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Food Price Volatility in International and Indian Markets

A Case of Rice and Wheat

by

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Abstract

This paper examines the transmission of food price volatility from international to domestic markets in India. For this purpose, the Multivariate Generalized Autoregressive Conditional Heteroscedasticity (MGARCH) model with Dynamic Conditional Correlation (DCC) specification is used. The weekly prices of main staples rice (1993-2015) and wheat (2005-2015) are considered for the analysis. The study finds limited evidence for volatility transmission from the international to Indian markets. Particularly, restriction on exports dampen the transmission of food price volatility from external shocks like the Global Food Crisis 2007/08. Lack of internal integration in Indian markets leads to regional-variation in the level of interdependence with the world market. Results of the study dispel fears on agricultural trade liberalization in rice and wheat markets as volatility spillovers from the world markets are limited. Further, it highlights the negative implications of export restrictions on farmers and food importing nations.

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Introduction

1.1 Background and Research Problem

"We only buy in small quantities for daily use and avoid using expensive vegetables as much as we can" (Jadhav and Ahmed, 2020, n.p), is the response of 29 years old Mumbai based Anand Solanki when the media questioned him about the rise in food prices. With an average Indian spending about 45 percent of his/her disposable income on food any abrupt price changes can affect them dearly (National Sample Survey office, 2013). This makes food price volatility an issue of importance in India. Large sections of the society including consumers, traders and farmers are affected by food price volatility. Farmers and farm laborers who make up to 41 percent of India's workforce will be drastically affected if their revenue expectations are not met due to frequent changes in output prices (Sekhar, 2004). Politically too food price volatility is a sensitive issue as electoral outcomes are often based on the ruling governments ability to control prices of basic food items (Kalkuhl et al., 2016).

There are multiple reasons for food price volatility, as it not merely a demand supply problem, with volatility emerging from demand or supply shocks (Kalkuhl et al., 2016). In recent times, complex market inter-linkages (e.g. futures trading of agricultural commodities in financial markets), climate change, international trade, cost of inputs etc. play an important role in affecting food prices. This paper examines how the price dynamics in the world food market affects local food markets in a country like India. In particular, it attempts to focus on the transmission of food price volatility from international to local markets in India.

This question is mainly relevant for two reasons a) in wake of the Global Food Crisis in 2007/08, and b) in the light of trade liberalization of agricultural markets in India since the 1990s. The Global Food Crisis in 2007/08 is characterized by a sudden increase in global food prices. Prices of various agricultural commodities increased steeply as with the Food and Agricultural Organisation (FAO) food price index rising by 63 percent in 2007/08 compared to just 6 percent annual increase in 2006/07 (Rapsomanikis and Mugera, 2011). Prices of staples like rice and maize increased by 166 and 74 percent respectively (Rapsomanikis and Mugera, 2011) and this resulted in increased food inflation in many lower middle income countries.

Similarly, during 2007/08 the food price volatility for rice and wheat rose by 87 and 102 percent compared to the period before the crisis (Minot, 2014). This dramatic unexpected rise in food prices in the world market was transmitted to local markets and it created a panic in many lower middle income countries as a large part of their populations found it difficult to purchase food commodities. It is predicted that more such food crises globally would follow as agricultural markets have witnessed increased financialization, close links with alternative energy markets (like bio-fuel), and increased climate risks due to global warming. Thus, given this, it is important to understand the dynamics of volatility transmission between Indian and local markets to make effective policies to maintain price stability locally.

Secondly, the Indian economy since the 1991 Economic Reforms witnessed a series of changes which included trade liberalization of the agricultural markets. Imports and exports of various agricultural commodities were allowed and thus this increased the exposure of Indian markets to the outside world. India now has a large footprint in the international food market and thus is also susceptible to shocks from there. Hence, it's critical to examine the issue of volatility spillovers from the world market to India. Further details on India's trade policy and changes are discussed in Section 1.2.

Given this, the paper attempts to evaluate to the transmission of food price volatility from international to local markets in India. Weekly prices of rice and wheat from the international market and various Indian markets have been used for this. The period of the analysis is 1995-2015 for rice and 2005-2015 for wheat. This sample period accounts for major events of interest such as economic reforms in India and the Global Food Crisis in 2007/08. Particularly, rice and wheat have been chosen as they constitute the highest share in an Indian diet (Department of Economic Affairs, 2020) and high-frequency data for this is also readily available. MGARCH-DCC approach proposed by Engle (2002) has been used for analysis. The main advantage of this is that it estimates dynamic correlations which can be used to precisely understand the times when transmissions were higher and vice-versa.

This paper contributes to the literature in the following ways: It is one of the few papers that have attempted to examine the transmission of food price volatility from international to the Indian market. The other papers in the literature usually explore mean price transmission or have India as one of the countries in their panel with usually one food commodity. No detailed analysis of this sort connecting India's trade-food security policy with volatility transmission has been conducted. Secondly, this paper uses a MGARCH-DCC model with time-variant features. The DCC specification has not been employed before in previous studies with regard to India. Finally, this paper uses a uniquely constructed data set with weekly frequency data from multiple local markets in India. This gives a better understanding of the volatility dynamics as previous studies rely on monthly data and cover only one or two major regions from India.

The remainder of this paper is organized as follows. Section 1.2 describes India's agricultural trade policy. Section 2 provides a detailed discussion of previous literature. Followed by this Section 3 explains the various methods that are used in the analysis. Description of the data and some simple analyses are presented in Section 4. Results are discussed in detail in Section 5 and are finally followed by a conclusion in Section 6.

1.2 Agricultural Trade Policy in India

The degree of volatility transmission from international to domestic market of any country is directly related to the trade policy of that country. According to Ceballos et al. (2016) several factors such as a) trade restrictions, b) cross-border transportation costs, c) the level of export/import of a particular commodity, and d) level of government intervention in regulating the local commodity prices play a major role in determining the level of volatility transmission. Thus, in this context, the paper examines India's agricultural trade policy before the econometric analysis.

Historically, India had a very restrictive agricultural trade policy. Most of the imports were routed through state run monopolies and private participation was not encouraged. Only important cereals, pulses and edible oils were imported as when there were domestic shortfalls. Similarly, export policy was also based on the local needs as exports were banned as and when there were domestic shortfalls. Other restrictions like a minimum export price and quotas were also prevalent (Saini and Gulati, 2016).

Only in the middle of 1990s, India started liberalizing its agricultural trade policy. The motivation to do this now was mainly due to IMF's Structural Adjustment Program in the backdrop of India's exchange rate crisis in 1991. World Trade Organization's (WTOs) Uruguay Round Agreement on Agriculture is also said to have played a role in opening up of India's agricultural markets (Bathla, 2012). Edible oil was one the first commodities to be opened up for imports and it has emerged to be one of the top items imported into India every year as almost two-third of domestic demand is met through imports (Bhardwaj and Jadhav, 2021). Restrictions on other food items and cereals were only removed gradually with some restrictions lasting up to 2002. Though, India adopted a liberalized trade regime, its trade policy in general is not consistent as export/import bans and quotas are often introduced as and when there are shortfalls or price rise in the domestic market. The government actively intervenes in the market to stabilize the prices and flow of goods (Sekhar, 2004). Since this paper is concerned about cereals such as rice and wheat, its trade policy is discussed in depth.

Common rice and wheat exports were lifted in 1994 and 1995 respectively. India's rice exports were highly competitive and it emerged as second largest exporter in the world (Saini and Gulati, 2016). Similarly, wheat exports also witnessed an increase. However, since these cereals were sucked away by the international market, prices in the domestic market increased and this forced the government to impose a ban on exports of these cereals in 1996-1997. After this episode, over-accumulation of rice and wheat in the government granaries and a decreasing number of beneficiaries receiving subsidized cereals from the government, motivated the policymakers to again promote exports of rice and wheat in the year 2000. However, this decision was again reversed in 2007 as due to shortage of wheat in the domestic market. This led to the government banning wheat exports again. Banning of exports in 2007 paved the way for reduction and stabilization of wheat prices in India.

Similarly, for rice, in the wake of Global Food Crisis is 2008, India gradually raised restrictions on rice exports and banned exports completely in 2008. Only exports to some neighboring countries and low income countries was continued to avert any food crisis there. Following the Global Food Crisis, export of rice and wheat resumed in 2011. Notably, wheat export reached record heights in the year 2012 touching 6.5 Million Metric tons (MMT) compared to the previous peak of 4 MMT in 2003 (Saini and Gulati, 2016). India also has been the second largest exporter of rice since 2011.

Overall India, is a net exporter of agricultural commodities. It has a large exportable surplus especially in cereals. As per WTO records, India's share in global exports of agricultural commodities has increased from 0.8 percent to 2.6 percent in 2012. It has remained the largest exporter of rice for several years when exports were allowed. Though, it is the second largest wheat producer in the world followed by China, its presence in the international market is limited to just 5 percent of the world trade as more than 90 percent of wheat is consumed domestically (Saini and Gulati, 2016).

The need to formulate an effective trade policy has been one of the objectives of Indian policymakers in recent times. The effectiveness of this export-restriction based trade regime has become a point of debate. There are questions on the impact these export restrictions on food prices in India and farmers interests (Goel and Krishnan, 2021). A number of studies find export restrictions to be instrumental in preventing volatility spillover during Global Food Crisis in 2007/08 (Rapsomanikis and Mugera, 2011; Saini and Gulati, 2016; Ceballos et al., 2016). This paper further attempts to explore this question and discussions the implications of having such a policy.

2

Literature Review

There are broadly two kinds of studies on the interaction between international and domestic food markets. The first type of study focuses on the transmission of food prices (mean spillover) and the second type is on the volatility spillover between international and local food markets[1]. This paper is related to the later type as it focuses on transmission of food price volatility from international to domestic markets. Studies with regards to volatility spillover are common in finance literature but are rarely used in analyzing the food markets (Ceballos et al., 2016). Only after the Global Food Crisis in 2008, interest to study volatility spillovers in agricultural markets increased. Most of the papers examining volatility spillovers use MGARCH models with different specifications.

Rapsomanikis and Mugera (2011) evaluate the mean and volatility spillovers between international and local food markets in India, Malawi, and Ethiopia. Their main motivation is to understand the impact of the Global Food Crisis in 2007/08 on the food prices in these developing countries. For this study, they consider the wheat market for Ethiopia, rice market for India, and maize market for Malawi. By using the MGARCH model with BEKK (Based from the names of researchers Baba, Engle, Kraft and Kroner) specification, they find that volatility transmission occurs only on a limited scale between the international market and the countries considered. The authors conclude that in these countries, shocks in the local economy have a greater contribution to volatility than the shocks from the world markets. Volatility spillover is greatest during extraordinary events like the Global Food Crisis in 2007/08.

[1]The main difference between these two kinds of studies is that the former examines the transmission of prices in levels whereas the latter is concerned with co-movement of the variance (Rapsomanikis and Mugera, 2011). Though it is plausible to say that high transmission of prices equates to high volatility spillover, there are still many be cases where it is not true. As described by Ceballos et al. (2016), even in markets where there is a high transmission of volatility, it takes up to 6 months for the effect of international prices to be felt in the local market, thus due to this the immediate effect of high volatility will not be transmitted into local markets and they will end up having low volatility overall. Similarly, in markets with no price transmission, just the news of high volatility can lead to uncertainty and fuel volatility in the local markets (Ceballos et al., 2016).

With regards to the Indian rice market, they again find that the volatility spillover is limited due to the government's intervention in regulating the prices by banning exports. However, they also observe that India's export ban could have induced higher volatility in the international rice market as India is one of the major exporters of rice.

On the same lines Ceballos et al. (2016), in their seminal paper, examined volatility spillovers from international to domestic markets for 27 developing countries from Asia, South America and Africa. For this purpose, they used a MGACRH-BEKK model and further calculated a volatility transmission estimator using the results of the model. Their result was that volatility transmission to a particular local market depended on the level of interaction between a particular country with the world market. For instance, countries that import large quantities of agricultural commodities to meet domestic consumption witnessed high degree of transmission from the world market. Overall, larger transmissions from the world market is experienced when the proportion of export/import vis-a vis domestic production is greater than 40 percent for a particular commodity. About 29 of the 41 countries (and sub-regions) evaluated by the authors followed this rule. Another important finding is that countries in Africa experienced more food price volatility than countries in Asia and Latin America. With regards to India, volatility spillovers from world to local markets were not significant in the rice market. The authors believe that low dependence on import of rice and government intervention to stabilize prices could be a plausible explanation for this. On the contrary, volatility spillovers were observed in the wheat markets in India. This is a surprising result according to the authors and they could not explain it as India's wheat trade (international) is just around 2 percent vis-à-vis domestic production.

Another paper that makes significant contributions is the paper by Guo and Tanaka (2019). This paper evaluates volatility spillover from world to local markets of several wheat importing countries. Further, the authors also examine if self-sufficiency rate[2] (SSR) in wheat production stalls volatility transmission from the world market. Unlike the previous papers the authors use a MGARCH model with DCC specification (MGARCH-DCC) model for their analysis. The aim behind using a DCC specification is to capture the precise periods when volatility spillovers increased as the DCC model estimates time-variant conditional correlations. Their results suggest that volatility in international wheat prices significantly affect the volatility in domestic prices in these countries.

[2]According to Guo and Tanaka (2019), this is calculated as the ratio of domestic production to net production inclusive of imports and exclusive of exports, i.e. $production/(production+imports-exports)$

This is true especially when their domestic production falls (SSR falls) and they import wheat from the international market. They conclude that higher self-sufficiency attained by increasing domestic production and reducing imports limits volatility spillover from the international wheat markets.

Apart from directly examining spot prices, Hernandez et al. (2014) examine returns from futures prices from different exchanges across the world to see if there are volatility spillovers between them. They use MGACRH models of different specifications like BEKK, CCC (Constant Conditional Correlation) and DCC. Their results suggest that presence of cross-volatility spillovers in agricultural commodity markets amongst these exchanges situated in USA, Europe and Asia. As a policy suggestion they advocate for better coordination amongst these markets to control futures price volatility.

Apart from these papers, some papers use co-movement of standard deviations of local and international logarithmic prices of various agricultural commodities to comment on the volatility transmission. Mittal et al. (2018) compare prices from different local markets in India with the prices from international for rice and wheat. They find that the standard deviation is higher in the international markets compared to the Indian markets for both wheat and rice. They also find that certain markets like Uttar Pradesh in Northern India have a higher standard deviation compared to rest of the India due to presence of large number of intermediaries in the trade. In similar vein, Sekhar (2004) paper also compute and compare standard deviations of prices between local and international markets for a range of commodities like rice, wheat, cotton, oils and tea. The author finds that in the long-run, standard deviations of Indian prices are much lower than the international prices. However, in certain periods the standard deviations of the domestic prices (in logs) are close and sometimes even higher than the international prices.

3

Methodology

This section explains the methods that will be used for the analysis. In particular, the features of the Granger Causality test and the MGARCH-DCC model are explained. At first, the Granger Causality test is used to understand the causality relationships between international and domestic markets. This will be helpful to ascertain the direction of volatility spillovers when the conditional correlations are examined. The dynamics of volatility are evaluated using the MGARCH model with DCC specification. The DCC specification proposed by Engle (2002), helps in generating dynamic conditional correlations which can be used to understand the level of volatility spillovers between international and domestic markets across time. It has computational advantages compared to the other specifications as the number of parameters that are needed to estimated are lower. This specification is also widely used in the finance literature to model volatility spillovers (Guo and Tanaka, 2019).

3.1 Granger-Causality Test

The Granger Causality test evaluates if a variable x "Granger causes" y. Here Granger causes implies that the lagged values of x can be used to predict the present value of y, given the past values of y. For this test, variable y is regressed on its own lagged values and the lagged values of x (StataCorp, 2021). The null hypothesis of this test is that the coefficients of the past values of x are jointly zero (Granger, 1969). A rejection of the null hypothesis indicates that x Granger causes y.

3.2 DCC Model

The model consists of a conditional mean and conditional variance equation for each of the weekly returns price series considered. Price returns are computed as $ln(p_t/p_{t-1})$, where p_t can be either the price of a commodity at an international market or domestic markets at time t. The graphs containing the returns of each series can be found in Figure 3 in the Section 4.2.

The conditional mean equation is a vector auto-regressive (VAR) model and is given by Equation 3.1

$$r_t = \gamma_0 + \sum_{n=1}^{p} \gamma_n r_{t-n} + \epsilon_t, \epsilon_t | I_{t-1} \sim (0, H_t), \tag{3.1}$$

here, r_t is a 4×1 vector containing price returns of international and Indian prices from three major market zones at week t. γ_0 is a 4×1 vector containing the constants. γ_n is a 4×4 parameter matrix, such that $n = 1, .., p$. These parameters capture the own and cross dependence that exists across markets at the mean level (Ceballos et al., 2016). ϵ_t is a vector containing the error terms and it is conditional on the past information I_{t-1}. Additionally, the conditional variance-covariance matrix is given by H_t. Lags p for the conditional mean equation were determined based on the Bayesian information criterion (BIC). Based on the BIC, one lag for rice and zero lag for wheat were chosen. As in previous literature, to capture the dynamic link between prices of different markets in the most original form, other control variables are not included in the mean and variance equations (Rapsomanikis and Mugera, 2011; Hernandez et al., 2014; Ceballos et al., 2016; Guo and Tanaka, 2019).

The conditional variance-covaricance matrix of returns expressed in Equation 3.1 can be expanded as

$$H_t = D_t R_t D_t, \tag{3.2}$$

here H_t in Equation 3.2 is a product of D_t, the diagonal matrix with conditional standard deviations, and R_t, the conditional correlation matrix. D_t is given by

$$D_t = diag(h_{11,t}^{\frac{1}{2}}, ..., h_{44,t}^{\frac{1}{2}}), \tag{3.3}$$

$$h_{ii,t} = \omega_0 + \sum_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j h_{ii,t-j}, \tag{3.4}$$

here $h_{ii,t}$ such that $i = 1, .., 4$ is the conditional standard deviation obtained from a univariate GARCH (p,q) model. α_j and β_j capture the ARCH and GARCH effects respectively. Their sum represents the persistence of volatility and has to be less than one. The lag order p and q was chosen by the BIC. Further R_t, the conditional correlation matrix is given by

$$R_t = diag(q_{11,t}^{\frac{-1}{2}}, ..., q_{NN,t}^{\frac{-1}{2}}) Q_t diag(q_{11,t}^{\frac{-1}{2}}, ..., q_{NN,t}^{\frac{-1}{2}}), \tag{3.5}$$

where, $Q_t = q_{ij,t}$ such that $i, j = 1, .., k$. Q_t is a symmetric and positive definite matrix with the following form:

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 \lambda_{t-1}\lambda'_{t-1} + \theta_2 Q_{t-1}, \tag{3.6}$$

$\bar{Q}$ is the unconditional variance matrix of the standardised residuals given by θ_t ($\theta_{it} = \frac{\epsilon_{it}}{\sqrt{h_{iit}}}$).The adjustment parameters θ_1 and θ_2 must be non-zero to ensure that the conditional correlations are dynamic. Further, the sum of these adjustment parameters must be less than one to ensure that the model is mean reverting.

The correlation coefficient between the international and domestic series is given by $\rho_{ij,t}$. Here, $\rho_{ij,t}$ is defined as

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}, i \neq j, \text{and} i, j = 1, 2, .., k \tag{3.7}$$

The direction and strength of the correlation is captured by $\rho_{ij,t}$. According to Lean and Teng (2013), if positive, the correlation between the series is in the same direction and is rising. Quasi-maximum likelihood estimation is used for estimating the parameters of the DCC model (Bollerslev and Wooldridge, 1992). The joint log-likelihood function is constructed as the sum of mean and the variance part (further divided into volatility and correlation parts). The parameters in D_t, i.e the (ω, α, β) from the GARCH part of Equation 3.4 are estimated from the volatility part. Additionally, from R_t (correlation part) the adjustment parameters (θ_1, θ_2) are estimated.

4

Data

The data used for the analysis are International and Indian weekly prices of rice and wheat. This data has been mainly compiled from two sources. The weekly domestic prices for rice and wheat have been sourced from India's Open Government Data Platform. This platform publishes prices of various essential commodities collected from various markets situated in different parts of the country through their Price Monitoring Cells (PMCs). To capture India's vastness and price difference, various markets have been clubbed together into three zones based on their geographical location. The average price for each of these zones has been computed, for example, the North Zone contains the average prices of various North Indian cities/towns like Kanpur, Amritsar, and Chandigarh. Table 1 contains the list of cities/towns under each zone. Due to a large number of missing data, the Eastern zone containing cities from Eastern parts of India has been excluded from the analysis.

Table 1: Cities/towns in each zone for rice and wheat

North Zone	**West Zone**	**South Zone**
Amritsar	Ahmedabad	Bangalore
Chandigarh	Bhopal	Chennai
Delhi	Indore	Ernakulum
Hisar	Jaipur	Hyderabad
Kanpur	Jodhpur	Madurai
Karnal	Mumbai	Puducherry
Lucknow	Nagpur	Thiruvananthapuram
Ludhiana	Rajkot	Vijayawada

As followed in the literature, domestic prices denominated in Indian rupees were converted to US dollars using weekly exchange rate data from the Federal Reserve Bank of St. Louis's (FRED) database. Thus, all the commodities are now expressed as US dollars per quintal (100 kg).

The weekly international prices of rice and wheat have been collected from the Food and Agricultural Organization International Commodity database (FAOSTAT). The international price of rice and wheat is represented by the export price from Thailand (A1 super, white broken rice, Bangkok) and U.S Gulf Coast (No.2 hard red winter wheat, US Gulf) respectively. These prices have been commonly used as benchmark international prices for rice and wheat in the previous literature (Ceballos et al., 2016; Sekhar, 2004; Guo and Tanaka, 2019; Mittal et al., 2018).

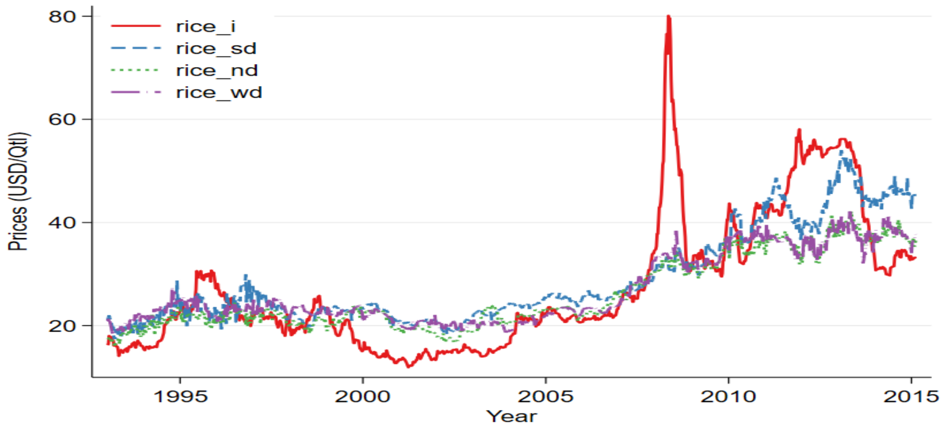
The data for rice is from January 1993 to February 2015. However, the data for wheat begins only in January 2005 (to February 2015), as higher frequency data before that is not available. Nevertheless, this sample period is important as major events such as the Global Food Crisis in 2007/08 are encompassed in it.

4.1 Trends in Rice and Wheat Prices

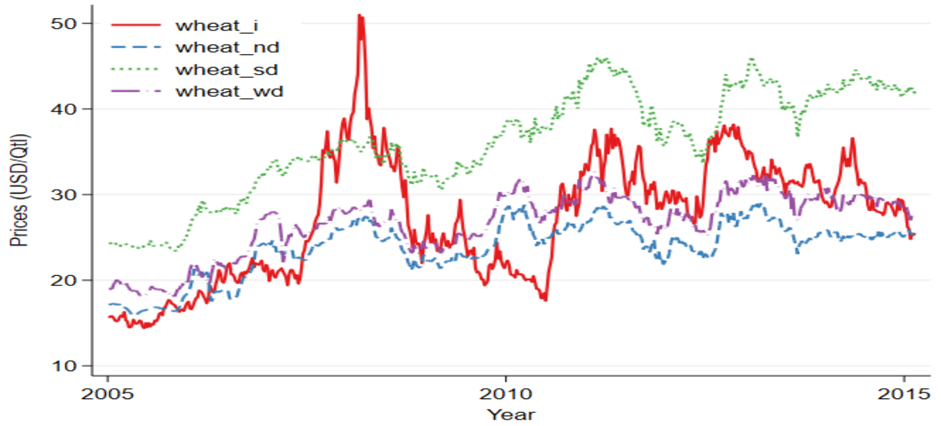
Figure 1 depicts the trends in international and domestic prices for rice and wheat. Visually the domestic prices of both commodities, seem to co-move with the international prices. Both the international and domestic prices of rice have risen over time. Notably, a ban on the export of rice and wheat by India during the Global Food Crisis in 2007/08 protected Indian markets from experiencing a steep price rise as witnessed in the world market (Ganguly and Gulati, 2014).

From Figure 1, we can also notice that in the long-run, Indian and international prices converge. This is similar to the findings of Saini and Gulati (2016) as they find that international and Indian prices converge in the long-run. The Economic Survey of India's (2015) view that Indian and international prices do not converge is only true in the short periods during the Global Food Crisis as in the long run Indian prices follow the international prices. (Department of Economic Affairs, 2015).

To compare the congruence in volatilities between domestic and international markets, the quarterly standard deviation is calculated using weekly prices for both commodities and is presented in Figure 2. Note for this, the weekly standard deviation is calculated as the standard deviation of price returns for that particular week and the preceding 12 weeks (a quarter) (Ceballos et al., 2016).



(a) Rice Prices from 1993-2015



(b) Wheat Prices from 2005-2015

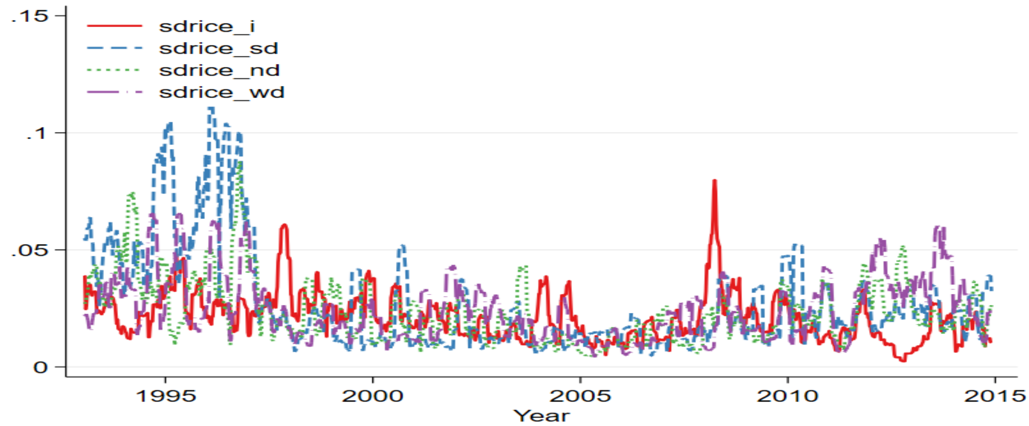
Figure 1: Evolution of international and domestic prices expressed in USD/Qtl. Note: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone

For rice, based on Figure 2 and the discussion's on India's trade policy in Section 1.2, four phases can be categorized. This categorization will later come handy when analyzing the dynamic conditional correlations in the results section. The periods of interest are:

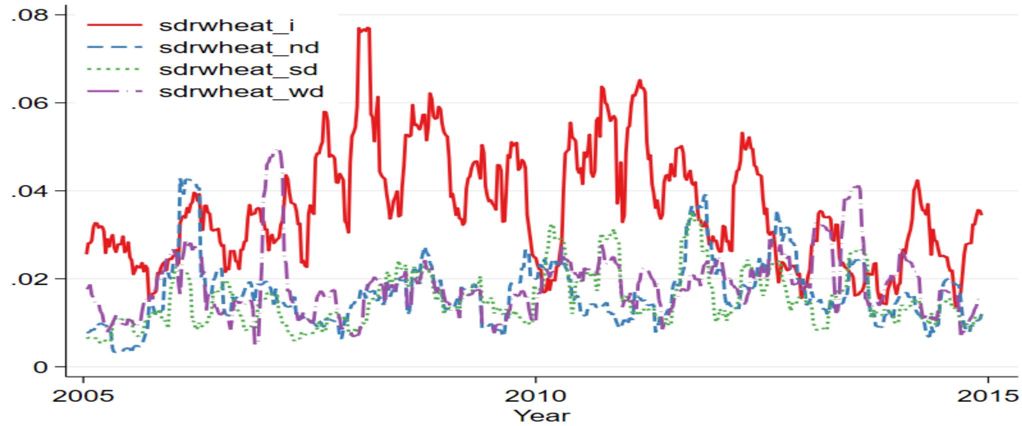
(a) 1995-1998: During this period the domestic price volatility is greater than the international price volatility and thus there is no congruence. This is also the first time rice exports are allowed out of the country and it was eventually banned in 1998 due to price instability within India,

(b) 2000-2007: In this phase the international and domestic prices volatilities are congruent and co-move with each other until the Global Food Crisis in 2007/08. Rice exports which were banned in 1998 was lifted again in 2000,

(c) 2007-2010: This a period when the Global Food Crisis occurred and as seen in Figure 2, international rice prices were more volatile than the Indian rice prices and thus are not congruent. Rice exports out of India were banned in early 2008,



(a) Rice Prices from 1993-2015



(b) Wheat Prices from 2005-2015

Figure 2: Volatility of international and domestic prices. Note: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone

(d) 2010-2015: During this phase domestic rice prices appear to be more volatile compared to international prices. Exports out of India were allowed again in 2011.

Similarly, for wheat two categorizations can be made based on Figure 2 and discussions in Section 1.2. The phases are:

(a) 2005-2010: During the Global Food Crisis, volatilities are not congruent. The world wheat price volatility was much higher than the domestic prices,

(b) 2010-2015: Not congruent until 2012 as the volatility of the international prices were higher compared to the domestic prices. However, close to 2015 the volatilities co-move. Notably, wheat exports were allowed back in 2011.

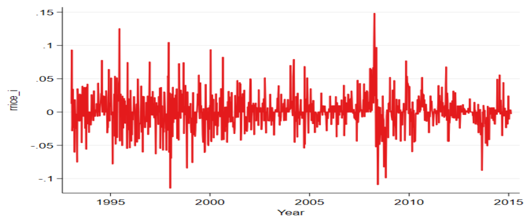
4.2 Summary Statistics

Table 2: Summary Statistics

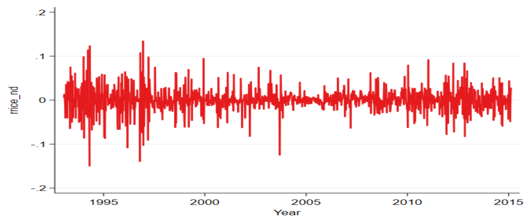
	N	Mean	SD	Skew.	Kurt.	ADF
Rice Price Returns						
International Series (rrice_i)	1,153	0.00061	0.29146	0.29146	6.7678	-28.417^{***}
India: North Zone (rrice_nd)	1,153	0.00065	0.02649	-0.14625	7.70426	-45.529^{***}
India: South Zone (rrice_sd)	1,153	0.00066	0.03451	-0.0752853	14.07869	-47.189^{***}
India: West Zone (rrice_wd)	1,153	0.00051	0.02705	0.14490	7.1925	-47.435^{***}
Wheat Price Returns						
International Series (wheat_i)	528	0.00093	0.03840	0.04333	3.9478	-22.234^{***}
India: North Zone (wheat_nd)	528	0.00071	0.01863	-0.69206	7.2267	-21.563^{***}
India: South Zone (wheat_sd)	528	0.00102	0.01653	0.18946	5.4731	-25.043^{***}
India: West Zone (wheat_wd)	528	0.00070	0.02013	-0.44663	6.2069	-23.717^{***}

Notes: *** denotes rejection of null hypothesis at 1 percent significance level. SD denotes standard deviation, Skew. denotes skewness, Kurt. denotes kurtosis and ADF denotes Augmented Dickey Fuller test

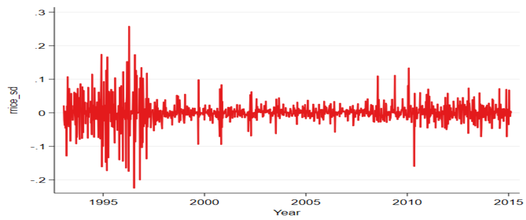
Table 2 presents the summary statistics for the price returns on rice and wheat. It can be observed that the mean of all the returns series are positive indicating that there has been an overall price increase in all the markets. In terms of standard deviations for rice, except for the Southern Zone all the other domestic zones have a standard deviation less than the international market. For wheat, the international series has the highest standard deviation pointing out the presence of higher fluctuations globally. These are in line with Mittal et al. (2018), as they found that the international wheat returns had a higher standard deviation than the domestic returns in their sample. Augmented Dickey-Fuller (ADF) performed on each of the return series indicates that they are stationary. Finally, the international series for both the commodities are positively skewed indicating that the positive returns are higher than the negative returns. For the domestic series, a couple of zones are negatively skewed indicating a larger presence of negative returns. The kurtosis are greater than 3 for all the series pointing the presence of flat tails compared to a normal distribution. Figure 3 presents the graphs containing the weekly returns of rice and wheat. Mean reversion and volatility clustering is observed across the price returns.



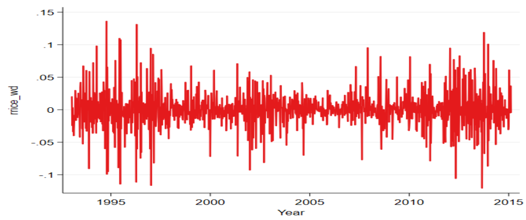
(a) International Rice series



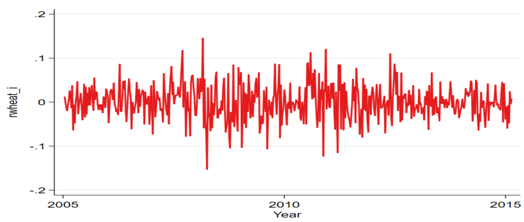
(b) India Rice: North Zone



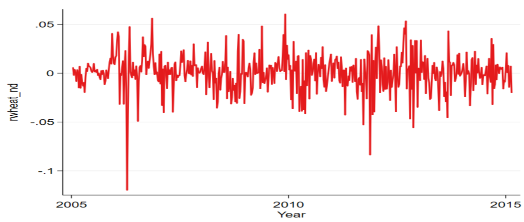
(c) India Rice: South Zone



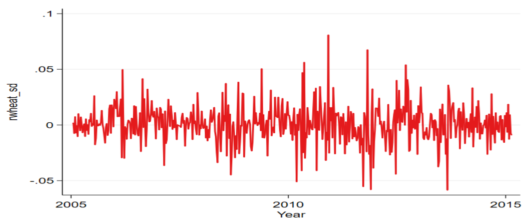
(d) India Rice: West Zone



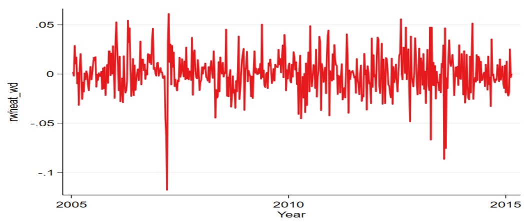
(e) International Wheat Series



(f) India Wheat: North Zone



(g) India Wheat: South Zone



(h) India Wheat: West Zone

Figure 3: Weekly Returns of rice and wheat

5

Empirical Analysis

This section explains the results from various stages of analysis for both rice and wheat. At first, the directional relationship between international and local price returns is analyzed using the Granger Causality test. Following this, the MGARCH-DCC model is used to estimate the dynamic conditional correlations. These conditional correlations are analyzed to understand the interdependence between the Indian and international food markets.

5.1 Results from the Rice Market

5.1.1 Results from the Granger-Causality Test

The Granger Causality test is conducted to understand the direction of volatility spillover between the domestic and international markets. As mentioned in Section 3, this will be useful when the dynamic conditional correlations derived from the MGARCH-DCC model are examined. Similar tests have been employed by various authors including Robles et al. (2009) and Guo and Tanaka (2019). Results of this test have been presented in Table 3.

The results presented indicate presence of no Granger causality relationship between international and domestic returns. This is not surprising as several factors such as self-sufficiency in food grain production, control over input prices (fertilizers and fuel), and government intervention to stabilize prices, dampen the impact of international prices on Indian prices. Additionally, the level of interaction with the world market is also low as India only exports less than 21.5 percent of its rice production relative to Thailand which exports about 70 percent of of its total rice production (Goel and Krishnan, 2021). Several studies, including those by Sekhar (2004) and Ceballos et al. (2016) find low levels of interdependence between the Indian and international rice markets.

However, this result contradicts the hypothesis proposed by Rapsomanikis and Mugera (2011) as they had claimed that there existed a direction of spillover from Indian to world rice prices. This is because India is one of the largest exporters of rice and thus its prices can be influential in the world market. This paper finds no evidence of this now as domestic prices returns do not Granger cause international prices returns. The plausible reason could be that India had imposed either a complete export ban or restrictions for about 10 years in the total sample periods of 25 years between 1993-2015. Even in the years when there were no restriction India was the second-largest exporter followed by Thailand only in few select years like 1995-1996 and post 2011.

Another result that we derive from this analysis is that local prices Granger cause each other. This is not a surprising result as the zones are located close to each other and are interdependent to meet their food needs. These results are not presented here as the paper deals with examining dynamics of volatility between international and domestic markets.

Table 3: Granger Causality Test for returns on rice prices

Null Hypothesis	**Chi2**	**Prob.**
rrice_i does not granger cause rrice_nd	0.68	0.711
rrice_i does not granger cause rrice_sd	2.425	0.462
rrice_i does not granger cause rrice_wd	1.641	0.373
rrice_nd does not granger cause rrice_i	1.648	0.559
rrice_sd does not granger cause rrice_i	1.544	0.462
rrice_wd does not granger cause rrice_i	1.973	0.373

Notes: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone.

5.1.2 Results from the MGARCH-DCC Model for rice

The result of the MGARCH-DCC model for rice is presented in Table 4. Lag-length (one lag) for this model was selected by using the BIC criterion. The results consist of three parts, namely the results of conditional mean, conditional variance-covariance equation and adjustment parameters. The conditional mean equation represents the own and cross market dependence at the mean level. Own market dependence is represented by diagonal elements (such as $\gamma_{111}, \gamma_{222}, \ldots$) and they capture the effect of lagged returns on the present returns in the same market. Cross market dependence is represented by off-diagonal elements (such as $\gamma_{121}, \gamma_{212}$,...) and they denote the inter-relationship between different markets as they capture the effect of lagged returns on the present returns in a different market. Since, the conditional mean equation is a VAR process, the results of the cross-market dependence is similar to that of the Granger causality test as they both capture the inter-relationship between different markets (in this case international and domestic markets). Thus, at least at the mean level the cross market dependence is not significant between international and domestic rice markets.

An interesting observation in Table 4, is that international markets have a positive own-market dependence whereas the Indian markets exhibit negative own-market dependence. Since, cereals like rice and wheat are Giffen goods an increase in returns (price rise) must lead to an increase in demand. In this results, it can be observed that this dictum applies only to the international prices as domestic price returns exhibit negative own-market dependence. There could be multiple reasons for this, as consumers may be substituting with other cereals or maybe enrolling themselves in government schemes to get subsidised food grains outside the market. Finally, there exists cross market mean spillover between Indian markets of different zones but their effect is marginal.

Table 4: MGARCH-DCC estimates for rice

Coefficient	**rrice_i**	**rrice_nd**	**rrice_sd**	**rrice_wd**
Conditional Mean Equation				
γ_0	0.00072	0.00082	0.00095	0.00367
	(0.227)	(0.178)	(0.130)	(0.203)
γ_{11i}	0.1898	0.0294	0.0102	0.0485172
	(0.000)	(0.241)	(0.719)	(0.884)
γ_{12i}	0.0157	-0.244888	0.0634	0.0715163
	(0.498)	(0.000)	(0.041)	(0.092)
γ_{13i}	0.0248	0.0317695	-0.2455	0.0007746
	(0.239)	(0.238)	(0.000)	(0.003)
γ_{14i}	0.028611	0.0270156	0.0470	-0.2977
	(0.207)	(0.332)	(0.089)	(0.000)
Conditional Variance Equation				
ω_0	0.0000126	0.0655411	0.000015	0.0000196
	(0.003)	(0.034)	(0.000)	(0.001)
$\sum_{j=1}^{p_i} \alpha_j$	0.0861721	0.0655411	0.0900038	0.1222355
	(0.000)	(0.000)	(0.000)	(0.000)
$\sum_{j=1}^{q_i} \beta_j$	0.8957803	0.9233486	0.8954821	0.8598887
	(0.000)	(0.000)	(0.000)	(0.000)
Adjustment Parameters				
θ_1				0.0308033
				(0.000)
θ_2				0.8631678
				(0.000)

Notes: Standard errors are presented in the parenthesis. γ_i are the parameters from the conditional mean equation. α_j and β_j are ARCH and GARCH effects from Equation 3.4. θ_1 and θ_2 are adjustment parameters from Equation 3.6.

The results of the conditional variance-covariance equation in Table 4 captures the ARCH and GARCH effects respectively. The GARCH effect (β) is larger than the ARCH effect (α) for all the series. Higher GARCH effect indicates high degree of persistence and volatility clustering due to change of prices. The sum of the ARCH and GARCH effects is less but very close to one indicating a slow mean reverting process.

Next in order to further validate the model, results of the adjustment parameters (θ_1 and θ_2) are considered. As mentioned in Section 3.2, they must be non-zero to ensure that the dynamic correlation coefficient estimates which are derived from the model are time-variant and dynamic. This is tested using the Wald test and it rejects the null hypothesis that the adjustment parameters are equal to 0 at 1 percent significance level.

5.1.3 Discussions

The Dynamic conditional correlations (DCC) estimates are plotted in Figure 4. As noted earlier, the conditional correlation estimates indicate the direction and strength of the volatility interdependence. Positive values indicate that the correlation between the series are in the same direction and are rising (Lean and Teng, 2013). The correlation estimates in Figure 4, are not consistently positive as they move between the negative and positive territory around 0. This indicates that the volatility spillover between the international and Indian markets is either absent or marginal. Further, the mean values of the conditional correlation estimates also indicate a low level of spillovers as they are close to zero, with the mean for the Northern India zone being negative.

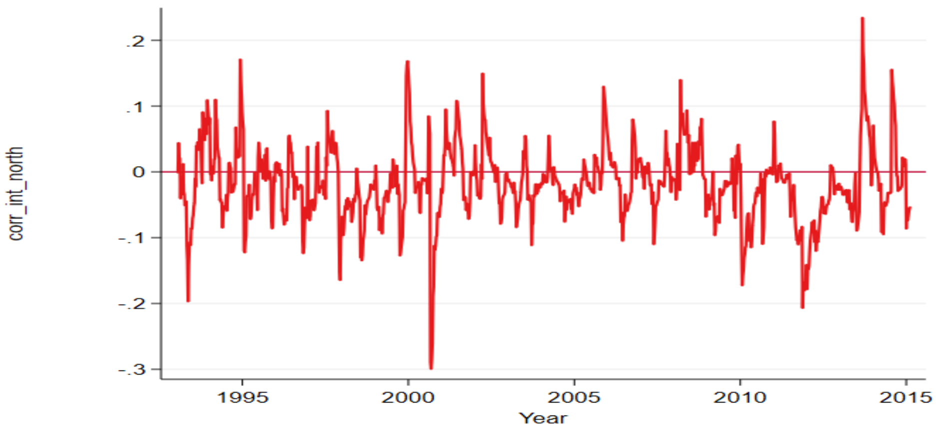
Table 5: Summary Statistics: DCC estimates for rice

Variable	Mean	Std. dev	Min	Max
North India (nd)	-0.0183607	0.0565793	-0.2993137	0.2341691
South India(sd)	0.0378665	0.0612586	-0.1931089	0.3566147
West India (wd)	0.0418028	0.0544357	-0.1702067	0.3990499

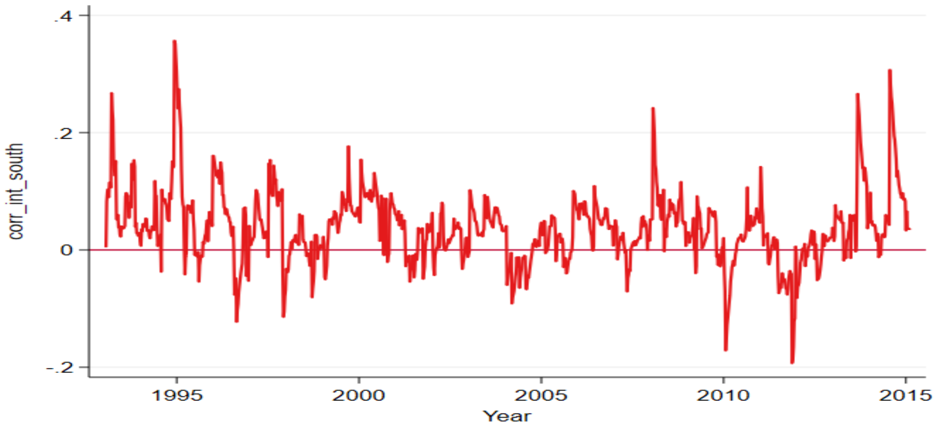
Notes: This table presents the summary statistics of dynamic conditional correlations between international and domestic zones. For example, “North India” denotes the correlation between international market and local market from North India.

This is in line with the findings of previous studies. Ceballos et al. (2016) found limited evidence for volatility transmission from international to major Indian markets (Mumbai and Delhi). The authors find self-sufficiency in rice production to be a major factor influencing volatility transmission to India. In their study other countries which either export or import large quantities vis-a-vis their local production witness significant volatility spillover. Though India is one of the largest exporter of rice, its total exports out of the production are relatively small compared to other large exporters like Thailand, where around 70 percent of domestic production is exported (Ceballos et al., 2016). Apart from this, other measures taken by the Indian government to insulate the local prices also impact volatility spillovers. For instance, during the Global Food Crisis 2007/08, exports were banned, prices of fertilizers and petroleum products were subsidized, a ban on futures trading was imposed and the domestic production of rice was enhanced. These policies according to Acharya et al. (2012) prevented India from witnessing any major spikes during the Global Food Crisis in 2007/08. Though overall the level of volatility spillover is limited in India, interesting observations can be made by looking at regional variations and important events.

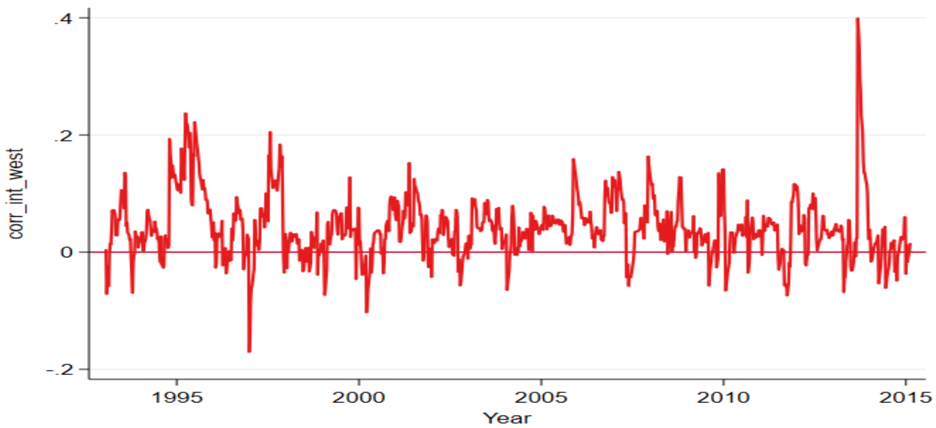
Firstly, from Table 5, it can be noticed that the mean and standard deviations of conditional correlations are different for each of the zones. This can also be visually confirmed by looking at the graphs in Figure 4, as each of the regions have their unique correlation pattern with the world market. This is an important result as we find regional variations in exposure of local rice markets with the world market. This is in line with the findings of Sekhar (2004) and Ceballos et al. (2016) as these studies find regional differences within India with respect to the level of interdependence with the world market. A detailed study on price transmission by Hatzenbuehler et al. (2017), in the Nigerian context, found ample evidence for regional variations in the level of exposure to the world market. In Nigeria, rural areas were insulated from spikes in the world market compared to urban areas and commercial hubs. We also find some evidence of this in our analysis as the Southern and Western parts of the country with higher urbanization levels witness greater correlations than the rural northern zone. Apart from urbanization, other factors such as level of consumption, production, local taxation laws, and location of the market play an important role. Keeping eye regional variations is key as according to Acharya et al. (2012), certain areas in the country may face more pressure from international food price volatility than the others during a potential food crisis. It also indicates the lack of regional integration within agricultural markets in India.



(a) Dynamic Correlation rrice_i and rrice_nd



(b) Dynamic Correlation rrice_i and rrice_sd



(c) Dynamic Correlation rrice_i and rrice_wd

Figure 4: Dynamic Correlations for rice. Note: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone

Secondly, as seen in Section 4, dynamics of volatility also change by time, and thus important phases as outlined in Section 4 are also examined:

(a) 1995-2000, is the first phase of interest as it was only in 1994, common rice exports were allowed from India. During this phase, food price volatility in Indian markets rose by manifolds and this can be also visually confirmed in Figure 2. According to Saini and Gulati (2016), the increased demand for rice in the global market during this phase increased the need for Indian rice globally. Due to this, local producers in India preferred to sell their farm produce abroad for better prices, thereby subsequently leading to price rise and increased volatility in the domestic markets. Notably, this can be confirmed by our correlation estimates from Figure 4. Spikes in correlations around 1995 can be witnessed across all zones. A more profound increase can be witnessed in the South Zone, which is also the main rice-consuming zone in India. Thus, we can confirm that during this phase spillover between the international and local markets was higher. Noticing the increased volatility in the local markets, the government imposed a ban on rice exports in 1997, just before the Asian financial crisis. Thus, further spillovers were avoided and there was a decrease in the correlations as seen in Figure 4.

(b) 2000-2007: Rice exports which were banned in 1997, were again lifted in the 2000s. During this period as observed in Figure 2, both international and domestic volatilities were congruent. Spikes in correlations were witnessed only during the beginning of the 2000s and according to Rapsomanikis and Mugera (2011), this was mainly due to domestic reasons as there was a shortfall in farm output because of events like droughts and floods. The food price volatility and correlations as seen in Figure 2 and Figure 4 are generally low during this period, indicating limited volatility spillovers.

(c) 2007-2010: The Global food crisis of 2007/08 occurred during this phase. International rice price volatility witnessed a huge increase during this phase. In India, however, the effect was muted. As seen in Figure 4, only the southern zone witnessed a spike in correlations for a short interval. A large number of studies including Ceballos et al. (2016) and Rapsomanikis and Mugera (2011), confirm this as they conclude that the export bans imposed by India limited the level of transmission from the world markets. Along with this, various price stabilization measures subsidizing fertilizers increased farm output, and distributing grains at subsidized prices has paved the way for dampening the impact of the crisis.

(d) 2010-2015: As seen in Figure 2, during this phase food price volatility in India was greater than the global food price volatility. According to Saini and Gulati (2016), Indian prices remained at the same level and did not fall rapidly like the international prices in the aftermath of the Global Food Crisis. They find that the export ban imposed by the government helped in smoothing out the effect of the Global Food Crisis from both price spikes and troughs in the international market. We find evidence for this in our correlation estimates reported in Figure 4, as we can see negative correlations in the period between 2010-2012. Post this, in 2012, the export ban was lifted. Indian exports reached record levels during this phase as India emerged as the second-largest exporter. At the same time Macroeconomic instability in India due to multiple doses of fiscal stimulus during and aftermath of the Global Financial Crisis of 2008, resulted in increased inflation in India. This resulted in spikes in correlation in the latter part of this phase.

From the above discussions several patterns can be noticed. There are regional variations in the level of interdependence of different regions in India to global food price volatility. With respect to rice, the Southern Zone has more profound spikes and troughs as compared to the other regions in India (highest standard deviations). In the phase-wise, analysis it can be noticed that the export restrictions are highly effective in reducing transmission from international to Indian markets. They helped in smoothing out Indian rice prices during the period of increased volatility in 1995s and the Global food crisis in 2007/08. Further, we can notice that during the period when there are no external shocks the correlations between Indian and world prices are limited.

5.2 Results from the Wheat Market

5.2.1 Results from the Granger-Causality Test

For wheat, we observe similar results as there is no Granger causality relationship between international and domestic wheat prices. Again this is not surprising as India is largely self-sufficient in wheat and imports only limited quantities during exceptional circumstances. Most of the wheat produced is consumed within India as only 5 percent is traded abroad (Ceballos et al., 2016). The government intervention to stabilise prices similar to that of rice further prevents volatility spillovers.

Table 6: Granger Causality Test for returns on wheat prices

Null Hypothesis	Chi2	Prob.
rwheat_i does not granger cause rwheat_nd	2.692	0.26
rwheat_i does not granger cause rwheat_sd	1.264	0.531
rwheat_i does not granger cause rwheat_wd	0.646	0.724
rwheat_nd does not granger cause rwheat_i	2.37	0.306
rwheat_sd does not granger cause rwheat_i	0.005	0.997
rwheat_wd does not granger cause rwheat_i	0.279	0.87

Notes: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone.

5.2.2 Results from the MGARCH-DCC Model for wheat

Table 7 presents the results of the MGARCH-DCC model for wheat. Appropriate lag-length (one lag) for the model was chosen based on the BIC criterion. Since, the VAR conditional mean equation for this model has no lags, there are no spillovers at mean level. The constant values are presented in the Table 7 and they are not significant for any of the series.

Similar to the estimates for rice, the GARCH effects in this model are larger than the ARCH effects, thus indicating high degree of volatility clustering due to change in prices. The sum of the ARCH and GARCH parameters are all less than 1, thereby indicating that the estimated DCC are mean reverting. An interesting fact to note, is that the sum of ARCH and GARCH parameters is higher for international wheat returns compared to the rest of the series indicating a relatively high degree of volatility persistence.

Further, the Wald test rejects the null hypothesis that the adjustment parameters are not equal to 0, thereby indicating the that the conditional correlations estimates derived from the model are dynamic and time-variant.

Table 7: MGARCH-DCC estimates for wheat

Coefficient	rwheat_i	rwheat_nd	rwheat_sd	rwheat_wd
Conditional Mean Equation				
γ_0	0.000106	0.000101	0.00076	0.00055
	(0.934)	(0.884)	(0.238)	(0.458)
Conditional Variance Equation				
ω_0	0.000053	0.00081	0.000046	0.00015
	(0.205)	(0.011)	(0.009)	(0.001)
$\sum_{j=1}^{p_i} \alpha_j$	0.1083	0.2828	0.1618	0.2619
	(0.038)	(0.001)	(0.001)	(0.000)
$\sum_{j=1}^{q_i} \beta_j$	0.8622	0.5178	0.6866	0.3660
	(0.000)	(0.000)	(0.000)	(0.005)
Adjustment Parameters				
θ_1				0.0502
				(0.001)
θ_2				0.8297
				(0.000)

Notes: Standard errors are presented in the parenthesis. γ_0 is the constant from the conditional mean equation. α_j and β_j are Arch and Garch effects from Equation 3.4. θ_1 and θ_2 are adjustment parameters from Equation 3.6.

5.2.3 Discussions

Table 8: Summary Statistics for DCC estimates wheat

Variable	Mean	Std. dev	Min	Max
North India (nd)	0.0651761	0.0872337	-0.470149	0.3424121
South India(sd)	0.0965745	0.0776554	-0.1280026	0.3559242
West India (wd)	0.038987	0.0835066	-0.2616619	0.307566

Notes: This table presents the summary statistics of dynamic conditional correlations between international and domestic zones. For example, "North India" denotes the correlation between international market and local market from North India.

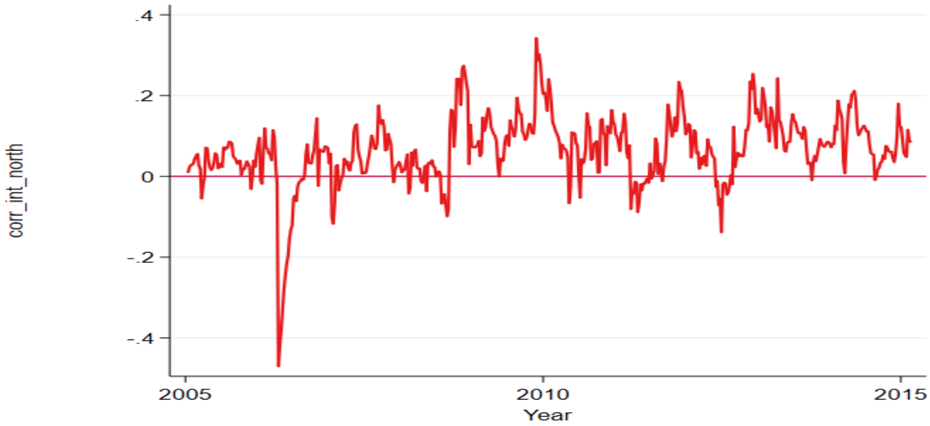
The DCC estimates for wheat are plotted in Figure 5 and the summary statistics are presented in Table 8. The mean DCC estimates are positive across all three zones. This can be visually confirmed in Figure 5 as apart from a few episodes' in negative territory, the DCC estimates are largely positive. Thus, there is a positive volatility spillover between Indian and international markets. The level of spillover, however, is limited and close to 0. This is expected as India is largely self-sufficient in wheat and its exports as a percentage of total production are about 5 percent (Saini and Gulati, 2016). These results contradict the findings of Ceballos et al. (2016). They in their study find an unexplainable, but significant volatility spillover from international to domestic wheat markets. According to their study, these results are an exception as only countries which either import or export large quantities of wheat experienced volatility transmission in their sample. However, various other studies like Acharya et al. (2012) and Dasgupta et al. (2011) find no evidence for price (mean) transmission from international to domestic markets. These studies also find great discrepancies in the volatility experienced in the world and Indian wheat markets, thus concluding that there is limited case for volatility transmissions.

Similar to the case for rice, we find regional variations in the conditional correlations estimates. Each of the regions display their own pattern of correlations as seen in Figure 5. The average correlation is highest for the Southern Zone, followed by the Northern and Western Zone. This is surprising as Wheat is the main staple in the North and West of the country, but experiences a low level of interdependence. As already seen, the reason for this could be due to factors like the level of urbanization, consumption, production and local taxation laws have an impact on the level of interdependence in the world market.

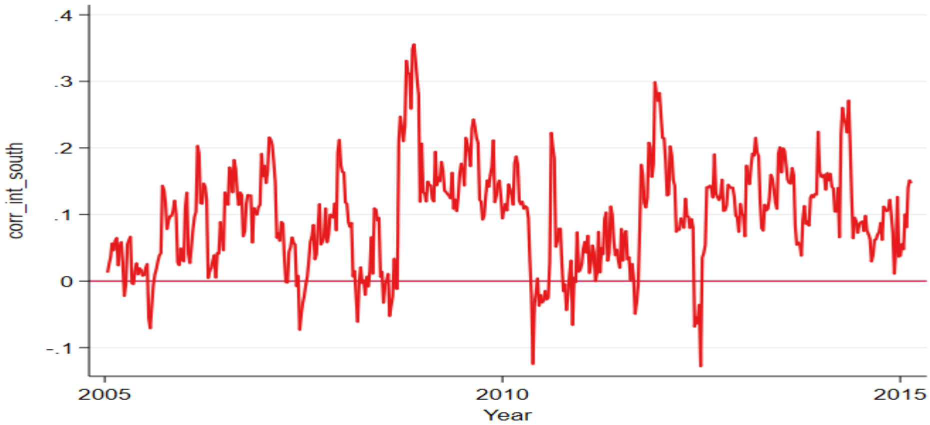
Following this, important observation can be made by looking at different phases and examining volatility trends:

(a) 2000-2005: During this phase, we find low correlations between the world and certain domestic (North and Western Zone) wheat markets. This is in line with the volatilities presented in figure Figure 5, as it can be seen that the standard deviation of Indian prices was stable and did not rise immediately during the Global Food Crisis in 2007/08. Various measures taken by the government like a ban on exports, futures trading, subsidies on fertilizers, and measures to boost domestic wheat production have softened the impact of transmission. In fact, according to Ganguly and Gulati (2014), there was only a delayed transmission as the Indian wheat prices rose only towards 2009/10. In our correlation estimates, there is such evidence of late transmissions as spikes were witnessed closes to 2010. However, on the contrary, Baltzer (2014) claims that the increase in wheat prices in 2009/10 was due to poor harvests in 2009. It is important to note that, the South Zone witnessed larger spikes during this period compared to the other zones.

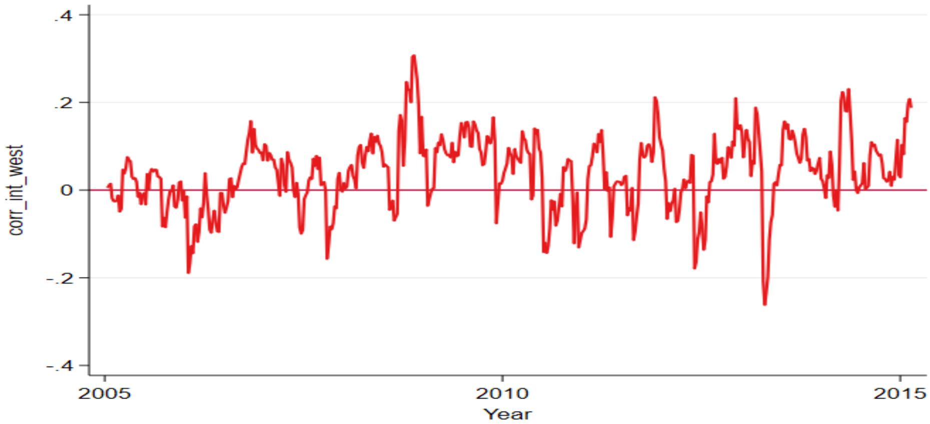
(b) 2010-2015: The period post the crisis, when the global volatility is decreasing, negative correlations can be seen in the Southern and Western Zones. This is because the export ban ensured that the Indian markets were isolated and thus the fall in world prices did not affect the domestic markets. The export ban was lifted closer to 2012, we see that the correlations become positive across all zones indicating transmissions across the markets. Notably, during this phase, India's wheat exports grew at a record pace (Saini and Gulati, 2016).



(a) Dynamic Correlation rwheat_i and rwheat_nd



(b) Dynamic Correlation rwheat_i and rwheat_sd



(c) Dynamic Correlation rwheat_i and rwheat_wd

Figure 5: Dynamic Correlations for wheat. Note: the suffix "_i"=international series, "_nd"=North India Zone, "_sd"= South India Zone and "_wd"= West India Zone

5.3 Further Discussions and Practical Implications

From the above discussions for both rice and wheat, several interesting observations can be made. Firstly, from both the analysis, it can be found that the export restrictions were instrumental in protecting Indian food markets from adverse shocks in the world market. The surge in domestic price volatility both during the mid-1990s and the Global Food Crisis was halted due to export restrictions. The conditional correlation estimates for both wheat and rice indicate this as, export restrictions smooth out the effect of both rising and falling volatility during the Global Food Crisis. According to Baltzer (2014), countries like India, China, and Vietnam can be classified as *export stabilizers*, as these countries are known for using export restrictions to protect themselves from shocks emerging in the world market. Being self-sufficient and having a significant exportable surplus is a feature of these *export stabilizers*.

A direct implication of this kind of policy is that it leads to a shortage of agricultural commodities in the international market. Countries that rely on imports for meeting their food requirements are adversely affected by export bans from major producers. (Rapsomanikis and Mugera, 2011) points out that export bans from large producers like India during the beginning of the Global Food Crisis further increased prices and volatility in global markets. Shortage in the availability of food results in hunger and food inflation in many developing countries. Countries like Bangladesh, Nepal, and Bhutan, which are reliant on Indian food exports had a hard time when export bans were imposed by India in 2007/08. After a long negotiation, the Indian administration had to open exports to these neighboring countries under a special agreement.

Another implication of export bans is that it negatively affects the planning of domestic farmers, investors, and exporters. Since in the agricultural sector, plans on the level of output and price to produce are made months ahead of the harvest, abrupt export bans create uncertainty and can affect the expectations of the stakeholders in the agriculture sector (Goel and Krishnan, 2021). Additionally, export bans also erode confidence among India's overseas trade partners. For example, countries like Bangladesh are losing confidence in India and have begun to look at other countries like Egypt and Turkey to meet their food requirements (Basu, 2020). Thus, in the long run, India's agricultural exports will be affected if other countries find it to be unreliable.

A second common observation in both domestic rice and wheat market is that they exhibit regional variation in correlation with the international market. This observation suggests that there is a lack of internal market integration within India. As already seen several factors like state-level taxation laws, state-level production/consumption, cost of transportation, and lack of storage facilities act as an impediment for internal market integration within India (Acharya et al., 2012). According to Sekhar (2004) internal market integration is an important feature that liberalized economies must have. Lack of this is a serious concern as it can lead to some parts of India being more vulnerable to external shocks in the world market and thus make measures like export restrictions ineffective.

Finally, another important observation is that the level of volatility transmission is low during phases when there are no external shocks in the world market. Reasons such as self-sufficiency in food production and low proportion of exports out of total production are the main factors behind this. This finding is useful in support of trade liberalization in India as volatility from the international market will not affect Indian prices during normal times. Thus, the fear of trade liberalization resulting in increased volatility spillovers from abroad is unfounded.

6

Conclusion

Food price volatility assumes enormous importance in a developing country like India, as people spend a substantial part of their earnings on food. With agricultural trade liberalization in the mid-1990s, the need to examine the role of external markets in causing food price volatility assumes significance. Factors like complex market inter-linkages, climate change, and financialization of agricultural markets have increased the risks of instability in the global markets and thus thereby increasing the risks for domestic markets which are connected with them. Thus, in this context, this paper attempts to examine the transmission of food price volatility from international to Indian markets.

The paper primarily relies on conditional correlation estimates which are derived from the MGARCH-DCC model for the analysis. The Granger-Causality test and quarterly standard deviations are computed to aid the understanding of these conditional correlations estimates. The results for both rice and wheat based on weekly price returns finds limited evidence for volatility spillovers between the international and domestic markets. Factors such as self-sufficiency in food production and a low proportion of exports out of total production are considered to be the main factors behind this. Further, even during major external shocks like Global Food Crisis, volatility spillovers are limited as export restrictions imposed by the government prevent volatility spillovers. In fact, over time these export restrictions have emerged as the main policy tool to control volatility spillovers from abroad post-agricultural trade liberalization. This policy has negative implications on farmers and exporters in India. Additionally, nations that are reliant on Indian food exports are also badly affected by this sort of trade regime.

Another observation is the presence of regional variation within different Indian zones with respect to the level of exposure with the international market. This points out the lack of regional integration within Indian markets and is an area of concern as certain areas may be more vulnerable to volatility spillovers compared to the others. The reasons behind this sort of regional variation can be a question for future research.

As mentioned by Nayyar and Sen (1994), the imperfect nature of agricultural markets leads to various limitations while comparing international and domestic prices. Lack of standardization in agricultural products makes it difficult to carry out comparisons as it is difficult to find the price of an exact product specification in both the world and domestic market. Further, factors such as differences in production methods, transportation costs and exchange rate add to discrepancies in these kind of comparisons. Thus, any comparisons between international and domestic markets suffer from this limitation thus has to be kept in mind.

Another limitation is from the modelling part. Though the MGARCH-DCC model leads to conditional correlation estimates that can be used to identify periods of high and low spillovers, there are no parameters which comment on the overall level of spillovers between different markets. This is a potential limitation as it difficult to exactly quantify the amount of volatility spillovers. Thus a combination of different methods may be required when analyzing volatility spillovers between different markets and this can be a potential extension of this study. Other potential extension based on this study can focus on analyzing volatility transmissions in other agricultural commodities. Commodities like edible oil and pulses constitute a large part of India's food imports, thus provided availability of data, analyzing volatility transmission from international market for these commodities may yield interesting results.

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