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A Study of Tomato Price Integration Across Key Indian Markets

Mini Goyal, Amarpreet Kaur, M K Sekhon and Shruti Chopra

Department of Economics and Sociology, Punjab Agricultural University, Ludhiana,

Abstract

The study used Johansen's multivariate cointegration approach to investigate market integration in eight major wholesale tomato markets across the country, including Azadpur, Chomu, Ghaziabad, Gorakhpur, Kolar, Pimplagaon, Mulakalacheruvu, and Vyra. The study has confirmed the presence of cointegration, implying the long-run price association among the markets. To determine the direction of price transmission between market pairs, the Granger causality test was used, which confirmed Gorakhpur as the price-determining market. Ghaziabad and Gorakhpur had been found comparatively more efficient as they depicted most of the bidirectional causal relations with other markets. The pairs with the Chomu market have not shown any causal relation between them. The study conducted impulse response functions which confirmed the results of co-integration and Granger causality. However, the vector error correction method (VECM) revealed that the speed of price transmission was relatively low in certain market pairs that are spatially disintegrated. It was concluded that the direction and intensity of price changes may be affected by the dynamic linkages between the demand and supply of tomatoes. Despite having a good information system and communication, farmers were still at risk due to varying tomato prices in different markets across the country.

Key Words: Co Integration, Granger Causality, VECM

Jel Classification: Q13, Q11, C32

Introduction

Tomato *Solanum lycopersicum*is themost popular horticultural crop and one of the most widely cultivated vegetables in the tropics (Afolabi, 2019). It is grown worldwide for local use or as an export crop and is the world's largest vegetable crop after potato and sweet potato but it tops the list of canned vegetables. In 2014, the global area cultivated with tomato was 5 million hectares with a production of 171 million tonnes, the major tomato-producing countries and India (FAOSTAT, 2023). Today farmers are more interested in tomato production than other vegetables for its multiple harvests, which result in high profit per unit area. It is an important cash-generating crop to small-scalefarmers and provides employment in the production and industries(Meniga, 2014).

Despite being the largest vegetable crop produced in the world, tomato is known as protective food due to its unique nutritional value and wide distribution (Ramappa and Manjunatha, 2017 and Taylor, 1987). The total area under tomato in India is 865 million hectares with a production of 21056 million tons in the year 2020-21 (Annexure 1).

Corresponding author email: shrutichopra95@gmail.com

A continuous increase can be witnessed in the area, production and yield of tomatoes in India during the period 2007-08 to 2020-21. The production of tomatoes is largely localized in Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Delhi, Rajasthan and Uttar Pradesh. The supply shock in such large markets is quickly transmitted to the other markets (Sendhil et al, 2014; Singla, 2015). Occasionally, prices of various agricultural commodities like tomatoes, potatoes and onions remain quite volatile in domestic markets.

Since the demand for tomatoes is inelastic, a small change in its supply leads to high price volatility in the domestic markets, and therefore marketing is a major concern for farmers (Saragih *et al*., 2023). Markets of horticultural products are geographically dispersed but prices in these markets show long-run spatial causality suggesting that markets are integrated (Ghosh, 2010).Market integration shows the extent to which prices in different markets move together (Barret, 2001) and is considered as pre-condition for affective marketing reforms to take place. The high degree of market integration indicates the competitiveness of the markets and market integration also plays a vital role in determining pattern and pace of diversification towards the high value crops (Sidhu et al., 2010). Therefore, the present study analyses market efficiency through examining spatial integration in tomato and its price transmission analysis in selected markets of India.

Data Sources and Methodology

The study was exclusively based on secondary data which was collected from Agmark portalto work out the integration among various markets. The, data on monthlywholesale prices pertained to the period 2007-2021. The selection of major markets for tomato was based on triennium ending (TE) arrivals for the period 2018-19, 2019-20 and 2020-21. Markets selected for the study were Azadpur (Delhi), Chomu, Ghaziabad, Gorakhpur, Kolar, Mulakalacheruvu, Pimplagaon and Vyra.Apart from this, as data on price of tomatowere taken from January to December to explore the instability in market price of tomato over a period of 14 years (2007-2021). Different statistical methods, namely testing stationarity, Johansen co integration, Granger causality testing, vector error correction method and impulse response function have been used. These techniques allow one to quantify the degree of interconnectedness between the markets. For testing the stationarity of time series data, the tests, namely Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) have been applied. The statistical techniques which were used in the present investigation are described below in brief.

Augmented Dickey-Fuller test (ADF)

The Augmented Dickey- Fuller based unit root test procedure was applied to check whether the wholesale price series of tomato in selected markets were stationary at their level or at their first difference. The rejection of the null hypothesis indicates that the series is non-stationary and vice-versa (Dickey and Fuller, 1981 and Ghafoor, et al., 2009). In the absence of stationarity, the estimated relationship may be counterfeit without any significant implication (Gujarati, 2003). It was found that the price series was stationary at the level form.

Johansen Approach

After confirmation of stationarity in the entire price series at the same order of differences, the co-integration of markets was tested by Johansen maximum-likelihood techniques. In this present context, the long-run price relationship between the markets was employed by conducting the Johansen cointegration test (Johansen and Juselius, 1990). The Johansen procedure examines a vector autoregressive (VAR) model of *Yt*, an (n × 1) vector of variables that were integrated into the order one— I (1) time series. This VAR can be expressed as an equation where Γ and Π are matrices of parameters, *p* is the number of lags (selected based on Schwarz information criterion), and ε*t*is an (n × 1) vector of innovations. The presence of at least one cointegrating relationship is necessary for the analysis of the long-run relationship of the prices to be plausible.

To detect the number of co-integrating vectors, Johansen proposed two likelihood ratio tests: trace test and maximum eigenvalue test, shown in Equations (3)where *T* is the sample size and λ^*I*is the *ith* largest established correlation. The trace test examines the null hypothesis of *r* co integrating vectors against the alternative hypothesis of *n* co-integrating vectors. The maximumigen value test, on the other hand, tests the null hypothesis of *r* co-integrating vectors against the alternative hypothesis of *r+1* co integratingvectors(Hjalmarsson and Osterholm, 2007).

$$\Delta Yt = \mu + \sum_{i=1}^{p-1} \Gamma i Y_{t-1} + \Pi Y_{t-1} + \varepsilon_t \quad \ldots\ldots (1)$$

$$J_{trace} = -T \sum_{i=r+1}^{n} In(1-\hat{\lambda}_i) \quad \ldots\ldots. (2)$$

$$J_{\max} = -TIn(1-\hat{\lambda}_r + 1) \quad \ldots\ldots.. (3)$$

Granger Causality Test

The Granger causality test conducted within the framework of a VAR model was used to test the existence and the direction of the long-run causal price relationship between the markets (Granger, 1969) to whether changes in one price series affect another price series. Taking the causality relationship between Azadpur and Chomu wholesale tomato markets as an example, the test was based on the following pairs of OLS regression equations through a bivariate VAR:

$$PInA_t = \sum_{i=1}^{m} \gamma_i PInA_{i=1} + \sum_{i=1}^{m} PInC_{t-j} + \varepsilon_{2t} \quad \ldots\ldots\ldots (4)$$

where,*A*isAzadpur market,*P*ln stands for price series in logarithm form and *t* isthe time trend variable. The subscript stands for the number of lags of both variables in the system. The null hypothesis in Equation (4), i.e. *H0:*β*1* = β*2* = ... = β*j*=0 against the alternative, i.e., *H1*: Not *H0,* is that *P* ln*At*does not Granger cause *P* ln *Ht*. So, a rejection of the null hypothesis will imply that there is Granger causality between the variables (Gujarati, 2003).

Vector Error Correction Method (VECM)

The co-integration 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 co-integrated, 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: where ECTt-1 is the lagged error correction terms and Yt are the variables under consideration transformed through natural logarithm and Yt-i are the lagged values of variables X and Y parameter 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 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).

Impulse Response Functions

Granger causality tests do not determine the relative strength of causality effects beyond the selected time span. In such circumstances, causality tests are inappropriate because these tests are unable to indicate how much feedback exists from one variable to the other beyond the selected sample period (Rahman and Shahbaz, 2013). The best way to interpret the implications of the models for patterns of price transmission, causality and adjustment are to consider the time paths of prices after exogenous shocks, i.e. impulse responses (Vavra and Goodwin, 2005). The impulse response function 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. In this study, we have used the generalized impulse response function (GIRF) originally developed by Koop *et al*. (1996) and suggested by Pesaran and Shin (1998). The GIRF in the case of an arbitrary current shock, δ, and history, $\omega t\text{-}1$.

$$GIRFY\ (h,\ \delta,\ \omega t\text{-}1) = E\ [Yt+h|\ \delta,\ \omega t\text{-}1] — E\ [yt+h|\omega t\text{-}1] \quad \ldots\ldots(5)$$

For$m$= 0, 1,..

Results and Discussion

The summary statistics of monthly wholesale prices of tomato for the period July 2007-08 to June 2021-22 are presented in Table 2. The analysis revealed that all the selected markets showed a symmetric trend in the movement of wholesale prices of tomato except for the markets of Ghaziabad and Gorakhpur which were mainly consuming markets with no production of their own. It was noticed that Mulakalacheruvu had the lowest prices because it was very near to the highest producing districts of Andhra Pradesh or it can be said that it was in the second highest producing state of the country at large which contributes 10.92 per cent to the total national production(NHB, 2021 and Ahmed and Singla, 2017). The highest price of tomato was found in Gorakhpur district of Uttar Pradesh because of its high consumption and no production (Tripathi, 2021). The prices of Pimplagaon (Nashik) market were highly volatile which is India's biggest producer of tomato and prices were dependent on exports as well as demand of tomato in other markets.

Table 3 .The empirical evidence suggests that price series had no unit root problem at their level form. The null hypothesis of the unit root at level form could not be rejected for all price series as the absolute values of the ADF statistics were well below the 5 percent critical values of the test statistics. Thus, it was concluded that the price series in all 8 markets (Azadpur, Chomu, Ghaziabad, Gorakhpur, Kolar, Mulakalacheuvu, Pimplagaon and Vyra) rejected the null hypothesis at level form implying that the time series were stationary.

Co integration Test Results in Price Series

With the proof that the price series were stationary and integrated the next step was to check the co integration among the different wholesale prices of tomato which was done by using Johansen Trace and Maximum Eigen Values approach (Beag and Singla, 2014).The results of both tests have given the same conclusion. It was revealed that there were all co integrating relations across the wholesale price markets of tomato within different selected states of the country at large. The study confirms that the domestic tomato markets are well co integrated and transmitted (Reddy et al, 2012, Sendil et al, 2014, Rajendran, 2015 and Ahmed and Singla, 2017)which implies that there exists long-run relationship between all the pairs of the selected tomato markets and price linkages were strong and stable (Table 4).

Table 1. Summary statistics of monthly wholesale prices of tomato in selected markets for the period, July 2007-08 to June 2021-22

Market	Observations	Monthly wholesale prices			Standard Deviation
		Max	Min	Mean	
Mulakalacheruvu	180	4640.00	108.00	874.53	711.88
Vyra	180	5635.00	305.00	1304.26	816.40
Kolar	180	4115.00	167.00	995.14	673.79
Pimplagaon	180	4183.00	141.00	888.59	750.68
Azadpur	180	11033.00	225.00	1344.08	1028.82
Chomu	180	4107.00	195.00	1217.78	779.58
Ghaziabad	180	3220.00	414.00	1304.38	618.43
Gorakhpur	180	4073.00	436.00	1442.57	767.42

(Rs/qtl)
Source: www.agmarknet

Table 2: ADF unit root test for wholesale prices of tomato

Market	At Level	T-Cal	(Prob*)	Remarks
Mulakalacheruvu	In A	-7.613608	0.0000	Stationary
Vyra	In A	-7.413589	0.0000	Stationary
Kolar	In A	-7.657642	0.0000	Stationary
Pimplagaon	In A	-7.513176	0.0000	Stationary
Azadpur (Delhi)	In A	-11.29587	0.0000	Stationary
Chomu	In A	-6.963969	0.0000	Stationary
Ghaziabad	In A	-5.820587	0.0000	Stationary
Gorakhpur	In A	-6.328128	0.0000	Stationary

Note: The astrerisks *indicate that unit root at level were rejected at 1 per cent as well as 5 per cent significance.
(The Prob.*) MacKinnon (1996) one-sided p-values.

Granger Causality Test

The Granger causality helps in establishing the direction of causation (if any) between the variables and thus helps in predicting the value of one variable on the basis of other variable. The basic idea is that variable *X* Granger causes *Y* if past values of *X* can help in explaining *Y*. The null hypotheses of the Granger causality test are: H0: X does not Granger-cause Y; and H1: X does Granger-cause Y. If null hypothesis was rejected, then the results were significant.The results revealed that no causal relationship was found between Kolar-Azadpur, VyraAzadpur, Ghaziabad-Chomu, Gorakhpur-Chomu, Pimplagaon-Ghaziabad and Mulakalacheruvu-Kolar. There were markets which showed reverse causal relationship and showed a bi-directional relationship namely Ghaziabad-Azadpur, Gorakhpur-Azadpur, Kolar-Ghaziabad,Mulakalacheruvu-Ghaziabad, Vyra-Ghaziabad, Kolar—Gorakhpur, Mulakalacheruvu-Gorakhpur, Pimplagaon-Gorakhpur and Vyra-Gorakhpur. This relationship implies that the information regarding wholesale prices had a two-way relationship that the former market granger causes with the latter market and provided information on wholesale prices and the latter market in return provide feedback to the former market.

A unidirectional relationship was found in rest of the markets which meant that price information was provided by one of the markets but the changes in prices was not feed backed by the other market. Hence, it was clear that a long-run relationship between the markets was there as there was acceptance of co integration between the series. It was found that Gorakhpur market influenced price at Azadpur, Kolar, Mulakalacheruvu, Pimplagaon and Vyra markets which meant prices were broadcasted both ways and these markets except for Kolar showed a uni-directional relationship with Mulakalacheruvu market. Pumplagaon market had the uni-directional causality with Kolar and Vyra ,Vyra with Kolar and Gorakhpur wtih Ghaziabad. So, this reveals that there was a strong integration among the selected tomato markets regarding price flow and that Gorakhpur market was the key influencer of wholesale prices at all other tomato markets (Table 6).

The graphic representation of the way of interaction, as resulted from pair-wise Granger causality testing has been

Table 3: Cointegration among different markets with respect to wholesale prices of tomato in India (with trace statistic)

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None	0.301526	288.2255	159.5297	0.0000
At most 1 *	0.274293	223.9899	125.6154	0.0000
At most 2 *	0.246273	166.6010	95.75366	0.0000
At most 3 *	0.195437	115.9931	69.81889	0.0000
At most 4 *	0.182677	77.06832	47.85613	0.0000
At most 5 *	0.101586	40.96032	29.79707	0.0017
At most 6 *	0.064181	21.78506	15.49471	0.0049
At most 7 *	0.053866	9.911458	3.841466	0.0016

*Note: *denotes rejection of the hypothesis at the 0.05 level*

Table 4: Cointegration among different markets concerning wholesale prices of tomato in India (with Eigen Value)

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None	0.301526	64.23555	52.36261	0.0020
At most 1 *	0.274293	57.38899	46.23142	0.0022
At most 2 *	0.246273	50.60790	40.07757	0.0023
At most 3 *	0.195437	38.92473	33.87687	0.0115
At most 4 *	0.182677	36.10800	27.58434	0.0032
At most 5 *	0.101586	19.17526	21.13162	0.0919
At most 6 *	0.064181	1 1.87361	14.26460	0.1155
At most 7 *	0.053866	9.911458	3.841466	0.0016

*Note: *denotes rejection of the hypothesis at the 0.05 level*

depicted in Figure 1 which clearly indicates how different tomato markets in India interact among themselves regarding wholesale price information flow. It appears that changes in wholesale prices of tomato in one market would cause a change in wholesale prices of tomato in other market.

Vector Error Correction Method (VECM)

The VECM was applied to check the speed of adjustment towards long-run equilibrium i.e. market efficiency among the selected markets. The speed of adjustment is given by the coefficient of error correction tern (ECT) which meant higher the speed of adjustment, higher the chances of correction of any disequilibrium. The study revealed that when the prices of Azadpur market were considered dependent upon prices of other markets to the extent of three per cent meaning that chances of correction were not very high. The statistically significant negative values of ECT at Azadpur market depicted the speed of adjustment in restoring the disequilibrium whereas the positive values of the ECT in rest of the markets showed the divergence from equilibrium. Also, the prices at Azadpur, Chomu and Kolar markets were influenced by their own lags of two months for the long-run equilibrium.

The equations of the markets are given below:

$\Delta lnAzadpurt$= -0.0318$ECT(t$-1) - 0.775$\Delta lnAzadpurt(-1)$- 0.428$lnAzadpurt(-2)$+ 1.227$\Delta lnGhaziabadt(-2 -)$

$\Delta lnChomut$= 0.113$ECT(t$-1) - 0.156$\Delta lnAzadpur(t$-1) -0.344$lnChomu(t$-1)- 0.274$\Delta lnChomu(t$-2) + 0.465$\Delta lnGhaziabad(t$-1)

$\Delta lnGhaziabadt$= 0.1007$ECT(t$-1) - 0.161$\Delta lnAzadpur(t$-1) -0.080$lnAzadpur(t$-2) + 0.3088$\Delta lnGorakhpur(t$-1)

$\Delta lnKolart$= 0.1394$ECT(t$-1) - 0.153$\Delta lnAzadpur(t$-1)+ 0.564$\Delta lnGorakhpur(t$-1)- 0.322$\Delta lnKolar(t$-1) -0.3018$\Delta lnKolar$ $(t$-2)-0.4812$\Delta lnPimplagaon(t$-1)-0.2923$\Delta lnPimplagaon(t$-2)

$\Delta lnMulakalacheruvut$= 0.1600$ECT(t$-1) - 0.2665$\Delta lnAzadpur$ $(t$-1)-0.1165$lnAzadpur(t$-2)+ 0.3483$\Delta lnGorakhpur(t$-1) +0.3423$\Delta lnGorakhpur(t$-2)-0.2772$\Delta lnPimplagaon(t$-1)- 0.3160$\Delta lnPimplagaon(t$-2)+ 0.2670$\Delta lnVyra(t$-1)

Impulse Response Function (IRF)

From the Granger Causality test, it was confirmed that Gorakhpur was the key market. The impulse response function (IRF) explicates the responsiveness of one standard deviation shock to one endogenous variable on the current and future values of all the other endogenous variables in the VAR system. The shock given to a variable affects the variable itself and it is also broadcasted on all other expounding variables (Ahmed and Singla, 2017). It highlighted the extent to which a standard deviation shock in Gorakhpur market affected the prices in all the other co integrating markets over the study period. An immediate high response of all the markets was witnessed after the shocks to the key market. Al the markets peaked in second and third month and started declining afterwards.

The response kept on declining thereafter and became negative in case of all the markets. This implies that a shock arising from Gorakhpur key market was transmitted to all the other markets and the response was higher in the following months. Similar results were given by Katoch and Singh, 2020.The way of interaction, as resulted from pair-wise Granger causality testing has been depicted in Figure 1 to 5 which revealed the effects of shocks being transmitted to other tomato markets. It was seen that all the tomato markets responded highly to the standard deviation shock in any of the other tomato market except for Chomu. So, it can be inferred that different tomato markets interacted among themselves in terms of providing information on the wholesale price flow which meant higher the level of integration, higher the market efficiency (Wahlang and Sekhon, 2019). Similar results were presented by Ahmed and Singla, 2017.

Conclusion and Policy Implications

Tomato crop is the major crop of concern for the farmers

Table 5. Pair-wise Granger causality in major tomato markets in India

Null Hypothesis:	Obs	F-Statistic	Prob.	Granger Cause	Direction
CHOMU does not Granger Cause AZADPUR	182	8.73959	0.0002**	Yes	Uni-directional
AZADPUR does not Granger Cause CHOMU		1.96933	0.1426	No	
GHAZIABAD does not Granger Cause AZADPUR	182	12.5395	0.0000**	Yes	Bidiretional
AZADPUR does not Granger Cause GHAZIABAD		11.1205	0.0000**	Yes	
GORAKHPUR does not Granger Cause AZADPUR	182	9.01626	0.0002**	Yes	Bidiretional
AZADPUR does not Granger Cause GORAKHPUR		6.05078	0.0029**	Yes	
KOLAR does not Granger Cause AZADPUR	182	0.17776	0.8373	No	None
AZADPUR does not Granger Cause KOLAR		2.17988	0.1161	No	
MULAKALACHERUVU does not Granger Cause AZADPUR	182	0.25325	0.7766	No	Uni-directional
AZADPUR does not Granger Cause MULAKALACHERUVU		4.08005	0.0185**	Yes	
PIMPLAGAON does not Granger Cause AZADPUR	182	4.47853	0.0127**	Yes	Uni-directional
AZADPUR does not Granger Cause PIMPLAGAON		1.09311	0.3374	No	
VYRA does not Granger Cause AZADPUR	182	1.74984	0.1768	No	None
AZADPUR does not Granger Cause VYRA		1.10066	0.3349	No	
GHAZIABAD does not Granger Cause CHOMU	182	1.84102	0.1617	No	None
CHOMU does not Granger Cause GHAZIABAD		0.76614	0.4663	No	
GORAKHPUR does not Granger Cause CHOMU	182	0.43406	0.6486	No	None
CHOMU does not Granger Cause GORAKHPUR		2.15650	0.1188	No	
KOLAR does not Granger Cause CHOMU	182	2.90183	0.0575	No	Uni-directional
CHOMU does not Granger Cause KOLAR		4.22135	0.0162**	Yes	
MULAKALACHERUVU does not Granger Cause CHOMU	182	1.53372	0.2186	No	Uni-directional
CHOMU does not Granger Cause MULAKALACHERUVU		3.60811	0.0291**	Yes	
PIMPLAGAON does not Granger Cause CHOMU	182	2.38894	0.0947	No	Uni-directional
CHOMU does not Granger Cause PIMPLAGAON		9.60769	0.0001**	Yes	
VYRA does not Granger Cause CHOMU	182	1.79494	0.1691	No	Uni-directional
CHOMU does not Granger Cause VYRA		10.2935	0.0000**	Yes	
GORAKHPUR does not Granger Cause GHAZIABAD	182	3.03547	0.0506**	Yes	Uni-directional
GHAZIABAD does not Granger Cause GORAKHPUR		2.86388	0.0597	No	
KOLAR does not Granger Cause GHAZIABAD	182	8.11163	0.0004**	Yes	Bidiretional
GHAZIABAD does not Granger Cause KOLAR		12.1138	0.0000**	Yes	
MULAKALACHERUVU does not Granger Cause GHAZIABAD	182	8.59701	0.0003**	Yes	Bidiretional
GHAZIABAD does not Granger Cause MULAKALACHERUVU		7.74875	0.0006**	Yes	
PIMPLAGAON does not Granger Cause GHAZIABAD	182	1.98507	0.1404	No	None
GHAZIABAD does not Granger Cause PIMPLAGAON		1.78041	0.1716	No	
VYRA does not Granger Cause GHAZIABAD	182	7.83897	0.0005**	Yes	Bidiretional
GHAZIABAD does not Granger Cause VYRA		13.3444	0.0000**	Yes	
KOLAR does not Granger Cause GORAKHPUR	182	6.00883	0.0030**	Yes	Bidiretional
GORAKHPUR does not Granger Cause KOLAR		10.0304	0.0000**	Yes	
MULAKALACHERUVU does not Granger Cause GORAKHPUR	182	7.02491	0.0012**	Yes	Bidiretional
GORAKHPUR does not Granger Cause MULAKALACHERUVU		6.61391	0.0017**	Yes	
PIMPLAGAON does not Granger Cause GORAKHPUR	182	6.80428	0.0014**	Yes	Bidiretional
GORAKHPUR does not Granger Cause PIMPLAGAON		3.36627	0.0367**	Yes	
VYRA does not Granger Cause GORAKHPUR	182	8.33507	0.0003**	Yes	Bidiretional
GORAKHPUR does not Granger Cause VYRA		10.5754	0.0000**	Yes	
MULAKALACHERUVU does not Granger Cause KOLAR	182	0.01125	0.9888	No	None
KOLAR does not Granger Cause MULAKALACHERUVU		0.18349	0.8325	No	
PIMPLAGAON does not Granger Cause KOLAR	182	6.72696	0.0015**	Yes	Uni-directional
KOLAR does not Granger Cause PIMPLAGAON		0.97297	0.3800	No	
VYRA does not Granger Cause KOLAR	182	3.61210	0.0290**	Yes	Uni-directional
KOLAR does not Granger Cause VYRA		0.75073	0.4735	No	
PIMPLAGAON does not Granger Cause MULAKALACHERUVU	182	3.65222	0.0279**	Yes	Uni-directional
MULAKALACHERUVU does not Granger Cause PIMPLAGAON		0.59346	0.5535	No	
VYRA does not Granger Cause MULAKALACHERUVU	182	3.40831	0.0353**	Yes	Uni-directional
MULAKALACHERUVU does not Granger Cause VYRA		1.98092	0.1410	No	
VYRA does not Granger Cause PIMPLAGAON	182	1.28855	0.2782	No	Uni-directional
PIMPLAGAON does not Granger Cause VYRA		5.81350	0.0036**	Yes	

*** denotes rejection of null hypothesis at 5 per cent level of significance*

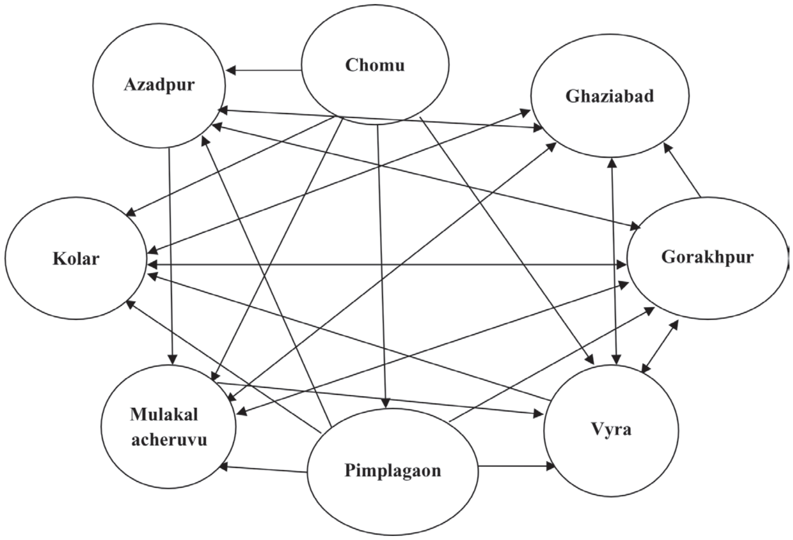

Figure 1: Granger Causality directions between the market pairs

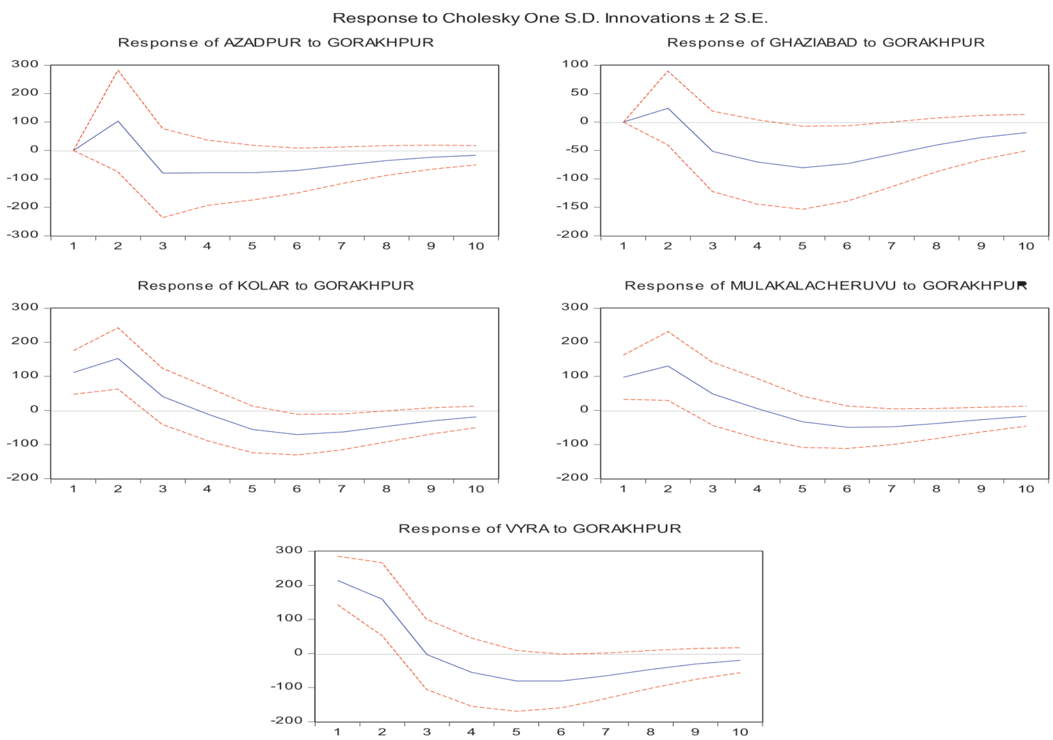

Figure 2 to 5: Impulse Response Function

due to its demand in all seasons but high volatility could be witnessed in the prices of the crop for the past few years. The present study is an attempt to analyse market integration in different wholesale price markets of the country. The study indicated that all the major tomato markets in the country were well integrated and efficient. The changes in wholesale prices of one market causing changes in other markets indicated the existence of market integration which is considered essential for the improvement of market efficiency. The key factors influencing tomato prices were seasonal variations, transportation costs, weather conditions & market demand, and supply.

The price series was stationary and the unrestricted co integration approach through Johansen co integration test revealed that all the tomato markets in the country were well-integrated and efficient and tomato prices in the selected markets had a long-run relationship. Granger Causality revealed that Gorakhpur as the key market was influencing the prices in rest of the selected markets. The standard deviation shock given to the key market stimulated an immediate high response in all the other markets. On the other hand, it was confirmed by the test that Chomu market was price follower. The impulse response function (IRF) initially increased but it declined after peaking and eventually became negative in all the markets. The vector error correction method (VECM) highlighted five cointegrating eqations at 0.05 level. The prices in Azadpur, Chomu, and Kolar were influenced by their one and two months lags. The speed of adjustment was found to be very slow which was three percent in case of Azadpur market whereas it was negligible in the case of the rest of the markets. It can be concluded that the direction and intensity of price changes may be affected by the dynamic linkages between the demand and supply of tomatoes.

Despite having a decent information system and communication, price differences were observed in various tomato markets across the country, putting farmers at risk. Overall it was suggested that regional markets for tomatoes in India were strongly integrated which actually limits the government intervention and allows private traders to manipulate tomato prices in times of shortage which is actually due to weather conditions or pest attacks. The acumens from the study can be used to improve information precision to envisage the price movements used by marketing operators for their strategies. The policy fabricators can use the information to design apt marketing strategies to bring more efficiency across the markets.

References

Afolabi S A 2019. Economic Analysis of Tomato Losses in Ibadan Metropolis, Oyo State, Nigeria. *National Horticultural Research Institute*, Idi-Ishin, Ibadan. Idoshi, Publication, pp. 89.

Ahmed M and Singla N 2017. Market Integration and price Transmission in Major Onion Markets of India. *Economic Affairs*. **62**: 405-417.

Barrett C B 2001. Measuring Integration and Efficiency in International Agricultural Markets. *Review of Agricultural Economics*, **23:** 19-32.

Beag F A and Singla N 2014. Cointegration, Causality and Impulse Response Analysis in Major Apple Markets of India. *Agricultural Economics Research Review*, **27**: 291-298.

Dickey D A and Fuller W A 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica: *Journal of the Econometric Society*. **49**: 1057-1072.

FAOSTAT. Database Results. 2022. Available at:<http://faostat3.fao.org/>. Accessed: September 20, 2022

Ghafoor A, Mustafa K and Mushtaq K 2009. Cointegration and Causality: An Application to Major Mango Markets in Pakistan. *The Lahore Journal of Economics*, **14**: 85-113.

Ghosh M 2010. Spatial Price Linkages in Regional Food Grain Markets in India. *The Journal of Applied Economic Research* **4**: 495-516. https://www.researchgate.net/publication/270709649

Granger C W 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica: *Journal of the Econometric Society*, **37**: 424-438.

Gujarati D N 2003. *Basic Econometrics Fourth Edition*. New York: McGraw Hill.

Hjalmarsson E and Osterholm P 2007. Testing for Co-Integration Using the Jhoansen Methodology When Variables are Near Integrated. Board of Governors of the Federal Reserve System. *International Finance Discussion Papers Number 915*, December 2007.

Johansen S and Juselius K 1990. Maximum likelihood estimation and inference on cointegration- With applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, **52**: 169-210.

Tripathi N P 2021. Tomato Price. *Jagran*https://www.jagran.com/uttar-pradesh/Gorakhpur-city-vegetable-market-of-deoria-filled-with-tomatoes-from-nashik-price-fall-due-to-increase-in-arrival

Meniga M 2014. The Major Problems and Prospects of Tomato Marketing: An Empirical Analysis. *International Journal of Management Research and Business Strategy*, **3**:80-3. https://www.researchgate.net/publication/330106967

Ahmed M and Singla N 2017. Market Integration and Price Transmission in Major Onion Markets of India. *Economic Affairs*, **62**:. 405-417, September 2017.DOI: 10.5958/0976-4666.2017.00051.1

National Horticulture Board (NHB) 2021. Indian Production of Tomato. https://agriexchange.apeda.gov.in/India_Productions.aspx?cat=Vegetables&hscode=1088

Pesaran M H and Y Shin 1998. Generalized impulse response analysis in linear multivariate models. *Economics Letters* **58** : 17–29. http://www.sciencedirect.com/science/article/pii/S0165–1765(97)00214–0

Katoch S and Singh R 2020. Assessment of Spatial Price Linkages in the Major Potato-assembling Markets in India. *Agricultural Economics Research Review*. **33** :75-84.

Koop G, Pesaran H and Potter S M 1996. Impulse response analysis in non-linear multivariate models. *Journal of Econometrics*, **74:** 119-148.

Rajendran S 2015. Price Transmission Process in Vertical Markets: an Empirical Analysis of Onion Markets in Tamil Nadu State (India). *European Journal of Sustainable Development*, **4**: 9-22.

Ramappa K B and Manjunatha A V 2017. *Tomato Value Chain in Karnataka* (Issue i, pp. 125–141). https://doi.org/10.1007/978-981-10-5957-5_7

Reddy B S, Chandrashekhar S M, Dikshit A K and Manohar N S 2012. Price trend and integration of wholesale markets for onion in metro cities of India. *Journal of Economics and Sustainable Development*, **3**: 120-130.

Saragih A L H, Lindawati and Supriana T 2023. Analysis of demand and supply of tomato in North Sumatra. *International Journal of Research and Review.***10**: 392-396.

Saxena R and R Chand 2017. Understanding the Recurring Onion Price Shocks: Revelations from Production-Trade-Price Linkages. *Policy Paper 33, ICAR-National Institute of Agricultural Economics and PolicyResearch(NIAP), New Delhi*. upload_files/policy_paper/Policy%20Paper%2033.pdf

Sendhil R, Sundaramoorthy C, Venkatesh P and Thomas L 2014. Testing market integration and convergence to the law of one price in Indian onions. *African Journal of Agricultural Research*. **9**: 2975-2984.

Sidhu R S, Kumar S, Vatta K and Singh P 2010. Supply chain analysis of onion and cauliflower in Punjab. *Agricultural Economics Research Review*, **23**: 445-453.

Singla N 2015. Tearing Onion Crisis. *The Daily Post*, Editorial and Opinion, page 8, 18th September.

Vavra P, and B Goodwin 2005. Analysis of Price Transmission along the Food Chain. *OECD Food, Agriculture and Fisheries Working Paper No 3. OECD Publishing, France. http://dx.doi.org/10.1787/*752335872456

Wahlang L and Sekhon M K 2019. Price Behavior and Market Integration of Chickpea in Major Producing States of India. *Indian Journal of Agricultural Marketing* **33** :54-72. https://www.cabdirect.org/cabdirect/abstract/20203006505

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Annexure 1. Area, production and yield of tomato in India, 2007-08 to 2020-2021

Year	Area (million ha)	Production (million tons)	Yield (tons/ha)
2007-08	566.30	10302.74	18.2
2008-09	599.11	11148.83	18.6
2009-10	634.39	12433.19	19.6
2010-11	864.92	16826.45	19.5
2011-12	907.05	18653.30	20.6
2012-13	879.63	18226.64	20.7
2013-14	882.03	18735.91	21.2
2014-15	767.32	16384.98	21.4
2015-16	773.88	18731.97	24.2
2016-17	796.86	20708.43	26.0
2017-18	789.15	19759.32	25.0
2018-19	781.01	19007.24	24.3
2019-20	817.78	20550.11	25.1
2020-21	865.29	21055.85	24.3