J. Agr. Sci. Tech. (2019) Vol. 21(3): 517-530

Price Dynamics and Extent of Integration in Indian Wholesale and Retail Wheat Markets

R. Sendhil[1*], T. Arti[2], P. Lal[2], B. M. Gururaj[2], A. Jamaludheen[2], U. Chaudhary[2], and R. Rathore[2]

ABSTRACT

Uncertainty in staple food prices places the economy under jeopardy if not managed coherently and markets are not integrated. An attempt was made to analyze the wheat price behavior and extent of integration across selected wholesale and retail markets in India sourcing monthly data from FAO (July 2000-June 2016). Findings indicated that the price in wholesale and retail markets as well as its divergence was lowest in Patna, implying a major production and consumption zone, and highest in Chennai, indicating a negligible production. Monthly price indices exhibited a clear-cut seasonality linking with the arrivals of post-crop harvest. Extent of price integration was examined using Johansen's approach to know whether markets share a linear deterministic trend followed by testing the Law Of One Price (LOOP). The maximum likelihood test indicated a strong integration in different combinations of markets with some market pairs showing unidirectional-causality, while the rest exhibiting either bidirectional-causality or no-causality. Barring Patna, Delhi, and Mumbai's retail and wholesale markets, the rest of the market combinations did not confirm the LOOP. The study advocates rational allocation of resources based on the extent of price integration and reducing the market distortion for improving the overall performance.

Keywords: Allocation of resources, Law of one price, Market integration, Price integration, Seasonal price index.

INTRODUCTION

Wheat is an integral part of food basket and a critical 'staff of life' for around 2.5 billion poor consumers earning less than US$ 2 per day, apart from around 30 million farm families producing the cereal (Singh *et al.*, 2016). India is the second largest producer of the nutritious cereal feeding million mouths irrespective of income categories. Production in rural farms and the subsequent price divergence between rural and urban areas is one of the major factors that influence the level of consumption (Ramdas *et al.,* 2012; Nasurudeen *et al.*, 2006). Wheat being a major staple food, its price volatility, which represents the risk (Sendhil *et al.*, 2014a), has a significant influence on production as well as consumption decisions. The price of the necessary commodity set by the interaction of demand and supply forces is by and large inclined to the production, stock, government policies on procurement, support price, and other subsidies which ultimately get reflected in the market (Acharya *et al*., 2012), and sometimes by international price movement (Bakucs *et al.*, 2015).

Well-functioning markets effectively transmit price signals, both spatially (across regions) and temporally (across time), which helps in distribution of market resources and encourages investment (Qureshi, 1974; Dagher *et al*., 1991; Kurosaki, 1996; Ahmad, 2003). Alternatively, market performance is decided by the degree (and direction) of price integration since stabilizing prices in one key market will produce a desired outcome in

[1] ICAR-Indian Institute of Wheat and Barley Research, Karnal-132001, Haryana, India.
[2] ICAR-National Dairy Research Institute, Karnal-132001, Haryana, India.
* Corresponding author; e-mail: r.sendhil@gmail.com

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

others through arbitrage process (Sharma and Burark, 2015). Volatility in commodity prices is a major concern since it has decided the fate and fortune of several countries on account of its association with information flow, particularly in an arbitrage free economy (Sendhil *et al.,* 2014a). In addition, economic policies like the recently proposed Goods and Services Tax (GST) do affect the functioning of the agricultural commodity market system.

Wheat price from the perspective of stakeholders is an important factor considered for ascertaining the market performance in an agrarian economy like India, which the government substantially controls in terms of production, procurement, stock, trade, and pricing. The extent of wholesale and retail price movement and their inter-relationship in different markets is also considered a major factor in determining the efficiency. Commodity prices are inherently noisy, non-stationary, and likely to be leptokurtic, and hence it becomes cumbersome to capture the dynamics (Sendhil *et al.,* 2014a). In addition, diversity in regional production and consumption adds more complexity. Unquestionably, several studies have been done on price analysis and spatial market integration, but the main motivation arises to understand the price dynamics along with integration (horizontal and vertical) and price transmission in wholesale and retail markets of wheat, a staple commodity that is largely supported by the government. Given the complex conditions prevailing in wholesale and retail markets, an in-depth investigation will help to prioritize investments, reduce distortions, and suggest policies for improving the overall performance. In the milieu, the present study was an attempt to address the fundamental issues in major Indian wheat markets.

MATERIALS AND METHODS

The study sourced wholesale and retail monthly price data on wheat for four selected markets *viz.*, Patna, Delhi, Mumbai and Chennai (Figure 1 and Table 1) in India from the FAO-FPMA (Food Price Monitoring and Analysis) tool. The data pertains to the agricultural year 2000-2001 to 2015-2016 (*i.e.* July 2000 to June 2016). Conventional tools

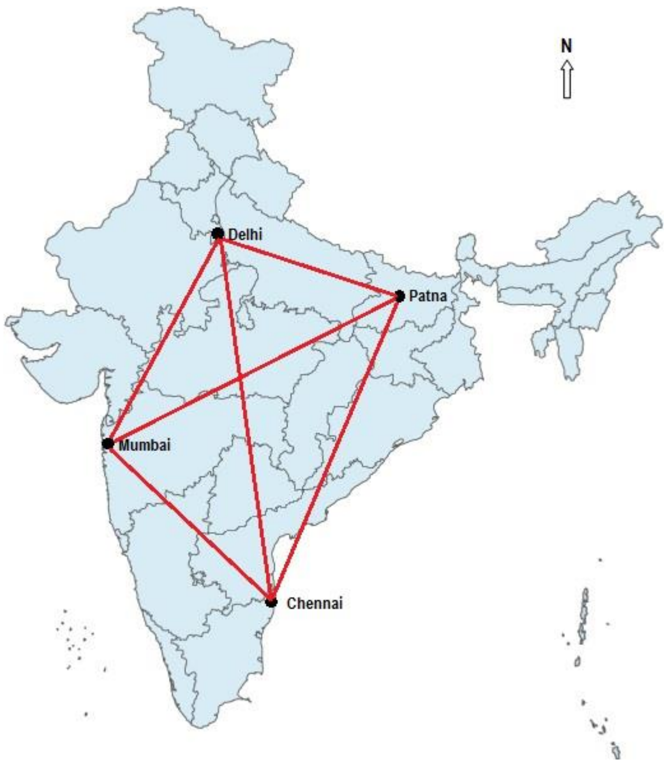


Figure 1. Selected wheat markets in India and their geographical location.

Table 1. Selected wheat markets and the basis for selection.

Markets (Wholesale and retail)	Basis for selection
Patna	Eastern India (High production and high consumption zone)
Delhi	Northern India (High production and high consumption zone)
Mumbai	Western India (Moderate production but high consumption zone)
Chennai	Southern India (Negligible production but increasing consumption zone)

and techniques were used to analyze the data for obtaining valid conclusions.

Compound Annual Growth Rate (CAGR)

The growth rate in wheat prices was estimated by the following formula (Gujarati, 2013; Sonnad *et al.,* 2011; Ramdas *et al.,* 2012):

$$Y_t = Y_O(1+r)^t \tag{1}$$

Take log on both side of the Equation (1) to transform into logarithmic form.

$$\ln Y_t = \ln Y_O + t\ln(1+r) \tag{2}$$

Where, Y_t is the price at time '*t*' for which growth has been calculated, Y_0 is a constant and *r* is the compound annual growth rate. The above equation was estimated using the Ordinary Least Square (OLS) method and the growth rate is interpreted in terms of percent.

Instability Index

To examine the extent of variation and risk involved in prices, instability index was calculated using the Cuddy-Della Valle approach (Cuddy and Della Valle, 1978).

$$CDVI = CV \times \sqrt{(1-R^2)} \tag{3}$$

Where, *CDVI* is the Cuddy-Della Valle instability Index in per cent, *CV* is the Coefficient of Variation in percent and R^2 is the coefficient of determination from a time trend regression. The estimated index is a close approximation of the average variation in monthly prices, which were adjusted for trend.

Seasonal Price Index

Seasonal variation in prices was estimated as a ratio of the actual month prices to the proportion of that particular month to the complete 12 months prices for the selected month's year. Then, the de-seasonalized data has been computed using the following formula:

$$\text{Deseasonalised data} = \frac{\text{Actual data for i}^{\text{th}}\text{ month}}{\text{Seasonal index of i}^{\text{th}}\text{ month}} \times 100 \tag{4}$$

The Intra-year Price Rise (IPR) and coefficient of Average Seasonal Price Variation (ASPV) was used to estimate the extent of seasonal variation in the prices.

$$\text{IPR} = \left[\frac{HSPI - LSPI}{LPSI}\right] \times 100 \tag{5}$$

$$\text{ASPV} = \left[\frac{HSPI - LSPI}{(HSPI + LSPI)/2}\right] \times 100 \tag{6}$$

Where, *HSPI* is the Highest Seasonal Price Index and *LSPI* is the Lowest Seasonal Price Index.

Market Integration

Market integration is an ideal situation wherein trade occurs between the selected markets with arbitraging in the presence of transaction cost (Ravallion, 1986; McNew, 1996; Baulch, 1997). A detailed review and application of market integration tools, particularly in developing countries, have been discussed by Rapsomanikis *et al.* (2006). Gonzalez *et al.* (2001), Omar *et al.* (2014), and Sendhil *et al.* (2013b and 2014b) opined that integrated markets facilitate the flow of information across space, time, and form. Several tests have been developed over a period of time and used to test the degree of price integration between markets since the procedure given by Engle and Granger (1987). The test is a two-step process, which is easy to apply but embedded with several limitations and, sometimes, can provide misleading results. An alternate approach is given by Johansen (1988) which can check for multiple co-integrating vectors. Kumar and Sharma (2003) reported the superiority of Johansen's test over others owing to its simplicity in computation, robustness sans a priori assumptions on variables either endogenous or exogenous in nature with testing simultaneously the number of co-integration vectors unimposed earlier. Amid typical statistical assumptions for price time series, Johansen's (1988, 1994, and 1995) co-integration test has been widely used in market integration studies (Sendhil *et al.*, 2013b and 2014b; Mahalle, 2015; Sharma and Burark, 2016) to address the problem of spurious relationship that exists among the non-stationary time series data. Prior testing for co-integration, the time series has to be tested for its stationarity or existence of unit root. The individual price series were tested for the order of integration to determine whether they are stationary at levels, also known as unit root testing (Gujarati, 2003). Dickey–Fuller test (Dickey and Fuller, 1979) is widely used to test the unit roots using the following forms:

(1) Y_t is a random walk without constant,

$$\Delta Y_t = \delta Y_{t-1} + e_t \quad (7)$$

(2) Y_t is a random walk with a constant,

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + e_t \quad (8)$$

(3) Y_t is a random walk with a constant and trend, $\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + e_t$ (9)

Where, t is the time or trend variable. Here, δ= 0 (ρ= 1) is null hypothesis, i.e. there is a unit root, it means that 't', the time series, is non-stationary. The alternative hypothesis is that δ is less than zero and the time series is stationary. Under the null hypothesis, the conventionally computed t statistics is known as the τ (tau) statistic, and its critical values were given by Dickey and Fuller (DF) (Dickey and Fuller, 1979). If the null hypothesis is rejected, it means that Y_t is a stationary time series with zero mean in the case of Equation (7), that Y_t is stationary with a non-zero mean (= β_1/ (1-ρ)) in the case of Equation (8), and that Y_t is a stationary around a deterministic trend in Equation (9).

To test the hypothesis that δ= 0, it is to be noted that the critical values of the tau test are different for each of the highlighted three specifications of the DF test. If the computed absolute value of the tau statistics exceeds the DF or MacKinnon critical tau values, the null hypothesis that δ= 0 will be rejected, implying the time series is stationary. Alternatively, if the computed (τ) value does not exceed the critical value, the null hypothesis will not be rejected, indicating the non-stationarity in the selected price time series. The DF test assumes the absence of correlation between the error-terms *i.e.* auto-correlation. However, if they are correlated, Dickey and Fuller have developed an alternate test known as the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) and it is conducted by "augmenting" the preceding equation by adding the lagged values of the dependent variable ΔY_t. The ADF test equation is as follows:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + u_t \quad (10)$$

Where, u_t is the pure white noise error-term and $\Delta Y_{t-1}= (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2}= (Y_{t-2} - Y_{t-3})$ and so on. The number of lagged difference terms to be included in the test equation is determined empirically and the idea behind inclusion is to make the error-terms serially uncorrelated. The null hypothesis is still that δ= 0 or ρ= 1, that is, a unit root exists in Y (i.e., Y is non-stationary).

Post unit root checking by ADF test, co-integration analysis was done using Johansen's (1988) approach. It is a multivariate generalization of DF test with the following formulation.

$$\mathrm{p_{it}} = \mathrm{A_1 p_{it-1}} + \varepsilon_\mathrm{t} \quad (11)$$

Subtracting $\mathrm{p_{it-1}}$ on both the sides, Equation (11) becomes,

$$\Delta \mathrm{p_{it}} = \mathrm{A_1 p_{it-1}} - \mathrm{p_{it-1}} + \varepsilon_\mathrm{t} \quad (12)$$

$$\Delta \mathrm{p_{it}} = (\mathrm{A_1} - \mathrm{I})\mathrm{p_{it-1}} + \varepsilon_\mathrm{t} \quad (13)$$

$$\Delta \mathrm{p_{it}} = \Pi \mathrm{p_{it-1}} + \varepsilon_\mathrm{t} \quad (14)$$

Where, *pit* and ε_t are (n×1) vectors; A1 is an (n×n) matrix of parameters; *I* is an (n×n) identity matrix; and $\boldsymbol{\Pi}$ is the (A1–I) matrix. The rank of (A1–I) matrix equals the number of co-integrating vectors and is determined by the trace statistic.

$$\lambda_{\mathrm{trace}}\,(\mathrm{r}) = -\mathrm{T} \sum_{j=r=1}^{n} \ln\,(1 - \hat{\lambda}_j) \quad (15)$$

Where, λ_j denotes the estimated values of the characteristic roots (Eigen values) obtained from the estimated Π matrix; and T is the number of usable observations.

Price Transmission

Prices from one market to the other are transmitted owing to perfect integration coupled with the development in information and communication technologies. In addition, the speed of price convergence depends on the market regulations and policy reforms (Sendhil, 2013a). Sometimes, exogenous variables also influence price transmission (Hassouneh *et al*., 2016). In the present study, Granger (1969) causality test was conducted after Johansen's procedure to find out the direction of price transmission. The test helps to know whether market $p1$ Granger causes market $p2$ or vice-versa, and it was tested using the following equation:

$$p_{it} = \mathrm{c} + \sum_{j=1}^{n} (\phi\, p_{1t-j} + \delta_j\, p_{2t-j}) \qquad (16)$$

The null hypothesis of the joint significance δ_n was tested for the causal relationship between two selected markets. The test determines the effect of lagged values of explanatory variables on the current values of dependent variable. However, it does not imply the instant causality or transmission and hence the results were reported with a concern/caution for short-run relation, which is also a limitation for this study.

$$H_0 : \delta_1 = \delta_2 = \ldots \delta_n = 0 \qquad (17)$$

Law of One Price (LOOP)

In spatial terms, the classical paradigm of the law of one price, as well as the predictions on price integration provided by the typical spatial price determination econometric models (Enke, 1951; Samuelson, 1952; Takayama and Judge, 1971) assume that price transmission is complete with equilibrium prices of a commodity sold at competitive markets *viz.* foreign and domestic markets differ only by transfer costs under common currency conversion. This postulation shall be validated by the LOOP against its strong version *vis-à-vis* weak version (Bakucs *et al.*, 2015).

The law of one price, in its weak version, was tested following the approach of Gandhi and Koshy (2006), Awokuse and Bernard (2007), and Sendhil *et al.* (2013b, 2014b) to identify whether wheat had the same price in spatially separated wholesale and retail markets barring the transfer costs**.** The ideal condition can be tested using the α and β coefficients obtained from the Johansen's co-integration equation by imposing restrictions. For instance, while testing the integration between two spatially separated commodity markets, the rank of $\pi = \alpha\beta'$ will be equal to one and, therefore, matrices for α and β take the order 2×1. Subsequently, the restriction of $\beta' = (1, -1)'$ was imposed to test the LOOP for two markets, and it was considered as a valid test in the long-run owing to the long-run parameters of the co-integrated system embedded by the β matrix. On the other hand, the *n*–1 co-integrating vectors indicate that all prices in different markets follow the same stochastic trend and hence pairwise co-integration exists, validating the law. The approach shall be generalized for 'n' number of markets as well by imposing the required restriction (Gandhi and Koshy, 2006).

RESULTS AND DISCUSSION

Price Dynamics

Deciphering the price trends across spatially separated markets provides the dynamism behaviour of the time series in different regions (Figure 2) which facilitates drawing of economic implications. It is explicit that the prices have been surging from 2000-2001 to 2015-2016 irrespective of market category and regions. Agricultural production is biological in nature with geographical concentration, thus wheat prices in selected markets across India (Table 1) exhibited spatial and temporal variations (Sendhil *et al.*, 2014a). However, it is interesting to note that the price divergence between the markets witnessed a sharp increase from the initial selected period, 2000-2001 to the recent period, 2015-2016 (Figure 2), indicating the need to study the degree of price integration and price transmission among the selected markets.

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

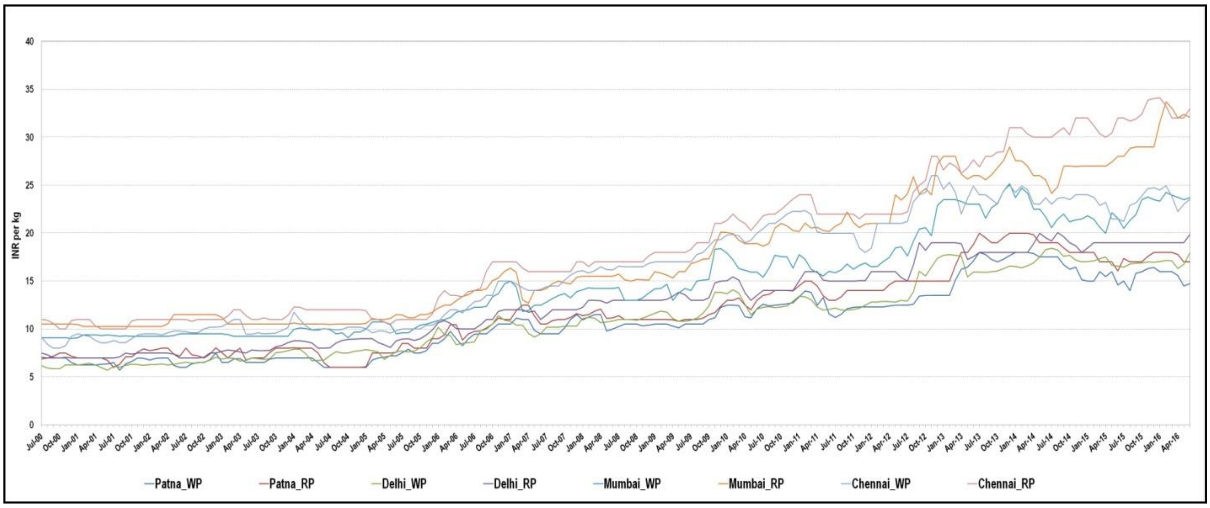


Figure 2. Price trend in selected wheat markets (AY 2000-2001 to 2015-2016)

The growth, variation, and descriptive statistics of wheat prices in different regional markets indicated a clear-cut difference between the wholesale and retail prices (Table 2). A symmetric pattern was observed in all the estimated parameters for the wholesale and retail prices. Patna witnessed the lowest estimates for the majority of the parameters. The wholesale and retail prices were highest in the case of Chennai (Wholesale price: `26 $kg^{-1}$ and Retail price: `34.14 kg^{-1}), indicating the lack of production in that zone despite growing consumption demand for wheat-based products in the southern region. However, the price divergence between the retail and wholesale markets was highest in Mumbai (`2.68 $kg^{-1}$), followed by Chennai (`2.63 kg^{-1}), Delhi (`1.57 $kg^{-1}$) and Patna (`1.07 kg^{-1}). The wholesale and retail prices were lowest in Patna implying the region is a major production and consumption zone. The wholesale prices were considered as a proxy for the producer or farm gate prices (Acharya *et al.*, 2012). The selected price series were positively skewed ranging from 0.08 to 0.57, indicating that the distribution tail is longer on the right side in comparison to the left. Alternatively, the majority of the monthly prices clustered towards the left of the mean, with only a few extreme observations found on the right side of the tail, a common feature of the high frequency time series data (Sendhil *et al.*, 2013b). Agricultural commodity prices in general behave non-stationary with leptokurtic distribution (Sendhil *et al.*, 2014a). However, the estimates of kurtosis was found to be negative for all the markets, specifying the platykurtic (fat or short tailed) distribution *i.e.*

Table 2. Summary statistics for the wheat market prices (AY 2000-01 to 2015-2016), (n=192).

Particulars	Patna		Delhi		Mumbai		Chennai	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
Maximum (` kg^{-1})	18.00	20.00	18.44	20.05	25.16	33.69	26.00	34.14
Minimum (`kg^{-1})	5.70	6.00	5.72	7.00	9.02	10.25	8.00	10.00
Range (`kg^{-1})	12.30	14.00	12.72	13.05	16.14	23.44	18.00	24.14
Mean (`kg^{-1})	10.77	11.84	11.19	12.77	14.88	17.56	16.29	18.91
Standard Deviation	3.69	4.18	3.92	4.31	5.11	6.79	5.79	7.52
Skewness	0.36	0.39	0.30	0.16	0.48	0.57	0.08	0.51
Kurtosis	-1.02	-1.07	-1.20	-1.36	-1.12	-1.00	-1.53	-1.07
Coefficient of Variation (%)	34.23	35.35	35.02	33.76	34.32	38.69	35.56	39.78
Cuddy-Della Valle Index (%)	11.37	11.50	8.71	6.40	10.57	11.34	9.61	10.48
CAGR (%) [a]	0.60	0.62	0.64	0.63	0.59	0.67	0.66	0.70

[a] Compound Annual Growth Rate

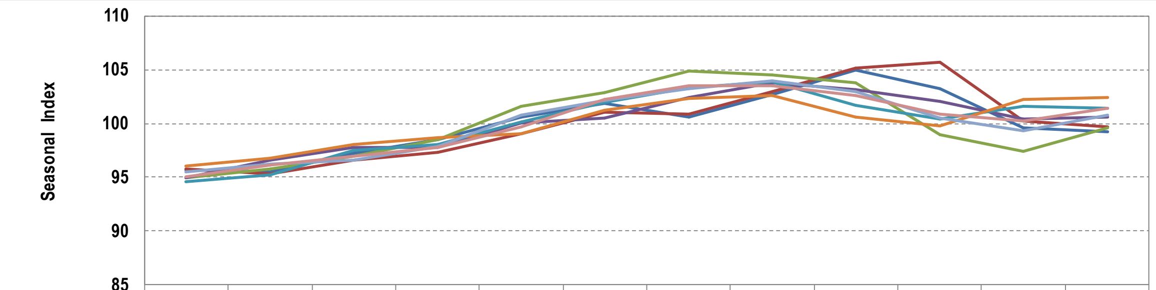
relatively flatter than a normal distribution but with a wide peak. Further, the skewness and kurtosis estimates imply that the monthly prices in the respective markets are widely spread around its mean (Table 2). *Inter alia*, government control over the staple's price shall be attributed to the witnessed dynamics and distribution pattern.

On perusal of the Table 2, it can be concluded that the standard deviation and variation were highest in Chennai's wholesale and retail markets corroborating the fact that Chennai is a metro city with increasing consumption rate but nil production. Likewise, it was lowest for Patna markets being the major production and consumption region. The risk in prices accounted by the Cuddy-Della Valle index indicated that barring Chennai wholesale and Delhi wholesale and retail markets, the rest exhibited instability by more than 10%. The growth in monthly prices – estimated by the Compound Annual Growth Rate (CAGR) – revealed a positive but less than one per cent change for each month. It was highest in the case of Chennai's retail price (0.70%), followed by Mumbai's retail price (0.67%) and Delhi's wholesale price (0.64%).

Seasonal Variation in Prices

Seasonal fluctuation in agricultural products are periodical in nature and have to be monitored continuously for taking economic decisions based on the past pattern as well as future values. Seasonal indices of monthly prices revealed a clear-cut seasonal price variation in different wheat markets across the country (Figure 3). The index was highest in Patna retail market (April: 105.71) and lowest in Mumbai wholesale market (July: 94.61). The indices across markets were peaking highest during the months prior to harvest *i.e.* January to March, because of the dearth in wheat supply. Thereafter, the indices started to decline owing to the market arrivals after harvest supporting the findings of Mahalle *et al.* (2015). Seasonal price variation in general was highest in Patna and lowest in Delhi in comparison to the rest. The indices were highest in February for three markets, with the exception of wholesale market in Delhi and retail market in Chennai, wherein, January registered the highest variation. The price variations were lowest during July in three markets barring Patna. The lower price indices were observed from May to October because of high market arrivals and release of public stocks.

The average de-seasonalized values for each month explicitly revealed the fact that the wholesale prices were lower than the retail prices for all the months, and the divergence between them was relatively higher in Chennai and Mumbai (Table 3). Further, the average



	July	August	September	October	November	December	January	February	March	April	May	June
Patna_WP	95.73	95.55	97.27	98.51	100.58	101.90	100.61	102.74	105.02	103.26	99.61	99.22
Patna_RP	95.80	95.36	96.61	97.36	99.10	101.09	100.92	102.94	105.18	105.71	100.28	99.67
Delhi_WP	94.93	95.80	96.92	98.55	101.57	102.88	104.92	104.55	103.83	98.99	97.45	99.61
Delhi_RP	94.94	96.60	97.75	97.76	100.04	100.54	102.39	103.83	103.12	102.04	100.40	100.58
Mumbai_WP	94.61	95.24	97.54	98.05	100.16	101.99	103.30	103.87	101.72	100.46	101.62	101.45
Mumbai_RP	96.03	96.79	98.07	98.73	99.06	101.29	102.35	102.62	100.59	99.76	102.25	102.47
Chennai_WP	95.51	96.28	96.56	97.88	100.77	102.17	103.22	104.01	102.96	100.55	99.32	100.77
Chennai_RP	95.05	96.13	96.95	97.75	99.70	102.23	103.57	103.50	102.59	100.91	100.21	101.42

Figure 3. Seasonal indices of monthly prices in selected wheat markets (AY 2000-2001 to 2015-2016).

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

de-seasonalized prices across the months were observed to be similar in the respective wheat markets. It was lowest in the case of Patna, followed by Delhi, Mumbai, and Chennai. The seasonal price indices *vis-à-vis* de-seasonalized prices carry economic implications to different stakeholders in the wheat production system *viz.*, producers, middlemen, and consumers for taking rational decisions like buying, selling, and stocking. Across wheat markets, the estimated growth (CAGR) in seasonal indices was positive but minimal, and found to be less than one per cent. The *CV* for seasonal indices was hovering around 3 per cent (Table 4) and it ranged between 2.29 per cent (Mumbai retail market) and 3.48 per cent (Delhi wholesale market). The Intra-year Price Rise (IPR) and Average Seasonal Price Variation (ASPV) were found to be highest in Patna retail market and lowest in Mumbai retail market (Table 4). The IPR ranged from 6.86 to 10.85%, while the ASPV ranged from 6.63 to 10.29%. The coefficients of IPR and ASPV also provide implications for taking decision related to production, consumption, and trade (Mahalle *et al.*, 2015).

Market Integration

The hypothesis under efficient markets is perfect integration of commodity prices, which should adjust and correct instantly with the available information (Sendhil *et al*., 2014b). 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 non-stationarity in their first differencing (Table 5). 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 the Johansen's

Table 3. Average de-seasonalized monthly prices in wheat (AY 2000-2001 to 2015-2016).

Month	Patna		Delhi		Mumbai		Chennai	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
July	10.83	11.94	11.17	12.76	14.74	17.38	16.23	18.82
August	10.81	11.94	11.20	12.80	14.81	17.46	16.39	18.90
September	10.80	11.88	11.23	12.82	14.88	17.51	16.42	18.92
October	10.77	11.85	11.19	12.78	14.91	17.51	16.39	18.92
November	10.75	11.84	11.16	12.75	14.93	17.51	16.39	19.05
December	10.73	11.82	11.16	12.72	14.98	17.59	16.33	19.03
January	10.79	11.85	11.15	12.72	14.92	17.62	16.21	18.92
February	10.74	11.79	11.17	12.73	14.91	17.70	16.30	18.89
March	10.75	11.75	11.19	12.75	14.90	17.71	16.23	18.82
April	10.73	11.74	11.26	12.78	14.84	17.60	16.12	18.82
May	10.80	11.82	11.21	12.80	14.87	17.57	16.21	18.89
June	10.79	11.85	11.24	12.80	14.86	17.54	16.24	18.95

Table 4. Growth and variation in seasonal price index.

Market	*CAGR* (%)[a]	*CV* (%)[b]	*IPR* (%)[c]	*ASPV* (%)[d]
Patna WP	0.55	2.96	9.90	9.44
Patna RP	0.71	3.42	10.85	10.29
Delhi WP	0.42	3.48	10.52	10.00
Delhi RP	0.59	2.73	9.36	8.94
Mumbai WP	0.65	3.00	9.78	9.33
Mumbai RP	0.54	2.29	6.86	6.63
Chennai WP	0.53	2.90	8.90	8.52
Chennai RP	0.61	2.92	8.96	8.58

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

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

Table 5. Estimates of Augmented Dickey Fuller (ADF) test for the monthly prices.

Market	ADF statistic for testing unit root		Order
	Level (Assumption: Constant, linear trend)	1st Difference (Assumption: Constant)	
Patna WP	-0.93	-13.38*	I (1)
Patna RP	-0.95	-11.38*	I (1)
Delhi WP	-0.99	-11.36*	I (1)
Delhi RP	-0.74	-11.16*	I (1)
Mumbai WP	-0.59	-13.68*	I (1)
Mumbai RP	0.16	-12.46*	I (1)
Chennai WP	-0.85	-12.15*	I (1)
Chennai RP	-0.21	-11.07*	I (1)

* Indicates the significance at 1% of MacKinnon (1996) one-sided *P*-values.

approach of co-integration analysis (Gurmu *et al.,* 2017).

Prior to performing the co-integration analysis, correlation between market prices was investigated. Table 6 shows the degree of short-run linear association as revealed by the correlation coefficients. All the market pairs exhibited a strong level of significant correlation (> 0.94) owing to the symmetric price movement in all the markets as evident from Figure 2.

Subsequently, Johansen's co-integration analysis was done after identifying the optimal lag length using the Akaike Information Criterion (AIC) value. The long-run integration was established by the Eigen value and trace statistics (Table 7). Despite the presence of short-run linear association between the wholesale and retail prices in all the markets, Chennai failed to exhibit the long-run linear co-movement in wheat prices. This might be due to the absence of production in that zone, increasing transaction costs (Mukim *et al.,* 2009), and transfer costs (Rapsomanikis *et al.,* 2006). The test rejected the null hypothesis of no co-integration (r= 0) between the retail and wholesale prices at 5% probability level for the rest of the markets, indicating the presence of one co-integration vector among the retail and wholesale wheat markets (Acharya *et al.,* 2012; Mahalle *et al.,* 2015).

Co-integration among the retail, wholesale, and retail-wholesale prices of all markets were also tested after identifying the optimum lag length in each category (Table 7). The idea behind the test was to find whether the selected wheat markets were integrated in the long-run and thereby price transmission held true in each market group. In the case of wholesale prices, Johansen's test indicated the possibility of two co-integration vectors among the selected markets by rejecting the framed null hypothesis of no co-integration (r= 0) to utmost one relationship (r≤ 1) between wheat markets at 1% probability level. Likewise, one co-integration vector was identified between the retail prices. In the case of co-integration comprising both wholesale and retail prices, the test rejected the null hypothesis for utmost two relationships (r≤ 2) at 1% level of probability, indicating that there

Table 6. Estimates of correlation analysis.

Market	Chennai RP	Chennai WP	Delhi RP	Delhi WP	Mumbai RP	Mumbai WP	Patna RP	Patna WP
Chennai RP		0.96*	0.98*	0.97*	0.95*	0.96*	0.95*	0.95*
Chennai WP	0.96*		0.97*	0.98*	0.98*	0.98*	0.97*	0.96*
Delhi RP	0.98*	0.97*		0.99*	0.96*	0.97*	0.96*	0.96*
Delhi WP	0.97*	0.98*	0.99*		0.96*	0.98*	0.96*	0.96*
Mumbai RP	0.95*	0.98*	0.96*	0.96*		0.98*	0.95*	0.94*
Mumbai WP	0.96*	0.98*	0.97*	0.98*	0.98*		0.97*	0.97*
Patna RP	0.95*	0.97*	0.96*	0.96*	0.95*	0.97*		0.99*
Patna WP	0.95*	0.96*	0.96*	0.96*	0.94*	0.97*	0.99*	

* Indicates the significance of Pearson's correlation coefficient at one per cent level of probability (2 tailed).

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

Table 7. Estimates of Johansen's co-integration analysis (Assumption: Linear deterministic trend).

Markets	Lag length (AIC value)	H_0: Rank= r	Eigen value	Trace statistic	Critical value
Patna WP	1	$r= 0^a$	0.156	33.17	15.50
Patna RP	(-7.25)	$r\leq 1$	0.005	0.911	3.841
Delhi WP	3	$r= 0^a$	0.093	18.82	15.50
Delhi RP	(-8.33)	$r\leq 1$	0.002	0.379	3.841
Mumbai WP	1	$r= 0^a$	0.083	16.47	15.50
Mumbai RP	(-7.98)	$r\leq 1$	0.000	0.001	3.841
Chennai WP	5	$r= 0$	0.026	6.396	15.50
Chennai RP	(-8.46)	$r\leq 1$	0.008	1.440	3.841
Patna WP		$r= 0^a$	0.142	66.88	47.86
Delhi WP	1	$r\leq 1^a$	0.123	37.87	29.80
Mumbai WP	(-14.68)	$r\leq 2$	0.063	12.83	15.49
Chennai WP		$r\leq 3$	0.003	0.541	3.841
Patna RP		$r= 0^a$	0.151	58.36	47.86
Delhi RP	2	$r\leq 1$	0.080	27.47	29.80
Mumbai RP	(-15.86)	$r\leq 2$	0.060	11.75	15.49
Chennai RP		$r\leq 3$	0.000	0.007	3.841
Patna WP		$r= 0^a$	0.226	198.7	159.5
Delhi WP		$r\leq 1^a$	0.212	149.9	125.6
Mumbai WP		$r\leq 2^a$	0.174	104.7	95.75
Chennai WP	1	$r\leq 3$	0.144	68.39	69.82
Patna RP	(-32.44)	$r\leq 4$	0.087	38.89	47.86
Delhi RP		$r\leq 5$	0.074	21.64	29.80
Mumbai RP		$r\leq 6$	0.036	7.129	15.49
Chennai RP		$r\leq 7$	0.001	0.200	3.841

[a] Denotes rejection of the null hypothesis at five per cent level of MacKinnon-Haug-Michelis (1999) probability.

could be three possible co-integration vectors among the selected wheat markets (Table 7).

Price Transmission

The pair-wise Granger causality test indicated a bi-directional influence of prices in Chennai retail and Delhi wholesale market on all other markets, with the exception of Chennai wholesale, and, Patna retail and wholesale markets, respectively (Table 8). Chennai wholesale market had shown a bi-directional influence of prices on Delhi retail as well as wholesale and Patna wholesale markets, with a uni-directional transmission to the rest. Likewise, Delhi retail market had a bi-directional influence of prices on all the markets barring Patna retail and wholesale markets. However, Patna retail and wholesale prices had no causal relationship with the Delhi retail prices. Further, Patna retail prices had no influence on Chennai wholesale, and, Mumbai retail and wholesale prices.

Similarly, Patna wholesale prices had no influence on Delhi wholesale, and, Mumbai retail and wholesale prices as well. Unexpectedly, there was no price transmission from the wholesale prices in Chennai and Mumbai to their respective retail markets. *A priori*, a bi-directional influence of prices was noticed only in Delhi market indicating the price transmission from wholesale to retail markets and *vice-versa*. A majority of the markets exhibited a bi-directional transmission leading to price adjustment from the demand and supply information

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

available between markets (Mahalle *et al.*, 2015).

Law of One Price (LOOP)

Out of four bivariate relationships *viz*., Patna (WP and RP), Delhi (WP and RP), Mumbai (WP and RP) and Chennai (WP and RP), three showed the presence of one co-integrated vector (Table 9). The numbers of stochastic trends were found to be one, having two markets in total. The conformation of LOOP was validated in all the three regions, except Chennai. The implication is that out of four regional markets, three have the same price barring the transfer cost.

Likewise, the LOOP was tested in different combination of markets. The retail, wholesale, and the subsequent combination of retail and wholesale markets failed to exhibit the LOOP, indicating the presence of distortion leading to differential prices. Markets that fulfill the LOOP indicate that any price shock originated at one market is fully reflected at the market, a consequence of perfect market integration (Zahid *et al.*, 2007). Alternatively, transfer costs of commodities in developing countries may give rise to a threshold over which eliminating the arbitraging process and result in market disintegration (Rapsomanikis *et al.,* 2006).

CONCLUSIONS

Commodity prices transmit signal to the stakeholders and facilitate them to take economic decisions. Analysis on prices indicates that the wholesale and retail prices were highest in the case of Chennai, indicating the lack of production in that zone. Price divergence between the retail and wholesale markets was highest in Mumbai because of lack of production and high consumption demand for wheat and was lowest in Patna, implying the region is a major production and consumption zone. Monthly price indices exhibited a clear-cut seasonal price variation peaking highest during the months prior to

Table 8. Price transmission between markets by Granger causality test.

Market	Chennai_RP	Chennai_WP	Delhi_RP	Delhi_WP	Mumbai_RP	Mumbai_WP	Patna_RP	Patna_WP
Chennai_RP		X	↔	↔	↔	↔	↔	↔
Chennai_WP	X [a]		↔	↔	→ [c]	→	→	↔
Delhi_RP	↔ [b]	↔		↔	↔	↔	→	→
Delhi_WP	↔	↔	↔		↔	↔	↔	→
Mumbai_RP	↔	X	↔	↔		→	→	→
Mumbai_WP	↔	X	↔	↔	X		→	→
Patna_RP	↔	X	X	↔	X	X		X
Patna_WP	↔	↔	X	X	X	X	→	

[a] *No causality,* [b] *Bi-directional, and* [c] *Uni-directional.*

Table 9. Confirmation of the LOOP for wheat markets.

Markets	Number of co-integrated vectors	Number of stochastic trends	Confirmation of LOOP
Patna WP-Patna RP	1	2–1= 1	Yes
Delhi WP-Delhi RP	1	2–1= 1	Yes
Mumbai WP-Mumbai RP	1	2–1= 1	Yes
Chennai WP-Chennai RP	0	2–0= 0	No
Patna WP-Delhi WP-Mumbai WP-Chennai WP	2	4–2= 2	No
Patna RP-Delhi RP-Mumbai RP-Chennai RP	1	4–1= 3	No
Patna WP-Delhi WP-Mumbai WP-Chennai WP- Patna RP-Delhi RP-Mumbai RP-Chennai RP	3	8–3= 5	No

[DOR: 20.1001.1.16807073.2019.21.3.2.5]

harvest because of dearth in wheat supply, and lower after harvest because of high market arrivals and release of public stocks. The estimated growth in seasonal indices was positive but found to be less than 1%, indicating price insulation. Co-integration analysis showed the presence of integration between the wholesale and retail prices in all the markets, but Chennai failed to exhibit the long-run linear co-movement in wheat prices due to the absence of production in that zone. The pair-wise Granger causality test indicated a bi-directional influence of prices in one market with the other for the majority of the cases. Barring Patna, Delhi and Mumbai's retail and wholesale markets, the rest of the combinations did not confirm the existence of LOOP. The study calls for a pragmatic approach on rational allocation of resources based on the extent of price integration across wholesale and retail markets as well as reducing the price distortion in less integrated markets through reduction in transaction and transfer costs for improving the overall performance of wheat markets in India.

ACKNOWLEDGEMENTS

The authors duly acknowledge the useful comments and constructive suggestions made by the anonymous reviewers, which improved the quality of the manuscript.

REFERENCES

1. Acharya, S. S., Chand, R., Birthal, P. S., Kumar, S. and Negi, D. S. 2012. Market Integration and Price Transmission in India: A Case of Rice and Wheat with Special Reference to the World Food Crisis of 2007-08. Food and Agriculture Organization, Rome. 1-67.
2. Ahmad, M. 2003. Agricultural Product Markets in Pakistan. Pakistan Institute of Development Economics, Islamabad.
3. Awokuse, T. O. and Bernard, J. C. 2007 Spatial Price Dynamics in US Regional Broiler Markets. *J. Agr. App. Econ.*, **39(3):** 447–456. doi: 10.1017/S1074070800023191.
4. Bakucs, L. Z., Bojnec, S. and Ferto, I. 2015. Spatial Product Market Integration between Two Small, Open Neighboring Economies. *Agribus.*, **31(2):** 171-187.
5. Baulch, B. 1997. Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration. *Am. J. Agr. Econ.*, **79**: 477–487.
6. Cuddy, J. D. A. and Della Valle, P. A. 1978. Measuring the Instability of Time Series Data. *Oxf. Bull. Econ. & Stat.*, **40(1)**: 79-85.
7. Dagher, Magid A., Christy, Ralph D. and McLean-Meyinsse, Patricia E. 1991. Limited Resource Farmers and the Marketing System. *Am. J. Agr. Econ.*, **73(5)**: 1485-1489. doi: 10.2307/1242408.
8. Dickey, D. and Fuller, W. A. 1979. Distribution of the Estimators for Autoregressive Time Series Regressions with Unit Roots. *J. Am. Stat. Assoc.*, **74(366a)**: 427-431.
9. Dickey, D. and Fuller, W. A. 1981. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica*, **49(4):** 1057-1072. doi:10.2307/1912517
10. Engle, R. F. and Granger, C. W. J. 1987. Cointegration and Error-Correction: Representation, Estimation and Testing. *Econometrica*, **55(2):** 251-276.
11. Enke, S. 1951. Equilibrium among Spatially Separated Markets: Solution by Electrical analogue. *Econometrica*, **19(1)**: 40-47.
12. Gandhi, V. P. and Koshy, A. 2006. *Wheat Marketing and Its Efficiency in India*. Working Paper No.: 2006-09-03, Indian Institute of Management, Ahmedabad.
13. Gonzalez-Rivera, G. and Helfand, S. M. 2001. The Extent, Pattern, and Degree of Market International: A Multivariate Approach for the Brazillian Rice Market. *Am. J. Agr. Econ.*, **83(3):** 576–592.
14. Granger, C. 1969. Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. *Econometrica*, **37(3):** 424-438. doi:10.2307/1912791
15. Gujarati, D. N. 2003. *Basic Econometrics.* Fourth Edition, Tata McGraw-Hill Edition, India.
16. Gurmu, M. Y., Meyer, F. and Hassan, R. 2017. Modelling Price Formation and Dynamics in the Ethiopian Maize Market. *J. Agr. Sci. Tech.*, 19: 1439-1452.
17. Hassouneh, I., Serra, T., Bojnec, S. and Gil, J. M. 2016. Modelling Price Transmission and Volatility Spillover in the Slovenian Wheat Market. *Appl. Econ.*, **49(41):** 4116-4126.

18. Johansen, S. 1988. Statistical Analysis of Cointegration Vectors. *J. Econ. Dyn. Con.*, **12(2):**231-254.
19. Johansen, S. 1994. The Role of the Constant and Linear Terms in Cointegration Analysis of Nonstationary Variables. *Econ. Rev.,* **13(2):** 205-229.
20. Johansen, S. 1995. *Likelihood-Based Interference in Cointegrated Vector Autoregressive Models.* Oxford University Press, Oxford.
21. Kumar, P. and Sharma, R. K. 2003. Spatial Price Integration and Price Efficiency at Farm Level: A Study of Paddy in Haryana. *Ind. J. Agr. Econ.*, **58(2)**: 201-217.
22. Kurosaki, T. 1996. Government Interventions, Market Integration and Price Risk in Pakistan's Punjab. *T. Pak. Dev. Rev.*, **35(2)**:129–144.
23. Mahalle, S. L., Shastri, S. and Kumar, Sh. 2015. Integration of Wheat Markets in Maharashtra. *Agr. Econ. Res. Rev.*, **28(1)**: 179-187.
24. McNew, K. and Fackler, P. L. 1996. Testing Market Equilibrium: Is Cointegration Informative?. *Agr. Res. Econ.,* **22(2)**: 191–207.
25. Mukim, M., Singh, K. and Kanakaraj, A. 2009. Market Integration, Transaction Costs and the Indian Wheat Market: A Systematic Study. *Eco. Pol. Week.,* **44 (22)**: 149-155.
26. Nasurudeen, P., Kuruvila, A., Sendhil, R. and Chandrasekar, V. 2006. The Dynamics and Inequality of Nutrient Consumption in India. *Ind. J. Agr. Econ.*, **61(3)**: 362-370.
27. Omar, M. I., Dewan, M. F. and Hoq, M. S. 2014. Analysis of Price Forecasting and Spatial Co-Integration of Banana in Bangladesh. *Eur. J. Bus. Mgmt.,* **6(7)**: 244-255.
28. Qureshi, S. K. 1974. The Performance of Village Markets for Agricultural Produce: A Case Study of Pakistan. *T. Pak. Dev. Rev.,* **8(3)**: 280–307.
29. Ramdas, S., Singh, R. and Sharma, I. 2012. Exploring the Performance of Wheat Production in India. *J. Wheat Res.,* **4(2)**: 37-44.
30. Rapsomanikis, G., Hallam, D., Comforti, P. and Sharma, R. 2006. *Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and Applications*. Food and Agriculture Organization, Rome, PP. 1-20.
31. Ravallion, M. 1986. Testing Market Integration. *Am. J. Agr. Econ.,* **68(1)**: 102–109.
32. Samuelson, P.A. 1952. Spatial Price Equilibrium and Linear Programming. *Am. Econ. Rev*., **42:** 560-580.
33. Sendhil, R., Kar, A., Mathur, V. C. and Jha, G. K. 2013a. Price Discovery, Transmission and Volatility: Evidence from Agricultural Commodity Futures. *Agr. Econ. Res. Rev.*, **26 (1)**: 41-54.
34. Sendhil, R., Babu, D., Kumar, R. and Srinivas, K. 2013b. How far Do Egg Markets in India Conform to the Law of One Price?. *Afr. J. Agr. Res.*, **8(48)**: 6093-6100. doi. 10.5897/AJAR2013.6988.
35. Sendhil, R., Kar, A., Mathur, V. C., and Jha, G. K. 2014a. Price Volatility in Agricultural Commodity Futures: An application of GARCH model. *J. Ind. Soc. Agr. Stat.*, **68(3)**: 365-375.
36. Sendhil, R., Sundaramoorthy, C., Venkatesh, P., and Thomas, L. 2014b. Testing Market Integration and Convergence to the Law of One Price in Indian Onions. *Afr. J. Agr. Res.*, **9(40)**: 2975-2984.
37. Sharma, H. and Burark, S.S. 2016. Extent of Market Integration of Wheat in Rajasthan. *Ind. J. Econ. Dev.*, **12(3)**: 445-452. doi. 10.5958/2322-0430.2016.00160.8.
38. Singh, G. P., Gupta, R. K. and Sendhil, R. 2016. Trends and Potential Pathways for Sustainable Wheat Production in India. *55th All India Wheat and Barley Research Workers' Meet Held at CCS Haryana Agricultural University,* Hisar from 21-24 August, 2016.
39. Sonnad, J. S., Raveendaran, N., Ajjan, N. and Selvaraj, K. N. 2011. Growth Analysis of Oilseed Crops in India during pre and Post WTO Periods. *Kar. J. Agr. Sci.,* **24(2)**: 184-187.
40. Takayama, T. and Judge, G. G. 1971. *Spatial and Temporal Price Allocation Models*. North Holland Pub. Co., Amsterdam.
41. Zahid, M. S., Qayyum, A. and Malik, W. S. 2007. Dynamics of Wheat Market Integration in Northern Punjab, Pakistan. *T. Pak. Dev. Rev.,* **46(4)**: 817-830.

پویایی قیمت و گستره یکپارچگی در بازارهای عمده فروشی و خرده فروشی گندم هندوستان

ر. سندهیل، ت. آرتی، پ. لال، ب. م. گروراج، ا. جمالودهن، ی. چادهری، و ر. راتور

چکیده

چناچه اقتصاد به گونه ای هماهنگ مدیریت نشود و بازارها یکپارچه (ادغام) نباشند، عدم قطعیت درقیمت غذای اصلی، اقتصاد را به مخاطره می اندازد. در این پژوهش، تلاش شد با استفاده از داده های ماهانه(ژوئیه ۲۰۰۰ تا ژوئن ۲۰۱۶)اخذ شده از فائو FAO، رفتار قیمت و گستره یکپارچگی در سراسر بازارهای عمده فروشی و خرده فروشی گندم در هندوستان تجزیه تحلیل شود. یافته ها چنین اشاره داشت که در (ناحیه) Patna قیمت در بازار عمده فروشی و خرده فروشی و نیز واگرایی قیمت کمترین مقدار را داشت و این امر نمایانگر آن بود که منطقه مزبور یک محل اصلی تولید و مصرف گندم بود در حالیکه در ناحیهChennai قیمت گندم و واگرایی آن بیشترین مقدار را داشت و نشانگر تولید ناچیز در آنجا بود. شاخص های قیمت ماهانه وابستگی فصلی کاملا روشنی را با ورود محصول بعد از برداشت محصول نشان میداد. برای دانستن اینکه بازارها در یک روند قطعی مشارکت دارند یا نه، گستره یکپارچگی (ادغام) قیمت با استفاده از روش جانسون بررسی شد و به دنبال آن آزمون قانون تک قیمتی (law of one price،LOOP). آزمون حداکثر احتمال حاکی از یکپارچگی شدیدی در ترکیبهای مختلف از بازارها بود و بعضی بازارهای جفت(market pairs) علیت یک جهتی(unidirectional-causality) نشان دادند در حالیکه بقیه بازارها یا علیت دو جهتی داشتند یا بدون علیت بودند. به استثنای بازارهای عمده فروشی و خرده فروشی نواحی Panta، دهلی، و مومبای، بقیه ترکیب بازارها LOOPرا تایید نکردند. این پژوهش، برای بهبود کلی عملکرد(اقتصادی)، از تخصیص منطقی منابع برمبنای گستره یکپارچگی قیمت و کاهش دخالت دولت (market distortion) حمایت می کند.

[DOR: 20.1001.1.16807073.2019.21.3.2.5]