-37.827***
d vadodara_rice	-11.770***	-11.784***	-11.617***	-598.981***	-29.881***	-599.008***	-29.910***	-600.590***	-29.804***
d mangalore_rice	-16.076***	-16.070***	-16.014***	-636.474***	-61.580***	-636.553***	-61.588***	-636.757***	-61.503***
d ernakulam_rice	-14.644***	-14.632***	-14.603***	-632.855***	-55.723***	-632.994***	-55.709***	-633.158***	-55.680***
d kachch_wheat	-12.566***	-12.545***	-12.453***	-707.752***	-50.165***	-708.096***	-50.120***	-708.950***	-49.890***
d mysore_wheat	-17.436***	-17.425***	-17.233***	-682.088***	-61.689***	-682.178***	-61.705***	-682.957***	-61.245***
d malda_wheat	-10.018***	-10.021***	-9.945***	-631.336***	-28.959***	-631.884***	-28.964***	-633.133***	-28.908***
d rice world	-7.370***	-7.381***	-7.343***	-707.359***	-28.371***	-707.330***	-28.401***	-708.278***	-28.374***
d wheat world	-9.776***	-9.784***	-9.743***	-586.017***	-25.294***	-586.110***	-25.314***	-586.973***	-25.298***
d delhi_rice	-13.865***	-13.886***	-13.695***	-642.721***	-48.012***	-642.720***	-48.063***	-643.634***	-47.822***
d mumbai_rice	-10.656***	-10.656***	-10.590***	-649.738***	-35.497***	-649.812***	-35.528***	-650.742***	-35.460***
d kolkata_rice	-12.452***	-12.452***	-12.231***	-638.622***	-43.817***	-638.991***	-43.763***	-640.735***	-43.400***
d delhi_wheat	-14.508***	-14.541***	-14.133***	-657.611***	-52.911***	-657.748***	-52.913***	-659.537***	-52.199***
d mumbai_wheat	-13.364***	-13.308***	-13.087***	-600.252***	-37.296***	-600.765***	-37.240***	-603.073***	-36.914***
d patna_wheat	-12.108***	-12.109***	-11.982***	-624.829***	-41.147***	-624.934***	-41.174***	-626.329***	-40.927***
d rainfall	-7.034***	-7.037***	-7.044***	-588.028***	-23.010***	-588.048***	-23.024***	-588.048***	-23.044***

Continued Appendix Table 2. Unit root tests for all variables used in the Study (Levels, Logs, Differences in Levels, Differences in Logs)

	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	**-3.96**	**-3.43**	**-2.58**	**-29.5**	**-3.96**	**-20.7**	**-3.43**	**-13.8**	**-2.58**
5% critical value	**-3.41**	**-2.86**	**-1.95**	**-21.8**	**-3.41**	**-14.1**	**-2.86**	**-8.1**	**-1.95**
10% critical value	**-3.12**	**-2.57**	**-1.62**	**-18.3**	**-3.12**	**-11.3**	**-2.57**	**-5.7**	**-1.62**
d ln bijnaur_rice	-14.264***	-14.278***	-14.099***	-610.938***	-48.229***	-610.949***	-48.283***	-611.991***	-47.925***
d ln burdwan_rice	-10.105***	-10.092***	-9.884***	-513.471***	-24.810***	-513.780***	-24.814***	-516.858***	-24.666***
d ln westgodavari_rice	-13.957***	-13.978***	-13.772***	-666.157***	-51.208***	-666.187***	-51.259***	-667.151***	-50.929***
d ln unnao_wheat	-10.493***	-10.486***	-10.383***	-419.525***	-19.460***	-419.656***	-19.478***	-419.919***	-19.433***
d ln ludhiana_wheat	-12.281***	-12.293***	-12.192***	-613.262***	-43.004***	-613.260***	-43.053***	-614.273***	-42.829***
d ln gurgaon_wheat	-11.280***	-11.292***	-11.170***	-576.044***	-37.090***	-576.129***	-37.121***	-577.238***	-36.949***
d ln vadodara_rice	-13.737***	-13.712***	-13.478***	-657.075***	-37.809***	-657.092***	-37.846***	-658.418***	-37.684***
d ln mangalore_rice	-14.812***	-14.805***	-14.606***	-632.263***	-54.807***	-632.417***	-54.775***	-633.241***	-54.408***
d ln ernakulam_rice	-15.262***	-15.268***	-15.266***	-633.106***	-57.938***	-633.151***	-57.979***	-633.207***	-58.010***
d ln kachch_wheat	-12.173***	-12.178***	-12.095***	-679.314***	-46.435***	-679.432***	-46.461***	-680.211***	-46.285***
d ln mysore_wheat	-17.096***	-17.112***	-16.946***	-698.103***	-62.959***	-698.100**	-63.030***	-698.810***	-62.596***
d ln malda_wheat	-10.487***	-10.501***	-10.430***	-646.086***	-34.817***	-646.226***	-34.844***	-647.223***	-34.760***
d ln rice world	-8.048***	-8.050***	-7.968***	-677.183***	-32.424***	-677.359***	-32.447***	-679.174***	-32.327***
d ln wheat world	-9.468***	-9.477***	-9.430***	-579.999***	-25.191***	-580.013***	-25.214***	-581.008***	-25.192***
d ln delhi_rice	-18.509***	-18.505***	-18.432***	-642.502***	-59.873***	-642.502***	-59.943***	-642.619***	-59.938***
d ln mumbai_rice	-11.700***	-11.665***	-11.516***	-648.849***	-41.872***	-649.030***	-41.890***	-650.235***	-41.701***
d ln kolkata_rice	-14.527***	-14.548***	-14.438***	-639.912***	-52.727***	-639.928***	-52.775***	-640.414***	-52.623***
d ln delhi_wheat	-18.430***	-18.435***	-18.318***	-649.569***	-62.860***	-649.569***	-62.933***	-649.762***	-62.856***
d ln mumbai_wheat	-13.516***	-13.505***	-13.326***	-587.827***	-36.261***	-597.935***	-36.273***	-589.848***	-36.028***
d ln patna_wheat	-14.656***	-14.670***	-14.627***	-621.017***	-52.771***	-621.018***	-52.832***	-621.299***	-52.754***
d ln rainfall	-7.487***	-7.493***	-7.501***	-576.987***	-22.977***	-576.927***	-22.985***	-576.920***	-23.005***

*** 1% significance, ** 5% significance and * 10% sognificance

Note: If p-value is significant, it means it is stationary. - can do VAR in levels. If insignificant, it means unit root. - data needs to be differenced.

Appendix Table 3. Wheat Exports in India in 1,000 MT from 2000-2013

Market Year	Exports in 1000 MT	Growth Rate
2000	1569	684.50%
2001	3087	96.75%
2002	4850	57.11%
2003	5650	16.49%
2004	2120	-62.48%
2005	801	-62.22%
2006	94	-88.26%
2007	49	-47.87%
2008	23	-53.06%
2009	58	152.17%
2010	72	24.14%
2011	891	1137.50%
2012	6824	665.88%
2013	6500	-4.75%

Source: http://www.indexmundi.com/agriculture/?country=in&commodity=wheat&graph=exports

Appendix Table 4. Detailed Cointegration Results for Rice, ER Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Burdwan	no cointeg	1.27	0.72	5.11	14.28	LC	11.78	no cointeg	no cointeg
	Kolkata-Burdwan	no cointeg	0.65	0.84	1.29	41.20	LC	19.17***	cointeg	no cointeg
	Mumbai-Burdwan	no cointeg	0.85	0.64	3.47	20.16**	TC	20.17	no cointeg	no cointeg
	Delhi-Bijnaur	no cointeg	0.23	0.72	2.99	21.95	LC	13.12***	cointeg	no cointeg
	Kolkata-Bijnaur	no cointeg	0.24	0.81	2.61	25.67	LC	15.6***	cointeg	no cointeg
	Mumbai-Bijnaur	no cointeg	0.15	0.64	5.40	11.13	LC	18.72***	cointeg	no cointeg
	Delhi-West Godavari	no cointeg	0.79	0.99	-6.07	19.58	LC	12.38	no cointeg	no cointeg
	Kolkata-West Godavari	no cointeg	0.82	1.14	-4.46	33.12	LC	15.82***	cointeg	no cointeg
	Mumbai-West Godavari	no cointeg	0.56	0.89	3.06	30.34	LC	12.96	no cointeg	no cointeg
Port-Producing	Mangalore-Burdwan	no cointeg	1.35	0.84	1.48	25.01	LC	16.74***	cointeg	no cointeg
	Ernakulam-Burdwan	no cointeg	1.06	0.78	1.84	34.15	LC	17.63***	cointeg	no cointeg
	Vadodara-Burdwan	no cointeg	-2.06	0.75	2.22	15.43	LC	12.64	no cointeg	no cointeg
	Mangalore-Bijnaur	no cointeg	0.41	0.82	1.15	26.19***	TC	9.29***	cointeg	cointeg
	Ernakulam-Bijnaur	no cointeg	0.54	0.76	2.07	29.09	LC	14.29	no cointeg	no cointeg
	Vadodara-Bijnaur	no cointeg	-0.54	0.73	3.25	23.57***	TC	11.53***	cointeg	cointeg
	Mangalore-West Godavari	no cointeg	1.43	1.19	5.06	25.67	LC	27.66	no cointeg	no cointeg
	Ernakulam-West Godavari	cointeg	1.31	1.06	-2.73	30.52	LC	14.81***	cointeg	cointeg
	Vadodara-West Godavari	no cointeg	-0.68	1.04	-0.37	12.56	LC	10.92	no cointeg	no cointeg
Consuming-Port	Delhi-Managalore	no cointeg	-4.17	0.84	-3.70	29.78	LC	8.92***	cointeg	no cointeg
	Kolkata-Mangalore	no cointeg	0.45	0.97	2.58	15.14	LC	10.25***	cointeg	no cointeg
	Mumbai-Mangalore	no cointeg	3.90	0.76	6.79	18.35	LC	17.45	no cointeg	no cointeg
	Delhi-Ernakulam	no cointeg	0.01	0.93	-5.40	23.40	LC	9.82	no cointeg	no cointeg
	Kolkata-Ernakulam	no cointeg	0.59	1.07	-2.18	31.75	LC	18.32***	cointeg	no cointeg
	Mumbai-Ernakulam	no cointeg	0.09	0.84	2.06	20.68	LC	18.02	no cointeg	no cointeg
	Delhi-Vadodara	no cointeg	-0.11	0.95	-3.12	21.59	LC	12.92***	cointeg	no cointeg
	Kolkata-Vadodara	no cointeg	-0.63	1.07	0.06	37.25	LC	8.83**	cointeg	no cointeg
	Mumbai-Vadodara	no cointeg	0.34	0.85	-1.15	10.02	LC	15.91	no cointeg	no cointeg
World-Port	World-Mangalore	no cointeg	4.52	0.92	4.14	27.09	LC	15.19	no cointeg	no cointeg
	World-Ernakulam	no cointeg	5.89	0.99	5.29	39.86	LC	13.66	no cointeg	no cointeg
	World-Vadodara	cointeg	-0.23	1.04	-2.48	13.18	LC	8.01***	cointeg	cointeg

Continued Appendix Table 4. Detailed Cointegration Results for Wheat, ER Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Unnao	no cointeg	0.45	0.66	-0.30	17.29*	TC	13.88	no cointeg	no cointeg
	Patna-Unnao	no cointeg	0.45	0.67	1.67	14.12	LC	14.05***	cointeg	no cointeg
	Mumbai-Unnao	no cointeg	0.17	0.49	1.77	9.94	LC	6.61	no cointeg	no cointeg
	Delhi-Ludhiana	cointeg	0.66	0.66	-1.64	43.05**	TC	15.82	no cointeg	no cointeg
	Patna-Ludhiana	cointeg	0.62	0.68	-1.60	42.25**	TC	14.23***	cointeg	cointeg
	Mumbai-Ludhiana	no cointeg	0.22	0.49	-1.60	45.22**	TC	12.38***	cointeg	cointeg
	Delhi-Gurgaon	no cointeg	0.43	0.69	-0.07	29.63	LC	17.10	no cointeg	no cointeg
	Patna-Gurgaon	no cointeg	0.36	0.69	0.91	27.01	LC	17.19	no cointeg	no cointeg
	Mumbai-Gurgaon	no cointeg	0.12	0.52	3.76	27.00	LC	8.10***	cointeg	no cointeg
Port-Producing	Kachch-Unnao	no cointeg	0.82	0.89	-1.84	32.74	LC	34.46	no cointeg	no cointeg
	Mysore-Unnao	no cointeg	0.43	0.64	0.03	42.92	LC	15.52***	cointeg	no cointeg
	Malda-Unnao	no cointeg	1.13	0.99	0.96	20.58***	TC	39.92***	cointeg	cointeg
	Kachch-Ludhiana	no cointeg	1.31	0.90	-1.76	32.96	LC	22.38***	cointeg	no cointeg
	Mysore-Ludhiana	cointeg	0.68	0.64	-0.21	36.71	LC	15.16	no cointeg	cointeg
	Malda-Ludhiana	cointeg	2.47	0.98	-0.90	43.46*	LC	12.15	no cointeg	cointeg
	Kachch-Gurgaon	no cointeg	0.82	0.91	-1.17	39.46***	TC	23.38***	cointeg	cointeg
	Mysore-Gurgaon	no cointeg	0.47	0.67	1.13	30.45	LC	13.43***	cointeg	no cointeg
	Malda-Gurgaon	no cointeg	1.12	1.03	-1.60	28.60	LC	31.77	cointeg	no cointeg
Consuming-Port	Delhi-Kachch	no cointeg	0.48	0.75	2.00	23.96	LC	16.7***	cointeg	no cointeg
	Patna-Kachch	cointeg	0.45	0.75	3.79	24.12	LC	16.36***	cointeg	cointeg
	Mumbai-Kachch	no cointeg	0.16	0.54	4.25	32.14	LC	7.51***	cointeg	no cointeg
	Delhi-Mysore	cointeg	0.93	1.04	-2.40	40.97***	TC	38.91***	cointeg	cointeg
	Patna-Mysore	cointeg	0.88	1.04	-2.49	29.79*	TC	37.68***	cointeg	cointeg
	Mumbai-Mysore	cointeg	0.38	0.76	-2.58	29.02	LC	7.88	no cointeg	cointeg
	Delhi-Malda	no cointeg	0.31	0.67	1.03	10.30	LC	17.90	no cointeg	no cointeg
	Patna-Malda	no cointeg	0.32	0.66	0.97	15.15	LC	21.71***	cointeg	no cointeg
	Mumbai-Malda	cointeg	0.12	0.74	0.32	11.36	LC	20.52	no cointeg	cointeg
World-Port	World-Kachch	no cointeg	0.08	0.90	4.98	26.92*	TC	21.05***	cointeg	cointeg
	World-Mysore	no cointeg	1.12	1.24	-7.43	31.76	LC	12.66***	cointeg	no cointeg
	World-Malda	no cointeg	0.10	0.83	0.24	14.17	LC	22.48***	cointeg	no cointeg

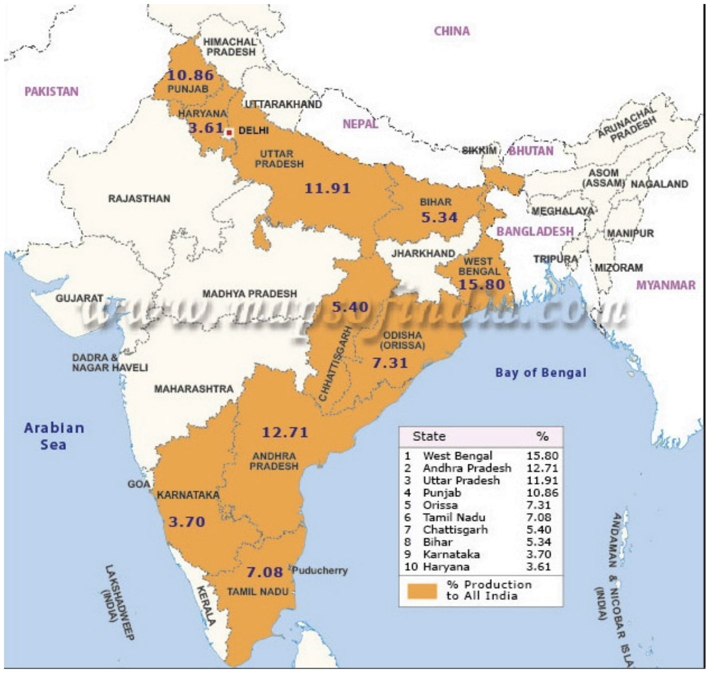
Continued Appendix Table 4. Detailed Cointegration Results for Rice, OT Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Burdwan	cointeg	0.48	0.89	-1.70	46.61***	TC	49.29***	cointeg	cointeg
	Kolkata-Burdwan	cointeg	0.52	0.84	1.29	25.98	LC	27.7	no cointeg	cointeg
	Mumbai-Burdwan	no cointeg	0.51	0.87	-0.37	36.73	LC	26.7	no cointeg	no cointeg
	Delhi-Bijnaur	cointeg	0.60	0.82	-1.31	61.18***	TC	46.1	no cointeg	no cointeg
	Kolkata-Bijnaur	no cointeg	0.47	0.89	-1.94	44.62**	TC	25.2	no cointeg	no cointeg
	Mumbai-Bijnaur	cointeg	0.61	0.79	0.73	53.70***	TC	30.13***	cointeg	cointeg
	Delhi-West Godavari	no cointeg	2.03	0.98	-0.03	59.46***	TC	18.08***	cointeg	cointeg
	Kolkata-West Godavari	no cointeg	2.30	1.04	1.05	32.92	LC	14.15***	cointeg	no cointeg
	Mumbai-West Godavari	cointeg	1.79	0.94	-2.45	36.24	LC	13.5	no cointeg	cointeg
Port-Producing	Mangalore-Burdwan	cointeg	1.24	0.93	0.13	32.66*	TC	38.5	no cointeg	no cointeg
	Ernakulam-Burdwan	no cointeg	2.95	0.82	2.00	43.11	LC	22.8	no cointeg	no cointeg
	Vadodara-Burdwan	no cointeg	0.31	0.93	-2.68	27.38	LC	18.0	no cointeg	no cointeg
	Mangalore-Bijnaur	no cointeg	1.21	0.85	-0.93	47.02**	TC	87.02***	cointeg	cointeg
	Ernakulam-Bijnaur	no cointeg	-0.43	0.76	-1.76	38.05***	TC	57.03***	cointeg	cointeg
	Vadodara-Bijnaur	cointeg	0.34	0.86	1.75	43.26***	TC	22.8	no cointeg	no cointeg
	Mangalore-West Godavari	no cointeg	4.82	0.99	1.95	36.42	LC	18.22***	cointeg	no cointeg
	Ernakulam-West Godavari	no cointeg	-2.78	0.87	3.54	33.48	LC	10.1	no cointeg	no cointeg
	Vadodara-West Godavari	no cointeg	0.95	1.02	1.38	46.77***	TC	20.4	no cointeg	no cointeg
Consuming-Port	Delhi-Managalore	cointeg	0.49	0.95	-1.88	63.7**	TC	47.38***	cointeg	cointeg
	Kolkata-Mangalore	cointeg	0.45	1.04	-1.95	45.17***	TC	31.7	no cointeg	no cointeg
	Mumbai-Mangalore	cointeg	0.53	0.92	-1.13	35.05	LC	30.14***	cointeg	cointeg
	Delhi-Ernakulam	no cointeg	0.17	1.06	-3.52	34.30	LC	16.67***	cointeg	no cointeg
	Kolkata-Ernakulam	no cointeg	0.32	1.16	-3.00	35.68	LC	18.67***	cointeg	no cointeg
	Mumbai-Ernakulam	no cointeg	-0.09	1.02	-3.50	28.39	LC	17.34***	cointeg	no cointeg
	Delhi-Vadodara	no cointeg	1.62	0.93	0.24	48.07***	TC	17.4	no cointeg	no cointeg
	Kolkata-Vadodara	no cointeg	1.74	1.01	-0.81	24.91	LC	15.8	no cointeg	no cointeg
	Mumbai-Vadodara	no cointeg	1.82	0.89	1.05	41.74**	TC	11.1	no cointeg	no cointeg
World-Port	World-Mangalore	no cointeg	0.36	1.24	-2.93	36.08***	TC	15.06***	cointeg	cointeg
	World-Ernakulam	no cointeg	-0.41	1.36	-5.43	39.92***	TC	14.27***	cointeg	cointeg
	World-Vadodara	no cointeg	0.96	1.19	1.71	39.23***	TC	23.08***	cointeg	cointeg

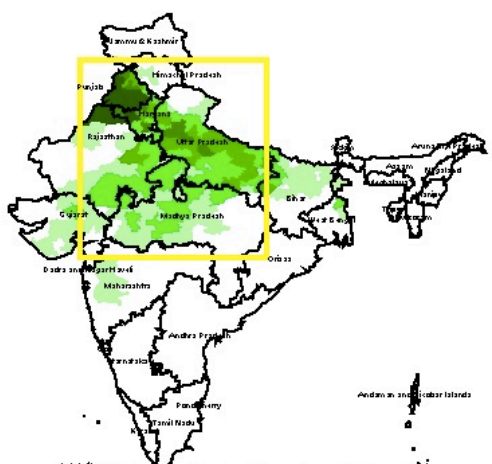
Continued Appendix Table 4. Detailed Cointegration Results for Wheat, OT Period

		Johansen Linear Cointeg Test Result	Estimated Beta Cointeg Vector in Linear VECM	Estimated Beta Cointeg Vector TVECM	Estimated Thresholds, Tau	Hansen Seo Threshold Cointeg Test Statistic Ho: LC	Hansen Seo Threshold Cointeg Test Result	Seo Threshold Cointeg Test Statistic (Ho: no Cointeg)	Seo Threshold Cointeg Test Result	Nested Conclusion from both Linear and Threshold Cointeg
Consuming-Producing	Delhi-Unnao	no cointeg	0.98	0.78	-0.23	26.78	LC	37.96	no cointeg	no cointeg
	Patna-Unnao	no cointeg	0.86	0.69	0.22	28.67	LC	13.94***	cointeg	no cointeg
	Mumbai-Unnao	no cointeg	0.72	0.50	-0.19	26.69	LC	33.14***	cointeg	no cointeg
	Delhi-Ludhiana	no cointeg	0.77	0.76	0.21	50.75***	TC	24.94***	cointeg	cointeg
	Patna-Ludhiana	no cointeg	0.74	0.74	0.03	52.38***	TC	25.87	no cointeg	no cointeg
	Mumbai-Ludhiana	no cointeg	0.16	0.51	0.16	43.32***	TC	23.54***	cointeg	cointeg
	Delhi-Gurgaon	cointeg	0.91	0.86	0.33	28.99	LC	28.16***	cointeg	cointeg
	Patna-Gurgaon	no cointeg	0.71	0.75	0.05	25.48	LC	15.30***	cointeg	no cointeg
	Mumbai-Gurgaon	no cointeg	0.85	0.53	0.65	31.44	LC	21.15	no cointeg	no cointeg
Port-Producing	Kachch-Unnao	no cointeg	0.70	0.90	0.21	20.92	LC	34.82***	cointeg	no cointeg
	Mysore-Unnao	no cointeg	0.72	0.70	-0.59	27.21	LC	31.84	no cointeg	no cointeg
	Malda-Unnao	no cointeg	0.62	0.98	0.44	29.48	LC	33.65	no cointeg	no cointeg
	Kachch-Ludhiana	no cointeg	0.32	0.92	-0.08	47.66***	TC	38.42	no cointeg	no cointeg
	Mysore-Ludhiana	no cointeg	0.65	0.73	-0.47	50.29***	TC	19.18	no cointeg	no cointeg
	Malda-Ludhiana	no cointeg	0.82	0.96	0.35	55.8**	TC	42.29	no cointeg	no cointeg
	Kachch-Gurgaon	cointeg	0.80	0.99	0.10	34.45	LC	42.36***	cointeg	cointeg
	Mysore-Gurgaon	no cointeg	0.81	0.77	0.63	29.33	LC	25.13	no cointeg	no cointeg
	Malda-Gurgaon	no cointeg	0.74	1.05	0.31	34.67*	TC	19.63	no cointeg	no cointeg
Consuming-Port	Delhi-Kachch	no cointeg	6.34	0.85	0.64	57.5***	TC	18.1***	cointeg	cointeg
	Patna-Kachch	no cointeg	1.02	0.79	0.19	30.21	LC	24.45***	cointeg	no cointeg
	Mumbai-Kachch	no cointeg	0.87	0.52	0.58	19.05	LC	20.93	no cointeg	no cointeg
	Delhi-Mysore	cointeg	1.49	1.11	-0.69	36.75	LC	34.16***	cointeg	cointeg
	Patna-Mysore	no cointeg	1.17	0.99	-0.97	29.60	LC	21.15***	cointeg	no cointeg
	Mumbai-Mysore	no cointeg	1.24	0.69	-0.92	30.00	LC	17.56***	cointeg	no cointeg
	Delhi-Malda	no cointeg	2.13	0.81	-0.31	37.55***	TC	24.36***	cointeg	cointeg
	Patna-Malda	no cointeg	0.94	0.74	0.32	30.27*	TC	20.30	no cointeg	no cointeg
	Mumbai-Malda	no cointeg	0.99	0.51	0.89	24.73	LC	17.01***	cointeg	no cointeg
World-Port	World-Kachch	no cointeg	1.00	1.04	1.05	24.5*	TC	36.64***	cointeg	cointeg
	World-Mysore	no cointeg	-2.88	1.35	0.82	31.29	LC	10.74***	cointeg	no cointeg
	World-Malda	cointeg	0.87	0.97	0.29	34.71***	TC	34.35***	cointeg	cointeg

Appendix Figure 1. Major Rice and Wheat Producing States



Source: http://www.mapsofindia.com/top-ten/india-crops/top-10-rice-producing-states-of-india.jpg



India Wheat Production - top five states	
State	5yr* Avg. Prod %
Uttar Pradesh	**34.6%**
Punjab	**20.7%**
Haryana	**11.5%**
Madhya Pradesh	**10.6%**
Rajasthan	**8.7%**
	*Years 1994 - 1998
1998/1999 season India produced 70,780,000 tons	
1997/1998 season India produced 66,350,000 tons	

Source: Joshi, A.K., B. Mishra, R. Chatrath, G. Ortiz Ferrara and R.P. Singh. 2007. “Wheat Improvement in India: present status, emerging challenges and future prospects”. *Euphytica* 157(3):431-446.

Appendix Figure 2. Major Ports of India

Source: http://ntseverma.blogspot.com/2013/10/lifelines-of-national-economy-meansof.html

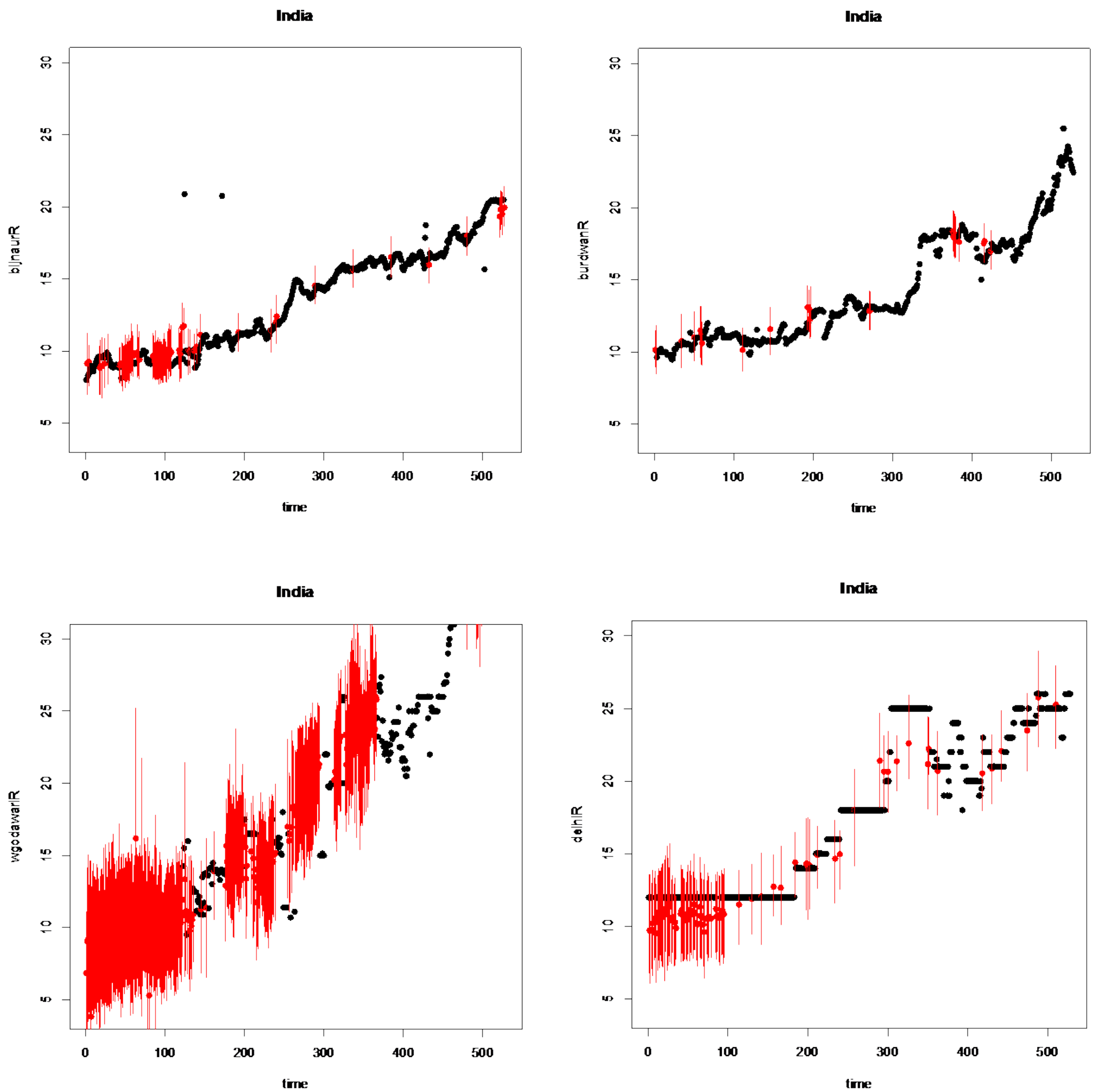
Appendix Figure 3. Imputed Data Plots

1) Aggregated the daily data to weekly by taking the median of price data in each week.
2) Used the multiple imputation method in the Amelia r package to reduce missing observations further.
3) Generated the plots below to see what the imputed data looks like.

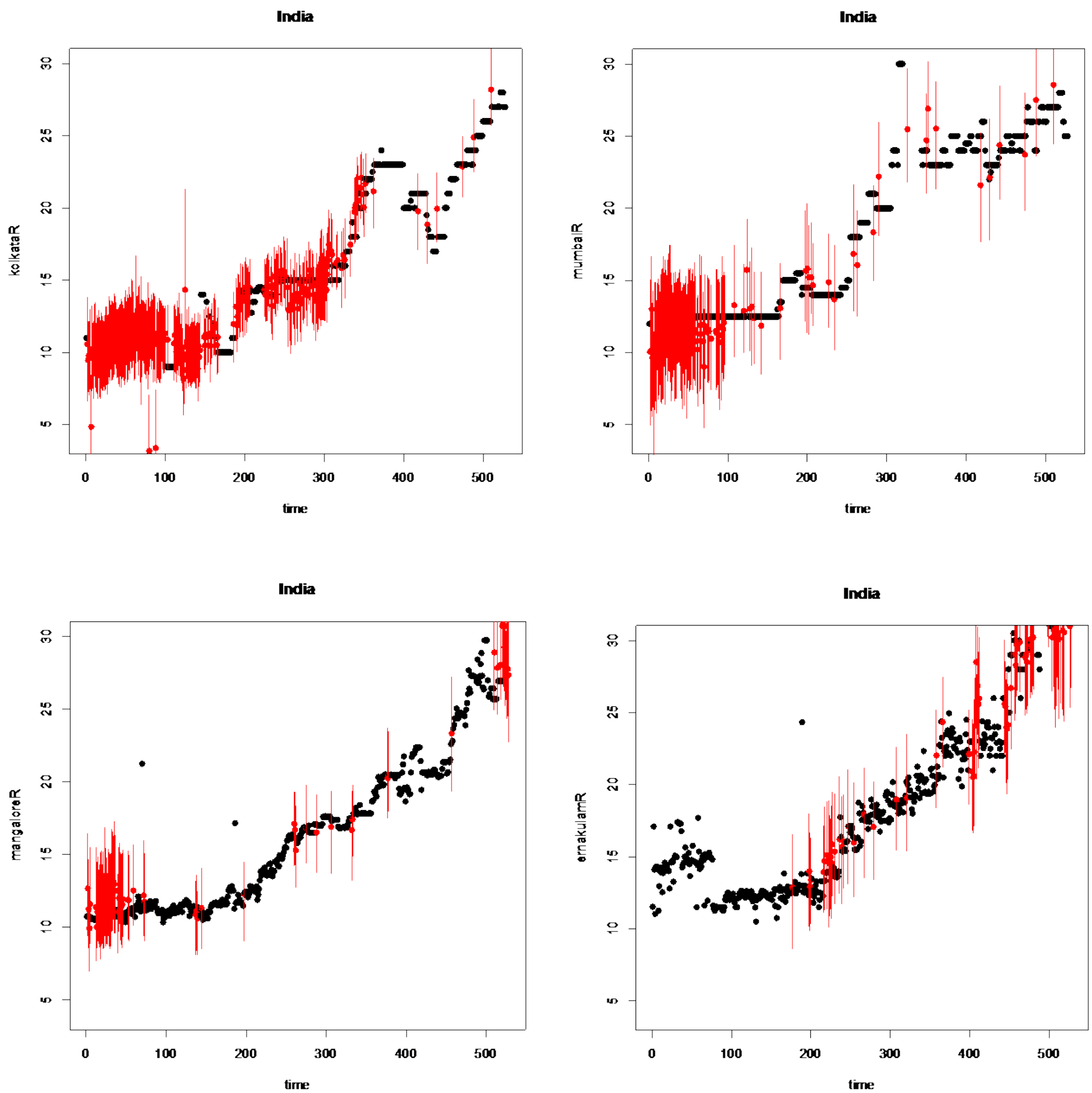
Notes:

- Black dots are actual monthly observations.
- Red dots are imputed.
- The red vertical lines are error bars that show the degree of uncertainty regarding imputed data point.
- The program generates many imputed datasets, then measures uncertainty by bootstrapping the imputed points. That is where the error bars come from.

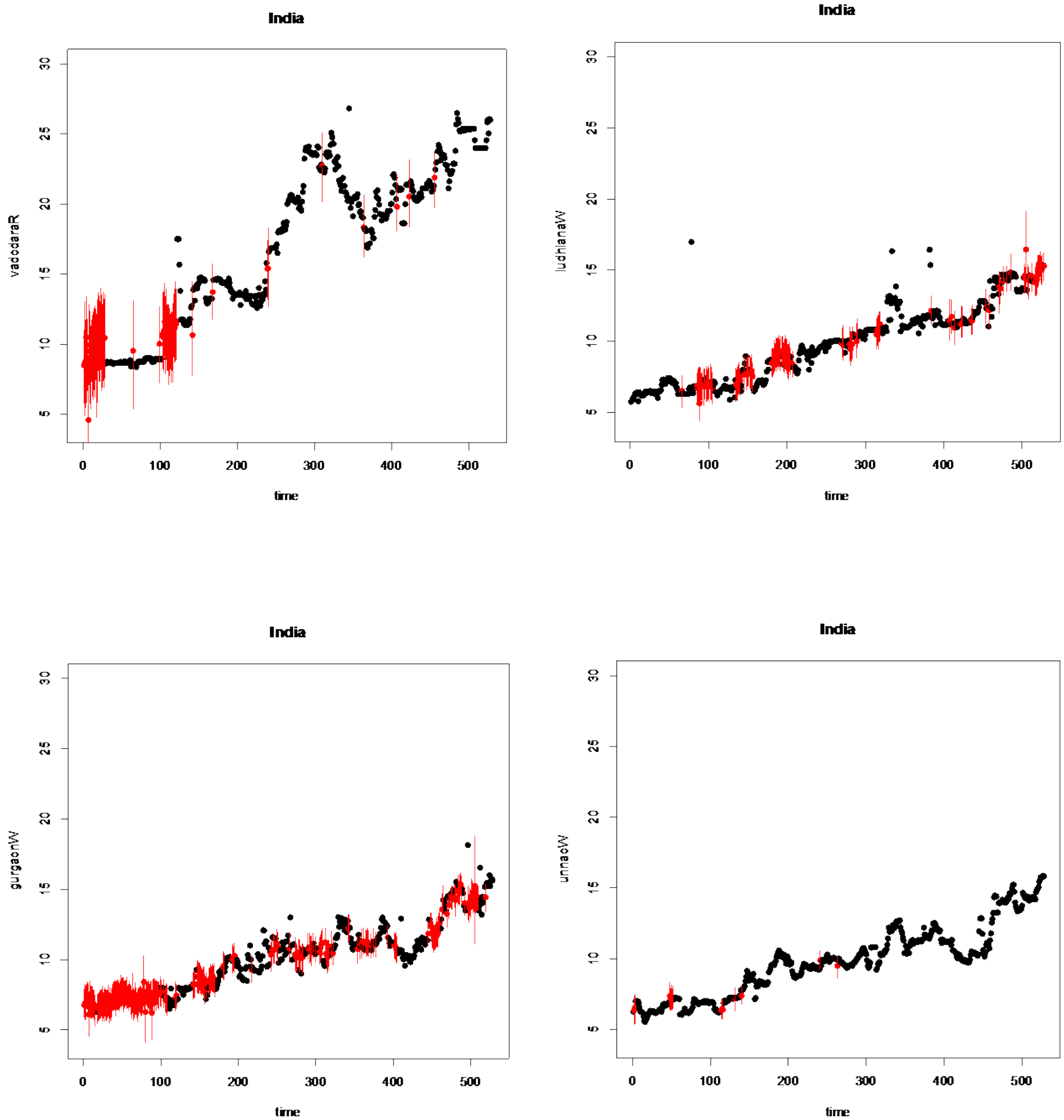
Continued Appendix Figure 3. Imputed Data Plots



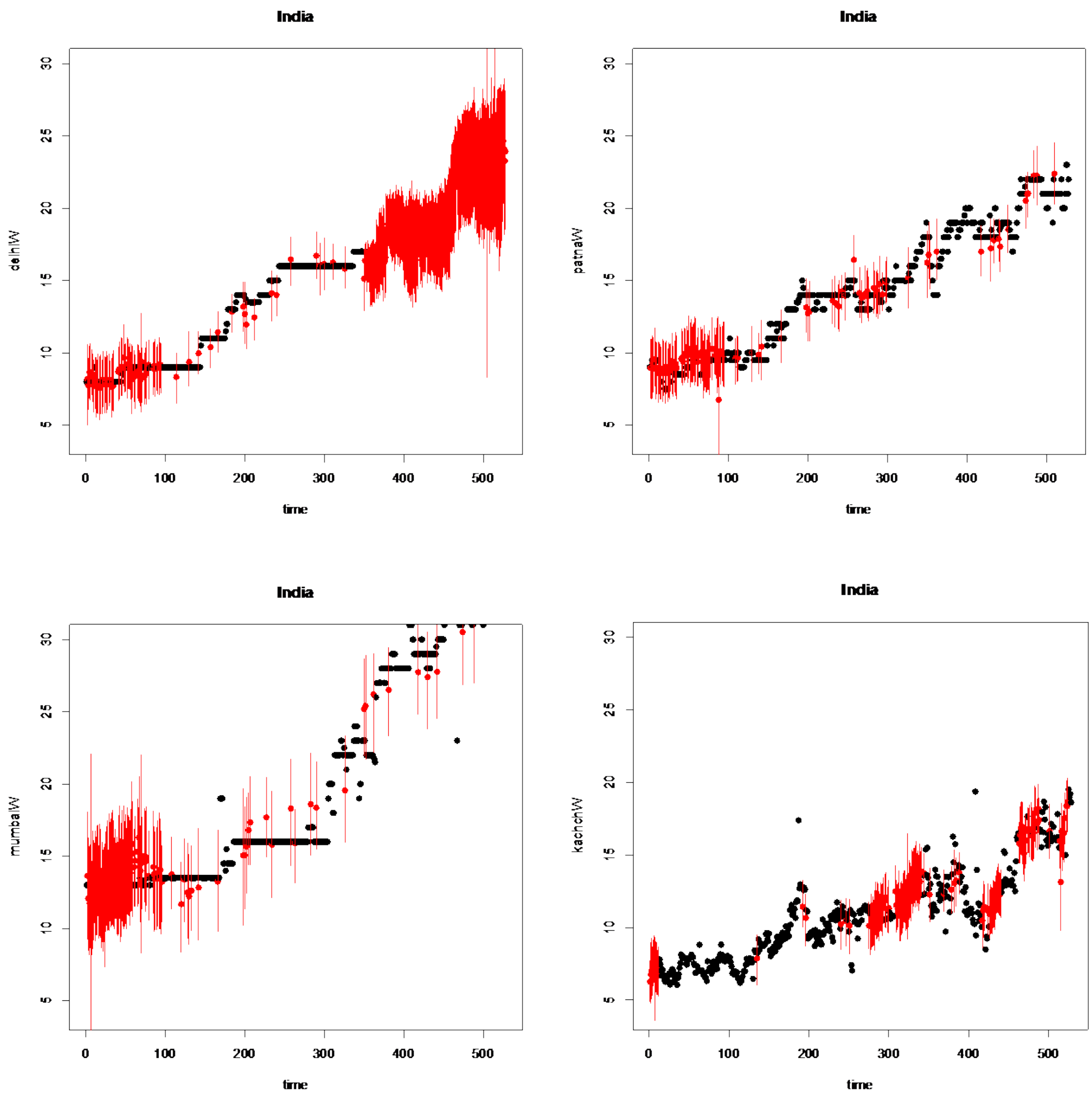
Continued Appendix Figure 3. Imputed Data Plots



Continued Appendix Figure 3. Imputed Data Plots



Continued Appendix Figure 3. Imputed Data Plots



Continued Appendix Figure 3. Imputed Data Plots