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Price Dynamics and Integration in India's Staple Food Commodities – Evidence from Wholesale and Retail Rice and Wheat Markets

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Abstract: Uncertain price movement in staple food commodities puts agrarian economies at risk if not monitored and managed consistently. Hence, an attempt has been made to analyze the price behavior and integration across major wholesale and retail markets for rice and wheat in India. Monthly data (July 2000 to June 2022) on prices viz., wholesale and retail were sourced from the Food and Agriculture Organization and analyzed using growth rate, instability index, seasonal price index, Johansen's test on cointegration, Granger causality test, and impulse response function. Findings indicated strong evidence of price dynamics in the selected markets in terms of spatial and temporal variation, clear-cut seasonality linking to production, and price divergence between wholesale and retail markets. Johansen's test indicated a strong integration between wholesale and retail markets exhibiting unidirectional-, bidirectional- and no-causality. Impulse response analysis revealed that the selected wheat and rice markets are efficient in terms of 'price discovery' which takes place initially in the wholesale market, and then transmitted to the retail market. The study advocates decision-making information to the producers, traders and consumers who have a potential interest in getting advantage of the price movement. It is concluded that strengthening the market intelligence and reducing the distortion in markets will improve the existing overall performance.

Keywords: commodity market; price integration; seasonal price index; cointegration; rice and wheat; impulse response function; wholesale and retail

1. Introduction

Agricultural prices inherently exhibit volatility – the degree of price movement, or the possibility of substantial, unexpected changes in the commodity price – and it is inextricably linked and affect the welfare of both producers and consumers [1]. Due to this, there is a marked impact on the supply chain which simultaneously affects other factors like investment, market performance, societal development, etc. India's trailing down in the hunger index can also be linked to the volatile agricultural food prices. The concern is spiraling food price volatility, especially in staple food like wheat and rice, has an adverse effect and can affect the stakeholders' interest along the supply chain. The price of an essential product that is determined by the extent of demand-supply is, for the most part, fixed disposed to the level of production, stock, government procurement, support price, and other policies and various subsidies that are eventually reflected in the marketplace [2].

Extreme price occurrences have the potential to exacerbate and influence broader societal concerns in terms of access to food, human development, and political as well as economic stability. Extensive research has been carried out already [3] on the past prevalence of food price crises and it has been attributed to several reasons like political and economic circumstances, such as the transmission of crises from agriculture practiced in rural to urban regions, and the occurrence of regional crises altered as markets became more integrated. Analyses of the 1970s worldwide food price crises focused on production and trade shocks [4]. Commodity markets that are efficient and functioning well are successful in communicating price signals geographically (across spatially separated regions) and temporally (through varying time periods), facilitating market resource distribution, and encouraging investment [5, 6, 7, 8]. Alternatively, the degree (and transmission direction) of price integration determines market performance since the price stabilization measures in one significant market produce the desired outcome in others via the arbitrage process [9].

Commodity price volatility is a key source of concern because it has determined the 'fate and fortunes' of several emerging economies due to its linkage to the flow of evidence-based information, especially in a free-market situation. In the realm of foodgrains, wheat and rice are the staple food for several nations, including the agrarian Indian economy. Hence, it becomes important to understand the extent of price behavior and integration as it affects not only production but also consumption decisions. Wheat and rice prices as well as price integration across markets serve as an important aspect to examine from the stakeholder point of view since it has central control on production and procurement having a major role in influencing the market efficiency and performance. As the regional production is affected by topography, soil conditions, etc., so are the consumer's preferences add to the commodity prices to be noisy, non-stationary, and possibly leptokurtic, making it difficult to capture the dynamics [10].

Several research on price analysis and spatial market integration have been undertaken, but little is known about the recent – especially during COVID-19 – price dynamics, degree of integration, and direction of price transmission in wholesale and retail markets of wheat and rice, a government-subsidized staple commodity in India. Given the complexities of wholesale and retail markets, a thorough evaluation will aid in prioritizing investments, removing distortions, and adopting policies to improve overall performance.

In the milieu, an attempt has been made to determine the price behavior in wholesale and retail markets of rice and wheat in addition to analyzing the extent of integration in major grain markets of the staple commodities. Such types of studies have to be revisited due to the changing economic scenario post-pandemic and breakthroughs in analytical methods of researching the causal factors and effects in the market ecosystem. The paper is further divided into section 2 which comprises a detailed description of data and analytical tools used in the study, section 3 presents the study results and in-depth interpretation after analysis, followed by section 4 as conclusions derived from the study.

2. Data and Methods

The study was marshaled on the wholesale and retail monthly prices of rice and wheat for four selected markets in India viz., Chennai (South), Delhi (North), Mumbai (East), and Patna (West) covering four major geographies. The price data in ₹ per Kg (₹ refers to Indian Rupee, the national currency) were compiled from the Food Price Monitoring and Analysis (FPMA)[1] tool of the Food and Agriculture Organization (FAO) of the United Nations for the agricultural year spanning from July 2000 to June 2022. Along with descriptive statistics, various analytical tools and techniques were used for better interpretation of the research findings and to draw some valid conclusions. The detailed tools used in the study are given as follows:

[1] https://fpma.fao.org/giews/fpmat4/#/dashboard/tool/domestic

2.1. Estimation of growth rate

The growth in wholesale and retail prices of both food commodities was calculated by using the below-mentioned formula [11, 12, 13]:

$$P_t = a_0(1+b)^t$$

The equation was transformed into logarithmic function before estimating the growth rate using the ordinary least squares method [13].

$$ln\ P_t = ln\ a_0 + t\ ln(1+b)$$

where,

P_t represents the price at time '*t*'

a_0 denotes constant, and

b represents the growth rate

2.2. Price instability index

Cuddy-Della Valle Index (CDVI) approach was used to examine the magnitude of variation and risk involved in the prices of rice and wheat [14].

$$CDVI = CV \times \sqrt{(1-R^2)}$$

where,

CDVI is the Cuddy-Della Valle instability Index (%)

CV is the Coefficient of Variation (%)

R^2 is the coefficient of multiple determination

2.3. Seasonal price index

The seasonal index – measured using the 12-months ratio to the moving average method – is a way to measure the variations in prices across the commodity production seasons. Subsequently, deseasonalisation was done to eliminate seasonal variations in wholesale and retail prices of rice and wheat for the selected markets in India. The de-seasonalized commodity prices were calculated by adopting the given formula:

$$\text{Deseasonalised data} = \frac{Actual\ Data\ for\ i^{th}\ month}{Seasonal\ index\ for\ i^{th}\ month} \times 100$$

In addition, the Intra-year Price Rise (IPR in %) and Average Seasonal Price Variation (ASPV in %) were estimated to evaluate the degree of seasonal price variation in rice and wheat for the selected markets in India.

$$\text{IPR} = \frac{SPIH-SPIL}{SPIL} \times 100$$

$$\text{ASPV} = \frac{SPIH-SPIL}{(SPIH+SPIL)/2} \times 100$$

where,

SPIH is the seasonal price index with the maximum value

SPIL is the seasonal price index with the minimum value

2.4. Price integration

Price integration is an ideal situation wherein the prevailing prices of a commodity across locations follow a similar pattern in the long-run [15, 16]. Rapsomanikis et al. [17] discussed the application of price integration tools, particularly for developing countries. A series of studies conducted on price integration suggested that market functionaries can get benefits through integrated markets [18, 19, 20, 21]. Integrated markets encourage the dissemination of information across time, space, and form. Many studies have used the procedure given by Engle and Granger [22]to examine market integration. Thereafter, Johansen [23] introduced the alternative technique to examine price integration along with multiple cointegrating vectors. In this line, Kumar and Sharma [24] observed that the Johansen's test, having multiple advantages, is very easy to compute and robust enough with *sans apriori* assumptions on variables with testing simultaneously the number of cointegration vectors un-imposed earlier.

Before applying any test, the foremost important step in the time series data is to check the stationarity. A stationary time series is one whose statistical properties like mean, variance, and covariance are invariant. The estimated relationship may be counterfeit without any significant implication in the absence of stationarity. The wholesale and retail price-series of rice and wheat crops in selected markets were first checked for stationarity by using Augmented Dickey-Fuller (ADF) unit root test.

2.4.1. Unit root test

The Augmented Dickey-Fuller (ADF) test was carried out to examine the stationarity in the data [25]. The ADF test is executed by estimating the following equation:

$$\Delta P_t = \alpha_0 + \delta_1 t + \beta_1 P_{t-1} + \sum_{j=0}^{q} \beta_1 \Delta P_{t-j} + \varepsilon_t$$

where,

$\Delta P_t = P_t - P_{t-1},\ \Delta P_{t-1} = P_{t-1} - P_{t-2}, \ldots \Delta P_{n-1} = P_{n-1} - P_{n-2}$

P represents price

α_0 is the constant

t represents time

q is the number of lag length

ε_t is the random error-term

Unit root testing was done by framing the null hypothesis, H_0: $\beta_1 = 0$ and the alternative hypothesis, H_1: $\beta_1 < 0$. A non-rejection of the alternative hypothesis suggests that the particular price series is non-stationary [13].

2.4.2. Cointegration test

To test the long-run relationship in commodity prices between the wholesale and retail markets, the study used the cointegration test [26]. The null hypothesis (H_0) of utmost 'r' cointegrating vectors i.e., rank of error-correction coefficient matrix, against a general alternative hypothesis (H_1) of 'r+1' cointegrating vectors is tested by trace and maximum Eigen value statistics [23].

$$J_{trace} = -T\sum_{i=r+1}^{N} \ln(1-\hat{\lambda}_1)$$

$$\lambda_{max} = -T ln(1-\hat{\lambda}_{r+1})$$

Where, r is the of number cointegrated vector, $\hat{\lambda}_1$ is the eigenvalue and $\hat{\lambda}_{r+1}$ is the (r + 1)th largest squared eigenvalue obtained from the parameter matrix of the cointegrated system, and the T is the effective number of observations.

2.5. Granger causality test

Granger causality test has been employed to know the path of price transmission across markets [27]. Granger causality test is done for a market pari, testing whether price series P_t Granger-causes price series Q_t and vice versa. All sort of permutations and combinations are possible within the selected markets viz., univariate Granger causality indicating price transmission from P_t to Q_t or from Q_t to P_t, bivariate Granger causality depicting price transmission in both ways or absence of causality implying no price transmission. The above test is carried out using the following equation:

$$lnP_t = \sum_{i=1}^{m} \alpha_i\, lnP_{t-i} + \sum_{j=1}^{m} \beta_j ln\, Q_{t-j} + \varepsilon_{1t}$$

$$lnQ_t = \sum_{i=1}^{m} \alpha_i\, lnQ_{t-i} + \sum_{j=1}^{m} \beta_j ln\, P_{t-j} + \varepsilon_{2t}$$

where,

P and Q are the selected market prices series pair

ln is the logarithmic transformation of the selected price series

t indicates the time period

The subscripts, 'i' and 'j' represent the number of lags pertaining to the respective price series.

The null hypothesis states that ln P_t does not Granger cause ln Q_t and its rejection implies that there is Granger causality between the selected price series pair [13].

2.6. Impulse response function

The study has also calculated impulse response to obtain the dynamic interrelationships among prices of different markets. It was also used to investigate the mechanism of shocks. The analysis tracks the effect of 'one' SD (standard deviation) or 'one' unit shock imposed on one price series that gets reflected on the current and future values of all the endogenous variables over a specific time period [28]. In the present study, Generalized Impulse Response Function (GIRF) proposed by Koop *et al.* [29] and further advocated by Pesaran and Shin[30] has been used. The GIRF of a random current shock 'δ' and historical shock 'w_{t-1}' is given in the below equation:

$$GIRF\ Y\ (h, \delta, w_{t-1}) = E[Y_t + h|\delta, w_{t-1}] - E[y_t + h|w_{t-1}] \quad \text{for t = 0, 1, 2…n}$$

3. Results and Discussion

3.1. Price dynamics in rice and wheat markets

Deciphering the fluctuations in prices of agricultural commodities across spatially separated markets helps to understand the dynamic behavior of the timeseries across regions which facilitates sketching out the economic implications. Figure 1 shows the sharp fluctuations in the monthly price for selected rice markets. It is apparent that the commodity prices have been increasing during the study period i.e., from 2000-01 to 2021-22, regardless of market type and region. Both the rice and wheat prices show an upward trend, but a higher fluctuation is observed in wheat prices (Figure 2). Further, a common movement is observed in the prices of wheat and rice but differs in magnitude. A recurrent problem of Indian agriculture is the boom-and-bust cycle in commodity prices along with a geographical concentration in production. Accordingly, the rice and wheat market prices (Table 1) revealed a substantial variation, both spatially and temporally [31, 10]. Further, the price deviation between the wholesale and retail markets witnessed a considerable increase during the study period (Figure 2), signifying the necessity to investigate the extent of price integration and direction of price transmission for these two agricultural commodities.

Table 1. Summary statistics for the rice and wheat prices (2000-01 to 2021-22)

Particulars	Chennai		Mumbai		New Delhi		Patna	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Rice								
Mean (₹/Kg)	25.5	22.0	21.9	18.3	23.0	18.5	20.2	18.6
Min (₹/Kg)	10.0	8.4	11.0	9.0	11.5	8.8	8.0	6.8
Max (₹/Kg)	59.0	49.1	37.0	28.9	36.0	29.1	38.0	32.3
SD (₹/Kg)	14.0	11.8	8.5	6.4	8.4	6.7	9.9	8.9
CV (%)	139.7	141.0	77.2	70.6	72.8	76.0	124.9	132.5
CDVI (%)	16.1	20.0	6.0	5.7	5.0	5.8	12.4	16.5
CAGR (%)	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7
Skewness	0.8	0.9	0.0	-0.2	-0.1	-0.2	0.0	0.0
Kurtosis	-0.3	-0.2	-1.7	-1.6	-1.5	-1.5	-1.6	-1.6
Wheat								
Mean (₹/Kg)	23.3	19.7	21.8	18.3	15.4	13.6	14.5	12.8
Min (₹/Kg)	10.0	8.0	10.3	9.0	7.0	5.7	6.0	5.7
Max (₹/Kg)	40.3	34.7	40.4	32.7	26.0	23.2	28.0	21.6
SD (₹/Kg)	9.7	7.6	9.2	7.3	5.7	5.2	5.8	4.7
CV (%)	97.3	94.9	89.5	81.2	81.3	90.6	96.6	81.6
CDVI (%)	3.9	4.4	4.0	4.9	3.6	4.7	10.3	7.4
CAGR (%)	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Skewness	0.1	0.0	0.1	0.3	0.0	0.1	0.2	0.0
Kurtosis	-1.5	-1.2	-1.5	-1.2	-1.3	-1.3	-1.2	-1.3

The growth, variation, and summary statistics pertaining to major regional rice and wheat market prices showed a distinct pattern and behavior that existed between the wholesale and retail prices (Table 1). Among the regional markets, Patna registered the lowest estimated values for a majority of the price behavior indicators with respect to both rice and wheat. In the case of wheat, Chennai witnessed the highest wholesale (₹23.30 kg^{-1}) and retail prices (₹19.70 kg^{-1}). The possible reason is, inter alia, 'nil' production in and around the Chennai region, in spite of escalating demand for wheat and wheat-based food products, especially originating from the urban class. In the case of rice, the deviation between the wholesale and retail prices was highest in Delhi (₹4.50 kg^{-1}), followed by Mumbai (₹3.60 kg^{-1}), Chennai (₹3.50 kg^{-1}), and Patna (₹1.60 kg^{-1}). Likewise, the price divergence between wholesale and retail markets was highest in Chennai (₹3.60 kg^{-1}) with respect to wheat, followed by Mumbai (₹3.50 kg^{-1}), Delhi (₹1.80 kg^{-1}), and Patna (₹1.70 kg^{-1}). For both the staple food commodities, the wholesale and retail prices were lowest in the case of Patna indicating a region with abundant supply owing to substantial production in comparison to others. Inter alia, the quantum jumps in these commodities in the recent past i.e., between 2000-01 and 2017-18 led to increased supply and subsequently a decline in the wholesale prices, especially in rice [32], a proxy variable considered as a producer/farmer/farm-gate price [2].

Skewness estimates indicated positive values ranging between 0 and 0.90 for rice, and between 0 and 0.30 in the case of wheat. The positively skewed values explicitly indicate that the price series distribution is stretched over the right tail against the left. None of the markets satisfies the normal distribution criteria ($\gamma_1 = 0$ and $\beta_2 = 3$) which itself indicates that the price of all the markets exhibits fluctuation. Alternatively, most of the observations of the price series were present as a cluster on the left side of the tail of the series mean and only a set of limited observations were found on the right side supporting the characteristic of the high-frequency timeseries [19]. It is also evident that the price series pertaining to agricultural commodities, in general, exhibit non-stationary feature coupled with leptokurtic type of distribution [10]. In contrast, the estimates of kurtosis were negative for all the price series pertaining to rice and wheat markets, implying the flat/short-tailed (platykurtic) distribution i.e. comparatively a flat distribution in relation to normal distribution, however, a wide peak exists. In addition to the above implication, the estimates of skewness as well as kurtosis (Table 2) denote that the observations of the monthly price series were dispersed around their mean across all selected markets. Inter alia, government control (by offering a support price at which a substantial amount of the commodity is procured and stocked for public distribution) on both staples might be the probable reason for the observed pattern and price dynamics.

The estimates of standard deviation (SD) and CV indicated that it was highest in the case of Chennai for both types of cereals i.e., rice and wheat as well as for markets types i.e., wholesale and retail (Table 1). The possible reason is that Chennai from the southern zone of India is a region wherein the production capacity is low, especially for wheat and hence it has to depend on other production regions to manage the increasing consumption demand leading to higher SD and variation. On the contrary, Delhi witnessed the lowest values, the capital region with a higher rate of consumption. The Cuddy-Della Valle index, an indicator of price risk and instability, shows that with the exception of Delhi and Mumbai regions, the rest had more than 15 per cent CDVI in the case of rice. On the contrary, in the case of wheat, barring the wholesale and retail prices in Patna, the rest of the regions had CDVI less than five per cent. The analysis of price growth using the Compound Annual Growth Rate (CAGR) indicated a positive trend and it was less than one per cent per month. In the case of rice and wheat, the price growth was highest in Chennai.

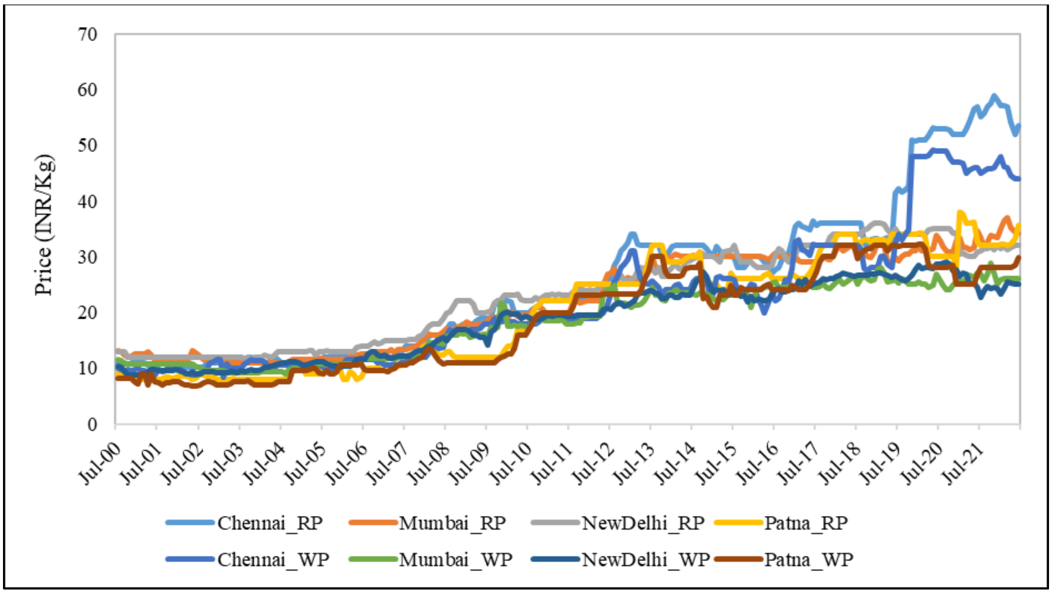


Figure 1. Price trend in selected rice markets of India.

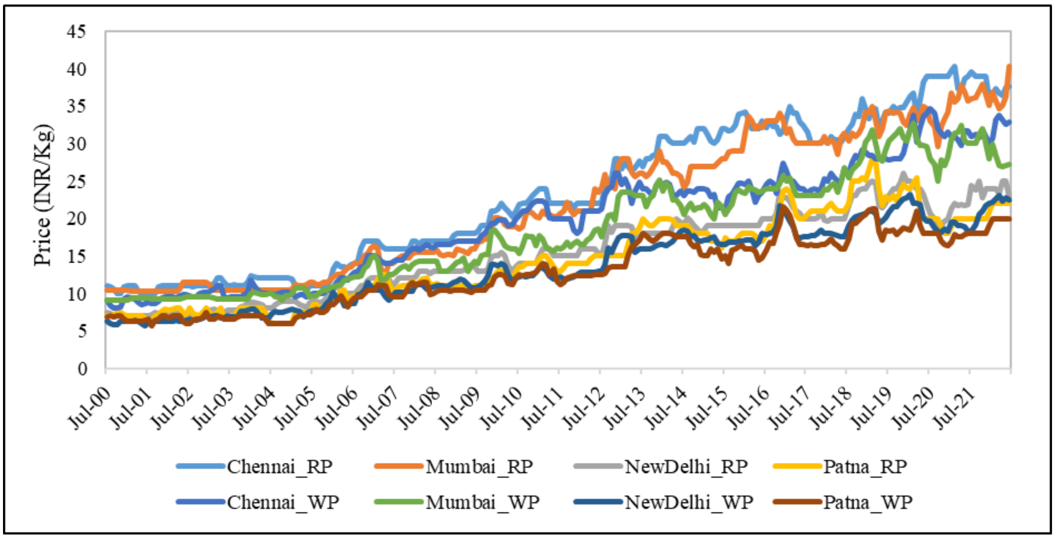
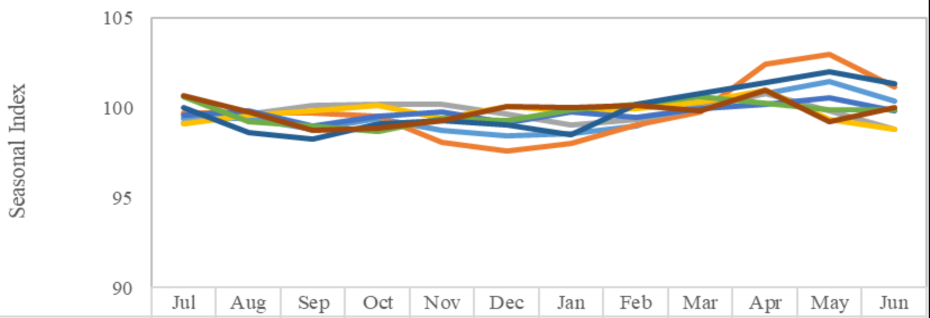


Figure 2. Price trend in selected wheat markets of India.

3.2. Seasonal variation in the prices of rice and wheat

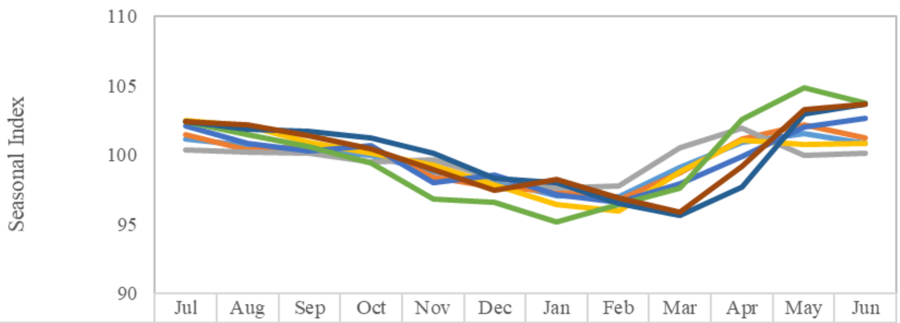
Comparing the seasonal indices of monthly prices for rice and wheat across the different markets in India would enhance our understanding of the price variation as the commodity is produced at some period of the year but consumption is throughout. Generally, the seasonal variations in agricultural food commodities occur regularly and it has to be monitored systematically for planning and taking agri-business decisions. Analysis of seasonal variation in rice and wheat prices showed a distinct pattern (Figure 3 & Figure 4). In the case of rice, the seasonal price index (Figure 3) was highest and lowest in Chennai wholesale market, respectively during May (102.96) and December (97.59). The estimated index values were higher during March and April i.e., before the crop harvest, wherein the rice supply is low resulting in higher indices. Subsequently, the index values witnessed a fall due to the increase in market arrivals post-harvest [34]. Among the regions, seasonal price variation was relatively more in Patna and less in Chennai. Among the months, it was higher during April to May for about three markets and it was lower during August for three markets with the exception of Delhi and Patna. Less variation is attributed to the market arrivals and/or release of public stock by the government.



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Chennai Retail	99.41	99.38	98.82	99.44	98.75	98.44	98.59	98.99	100.29	100.82	101.46	100.36
Chennai Wholesale	99.70	99.74	99.69	99.53	98.07	97.59	98.03	99.07	99.79	102.41	102.96	101.15
Mumbai Retail	99.18	99.68	100.12	100.20	100.19	99.64	99.04	99.38	99.98	100.82	99.81	98.81
Mumbai Wholesale	99.11	99.57	99.82	100.17	99.43	100.09	99.85	99.96	100.30	100.98	99.34	98.82
New Delhi Retail	99.59	99.84	98.96	99.55	99.77	99.19	99.76	99.48	99.94	100.18	100.55	99.85
New Delhi Wholesale	100.63	99.24	98.96	98.67	99.39	99.31	99.88	100.20	100.61	100.24	99.88	99.90
Patna Retail	100.01	98.64	98.27	99.14	99.29	99.03	98.48	100.17	100.81	101.40	101.99	101.31
Patna Wholesale	100.69	99.76	98.77	98.87	99.26	100.05	99.99	100.14	99.85	100.96	99.25	100.04

Figure 3. Seasonal price variation in rice markets

It is also interesting to make a comparison of the price variation of wheat across different markets in India. The seasonal index for wheat was highest in Delhi wholesale market (May: 104.83) and it also registered the lowest (December: 95.17). Overall, Delhi witnessed the higher seasonal price variation, whereas, Mumbai experienced the lower indices in comparison to other regions. The price indices for wheat were highest in the month of May for about three markets under study, barring the wholesale + retail markets in Mumbai and Patna. On the contrary, it was lowest in the month of July for about three markets. In general, January and February registered lower values owing to increased supply and/or public stock release [34, 35].



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Chennai Retail	101.16	100.68	100.36	99.95	98.82	98.12	97.07	96.96	99.06	100.93	101.55	100.82
Chennai Wholesale	101.43	100.39	100.62	100.43	98.37	97.67	97.34	96.72	98.72	101.15	102.15	101.24
Mumbai Retail	100.39	100.24	100.09	99.46	99.62	98.33	97.63	97.77	100.48	101.92	99.99	100.11
Mumbai Wholesale	102.45	102.12	100.89	100.11	99.28	97.83	96.43	95.98	98.80	101.06	100.77	100.85
New Delhi Retail	102.06	100.83	100.31	100.67	97.97	98.57	97.12	96.62	97.95	99.87	102.03	102.65
New Delhi Wholesale	102.37	101.46	100.63	99.41	96.80	96.57	95.17	96.39	97.61	102.59	104.83	103.75
Patna Retail	102.40	101.88	101.70	101.22	100.10	98.30	98.00	96.50	95.65	97.69	102.92	103.69
Patna Wholesale	102.39	102.14	101.42	100.46	98.96	97.47	98.24	96.93	95.85	99.18	103.29	103.67

Figure 4. Seasonal price variation in wheat markets

On perusal of Table 2, it is explicit that the average de-seasonalized price observations between 2000-01 and 2021-22 in the case of wholesale prices for both rice and wheat were lower to their counterpart, as expected. The deviation between wholesale prices and retail prices for rice was relatively higher in New Delhi, followed by Mumbai and Chennai (Table 2). Further, the average de-seasonalized price values pertaining to wheat were found to be of same level in terms of magnitude in the corresponding markets.

Table 2. Average de-seasonalized monthly prices of rice and wheat (2000-01 to 2021-22)

Particu-lars	Chennai		Mumbai		New Delhi		Patna	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Rice								
Jul	24.73	21.35	21.76	18.39	22.79	18.01	19.66	17.99
Aug	24.85	21.38	21.60	18.26	22.76	18.53	20.29	18.43
Sep	25.20	21.46	21.43	18.16	23.23	18.65	20.61	18.93
Oct	25.04	21.57	21.45	18.08	23.01	18.79	20.21	18.79
Nov	25.80	22.62	21.54	18.40	22.94	18.59	20.16	18.67
Dec	26.08	22.96	21.91	18.19	23.32	18.71	20.27	18.37
Jan	26.22	23.11	22.35	18.33	23.06	18.50	20.87	18.46
Feb	26.19	22.85	22.33	18.38	23.31	18.57	20.41	18.51
Mar	25.70	22.43	22.11	18.31	23.12	18.54	20.13	18.66
Apr	25.49	21.48	21.72	18.14	23.15	18.66	19.95	18.38
May	25.36	21.37	22.18	18.80	23.08	18.74	20.02	19.03
Jun	26.20	22.26	22.85	19.12	23.45	18.83	20.44	19.08
Wheat								
Jul	22.22	18.61	21.00	17.02	14.42	12.57	13.59	11.97
Aug	22.54	19.11	21.19	17.24	14.82	12.85	13.84	12.13
Sep	22.74	19.05	21.33	17.74	15.03	13.13	13.87	12.28
Oct	22.95	19.15	21.72	18.16	14.94	13.48	14.08	12.55
Nov	23.65	20.03	21.74	18.45	15.88	14.33	14.44	12.97
Dec	24.01	20.50	22.43	19.09	15.68	14.42	14.98	13.40
Jan	24.49	20.59	22.89	19.71	16.18	14.89	15.23	13.33
Feb	24.75	21.07	22.96	19.99	16.43	14.59	15.75	13.73
Mar	23.67	20.27	21.82	18.89	16.03	14.32	15.99	14.04
Apr	22.97	19.40	21.29	18.09	15.59	13.13	15.22	13.10
May	22.98	19.25	22.19	18.24	15.05	12.62	13.89	12.22
Jun	23.48	19.71	22.42	18.34	14.82	12.92	13.80	12.20

The indices were highest in Chennai, followed by Mumbai, and Delhi. The divergence between wholesale prices and retail prices for wheat was relatively higher in the period of May to June. Higher divergence of indices of wheat were noticed immediately after the harvest. A comparative analysis between price indices and de-seasonalized prices provides implications for multi stakeholders in the rice and wheat value chain namely, producers/farmers, traders, millers/processors and consumers who can use the vital information for taking rational agri-business decisions like production, purchase, marketing, processing, stocking, distributing, and consumption [35].

Across rice markets, the estimated growth (CAGR) in seasonal indices was found negative except for Mumbai retail price and the declining growth was less than 'one' per cent (Table 3). The coefficient of variation (CV) for seasonal indices hovered around 'one' per cent and it ranged between 0.42 and 1.66 per cent, respectively for Mumbai retail market and Chennai wholesale market. The Intra-year Price Rise (IPR) and Average Seasonal Price Variation (ASPV) for rice were highest in Chennai wholesale market whereas lowest in the case of Mumbai retail market (Table 3). The IPR with respect to rice ranged between 1.61 and 5.50 per cent, while the ASPV ranged from 1.59 to 5.36 per cent.

In the case of wheat, the estimated growth in seasonal indices was positive but less than 'one' per cent in all regions. The variation in seasonal indices hovered around 'two' per cent (Table 3) and it ranged between 1.24 and 3.26 per cent respectively for Chennai retail market and Delhi wholesale market. The IPR and ASPV for the wheat market were found to be highest in the New Delhi wholesale market and lowest in Mumbai retail market (Table 3). The IPR for wheat ranged from 4.40 to 10.15 per cent, while the ASPV ranged between 4.31 and 9.66 per cent. The estimates of IPR and ASPV also provide vital inferences for taking agri-business-oriented decisions. Finally, the extent of fluctuations in seasonal index values of wheat and rice was computed through the average seasonal price index variation (ASPV) as indicated in Table 3 [34].

Table 3. Growth and variation in seasonal price index of rice and wheat

Market	Prices	CV (%)[a]	CAGR (%)[b]	IPR (%)[c]	ASPV (%)[d]
Rice					
Chennai	Retail	0.97	-0.09	3.07	3.02
	Wholesale	1.66	-0.14	5.50	5.36
Mumbai	Retail	0.57	0.04	2.04	2.02
	Wholesale	0.58	-0.03	2.18	2.15
New Delhi	Retail	0.42	-0.05	1.61	1.59
	Wholesale	0.63	-0.12	2.00	1.98
Patna	Retail	1.26	-0.14	3.79	3.72
	Wholesale	0.67	-0.08	2.21	2.19
Wheat					
Chennai	Retail	1.60	0.11	4.74	4.63
	Wholesale	1.83	0.08	5.62	5.46
Mumbai	Retail	1.24	0.03	4.40	4.31
	Wholesale	2.10	0.21	6.74	6.52
New Delhi	Retail	2.05	0.16	6.24	6.05
	Wholesale	3.26	0.04	10.15	9.66
Patna	Retail	2.68	0.32	8.41	8.07
	Wholesale	2.61	0.17	8.16	7.84

[a] Coefficient of Variation, [b] Compound Annual Growth Rate, [c] Intra-year Price Rise, and [d] Average Seasonal Price Variation

3.3. Price integration in rice and wheat markets

The hypothesis under efficient markets is the perfect integration of commodity prices, which should adjust and correct instantly with the available information [33]. In order to know the extent of market integration, Augmented Dickey-Fuller (ADF) test was first done to check the stationarity and order of integration of level variables. The test indicated the presence of unit root in all the level series, followed by stationarity in their first differencing (Table 4). The original series of wholesale and retail price for both rice and wheat was non-stationary and non-significant, but the first order differenced series turned out to be stationary and is significant at five per cent level. It was concluded from the ADF test that the variables were integrated of order one [I (1)]. The confirmation that each level series is I (1) helped to proceed with Johansen's cointegration analysis.

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Table 4. Estimates of Augmented Dickey-Fuller (ADF) test for the monthly prices of rice and wheat markets

Market	Prices	Level (Assumption: Constant, linear trend)	First Difference (Assumption: Constant)
Chennai	Retail	0.64	-14.16*
	Wholesale	-0.10	-14.21*
Mumbai	Retail	0.29	-11.36*
	Wholesale	-0.63	-15.52*
New Delhi	Retail	-0.65	-14.86*
	Wholesale	-0.84	-15.23*
Patna	Retail	-0.49	-15.86*
	Wholesale	-0.65	-15.09*
Wheat			
Chennai	Retail	-0.39	-15.87*
	Wholesale	-0.46	-13.32*
Mumbai	Retail	0.06	-10.31*
	Wholesale	-0.95	-15.95*
New Delhi	Retail	-0.92	-14.39*
	Wholesale	-0.82	-13.25*
Patna	Retail	-1.01	-12.10*
	Wholesale	-0.65	-15.09*

*indicates the significance at five per cent level of MacKinnon (1996) one-sided probability value.

The correlation coefficient of wholesale and retail prices for rice and wheat in different market pairs was calculated to determine the degree of market association. Prior to performing the cointegration analysis, the correlation between market prices was investigated. The results furnished in Tables 5 and 6 show the degree of short-run linear association as revealed by the correlation coefficients. All the market pairs for rice exhibited a very high level of significant correlation (> 0.85) owing to the symmetric price movement in all the markets (Table 5). The value of the correlation coefficient between two market pairs of wheat i.e., Chennai-Delhi, Patna-Chennai, Patna-Mumbai, and Mumbai-Delhi was found positive and very high. The implication is that the retail and wholesale prices of wheat was interlinked in all the selected markets, i.e., if the prices increased in one market it leads to an increase in the prices in other markets (Table 6).

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Table 5. Estimates of the correlation for rice markets

Price	Markets	Chennai	Mumbai	New Delhi	Patna	Chennai	Mumbai	New Delhi	Patna
		Retail				Wholesale			
Retail	Chennai		0.92*	0.89*	0.90*	0.99*	0.89*	0.89*	0.87*
	Mumbai	0.92*		0.97*	0.96*	0.89*	0.99*	0.97*	0.95*
	New Delhi	0.89*	0.97*		0.95*	0.88*	0.98*	0.99*	0.96*
	Patna	0.90*	0.96*	0.95*		0.88*	0.96*	0.96*	0.99*
Wholesale	Chennai	0.99*	0.89*	0.88*	0.88*		0.87*	0.88*	0.85*
	Mumbai	0.89*	0.99*	0.98*	0.96*	0.87*		0.98*	0.96*
	New Delhi	0.89*	0.97*	0.99*	0.96*	0.88*	0.98*		0.96*
	Patna	0.87*	0.95*	0.96*	0.99*	0.85*	0.96*	0.96*	

*indicates the significance of Pearson's correlation coefficient at one per cent level of probability.

Table 6. Estimates of the correlation for wheat markets

Price	Markets	Chennai	Mumbai	New Delhi	Patna	Chennai	Mumbai	New Delhi	Patna
		Retail				Wholesale			
Retail	Chennai		0.99*	0.97*	0.94*	0.98*	0.97*	0.97*	0.96*
	Mumbai	0.99*		0.97*	0.95*	0.97*	0.98*	0.97*	0.96*
	New Delhi	0.97*	0.97*		0.97*	0.97*	0.97*	0.99*	0.97*
	Patna	0.94*	0.95*	0.97*		0.93*	0.96*	0.97*	0.98*
Wholesale	Chennai	0.98*	0.97*	0.97*	0.93*		0.97*	0.97*	0.95*
	Mumbai	0.97*	0.98*	0.97*	0.96*	0.97*		0.97*	0.96*
	New Delhi	0.97*	0.97*	0.99*	0.97*	0.97*	0.97*		0.98*
	Patna	0.96*	0.96*	0.97*	0.98*	0.95*	0.96*	0.98*	

*indicates the significance of Pearson's correlation coefficient at one per cent level of probability.

It was necessary to determine the optimum lag length before cointegration analysis since Johansen's cointegration is much sensitive to the number of lags [36]. The optimum lag length was identified as 'six' and 'seven' for rice and wheat, respectively using the AIC criterion. The results, based on trace test and Eigen value, show that the long-run integration was established and confirmed the price integration in rice and wheat markets (Tables 7 and 8).

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Table 7. Estimates of Johansen's cointegration analysis of rice markets (Assumption: Linear deterministic trend)

No. of Cointegrating Equations	Eigenvalue	Trace Test Statistic	Critical Value	Probability Value**
None *	0.375173	488.8243	159.5297	0.0000
At most 1 *	0.334889	379.2491	125.6154	0.0000
At most 2 *	0.290884	284.2314	95.75366	0.0000
At most 3 *	0.240109	204.141	69.81889	0.0000
At most 4 *	0.197381	140.1636	47.85613	0.0000
At most 5 *	0.183114	88.93282	29.79707	0.0000
At most 6 *	0.164248	41.80735	15.49471	0.0000
At most 7	7.64E-06	0.001779	3.841466	0.9636

Trace test indicates 'seven' cointegrating equations at five per cent level

* denotes rejection of the hypothesis at five per cent level

**MacKinnon-Haug-Michelis (1999) probability values

Overall, the cointegration test rejected the null hypothesis of no cointegration (r= 0) between the retail and wholesale prices at 5% probability level indicating the presence of cointegration vectors among the retail and wholesale wheat and rice markets [2, 34]. The implication is that the wheat and rice markets are strongly integrated in the long-run. Despite the presence of short-run linear association and long-run integration as evident by cointegration analysis, past research [35] identified that Chennai failed to exhibit the long-run linear co-movement in wheat prices. The possible reason might be due to the absence of production in that zone along with increasing transaction costs [37], and transfer costs [17].

Table 8. Estimates of Johansen's cointegration analysis of wheat markets (Assumption: Linear deterministic trend)

No. of Cointegrating Equations	Eigenvalue	Trace Test Statistic	Critical Value	Probability Value**
None *	0.34815	566.937	159.5297	0.0000
At most 1 *	0.320181	456.5282	125.6154	0.0001
At most 2 *	0.309288	356.9586	95.75366	0.0000
At most 3 *	0.280665	261.4901	69.81889	0.0000
At most 4 *	0.21922	176.4976	47.85613	0.0000
At most 5 *	0.171378	112.6525	29.79707	0.0000
At most 6 *	0.149118	64.15076	15.49471	0.0000
At most 7 *	0.083473	22.48831	3.841466	0.0000

Trace test indicates 'eight' cointegrating equations at five per cent level

* denotes rejection of the hypothesis at five per cent level

**MacKinnon-Haug-Michelis (1999) probability values

3.4. Price transmission between wholesale and retail markets of rice and wheat

Table 9 and 10 show the results of pair-wise Granger causality tests which indicate the strength of causality in rice and wheat market. The pair-wise Granger causality test for rice indicated a bi-directional influence of prices in Delhi retail market on Delhi wholesale market and others (Table 9). Mumbai and Patna retail markets have shown a uni-directional influence of prices on New Delhi wholesale market. Likewise, New Delhi wholesale market had a bi-directional influence on prices in New Delhi retail market. In contrast, it

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had a uni-directional influence of prices on Mumbai retail market; and Chennai and Mumbai wholesale markets. Similarly, Mumbai and Patna wholesale markets had a uni-directional influence of prices on New Delhi's wholesale and retail markets, respectively. A similar kind of scenario prevailed for wheat (Table 10) corroborating price transmission across regions [38].

Table 9. Price transmission between the rice markets by Granger causality test

Price	Markets	Retail Price				Wholesale Price			
		Chennai	Mumbai	New Delhi	Patna	Chennai	Mumbai	New Delhi	Patna
Retail	Chennai		×	×	×	×	×	×	×
	Mumbai	×		×	×	×	×	→	×
	New Delhi	×	×		×	×	×	↔	×
	Patna	×	×	×		×	×	→	×
Wholesale	Chennai	×	×	×	×		×	×	×
	Mumbai	×	×	×	×	×		→	×
	New Delhi	×	→	↔	×	→	→		×
	Patna	×	×	→	×	×	×	×	

×*: No Causality;* →*: Uni-directional;* ↔*: Bi-directional*

Table 10. Price transmission between the wheat markets by Granger causality test.

Price	Markets	Retail Price				Wholesale Price			
		Chennai	Mumbai	New Delhi	Patna	Chennai	Mumbai	New Delhi	Patna
Retail	Chennai		×	×	×	×	×	×	×
	Mumbai	×		×	↔	×	×	↔	→
	New Delhi	×	×		↔	→	×	×	→
	Patna	×	↔	↔		×	×	↔	→
Wholesale	Chennai	×	×	×	→		×	×	↔
	Mumbai	×	×	×	×	×		×	×
	New Delhi	×	↔	→	↔	→	×		↔
	Patna	×	×	×	×	↔	×	↔	

×*: No Causality;* →*: Uni-directional;* ↔*: Bi-directional*

3.5. Impulse response function analysis

Figures 5 and 6 present the impulse response of Delhi wholesale market for the one-unit standard deviation (SD) innovation in retail as well as wholesale prices of the other markets. On a positive innovation observed in Chennai retail prices, the response of the Delhi wholesale price for rice turned negative and significant (Figure 5). The prevailed effects were intense but exist for a brief time as they turn non-significant after the eight and nine periods, respectively. This advocates, as anticipated, rice production in Chennai has been effective in increasing the supply of the food commodity that led to driving down the prices, corroborating the information given in Table 1.

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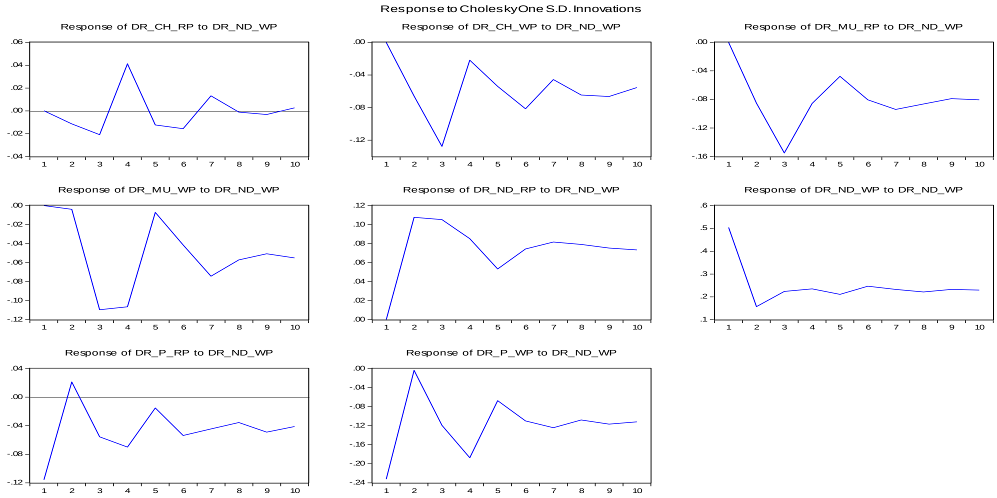

Figure 5. Impulse response of rice markets (Key market: New Delhi wholesale price)

However, impulse response function confirms that the Chennai wholesale price response to Delhi wholesale price shock is both significant and negative whereas the wholesale price in Mumbai to Delhi wholesale price shock have a strong influence of its past price movement upto three-to-four period and afterwards, the impact declines slowly. On positive innovation observed in the retail price of rice in Mumbai in response of Delhi wholesale price shock turned to be negative throughout the phase. Analysis of impulse-response again corroborates that the retail price in Patna in response to Delhi wholesale price shock turned significant but negative for the first two periods and later become positive for the next period, then again it turned negative (Figure 5).

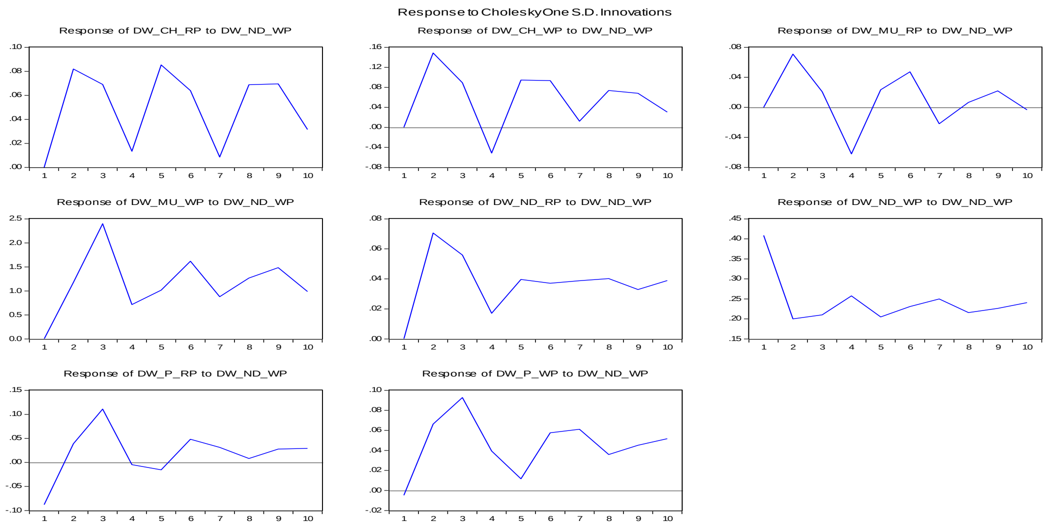

Figure 6. Impulse response of wheat market (Key market: New Delhi Wholesale Price)

In the case of wheat, the innovations of Chennai wholesale price to Delhi wholesale price shock were positive upto 'three' periods and later, it became negative. Through a positive innovation in Chennai retail prices for wheat, the response of Delhi's wholesale price turned positive throughout the period (Figure 6). Moreover, the impulse response function confirms that the wholesale and retail prices in Delhi's responses to its own shock were found both positive and significant (Figure 6). The wholesale price in Patna had a strong influence in response to Delhi wholesale price movement for upto 'five' periods and afterwards, the impact declined gradually. Thus, the major findings of this analysis disclose that the selected wheat and rice markets in India are efficient in 'price discovery' function as it precisely estimate the movement in commodity prices. However, the retail prices in both rice and wheat markets were strongly influenced by the wholesale prices in Delhi. Overall, the analysis confirms that 'price discovery' takes place initially in the wholesale market, and then gets transmitted to the retail market.

4. Conclusions

Price analysis on staple food commodities viz. rice and wheat exhibited strong evidence of spatial and temporal dynamics. In addition, a clear-cut seasonality has been witnessed, especially in wheat, linked to its harvest month(s). Further, price divergence between wholesale and retail markets was witnessed in rice and wheat over time and space. Johansen's test indicated a strong degree of price integration between wholesale and retail markets. In terms of causation, using the Granger causality test, the price series exhibited unidirectional-, bidirectional- as well as no-causality. Finally, the analysis of impulse response revealed the efficiency of rice and wheat markets in terms of 'price discovery'. The analysis also confirms that 'price discovery' takes place initially in the wholesale market, and then gets transmitted to the retail market. Overall, the research findings from analyzing the prices of rice and wheat wholesale and retail markets reveal some vital information to the stakeholders viz. producers, traders and consumers who have a potential interest in the market ecosystem. The derived information will facilitate them to take advantage of the price movement in staple commodities, either in buying, selling or distribution. The study advocates for strengthening the existing market intelligence, investing in infrastructure and reducing the distortion in markets to improve efficiency and overall performance.

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