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Assessment of spatial price linkages in the major potato-assembling markets in India

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Abstract The study analyses the spatial linkages of Agra, Hooghly, Firozpur, Pune, and Delhi potato markets. The Granger causality technique is used to identify the causal relationship between the price series in the potato markets, and the Delhi market is found to be the price leader. The shocks arising in the Delhi market are transmitted to all the other markets. To identify the price triggers in the major price-influencing markets, the variance decomposition technique is applied, which reveals that the forecast error variance in Delhi is explained by the variable itself both in the short and long run.

Keywords Cointegration, Granger causality, impulse response, instability, variance decomposition

JEL codes C21, C23, C32, Q13

The topography in India and its agroclimatic conditions are suitable for horticultural crops, and the cultivation of these crops has the potential of providing small and marginal farmers an ideal source of livelihood. India has come a long way in horticulture; the area under horticultural crops grew 2.6% over the last few years and production increased 4.8% annually. The production of horticulture crops in 2017–18 was 311.71 million tons from an area of 25.43 million hectares. At the moment, India is the second-largest producer of fruits and vegetables worldwide; fruits and vegetables account for nearly 90% of the total horticultural production, and the production of vegetables increased from 101.2 million tons in 2004–05 to 184.40 million tons in 2017–18 (Horticultural Statistics at a Glance 2018).

While the total production is being constantly augmented, it is essential to make the market network efficient so that farming communities can get remunerative prices for their produce. The existence of an efficient marketing network for agricultural outputs is one of the prerequisites for ensuring optimal resource allocation in the agricultural sector. The

efficient functioning of markets provides profitable prices to producers and fair prices to consumers (Mahalle, Shastri, and Kumar 2015). The integration of market prices of commodities across various markets is one of the stated objectives of many agricultural marketing reforms undertaken in the country. Well-integrated, efficient agricultural markets can allocate resources optimally and remove inefficiencies along the product value chain, thereby directly affecting farmer producer welfare (Thomas, Rajeev, and Sanil 2017).

The prices of some agricultural commodities—like tomato, onion, and potato—are highly volatile; this volatility originates primarily from production uncertainties and changes in the nature of demand. These demand characteristics have made prices vulnerable to violent fluctuations due to shocks in production. The potato, rightly assessed as the ‘king of vegetables’ by the FAO (2008), has been indicated as a crop that can help fight hunger and poverty in the future (Rana and Anwer 2018).

India is the second-largest potato producer worldwide; in 2019, it produced 52.59 million metric tons of the

crop. But its price is volatile, and marketing is a major concern for farmers. Marketing costs are high because the marketing infrastructure is inadequate and there are many intermediaries between producer and consumer, and these reduce farmers' profits. Markets are geographically dispersed, but prices at these market centres exhibit long-run spatial linkages, suggesting that all the exchange locations are integrated and that the prices provide the relevant market signals (Ghosh 2010). The accuracy and speed at which a price change in one market is transmitted to other markets is taken as an indicator of market integration. The extent of integration gives signals for efficient resource allocation, considered essential for ensuring greater market efficiency, price stability, and food security (Muhammad and Mirza 2014). Therefore, the present study attempts to analyse the market efficiency by examining the transmission and spatial integration of selected potato markets.

Materials and methods

Based on secondary data, the study attempts to investigate the market efficiency of the potato crop.

Data collection

The analysis is based on time series monthly data on prices and arrivals collected from five major producing and marketing states. The markets are chosen on the criteria of the major assembling markets of the country: Agra market of Uttar Pradesh; Champadanga market of Hooghly in West Bengal; Firozpur market of Punjab; Azadpur Mandi of Delhi; and Pune market of Maharashtra. We collected monthly time series data on potato prices from July 2005 to June 2020 from the <https://agmarknet.gov.in/> portal of the Ministry of Agriculture and Farmers Welfare, Government of India.

Data analysis

We employ several analytical tools to meet our objectives: the Cuddy–Della Valle index (CDVI), suggested by Cuddy and Della Valle (1978), to measure instability; the Augmented Dickey–Fuller (ADF) unit root test (Dickey and Fuller 1979) to check the series for stationarity; the trace ratio test statistics to test the number of cointegrating vectors; and the vector error correction method (VECM) to capture short-run disequilibrium situations as well as long-run equilibrium adjustments between the prices. The causal

relationship is approached through the Granger causality test (Granger 1969). For determining the relative strength of causality effects beyond the selected duration, the impulse response function (IRF) is used, and to identify the price triggers in major influencing markets, the variance decomposition technique is applied.

Instability analysis

The coefficient of variation (CV) measures instability, but the CV overestimates the level of time series data characterized by long-term trends (Nimbrayan and Bhatia 2019).

$$CV = \frac{\text{Standard Deviation}}{\text{Mean}} * 100$$

This limitation is overcome by the CDVI, a modification of CV that de-trends and shows the exact direction of the instability (Anuja et al. 2013).

$$CDVI = CV\sqrt{1 - AdR^2}$$

where, adjusted R^2 = coefficient of determination

The ranges of CDVI (Sihmar 2014) are 0–15 (low instability), 15–30 (medium instability), and >30 (high instability).

Seasonality index

Seasonality is estimated from the average monthly data on prices, as the monthly data for several years is first converted into a monthly index using January as the base month every year. This partially removes the over-time trend in the data if there is any (Ali 2000). The monthly averages over the years are taken and then seasonality is estimated

$$S_i = \frac{(I_h - I_l)}{I_l} * 100$$

Where, I_h = Highest average monthly index value and I_l = Lowest average monthly index value

Stationarity test

Cointegration depicts the existence of a long-term equilibrium; before cointegration is tested, the time series need to be stationary, and the first step in time series analysis is to examine the stationarity of each individual time series selected. The ADF unit root test

is conducted by augmenting the preceding three equations by adding the lagged values of the dependent variable ΔP_t . The ADF test here consists of estimating the following regression:

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

Where, $\Delta P_t = P_t - P_{t-1}$, $\Delta P_{t-1} = P_{t-1} - P_{t-2}$, $\Delta P_{t-2} = P_{t-2} - P_{t-3}$ etc.

P = the price in each market

α_0 = constant or drift

t = time trend variable

q = number of lag length selected based on Schwartz information criterion (SIC)

ε_t = pure white error term

The test for a unit root in the price series is carried out by testing the null hypothesis that β_1 (coefficient of P_{t-1}) is zero. The alternative hypothesis is that β_1 is less than 0. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary (Gujarati 2004).

Johansen's cointegration method

Cointegration depicts a long-term relationship between variables; even if two or more series are non-stationary, they are said to be cointegrated if there exists a stationary linear combination of them. After establishing that the price series are stationary at the level or same order of differences, the maximum likelihood method of cointegration is applied to check the number of cointegrating vectors (Johansen 1988; Johansen and Juselius 1990). The null hypothesis of at most 'r' cointegrating vectors against a general alternative hypothesis of 'r+1' cointegrating vectors is tested by trace statistics. The number of cointegrating vectors indicated by the tests is an important indicator of the extent of the co-movement of prices. An increase in the number of cointegrating vectors implies an increase in the strength and stability of price linkages.

VECM for short-term relationship

The cointegration analysis reflects the long-run movement of two or more series, although they may drift apart in the short run. Once the series is found to

be cointegrated, the next step is to find out the short-run relationship along with the speed of adjustment towards equilibrium using an error correction model, represented by the equations:

$$\Delta \ln X_t = \alpha_0 + \sum \beta_{1i} \Delta \ln Y_{t-i} + \sum \beta_{2i} \Delta \ln X_{t-i} + \gamma ECT_{t-1}$$

$$\Delta \ln Y_t = \beta_0 + \sum \alpha_{1i} \Delta \ln X_{t-i} + \sum \alpha_{2i} \Delta \ln Y_{t-i} + \gamma ECT_{t-1}$$

where, ECT_{t-1} is the lagged error correction term

X_t and Y_t are the variables under consideration transformed through natural logarithm

X_{t-i} and Y_{t-i} are the lagged values of variables X and Y

The parameter γ is the error correction coefficient that measures the response of the regressor in each period to departures from equilibrium. The negative and statistically significant values of γ depict the speed of adjustment in restoring equilibrium after disequilibria, and if it is positive and zero, the series diverges from equilibrium (Saxena and Chand 2017).

Granger causality test

After undertaking the cointegration analysis of the long-run linkages of the various variables, and after identifying they are linked, the causal relationship between the prices series in the selected potato markets is approached through Granger's causality technique. If a variable Y is Granger-caused by variable X, it means that the values of variable X help predict the values of variable Y and vice versa. The Granger causality test conducted within the framework of a vector auto regression (VAR) model is used to test the existence of a long-run causal price relationship between markets and the direction of that relationship. The F-test is used to check whether the significance of changes in one price series affects another price series. This test also identifies the key market, i.e., the market that influences the price of all other markets (price leader). The causality relationship between two price series, based on the following pairs of ordinary least square (OLS) regression equations through a bivariate VAR, is given by the equations below:

$$\ln X_t = \sum_{i=1}^m \alpha_i \ln X_{t-i} + \sum_{j=1}^m \beta_j \ln Y_{t-j} + \varepsilon_{1t}$$

$$\ln Y_t = \sum_{i=1}^m \alpha_i \ln Y_{t-i} + \sum_{j=1}^m \beta_j \ln X_{t-j} + \varepsilon_{2t}$$

where,

X and Y are two different market prices series

ln stands for price series in logarithm form

t is the time trend variable

the subscript stands for the number of lags of both variables in the system

The null hypothesis in both equations is a test that $\ln X_t$ does not Granger-cause $\ln Y_t$. In each case, a rejection of the null hypothesis will imply that there is Granger causality between the variables (Gujarati 2004).

Impulse response function

The Granger causality test does not determine the relative strength of causality effects beyond the selected duration. It is best to consider the time paths of prices after exogenous shocks, i.e., impulse responses, to interpret the model's implications for patterns of price transmission, causality, and adjustment (Vavra and Goodwin 2005). The IRF traces the effect of one standard deviation, or one unit shock, to one of the variables on current and future values of all the endogenous variables in a system over various time

horizons (Rahman and Shahbaz 2013). We use the generalized impulse response function (GIRF), originally developed by Koop et al. (1996) and suggested by Pesaran and Shin (1998). The GIRF of an arbitrary current shock and history given in Equation for $n = 0, 1, 2, \dots$

$$GIRFY(h, \delta, w_{t-1}) = E[Y_t + h \mid w_{t-1}]$$

Variance decomposition

The variance decomposition technique, applied to identify the price triggers in the major price-influencing markets, separates the variation in an endogenous variable into the shocks to the variables in the VAR. The variance decomposition technique provides information on the relative importance of each random innovation (price change in one market) in affecting the variables in the VAR (price changes in other markets).

Impulse responses trace out the moving average of the system, i.e., they describe how y_{it+T} responds to a shock in e_{it} ; how variance decomposition measures the contribution of to the variability of y_{it+T} ; how historical decomposition describes the contribution of shock e_{it} to the deviations of y_{it+T} from its baseline forecast path (Canova 2007).

Results and discussion

Table 1 presents the instability and seasonality indices of potato prices in the selected markets.

Table 1 Instability and seasonality in potato prices in selected markets

Month	Agra			Hooghly			Firozpur			Delhi			Pune		
	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI
Jan	52.54	40.14	1.45	67.87	58.50	1.36	55.77	53.11	1.47	54.24	46.81	1.43	38.80	31.51	1.16
Feb	39.86	29.53	1.47	48.29	39.65	1.58	45.01	43.95	1.60	36.92	30.67	1.47	33.78	22.74	1.26
Mar	41.09	28.73	1.22	51.57	42.87	1.38	52.90	49.92	1.31	42.57	35.63	1.30	36.31	22.16	1.24
April	48.06	37.76	1.12	48.84	38.89	1.01	72.16	67.49	1.29	43.27	37.32	1.15	37.56	24.20	1.06
May	47.27	38.78	0.94	45.84	34.71	0.83	64.18	56.69	1.01	45.19	39.34	1.03	35.02	25.54	0.92
June	46.27	37.17	0.83	49.79	39.00	0.82	54.95	43.87	0.81	38.50	34.43	0.83	33.15	24.93	0.91
July	47.63	40.54	0.76	48.12	42.47	0.83	50.08	46.15	0.68	33.30	29.16	0.73	37.36	32.10	0.91
Aug	52.48	47.32	0.78	50.70	45.32	0.82	59.23	56.16	0.68	40.41	35.38	0.74	39.07	34.95	0.92
Sept	53.64	49.55	0.78	50.49	46.77	0.82	61.87	56.89	0.65	40.85	36.63	0.67	38.56	33.83	0.89
Oct	54.45	49.83	0.74	47.91	43.17	0.78	57.17	53.01	0.67	40.06	36.78	0.64	40.58	34.13	0.86
Nov	50.96	47.49	0.79	45.16	39.58	0.78	51.82	49.13	0.78	41.51	37.38	0.75	41.12	38.55	0.90
Dec	44.89	39.71	1.10	54.69	50.15	0.99	50.22	46.96	1.06	50.21	44.22	1.24	42.05	38.87	0.96

CV-Coefficient of variation (%), CDVI- Cuddy-Della Valle index and SI-Seasonality Index

Table 2 Zero order correlation matrix for correlation in potato prices between selected markets

Markets	Agra	Hooghly	Firozpur	Pune	Delhi
Agra	1.0000				
Hooghly	0.8950*	1.0000			
Firozpur	0.7996*	0.7436*	1.0000		
Pune	0.9197*	0.9004*	0.7801*	1.0000	
Delhi	0.9150*	0.8256*	0.8266*	0.8636*	1.0000

*indicates $p < 0.05$

Seasonality and instability analysis

If the value of the CDVI exceeds 30%, price instability is high; if it is less than 30%, instability is low to medium. The value of the CDVI is maximum in the month of January for Hooghly and Delhi, October for Agra, September for Firozpur and December for Pune, and it is minimum in March for Agra and Pune, May for Hooghly, June for Firozpur, and July for Delhi. From December to April-May, the value of the seasonality index exceeds 1; farmers receive above-average prices during this period.

Correlation analysis

The correlation matrix between the average potato prices is computed to determine the extent of integration among the selected markets (Table 2). The values from the correlation matrix, ranging from 0.8950 to 0.8636, are found highly significant and positive. This means the potato prices in selected markets moved together and are well integrated, i.e., the price differential in these markets is not more than the transport cost and, consequently, these markets are efficient.

Augmented Dickey–Fuller test (ADF)

To avoid fictitious results, it is imperative to check whether the variables are stationary; therefore, applying the ADF unit root test is a prerequisite of checking for integration. The results of the ADF unit root test ‘at level’ prices indicate that the t-statistic values for all the markets are less than 1%, 5%, and 10% level of critical values given by the MacKinnon statistical tables at levels, implying that these series are stationary and free from the consequences of a unit root (Table 3).

Johansen cointegration test

Based on the Johansen cointegration procedure, the cointegration between the selected markets is analysed through the unrestricted cointegration rank test (trace statistic), which indicates the presence of five cointegrating equations at 5% level of significance. The results show that potato prices in the selected markets have a long-run relationship and imply that the price linkages are strong and stable (Table 4).

Vector error correction model (VECM)

The VECM is employed to know the speed of

Table 3 ADF test to check stationarity of data

Markets	At level		Stationarity	Test critical values
	t-statistic	p-value*		
Agra	-4.71818	0.0001	Stationarity	
Hooghly	-4.4223	0.0004	Stationarity	1% level: -3.46721
Firozpur	-4.15025	0.001	Stationarity	5% level: -2.87764
Pune	-4.0526	0.0015	Stationarity	10% level: -2.57543
Delhi	-4.95756	0	Stationarity	

*MacKinnon (1996) one-sided p-values.

Table 4 Johansen cointegration test (trace) of price variation in potato markets

Null hypothesis	Eigenvalue	Trace statistic	Critical value	Prob.**
None *	0.30682	154.7538	69.81889	0
At most 1 *	0.247216	90.62242	47.85613	0
At most 2 *	0.120642	40.92639	29.79707	0.0018
At most 3 *	0.062384	18.42779	15.49471	0.0176
At most 4 *	0.040062	7.155161	3.841466	0.0075

Trace test indicates five cointegrating eqn(s) at the 0.05 level

*denotes rejection of the hypothesis at the 0.05 level

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

adjustments for long-run equilibrium among the selected markets. The coefficient of the error correction term denotes the speed of adjustment; higher the speed of adjustment, higher the chance of correction of any disequilibrium. It has been found highest when the prices at Agra and Firozpur markets are considered dependent upon the prices at other markets to the extent of, respectively, 30% and 14%, meaning that the chances of correction of any disequilibrium are high in these markets. When the Delhi and Pune markets are considered dependent, the speed of adjustment has been low or, respectively, 11.2% and 0.07%. Also, the prices at Delhi and Firozpur markets are influenced by their own monthly lags, whereas the prices at the Agra and Pune markets are influenced by their two-month lagged prices for long-run equilibrium.

$$\Delta \ln Agra_t = -0.301ECT_{t-1} - 0.305\Delta \ln Agra_{t-2} + 0.540\ln Delhi_{t-1} + 0.211\Delta \ln Hooghly_{t-2} - 0.257\Delta \ln Pune_{t-2}$$

$$\Delta \ln Firozpur_t = -0.139ECT_{t-1} - 0.291\Delta \ln Firozpur_{t-1} + 0.117\ln Hooghly_{t-2} - 0.378\Delta \ln Pune_{t-2} + 0.383\Delta \ln Agra_{t-1} + 0.525\Delta \ln Delhi_{t-1}$$

$$\Delta \ln Delhi_t = -0.112ECT_{t-1} - 0.418\Delta \ln Delhi_{t-1} + 0.240\ln Firozpur_{t-2} - 0.345\Delta \ln Pune_{t-2}$$

$$\Delta \ln Pune_t = -0.078ECT_{t-1} - 0.283\Delta \ln Pune_{t-2} - 0.283\Delta \ln Agra_{t-2} + 0.328\Delta \ln Delhi_{t-1} + 0.320\Delta \ln Hooghly_{t-1}$$

$$\Delta \ln Hooghly_t = -0.007ECT_{t-1} - 0.277\Delta \ln Pune_{t-2} + 0.381\ln Agra_{t-1} + 0.252\Delta \ln Delhi_{t-1} + 0.181\Delta \ln Firozpur_{t-2}$$

The results of the error correction terms are interpreted to study the nature of the market and the movement towards long-run equilibrium, i.e., market efficiency.

The negative and statistically significant values of the error correction term at the Agra, Firozpur, Delhi, and Pune markets depict the speed of adjustment in restoring the equilibrium after disequilibria, whereas the positive value of the error correction term in the Hooghly series depicts the divergence from the equilibrium.

Granger causality test

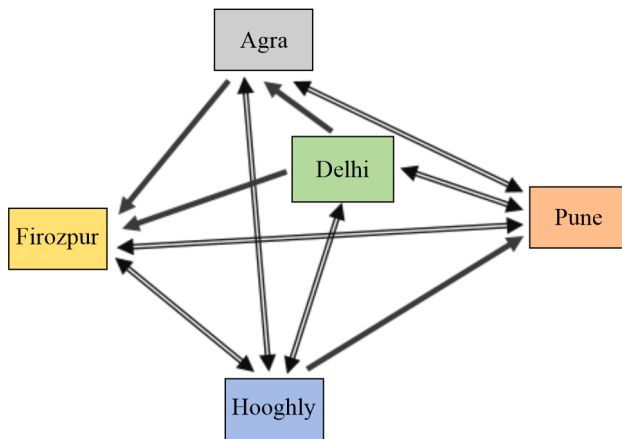
The causal relationship between the prices at the selected potato markets is approached through the Granger causality technique. It is found that the Delhi market prices influence the prices at the Agra and Firozpur markets and that these prices show bidirectional causality with the Hooghly and Pune markets (i.e., the prices are transmitted both ways). The Agra market causes unidirectional relationship with the Firozpur market, and it shows bidirectional causality with the Hooghly and Pune markets. The Firozpur market reveals bidirectional causality with the Hooghly and Pune markets. The Hooghly market prices influence the prices at the Pune market and these show a bidirectional relationship with the prices at the Firozpur, Delhi, and Agra markets. The prices at the Pune market show a bidirectional causality with the prices at the Delhi, Agra, and Firozpur markets. This reveals a strong market integration between the prices of the selected potato markets, and that the Delhi market is the key influencer of the prices at all other selected potato markets (Table 5, Figure 1).

Impulse response function (IRF)

Using the Granger causality technique shows that the Delhi market is key, and we interpret the response of other markets to changes in the prices at the Delhi

Table 5 Results of pair-wise Granger causality test of selected potato markets

Null Hypothesis:	F-Statistic	Probability
HOOGHLY does not Granger cause AGRA	4.705	0.010
AGRA does not Granger cause HOOGHLY	19.273	0.000
FIROZPUR does not Granger cause AGRA	0.401	0.671
AGRA does not Granger cause FIROZPUR	14.111	0.000
DELHI does not Granger cause AGRA	17.608	0.000
AGRA does not Granger cause DELHI	1.779	0.172
PUNE does not Granger cause AGRA	7.686	0.001
AGRA does not Granger cause PUNE	18.812	0.000
FIROZPUR does not Granger cause HOOGHLY	5.137	0.007
HOOGHLY does not Granger cause FIROZPUR	7.831	0.001
DELHI does not Granger cause HOOGHLY	17.084	0.000
HOOGHLY does not Granger cause DELHI	3.180	0.044
PUNE does not Granger cause HOOGHLY	2.480	0.087
HOOGHLY does not Granger cause PUNE	10.145	0.000
DELHI does not Granger cause FIROZPUR	21.293	0.000
FIROZPUR does not Granger cause DELHI	0.266	0.767
PUNE does not Granger cause FIROZPUR	9.626	0.000
FIROZPUR does not Granger cause PUNE	5.705	0.004
PUNE does not Granger cause DELHI	6.541	0.002
DELHI does not Granger cause PUNE	28.454	0.000

**Figure 1 Unidirectional and bidirectional relationship between markets**

*Single arrow shows a unidirectional relationship, *Double arrow shows a bidirectional relationship

market with the help of the IRF and variance decomposition. The IRF describes how much and to what extent a standard deviation shock in one of the markets—say, Delhi—affects prices in all the integrated markets over a period of 10 months (Figure 2).

When a standard deviation shock is given to the Delhi market, an immediate, high response is noticed in all the other markets. The Agra and Firozpur markets peaked in the second month and started declining after the third month. The Hooghly and Pune markets peaked in the third month and started declining after the fourth month. The response kept declining thereafter and became negative in all the markets. This shows that a shock arising in the Delhi market is transmitted to all the other markets and the response is higher in the following months. The response of the Agra and Firozpur markets has been stronger than in others.

Variance decomposition

The variance decomposition indicates the amount of information each variable contributes to the other variables in the VAR, and it determines how much of the forecast error variance of variables can be explained by the exogenous shocks to the other variables. The results reveal that in the short run 100% of the forecast error variance in Delhi is explained by the variable itself, which means that the other variables

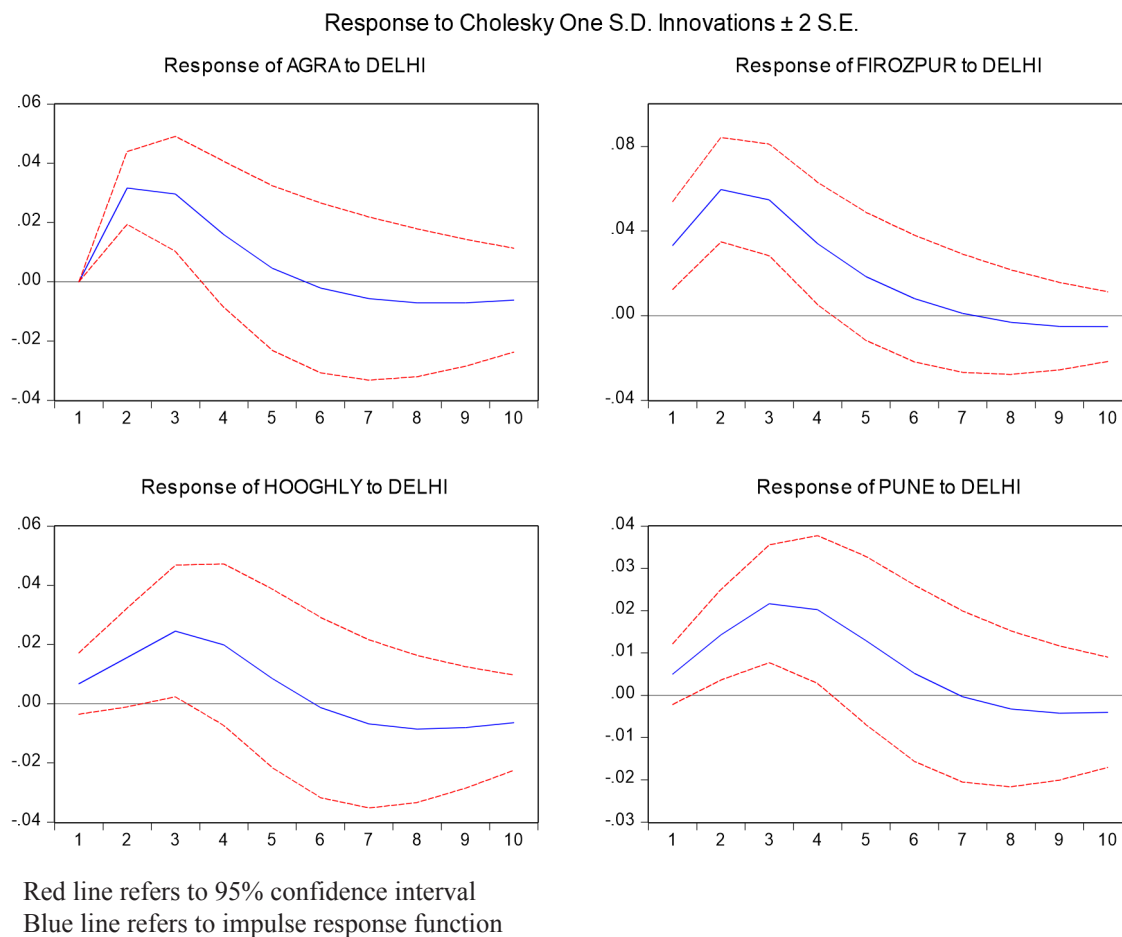


Figure 2 Response of other markets to change in Delhi market prices

Table 6 Variance decomposition of Delhi market

Period	S.E.	Delhi	Agra	Firozpur	Hooghly	Pune
1	0.086	100.000	0.000	0.000	0.000	0.000
2	0.135	97.326	1.543	0.031	0.345	0.755
3	0.167	92.375	3.737	0.021	1.835	2.031
4	0.186	86.356	6.035	0.034	4.039	3.535
5	0.197	81.048	7.886	0.051	6.052	4.964
6	0.203	77.365	9.070	0.057	7.353	6.154
7	0.206	75.262	9.672	0.056	7.964	7.046
8	0.208	74.256	9.900	0.058	8.146	7.639
9	0.208	73.849	9.947	0.073	8.152	7.980
10	0.209	73.698	9.934	0.098	8.129	8.141

in the model do not substantially influence the Delhi market (Table 6). The other markets have a robust exogenous impact, i.e., these do not influence Delhi at all in the short run. Even in the second period, the influence of other markets is low, implying that these

variables exhibit strong exogeneity and have a weak influence on the other markets in the future. In the long run, 73.69% of the forecast error variance of the Delhi market is explained by the market itself. Thus, the influence of the Delhi market is strong in the short run

and in the future, and the influence of the other markets, though rising every year, is weak overall.

Conclusions

The potato crop has been encountering high volatility in prices for the past few years, and marketing, which is critical for the crop, is a major concern for farmers. This study analyses market integration by examining the price transmission and spatial integration of selected potato markets. The accuracy and speed at which price changes in one market are transmitted to other markets is considered an indicator of market integration. The extent of integration gives signals for efficient resource allocation, which is considered essential for improving market efficiency.

The study reveals that in the selected markets, potato prices are unstable in January, October, September, and December, and from December to April-May farmers receive an above-average price. The correlation analysis shows that prices in the markets moved together, and they are well integrated, which implies that the price differential in the selected markets is not more than the transport cost. This signals that the markets are well integrated and efficient. The price series in the selected markets are stationary, and the unrestricted cointegration test indicates that potato prices in the chosen markets have a long-run relationship. The trace test indicates five cointegrating equation at the 0.05 level. Their own monthly lags influence the prices at the Delhi and Firozpur markets, whereas the Agra and Pune markets are influenced by their two-month lagged prices for long-run equilibrium.

The speed of adjustment is highest in the Agra (30%) and Firozpur (14%) markets, which means that in these markets the chances of correction of any disequilibrium are high. Granger causality reveals that Delhi is the key influencer of prices in the other selected markets: a standard deviation shock given to the Delhi market stimulates an immediate, high response in all the other markets; the impulse response increases initially, but it declines after peaking and eventually becomes negative in all the markets. This shows that if a shock arises in the Delhi market it is transmitted to all the other markets with a higher response in the following months. The variance decomposition reveals that the influence of the Delhi market is strong in the short run and in the future, whereas the influence of other

markets, though rising every year, is weak. It is concluded that prices fluctuate by season, and these price fluctuations can be managed by developing proper storage facilities and an efficient supply chain management system. A robust monitoring mechanism on potato prices and arrival should be developed in the Delhi market to check manipulation.

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