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Dynamics of Market Integration and Price Transmission in Tomato Crop: Evidence from India

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ABSTRACT

The present study provides valuable insight into the dynamics of major producing and consuming tomato markets in India, highlighting the relevance of integration among the markets and transmission of the price behaviors with the help of different econometrics approaches, i.e., Cuddy – Della Valle index, Johansen co-integration, Granger causality test, Vector error correction model, and Impulse response function. The results of the investigation showed that the markets were well integrated. Moreover, there is integration among the markets in the long run, but there is no significant relationship between markets in the short run. Granger causality showed that a bidirectional causal relationship existed between Mandi-Kolar and Delhi-Mandi, and there is no causality between Solan-Mandi, Delhi-Solan, and other markets with unidirectional relationships. The rate of adjustment of disequilibrium among market prices using the Vector Error Correction model was highest (35.25 per cent) in the Solan market. In contrast, Mumbai was the key market influenced by other markets. According to the impulse response function, the prices initially fluctuated when a degree of unit shock was given to markets. Still, after five months, prices started stabilizing in all the markets. These findings can be used to develop strategies for better managing tomato prices and arrivals in the studied markets. Further research and policy measures may be necessary to address the challenges of price volatility and market integration in the tomato sector.

Keywords: Tomato market, price transmission, market integration, agricultural price volatility

JEL codes: Q02, Q11, Q13

I

INTRODUCTION

Tomato is one of the essential cash crops grown globally and the second most consumed vegetable after potato worldwide (FAOSTAT 2021). With changing demands and income levels, tomato has become one of the most consumable crops among households. No kitchen works without the use of tomatoes. About 19 per cent of India's GDP comes from the agriculture sector, which is very important to the country's economy (2022a,b). Along with potatoes and onions, tomatoes are among the top three most important horticulture crops according to the Indian government's "TOP" priority list. The total production of tomato worldwide is 186 million tonnes (FAO 2021), of which India holds a share of 11 per cent, accounting for 21.18 million tonnes (PIB 2022a,b). Due to its perishable and short-duration nature, farmers face two major risks: production and price. This results in the volatility of the prices. To overcome these impediments, integration among the markets helps in better price transmission and reduces the production shocks of agricultural products. Market integration helps promote efficient operations among the markets, which allows

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farmers to receive remunerative prices for their products, simultaneously enabling the consumer to buy products at fair prices. Moreover, integration enhances the capability of markets to absorb inflationary-deflationary pressures in economic activity (Kumar and Gajanana, 2023). The signs of effective market functioning (Beag and Singla, 2014) help bring a high degree of integration, efficiency, and competitiveness among marketing yards. With the government's changing export and import policies, i.e., free trade agreements, comprehensive economic partnerships, early harvest deals, etc., market integration is a crucial economic concept for efficiency and equity. Regarding equity, pricing differentials between markets will result in spatial inequality of economic well-being between various markets/regions since earnings will not change to reflect the different costs of living. From an efficiency perspective, significant pricing variations between markets and regions may indicate higher living expenses in some places, which would raise the cost of production in those areas. As a result, it is essential to carry out research among markets to know the level of integration in the context of Indian markets, as food items comprise a large share of the consumption basket. Market integration becomes an essential tool in handling price changes in the domestic and international sphere (Mukim et al., 2009). The short-duration nature of the crop allows farmers to take three to four crops annually, providing them with good returns and employment opportunities. Therefore, studying important producers and consuming markets of tomato crops in India is necessary. The findings will have significant ramifications for agricultural price policy and aid in understanding price's short- and long-term characteristics.

II

MATERIAL AND METHODS

Study Area and Data Source

The objective of the study is to investigate the integration among five markets. Of these, three are producing markets, and two are consuming markets, viz., Delhi, Mumbai, Solan, Mandi, and Kolar, respectively. The secondary data of monthly wholesale prices for tomato crop from different marketing yards were collected from January 2010 to December 2022 from the Government of India’s agricultural price portal AGMARKNET. The important tomato markets were selected based on location, volume of produce handled, and data availability for study.

Analytical Tools

Instability Index: The coefficient of variation was calculated to determine the variability of prices and arrivals from their mean in selected markets. CV was calculated using the following formula

$$CV=\frac{STANDARD\ DEVIATION}{MEAN}*100$$

Previous research has shown that a long-term trend in time series data often causes the coefficient of variation to overestimate the degree of instability. As a result, we estimated the variability in prices using the Cuddy-Della Valle index to detect overestimation issues resulting from the coefficient of variation. The following formula has been used to calculate the variability coefficient:

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

Where,

CV = Co-efficient of variation

R^2= Co-efficient of determination

Unit Root Test

Before investigating the co-integration and Granger causality in time series analysis, each time series selected must first be determined to be stationary. To check for stationarity, the Phillips Perron test (Phillips and Perron 1988) and the enhanced Dickey-Fuller (ADF) unit root test (Dickey and Fuller 1979) were taken into consideration. Using the model, the test was used to confirm the order of integration:

$$\Delta P=\alpha_0+\delta_1 t+\beta_1 P_{t-1}+\sum \beta\Delta P_{t-1}+\varepsilon_t$$

Where,

P = the price in each market,

Δ = difference parameter (i.e., $\Delta P_1 = P_t - P_{t-1}$, $\Delta P_{t-1} = P_{t-1}) - P_{t-2}$, and $\Delta P_{n-1} = P_{n-1} - P_{n-2}$),

t=time trend variables

α_0 = constant or drift,

q = number of lag lengths and

ε_t = pure white error term,

According to the null hypothesis, (Pt-1) coefficient, β1, equals zero, and when β1 < 0 is the alternative hypothesis. The view of the time series framework may not be stationary if the null hypothesis is not rejected (Gujarati, 2010).

Correlation Analysis:- The Correlation coefficients are a valuable tool for determining how closely two time series are related linearly. Therefore, the correlation matrix of the prices for selected markets was computed to know the integration between them. The degree of correlation between tomato prices in particular markets was determined using Karl Pearson's correlation coefficient. The following equations were applied:

$$R(X,Y)=\frac{COV(X,Y)}{\sqrt{VAR(x).VAR(y)}}$$

Where X and Y are the two Price series

The t-test was used to determine the significance of the correlation coefficient, and the following are the null and alternate hypotheses:

(H_0): r = 0 indicates no correlation.
(H_1): $r \neq 0$ indicates a correlation.
The test statistic used for testing correlation coefficient is given by:

$$t=\frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t\ (n\text{-}2) \text{ degree of freedom}$$

A positive and significant correlation coefficient shows that the prices of the selected markets move in the same direction.

Johansen's Co-integration test:- The basis of the cointegration study is Johansen's co-integration method. The maximum likelihood method proposed by Johansen was employed to tackle the co-integration vector estimation. The "error correction" form for any p-dimensional vector autoregression is as follows (Johansen and Juselius, 1990).

$$\Delta P_t = \mu + \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-1} + \beta\mu_t + \epsilon_t$$

Where;
Pt = p-dimensional vector of I (1) processes,
μ = A constant
εt = A p-dimensional vector with zero mean (Δ is the variance-covariance matrix).
The Π matrix has a rank that is limited in the interval (0, r) and can be decomposed into components as follows;

$$\Pi = \alpha\beta'$$

Where,
α, β p×r matrices,
r: distinct co-integrating vectors.
Johansen and Juselius's Co-integration test determines the number of co-integration vectors: The Maximum Eigen value test and the Trace test.

Error Correction Method: The long-term co-integration between prices in particular markets is analysed using the Johansen Co-integration test. After co-integration, we used the Vector Error Correction Model (VECM) to investigate the short-term causality between prices. To construct the error correction model, firstly, we will check if there is any co-integration in the long run and if the variables differ. When confirmed that the price series is co-integrated with order 1, we worked out VECM. It explains how quickly different price series adjust from short-term disequilibrium to long-term equilibrium. VECM takes both short- and long-term price fluctuations into account. The ECM is based upon the Autoregressive Distributed lag model given by

$$\Delta X_t = \alpha_o + \sum \beta_{1i} \Delta Y_{t-i} + \sum \beta_{2i} \Delta X_{t-j} + \gamma ECT_{t-1}$$
$$\Delta Y_t = \beta_o + \sum \alpha_{1i} \Delta X_{t-i} + \sum \alpha_{2i} \Delta X_{t-j} + \gamma ECT_{t-1}$$

where,

ECT_{t-1} = Lagged error correction term

X_t and Y_t = Variables under consideration

X_{t-I} and Y_{t-I} = Lagged values of variables X and Y.

γ= Error correction coefficient, which measures how the regressor reacts to changes in equilibrium over each period.

This coefficient, or parameter (γ), ranges from 0 to 1. A value of 0 denotes no change, while 1 denotes an immediate change. These error correction terms must have negative and significant values to establish long-run equilibrium.

Granger Causality Test:- The Granger Causality test was employed to investigate the causal relationship between the tomato crop's selected markets. Additionally, Granger Causality helps identify the main market, which sends price signals to the maximum no. of markets. A Vector Auto Regressive (VAR) model, which illustrates the long-term causal relationship between multiple price series, was used to conduct the Granger causality test.. It tells whether the lagged values of one series affect the other price series. The equation is given here under;

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

Where,

X and Y = Two market price series,

T= time trend variable

The subscript represents the number of lags for both variables in the VAR system. (Selected based on Schwartz information criteria). To check the significance of the coefficient α_i, F test was conducted with m and (n-k) degrees of freedom under which the null hypothesis states that

(H_o): α_i =0 ., i=1,2,3...,m which means lagged X_t does not belong in VAR or is not significant, (H_1): $\alpha_i \neq 0$ which means it is significant

In other words, the alternative hypothesis asserts that a series X “Granger Causes” is a series Y, while the null hypothesis claims that a series X does not “Granger Cause” a series Y.

Impulse Response Function:-

The Granger causality test looks at causality's direction over the chosen time period. It indicates whether or not a particular price series sends price signals to other markets. Since the generalized impulse response function (GIRF) was first created by (Koop et al., 1996), its theory and applications have undergone numerous developments. According to Kirchgässner et al. (2012), the impulse response function (IRF) is a technique for analyzing the VAR model that enables us to determine when a shock starts from a particular equation and moves through the system. Nonetheless, IRF examines how one price series' unit standard deviation shock affects the present and future values of other endogenous variables, such as the other time series, and knows the effects on them. With the help of GIRF, we can easily interpret the current and future impact on the tomato crops in the given markets.

$$GIRF(H, \delta, W_{(t-1)})=E[Y_t + h\ (W_{(t-1)})]$$

Where,

δ = Arbitrary current shock

w_{t-1} = History given in Equation for n = 0, 1, 2.....

III

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics of monthly wholesale prices and arrival (Tons) for selected markets from January 2010 to December 2022. The findings indicate that the Kolar market recorded the lowest price, while the Mandi market recorded the highest. According to an analysis of price coefficient variation, the Kolar market had the highest value. The maximum arrival volume was also recorded in the Kolar market, whereas the lowest arrival was recorded in the Mandi market. The analysis of the variation coefficient in the tomato crop's arrival was recorded in the Solan market. Then, we found that results correlate when prices are high, arrival is low, and vice versa.

TABLE 1. DESCRIPTIVE STATISTICS OF MONTHLY WHOLESALE PRICES AND ARRIVAL FOR SELECTED MARKETS

Markets	Monthly Prices (₹/Qunital)				Monthly arrival (Tons)			
	Minimum	Maximum	Mean	CV(%)	Minimum	Maximum	Mean	CV(%)
Delhi	225.25	3895.43	1401.193468	54.27	271.48	875	465.2	22.25
Solan	378.33	4344.44	1516.4	46.91	1.25	2294	73.8	274.2
Mandi	576.39	4419.048	1819.44	44.37	0.9	76	3.72	162.56
Kolar	214	4114.51	1043.07	67.3	50.84	3511.09	645.83	104.35
Mumbai	484.61	4704.7	1562.78	57.2	10	385.65	247.04	32.22

Price Instability Index Among Different Markets

Several factors contribute to the extreme volatility of agricultural commodity prices. i.e., climatic factors, marketing infrastructure, cobweb phenomenon, and high price spread during marketing channels etc. These factors resulted in a mismatch of supply and demand in the marketing ecosystem. The Cuddy Della Valle index results help us understand the instability level among the different markets during different months. Figure 1 shows that the highest volatility in tomato prices was found in May, June, and November (more than 50 per cent), and the highest instability was noticed in the Kolar market. The instability can be curbed by better crop management during the monsoon times and the supply of tomatoes from the production centres to consumption points.

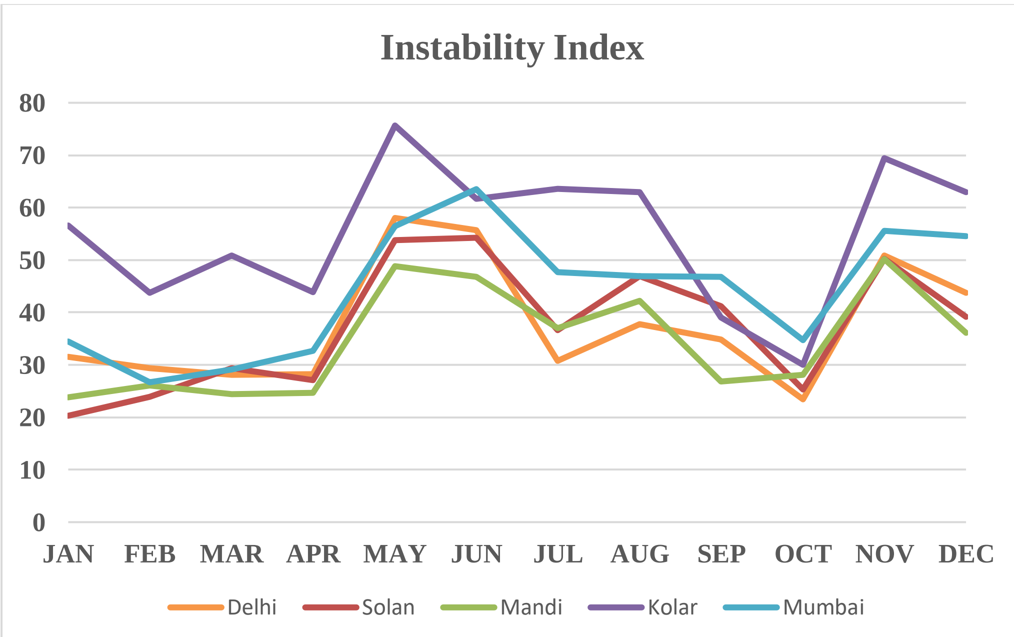

Figure 1. Results of the Cuddy Della Valle Index

Correlation Matrix

The correlation matrix helps us understand how markets are integrated. The estimates presented in Figure 2 reveal that Solan and Mandi markets are highly correlated because they are in geographical vicinity. The lowest correlation was recorded among the Kolar and Mumbai markets. However, various authors do not consider the correlation an efficient measure for market integration (Barrett (2005); Negassa et al., 2003). They have stated that correlation analysis has vague results because it hinders the presence of seasonality, inflation, general population growth, etc.

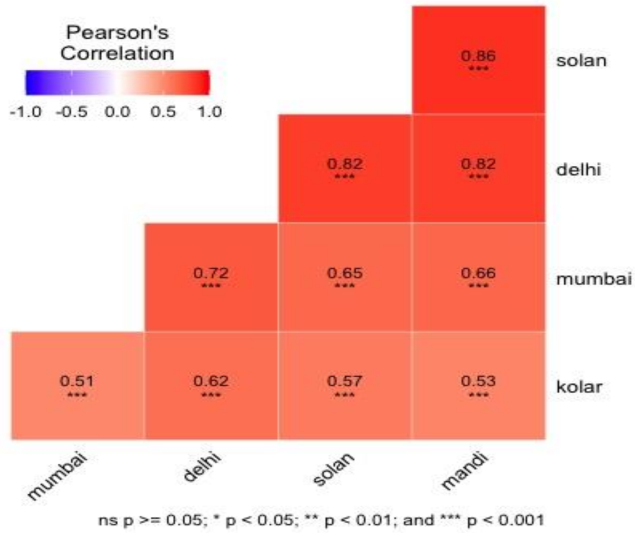

Figure 2. Correlation Matrix for Different Markets.

Unit Root Tests:- Unit root tests were used to see if the data was stationary or non-stationary. Although numerous ways exist to determine whether a unit root exists in the data, we used the Phillips Perron and augmented Dickey-Fuller tests. We selected the alternative hypothesis, indicating no unit root presence in the data, and rejected the null hypothesis after the test was completed. The test results are displayed in Table 2.

TABLE 2:- RESULTS OF UNIT ROOT TEST FOR DIFFERENT MARKETS

MARKETS	ADF Test Unit Root Test H_0:Data contains unit root H_1: Data is stationary		Phillips Perron test Unit Root Test H_0:Data contains unit root H_1: Data is stationary	
	t statistics	p value	z(alpha)	p value
Delhi	-6.71	0.01	-65.82	0.01
Solan	-5.23	0.01	-74.85	0.01
Mandi	-5.05	0.01	-73.47	0.01
Kolar	-4.63	0.01	-55.83	0.01
Mumbai	-4.98	0.01	-55.92	0.01

Johansen's Co-Integration Test:- The test aids in investigating the co-integration and long-term relationships between the chosen markets. Table 3 presents the results of the test. Because the value of trace statistics in all selected markets is greater than the value of the 0.05 critical level and accepts the alternative hypothesis at the 5 per cent significance level, the results show that all markets are co-integrated. The outcomes supported those of Shilpa et al., 2021).

TABLE 3:- RESULTS OF JOHANSEN'S CO-INTEGRATION TEST FOR SELECTED MARKETS

			Trace Statistics		Max-Eigen Statistics	
H0 (1)	H1 (2)	Eigen Values (3)	Trace Statistics (4)	0.05(Critical Values) (5)	Max-Eigen Statistics (6)	0.05 (Critical Values) (7)
r= 0	r>= 1	0.48	266.84	76.07	101.66	34.4
r<=1	r>=2	0.32	165.18	53.12	59.73	28.14
r<=2	r>=3	0.26	105.46	34.91	47.88	22
r<=3	r>=4	0.2	57.57	19.96	35.45	15.67
r<=4	r=5	0.13	22.12	9.24	22.12	9.24

Vector Error Correction Method:- The vector error correction method discusses two types of causality: long run and short run. The lag terms explain short-run causality, while the error correction term explains long-run causality. Table 4 presents the analysis findings, revealing that Delhi, Solan, and Mumbai markets show long-run causality with selected markets at 5 per cent and 10 per cent significance levels. The study of short-run causality was carried up to two lag terms, and it was found that short-run causality prevails in most of the markets, as out of two lag terms, only one lag term shows significant results from each other.

TABLE 4. RESULTS OF THE VECTOR ERROR CORRECTION METHOD FOR SELECTED MARKETS

Markets (1)	ECT (2)	Intercept (3)
Delhi	-0.3276(0.0948)***	30.47(44.0851)
Solan	-0.3525(0.910)***	33.55(42.2875)
Mandi	-0.0678(0.1160)	12.33(53.90)
Kolar	0.0517(0.0957)	-0.05(44.46)
Mumbai	0.2889(0.1155)*	-15.04(53.67)

Granger Causality Test**:-** To investigate the relationship between the chosen tomato markets. We conducted a Granger causality test to determine whether one market impacts another. The findings of the test are shown in Table 5 and Figure 3. The tests revealed unidirectional, bidirectional, and no causality among tomato markets. It is observed that there is unidirectional causality between Delhi-Kolar, Mumbai-Kolar, Delhi-Mumbai, Solan-Mumbai, Mandi-Mumbai, and Solan-Kolar markets, which means the prices of the former markets affect the latter markets. Still, the latter markets are not seen affecting the former markets. Between Kolar-Mandi and Delhi-Mandi, bidirectional causality was observed, indicating that both markets influence price transmission signals. Therefore, the test results concluded that the Mumbai market is one of the most important markets among all other tomato markets. Similar studies were conducted by Nandini et al. (2019) and Kumar and Gajanana (2023).

TABLE 5. RESULTS OF THE GRANGER CAUSALITY TEST IN THE SELECTED MARKETS

Null Hypothesis (1)	F-Statistics (2)	P- Values (3)	Granger cause (4)	Direction (5)
Delhi does not Granger cause Solan	0.7	0.49	No	
Solan does not Granger cause Delhi	0.08	0.91	No	No Causality
Solan does not Granger cause Mandi	0.24	0.77	No	
Mandi does not Granger cause Solan	2.8	0.06	No	No Causality
Kolar does not Granger cause Mumbai	0.04	0.84	No	
Mumbai does not Granger cause Kolar	3.6	0.02*	Yes	Unidirectional
Delhi does not Granger cause Kolar	7.23	0.001**	Yes	
Kolar does not Granger cause Delhi	1.9	0.1	No	Unidirectional
Mumbai does not Granger cause Delhi	1.25	0.2	No	
Delhi does not Granger cause Mumbai	13.74	0.00***	Yes	Unidirectional
Solan does not Granger cause Mumbai	8.3	0.0003***	Yes	
Mumbai does not Granger cause Solan	1.9	0.14	No	Unidirectional
Mandi does not Granger cause Mumbai	8.5	0.0003***	Yes	
Mumbai does not Granger cause Mandi	0.3	0.7	No	Unidirectional
Kolar does not Granger cause Mandi	3.2	0.04*	Yes	
Mandi does not Granger cause Kolar	7.5	0.001**	Yes	Bidirectional
Kolar does not Granger cause Solan	1.64	0.19	No	
Solan does not Granger cause Kolar	5.2	0.006**	Yes	Unidirectional
Delhi does not Granger cause Mandi	3.04	0.05*	Yes	
Mandi does not Granger cause Delhi	4.04	0.01*	Yes	Bidirectional

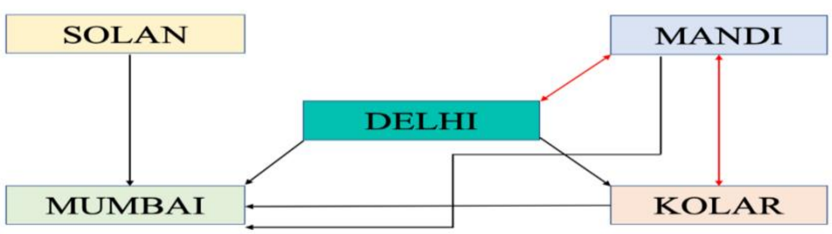

Figure 3. Results of The Granger Causality Directions Between Tomato Markets.

Impulse Response Function:-

Since causality tests cannot measure the amount of response from one variable to another beyond a predetermined time period, the impulse response function is used to assess the relative strength of the causality effect beyond a predetermined time span (Rehman and Shahbaz, 2013). Taking into account the time paths of prices following an exogenous shock, or impulse response, is the most effective method to interpret the implications of the models for the patterns of price transmission, causality, and adjustments. The VAR system's impulse response function explains how one endogenous variable responds to shock by examining the other endogenous variable's past, present, and future values. The shock passes through to the other explanatory variables and impacts the variable itself (Shilpa et al., 2021). The impulse response function helps understand the effect of one-degree standard deviation shock given to Solan, Mandi, Mumbai, Delhi, and Kolar markets and their impact on the prices.

Figure 4 presents the results of the impulse response function for the Delhi markets, estimating how the markets in Mandi, Mumbai, Solan, and Kolar would react to a standard deviation shock to the prices of tomatoes in Delhi. Following the shock, the other tomato markets reacted immediately, falling for four to five months before stabilizing for the remaining time. Figure 5 displays the impulse response function results for the Solan market. Following the recording of market responses, it was observed that all markets exhibit varying patterns. For example, while prices in Delhi decreased sharply in the first two months, they stabilized. Figure 6 displays the findings of the Mandi market's impulse response function. Market reaction was monitored, and it was discovered that a one-unit standard deviation caused prices to drop immediately. For the other markets, this stabilization occurred after four to five months. The Delhi market is almost inversely proportional to others. The results of the impulse response function for the Kolar market (Fig. 7) show that in the initial month, prices increase in all the markets and then start plummeting up to the third month, later stabilizing for the rest of the period. The impulse response function results for the Mumbai market (Figure 8) were nearly identical to those for the Kolar market; prices increased initially, started to decline, and stabilized after the fifth month.

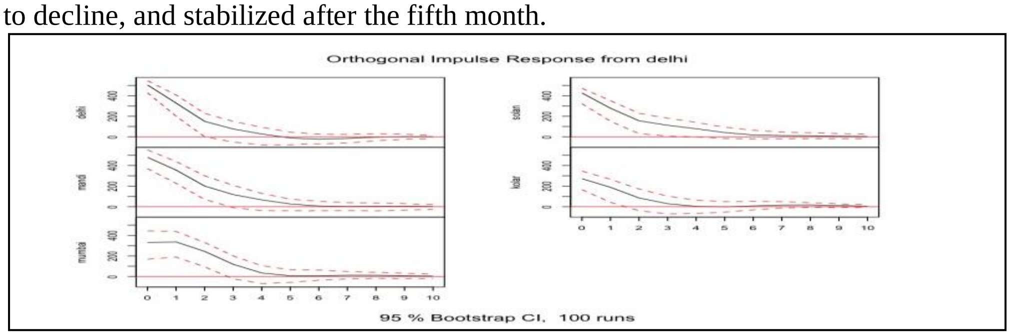

Figure 4. Impulse Response Function: Delhi to Other Markets.

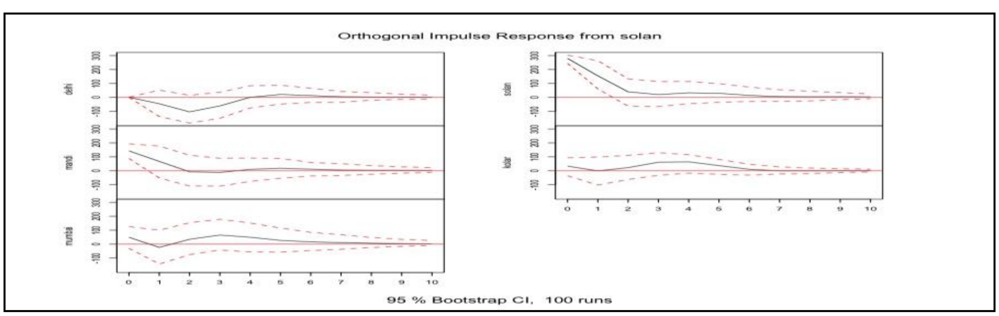

Figure 5. Impulse Response Function: Solan to Other Markets.

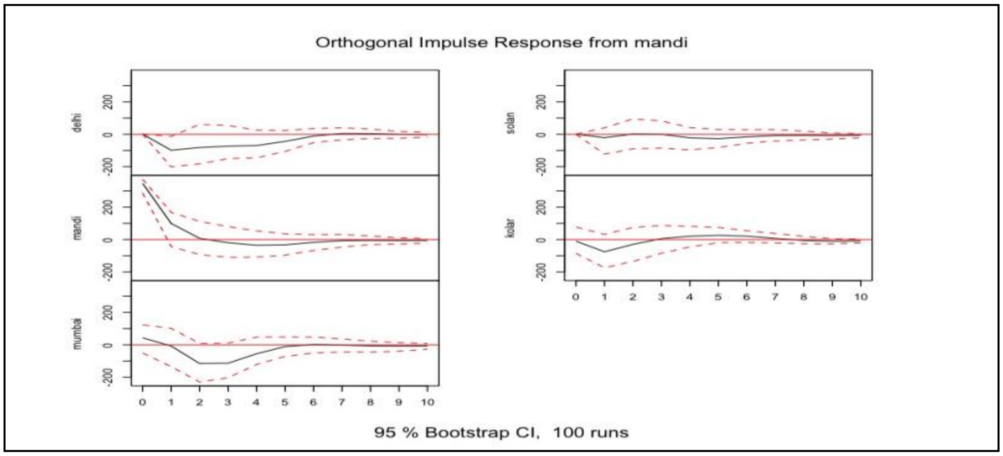

Figure 6. Impulse Response Function: Mandi To Other Markets.

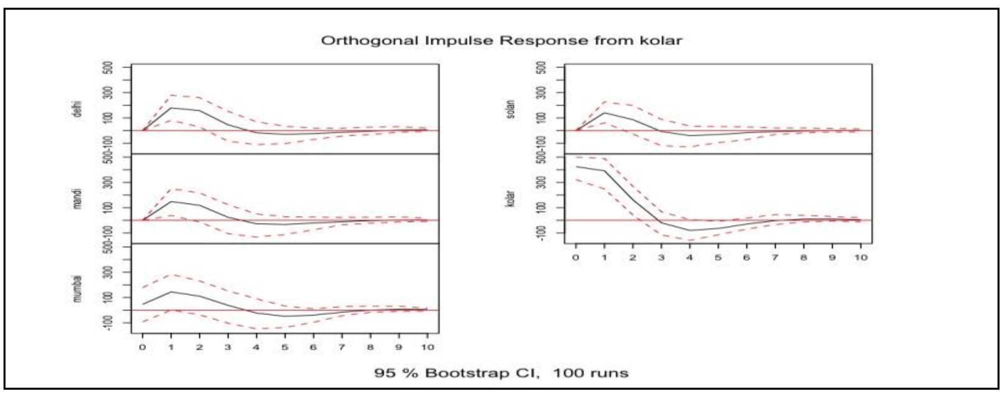

Figure 7. Impulse response function: Kolar to other markets.

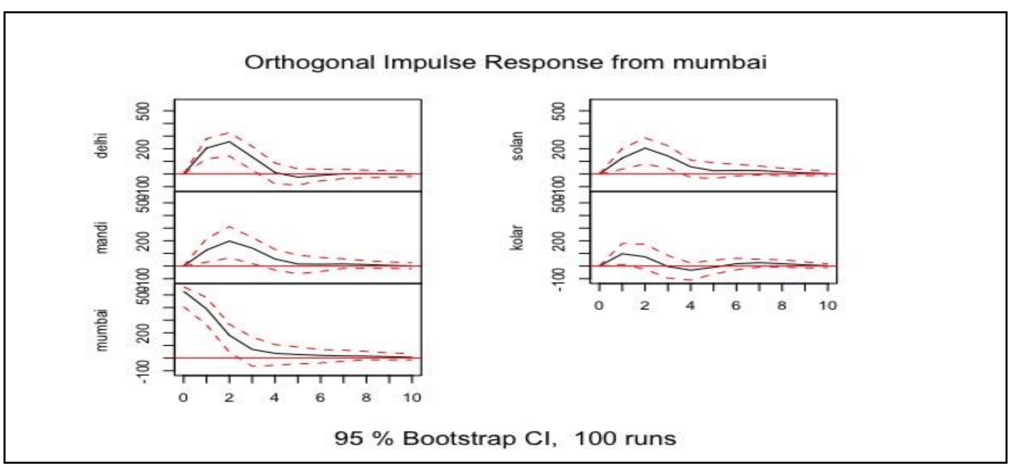

Figure 8. Impulse Response Function: Mumbai To Other Markets

IV

CONCLUSION

Tomato market integration is imperative for the economic well-being of farmers and consumers across different markets, as well as economic efficiency, given its large share in the Indian food consumption basket. The analysis showed that the price of tomatoes fluctuated in the selected markets, particularly in May, June, and November. The results of the correlation analysis suggested that the price differential in the chosen markets was not greater than the cost of transportation because prices in the markets moved together and were well integrated. This indicates that market efficiency is sufficient. The price series in the chosen markets were stationary, and the results of the unrestricted co-integration test showed a long-term relationship between the tomato prices in the chosen markets. Of the five markets, it was discovered that three had long-term equilibrium. In most of these markets, the prices of tomatoes were impacted by both their own lagged prices and the current and lagged prices of other carefully chosen markets. Furthermore, according to the Granger causality analysis, Mumbai was the primary market affected by changes in the prices of the other chosen markets because the chosen markets are not always spatially well integrated. Therefore, it was noticed that marketing efficiency has not yet reached its maximum potential. Inadequate physical infrastructure, sluggish information flow between markets, and low market intelligence could all contribute to this.

V

POLICY IMPLICATIONS

The policy interventions should focus on developing more efficient marketing channels and establishing a robust online marketing system with enhanced computerization and active networking. Strengthening market intelligence and improving physical infrastructure in all major markets is essential to ensure better integration and reduce price volatility. Given the seasonal fluctuations in tomato prices, it is crucial to raise awareness among farmers to help them make informed decisions about tomato cultivation. Additionally, value-addition practices should be promoted, and farmers should be trained to use these methods to minimize post-harvest losses. Reducing transportation costs is another critical area for improvement, as it will enable better cross-market trade and enhance market integration. These measures are necessary to ensure that the benefits of market integration are fully realized, both for producers in terms of fair pricing and consumers in terms of affordable access to agricultural products

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