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Market integration and price transmission in major tomato markets of Maharashtra

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Abstract
The data on arrivals and prices of tomato were collected for five markets *viz*; Mumbai, Nagpur, Nashik, Pimpalgaon and Pune for the period of nine years (2011-2019). The present investigation has been undertaken to study the relationship between arrivals and prices of tomato, to assess the price volatility and co-integration of tomato among the selected markets in Maharashtra.
It revealed that the maximum variability of tomato in arrivals was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune. The maximum variability of tomato in prices was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune. The overall significant negative correlation between arrivals and prices of tomato in Nagpur market was noticed. The market pair Nagpur-Pimpalgaon have bidirectional causality and Mumbai-Nagpur, Mumbai-Nashik, Mumbai-Pimpalgaon, Mumbai-Pune, Nagpur-Nashik, Pune-Nagpur, Pimpalgaon- Nashik and Pune-Pimpalgaon have a unidirectional causality. It is concluded that very high price volatility of tomato present in Mumbai, Nagpur, and Nashik and Pimpalgaon markets. It should be minimized and needs to protect price security for farming community.

Keywords: Market integration, price, tomato, granger causality and volatility

Introduction
Tomato is popularly known as protective foods because of numerous minerals and vitamin like vitamin C, vitamin K_1, folate and potassium. One of the largest cultivating vegetable crops next to potato is tomato and also tops in canned vegetables. In these days, arrivals and prices of horticulture produces are showing high volatility. The prices volatilization has a catastrophic effect on all the group of farmers involving consumption, production and marketing of the commodities. In the age of trade liberalization, the prevalence of the problem of high fluctuation in arrivals and prices in domestic as well as international markets has gain significance importance. The prices in a market are determined not only by the interplay of supply along with demand but also by socio-economic factors. The formulation of valid study on the market integration in tomato has potential application for the development of agricultural markets. Bhagat *et al*. (2023) [3] studied the instability in banana export from India and it is suggested that there is a need to give more attention towards export of banana. ARIMA (3, 1, 6) and Brown's exponential smoothing model was found best fit for banana export and its total value respectively. Madhusudan Ghosh (2000) [6] studied spatial integration of rice markets in India and found that intra-state and inter-state regional rice markets are integrated and linked together into a single financial market.
Market integration shows the extent to which prices in different markets move together. The high degree of market integration indicates the competitiveness of the markets. Market integration also plays a vital role in determining pattern and pace of diversification towards the high value crops. Further it also becomes difficult to comprehend trade policy as several obstructions such as stocking limits, weak supply chains inefficient markets and restrict the efficient functioning of the markets. The formulation of valid study on the market integration in onion has potential application for the development of agricultural markets. Bhagat *et al*. (2023) [4] studied the cointegration between the major markets of pomegranate in Maharashtra state and concluded that very high price volatility present in selected markets of pomegranate. It should be minimized and needs to protect price security for farming community.

The present investigation has been undertaken to study the relationship between arrivals and prices of tomato, to assess the price volatility and co-integration of tomato among the selected markets in Maharashtra.

Materials and Methods

The data on arrivals and prices of tomato were collected for five markets *viz*; Mumbai, Nagpur, Nashik, Pimpalgaon and Pune for the period of nine years (2011-2019) were obtained from NHB database.

The statistical analysis was carried out by using the following models and tests.

$$\textbf{\textit{Arithmetic mean}}\ (\bar{x}) = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Where, n is total number of observations, xi is the values of month wise arrivals of prices of tomato in a particular market

$$\textbf{\textit{Standard Deviation}}\ (\sigma) = \frac{1}{n-1}\sum_{i}(x_i - \bar{x})^2$$

$$\textbf{\textit{Coefficient of Variation}}\ (\%) = \frac{\sigma}{\bar{X}} X100$$

Karl Pearson's correlation coefficient

$$r_{xy} = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\left(\sqrt{\sum x^2 - \frac{(\sum x)^2}{n}} . \sqrt{\sum y^2 - \frac{(\sum y)^2}{n}}\right)}$$

Where

x and y are the month wise mean arrivals and prices of tomato in selected markets.

Unit Root test – Augmented Dickey Fuller Test

$$\Delta \ln P_t = \alpha_0 + \delta_1 t + \gamma ln P_{t-1} + \sum_{j=i}^{q} \vartheta_j \Delta ln P_{t-j} + \varepsilon_t$$

Where,

P is the price in each market.

α_0 is the constant

t is the time or trend variable

q is the number of lag length

ε_t is the error term

Autoregressive Conditionally Heteroscedasticity (ARCH) model

An ARCH (m) process is one for which the variance at time t is conditional on observations at the previous *m* times, and the relationship is

$$Var(y_t|y_{t-1},\dots,y_{t-m}) = \sigma_t^2 = \alpha_0 + \alpha_1 y_{t-1}^2 + \dots + \alpha_m y_{t-m}^2$$

Generalized Autoregressive Conditionally Heteroscedasticity (GARCH) model

It uses values of the past squared observations and past variances to model the variance at time t GARCH (1, 1) is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 y_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Johansen Co integration

To check long run price relation between selected markets.

$$P_t = \sum_{i=1}^{k} A_i P_{t-1} + \mu + \beta_t + \varepsilon_t \ ; (t = 1,2,3 \dots T)$$

The procedure for estimating the co-integration vectors is based on error correction model (ECM) given by

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

Where,

$\Gamma_i = -(I - \Pi_i - \dots\dots, T)$; i= 1,2 ….K-1; $\Pi = -(I - \Pi_i - \dots\dots, \Pi_k)$

μ is the constant, t is the time or trend variable, ε_t is the error term

Likelihood ratio test statistics (Trace and Max Eigen test Statistics)

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

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

Where,

r is no. of co integrated vector, $\hat{\lambda}_1$ eigen value and $\hat{\lambda}_{r+1}$ is the largest squared eigen value.

Granger causality test

To study direction of causality for the selected time. It involves estimation of the simple form of vector autoregressive model (VAR) is as below:

$$lnP_t^A = \sum_{i=1}^{n} \delta_i \, lnP_{t-1}^B + \sum_{j=i}^{n} \vartheta_j \, lnP_{t-j}^A + \mu_{At}$$

$$lnP_t^B = \sum_{i=1}^{n} \varnothing_i \, lnP_{t-i}^B + \sum_{j=i}^{n} \partial_j \, lnP_{t-j}^A + \mu_{Bt}$$

Where

Pt. are the prices and subscript A and B indicate the two markets.

T is the time trend.

μ_A, $\mu_B$are the error terms of both the model.

Results and Discussion

1.1 Variability in arrivals and prices of tomato in selected markets

The estimates of mean and coefficient of variation (C.V.) of arrivals and prices of tomato in selected markets of Maharashtra from the period of 2011 to 2019 are presented in

Table 1 and 2. The overall mean arrivals of tomato in Mumbai, Nagpur, Nashik, Pimpalgaon and Pune market were 6982, 1051, 1759, 2629 and 2311 metric tones and magnitude of coefficient of variation in arrivals were 21.28, 62.81, 67.05, 200.82 and 50.92 per cent, respectively during the study period. The maximum variability in arrivals was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune. The maximum variability in Pimpalgaon market was recorded in August month. While in case of Mumbai Nagpur, Nashik and Pune market maximum variability was recorded in June, November, May and July months, respectively. The minimum variability in arrivals of selected markets was observed during the months of September, April, August, July and December respectively. Bhagat *et al*. (2020) [1] stated that the coefficient of variation for minimum temperature (5.1%) was found higher than the maximum temperature (2.5%) during the season of green gram in Jalgaon district of Maharashtra state.

The overall mean prices of tomato in Mumbai, Nagpur, Nashik, Pimpalgaon and Pune market were Rs. 1645, Rs.1336, Rs.1540, Rs.1461 and Rs.1326 per quintal and magnitude of coefficient of variation in prices were 57.60, 59.85, 58.35, 60.57 and 60.50 per cent, respectively. The maximum variability in prices was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune.

Table 1: Variability in arrivals of tomato in major markets of Maharashtra (MT) (2011-2019)

Months	Mumbai		Nagpur		Nashik		Pimpalgaon		Pune	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
January	7990	18.73	1344	52.51	2424	58.39	2707	62.02	2338	49.80
February	7223	21.27	1251	54.15	2131	50.31	2261	45.79	2618	58.08
March	7196	25.06	1327	56.35	1702	65.92	1737	55.10	2522	46.22
April	6416	23.00	1066	52.00	1376	75.01	1551	63.26	2154	55.20
May	6020	18.79	1104	58.40	1314	84.78	1418	64.24	2716	54.33
June	6501	29.20	927	59.05	1181	64.54	3596	144.96	2232	53.64
July	7499	18.67	842	60.37	1060	68.50	1008	41.32	2324	58.22
August	7149	24.46	920	79.11	1277	47.89	7104	240.57	2099	56.48
September	7382	12.14	972	78.60	2027	61.81	2522	102.83	2115	53.79
October	6968	13.06	857	76.02	1944	55.87	2323	81.28	2049	45.18
November	6202	23.67	834	83.85	2027	62.41	2305	65.49	2254	54.47
December	7235	17.62	1160	64.78	2642	62.66	3021	60.72	2308	43.88
Overall mean	6982	21.28	1051	62.81	1759	67.05	2629	200.82	2311	50.92

The maximum variability in Pune market was recorded in November month. While in case of Mumbai market maximum variability was recorded in August and for Nagpur, Nashik and Pimpalgaon market in November month. The minimum variability in prices of selected markets was observed during the months of April, February, September and April respectively during the study period. The similar results were reported by Bhagat *et al*. (2021) [2] and Tamilselvi *et al*. (2020) [10].

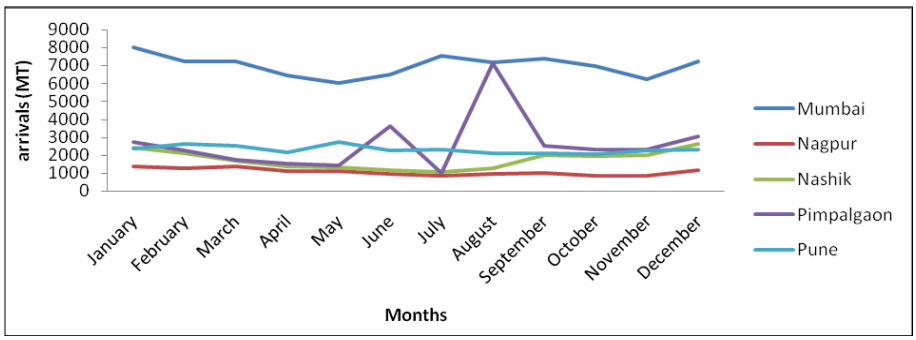

Fig 1: Month wise mean arrivals (MT) of tomato in major markets of Maharashtra

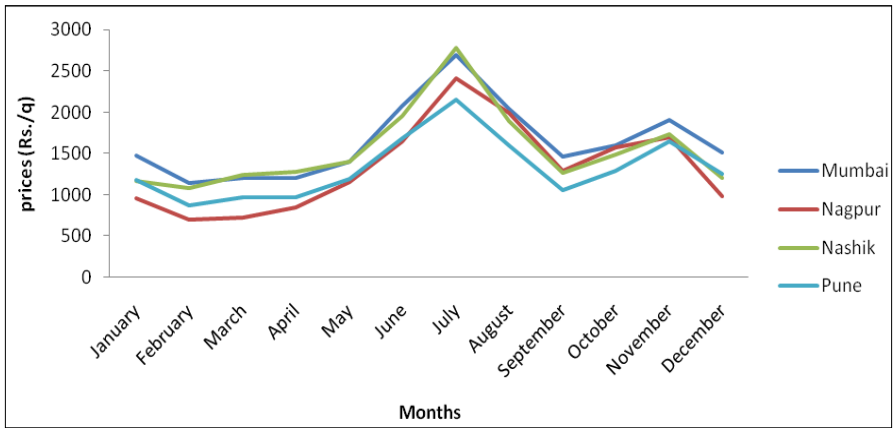

Fig 2: Month wise mean prices (Rs./q) of tomato in major markets of Maharashtra

Table 2: Variability in prices of tomato in major markets of Maharashtra (Rs./q) (2011-2019)

Months	Mumbai		Nagpur		Nashik		Pimpalgaon		Pune	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
January	1475	42.97	964	45.01	1166	55.77	1141	56.45	1182	57.84
February	1143	36.46	705	22.80	1078	46.36	1029	47.36	879	40.69
March	1204	36.86	724	45.81	1233	52.10	1167	53.13	973	37.36
April	1208	29.90	859	30.48	1272	49.01	1198	51.28	979	31.50
May	1396	47.25	1161	23.50	1396	43.13	1335	44.92	1195	47.77
June	2085	58.37	1650	31.70	1961	61.52	1871	62.42	1686	64.93
July	2695	50.19	2416	44.02	2784	42.36	2714	41.95	2149	47.35
August	2041	66.65	1992	56.37	1898	47.72	1616	59.02	1598	62.20
September	1468	48.05	1299	28.12	1269	33.07	1173	34.70	1058	45.51
October	1600	44.29	1578	39.21	1483	36.82	1550	40.90	1293	41.94
November	1910	64.80	1697	62.17	1737	70.27	1661	71.88	1652	73.44
December	1511	41.06	989	47.54	1207	51.73	1073	52.18	1262	55.50
Overall mean	1645	57.60	1336	59.85	1540	58.35	1461	60.57	1326	60.50

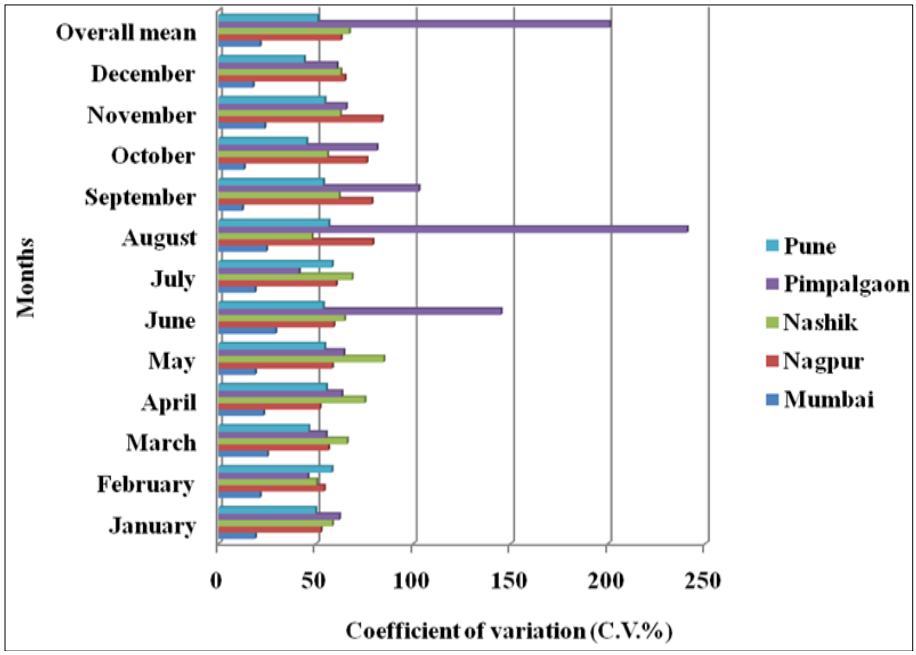

Fig 3: Month wise coefficient of variation in mean arrivals of tomato in major markets of Maharashtra

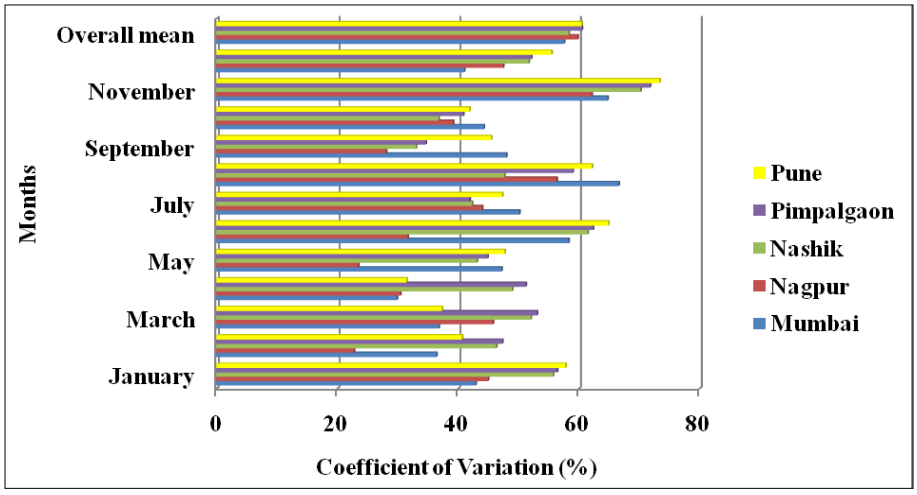

Fig 4: Month wise coefficient of variation in mean prices of tomato in major markets of Maharashtra

1.2 Correlation between arrivals and prices of tomato in selected markets: The results of correlation analysis are depicted in Table 3. It can be revealed that the overall negative significant correlation between arrivals and prices of tomato in Nagpur market.

Table 3: Correlation between arrivals and prices of tomato in selected markets of Maharashtra

Months	Mumbai	Nagpur	Nashik	Pimpalgaon	Pune
January	0.28	-0.01	-0.49	-0.46	-0.10
February	0.92**	-0.48	-0.73	-0.74	0.01
March	0.49	-0.65	-0.85**	-0.86**	0.07
April	0.47	-0.17	-0.71	-0.76*	-0.25
May	0.01	0.25	-0.77*	-0.76*	0.38
June	-0.06	-0.09	-0.50	-0.19	0.03
July	-0.64	-0.36	-0.10	-0.08	-0.08
August	-0.35	-0.52	-0.21	-0.45	-0.02
September	0.11	-0.27	-0.55	-0.57	0.11
October	-0.01	-0.49	0.12	-0.22	0.15
November	0.17	-0.51	-0.47	-0.44	-0.26
December	-0.49	-0.66	-0.44	-0.28	0.14
Overall	0.06	-0.84**	-0.67	-0.04	-0.28

It means that arrivals and prices of tomato have moved in opposite direction in Nagpur market during the period under study. However, non-significant negative correlation was observed in Nashik, Pimpalgaon and Pune market. The positive significant correlation coefficient was noticed in Mumbai market during the month of February. However, the negative significant correlation was noticed in Nashik and Pimpalgaon market during the months March, May and April respectively. However, there was non-significant correlation was noticed in all the months in Pune market. The similar results were reported by Bhagat *et al*. (2023) [4] for pomegranate markets in Maharashtra state and Tamilselvi *et al*. (2020) [10].

The checking of normality and stationarity for prices of tomato in selected markets was examined by Shapiro-Wilk test, ADF and pp test respectively. The results of these tests are presented in Table 4 and Table 5. The Shapiro-Wilk normality test results indicated that the prices of tomato in selected markets are not normal during the study period and also the prices of tomato in selected markets are non-stationary at level and stationary after first difference for both the test. The similar results were reported by Bhagat *et al*. (2023) [4].

Table 4: Result of Shapiro-Wilk Normality test for the prices of tomato in selected market.

Market	W	P value
Mumbai	0.97	0.04
Nagpur	0.92	0.00
Nashik	0.91	0.00
Pimpalgaon	0.30	0.00
Pune	0.94	0.00

Table 5: ADF and PP test for Unit Root in the prices of tomato.

Augmented Dickey-Fuller test results at level				Phillips-Perron test results at level		
Market	**t-statistic**	**Prob**	**Remarks**	**Adj. t -statistic**	**Prob.**	**Remarks**
Log Mumbai	0.09	0.71	Non -stationary	-0.09	0.65	Non -stationary
Log Nagpur	-1.03	0.27	Non -stationary	-1.63	0.10	Non -stationary
Log Nashik	-0.44	0.52	Non -stationary	-0.39	0.54	Non -stationary
Log Pimpalgaon	-0.45	0.52	Non -stationary	-0.51	0.49	Non -stationary
Log Pune	0.35	0.78	Non -stationary	0.44	0.81	Non -stationary
Augmented Dickey-Fuller test results after 1st diff.				**Phillips-Perron test results after 1st diff.**		
D(Log Mumbai)	-9.46	0.00	stationary	-39.23	0.00	stationary
D(Log Nagpur)	-13.71	0.00	stationary	-16.15	0.00	stationary
D(Log Nashik)	-9.45	0.00	stationary	-9.77	0.00	stationary
D(Log Pimpalgaon)	-8.38	0.00	stationary	-19.01	0.00	stationary
D(Log Pune)	-15.80	0.00	stationary	-16.11	0.00	stationary

1.3 Price Volatility of tomato in selected markets

The results of price volatility are depicted in Table 6. The sum of Alpha and Beta (a+b) indicated ARCH and GARCH effect for the selected tomato market. It was observed that among, the sum of Alpha and Beta is nearer to 1 that is 0.98, 0.98, 0.98 and 0.97 for Mumbai, Nagpur, Nashik and Pimpalgaon markets, respectively, indicated that the volatility shocks in the prices of tomato are quite persistence for long time in these markets. However, the sum of alpha and beta was not found near to 1 Pune market it revealed that volatility shocks in the prices of tomato for this market is not quite persistence for long period of time. Sadiq *et al*. (2018) [9] studied the causes of price volatility and the process of price discovery of okra in India.

Table 6: Results of ARCH-GARCH analysis of tomato prices for selected markets

Parameter	Mumbai	Nagpur	Nashik	Pimpalgaon	Pune
Alpha(a)	-0.10	-0.11	-0.11	-0.12	-0.07
Beta(b)	1.08	1.09	0.49	1.09	0.33
Sum (a+b)	0.98	0.98	0.98	0.97	0.27

1.4 Co integration analysis

Johansen multiple co-integration trace test was applied for indicating the long run relationship between the price series of selected markets of tomato. The results are depicted in Table 7. The results showed that five co-integration equations were significant at 5 per cent level of significance which implied that there existed co-integration among the markets.

Table 7: Results of multiple co-integration analysis of logged tomato prices for the selected markets.

Hypothesized No. of CE(s)	Trace Statistics			Max-Eigen statistics			No. of Co-integrating equation CE(s)
	Trace statistics	0.05 critical value	P value	Max-Eigen Statistic	0.05 critical value	P-value	
None *	139.56	69.82	0.00	53.33	33.88	0.00	05
At most 1 *	86.24	47.86	0.00	35.73	27.58	0.00	
At most 2*	50.51	29.80	0.00	29.75	21.13	0.00	
At most 3*	20.76	15.49	0.01	13.52	14.26	0.07	
At most 4*	7.24	3.84	0.01	7.24	3.84	0.01	

The results of pair wise Johansen co-integration test for the prices of tomato are depicted in Table 8. The results clearly indicated that there exists co-integration equation in all the pairs of markets. It means that the prices of tomato are co-integrated in the long run. The prices of tomato in these pair of markets move together and efficiently functioning. The similar results were also reported by Reddy *et al*. (2012) [8], Mumtaz *et al*. (2017) [7]. It indicated that the prices are competitive and closely associated. After confirming the cointegration of prices series, in next step, performed pair wise Granger causality test for four tomato markets to comprehend causal relation between them. Granger causality test, tests the null hypothesis of no causality between the selected pairs of tomato markets.

The results presented in Table 9 explicates that the market pair Nagpur-Pimpalgaon have bidirectional causality. It means that a price change in the former market in each pair granger cause the price formation in the latter market, whereas the price change in the latter market is feed backed by the price change in the former market. However, the market pairs Mumbai-Nagpur, Mumbai-Nashik, Mumbai-Pimpalgaon, Mumbai-Pune, Nagpur-Nashik, Pune-Nagpur, Pimpalgaon- Nashik and Pune-Pimpalgaon has unidirectional causality. It means that a price change in the former market in each pair granger cause the price formation in the latter market, whereas the price change in the latter market is not feed backed by the price change in the former market. The rest of market pairs do not showed causality. The similar results were reported by Reddy *et al*. (2012) [8] and Mumtaz *et al*. (2017) [7] and Bhagat *et al*. (2023) [4] for major markets of pomegranate in Maharashtra.

Table 8: Pair wise Johansen co-integration test results for the prices of tomato.

Markets pair	Hypothesized No. of CE(s)	Trace Statistics			Max-Eigen statistics		
		Trace statistics	0.05 critical value	P value	Max-Eigen Statistic	0.05 critical value	P-value
Mumbai - Nagpur	None *	67.28**	15.49	0.00	36.80**	14.26	0.00
	At most 1*	30.48**	3.84	0.00	30.48**	3.84	0.00
Mumbai - Nashik	None *	75.92**	15.49	0.00	45.69**	14.26	0.00
	At most 1 *	30.23**	3.84	0.00	30.23**	3.84	0.00
Mumbai - Pimpalgaon	None *	75.82**	15.49	0.00	45.15**	14.26	0.00
	At most 1 *	30.67**	3.84	0.00	30.67**	3.84	0.00
Mumbai - Pune	None *	71.02**	15.49	0.00	42.31**	14.26	0.02
	At most 1 *	28.71**	3.84	0.00	28.71**	3.84	0.00
Nagpur - Nashik	None *	75.58**	15.49	0.00	39.25**	14.26	0.00
	At most 1	36.33**	3.84	0.00	36.33**	3.84	0.00
Nagpur - Pimpalgaon	None *	77.10**	15.49	0.00	42.46**	14.26	0.00
	At most 1*	34.64**	3.84	0.00	34.64**	3.84	0.00
Nagpur - Pune	None*	63.53**	15.49	0.00	32.47**	14.26	0.00
	At most 1*	31.06**	3.84	0.00	31.06**	3.84	0.00
Nashik -Pimpalgaon	None *	63.33**	15.49	0.00	34.60**	14.26	0.00
	At most 1	28.73**	3.84	0.00	28.73**	3.84	0.00
Nashik - Pune	None *	74.44**	15.49	0.00	44.49**	14.26	0.00
	At most 1 *	29.95**	3.84	0.00	29.95**	3.84	0.00
Pimpalgaon - Pune	None *	82.40**	15.49	0.00	52.65**	14.26	0.00
	At most 1*	29.75**	3.84	0.00	29.75**	3.84	0.00

*, ** denote significance at 5 and 1 per cent level

Table 9: Market pair wise results of Granger Causality test for the price of tomato.

Market Pairs	No. of obs.	F-Statistic	P-value	Remarks
Mumbai - Nagpur	105	4.41*	0.01	Unidirectional
Nagpur-Mumbai	105	1.49	0.23	No causality
Mumbai - Nashik	105	5.18*	0.01	Unidirectional
Nashik -Mumbai	105	0.12	0.89	No causality
Mumbai - Pimpalgaon	105	10.03**	0.00	Unidirectional
Pimpalgaon-Mumbai	105	0.71	0.49	No causality
Mumbai - Pune	105	4.44*	0.01	Unidirectional
Pune-Mumbai	105	1.35	0.26	No causality
Nagpur - Nashik	105	3.66*	0.03	Unidirectional
Nashik-Nagpur	105	3.09	0.05	No causality
Nagpur - Pimpalgaon	105	6.27**	0.00	Bidirectional
Pimpalgaon-Nagpur	105	4.72*	0.01	Bidirectional
Nagpur - Pune	105	2.59	0.08	No causality

Pune-Nagpur	105	3.23*	0.04	Unidirectional
Nashik -Pimpalgaon	105	2.74	0.07	No causality
Pimpalgaon-Nashik	105	3.93*	0.02	Unidirectional
Nashik - Pune	105	0.68	0.51	No causality
Pune-Nashik	105	2.40	0.10	No causality
Pimpalgaon - Pune	105	1.61	0.20	No causality
Pune-Pimpalgaon	105	7.11**	0.00	Unidirectional

Conclusions

The maximum variability of tomato in arrivals was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune. The maximum variability of tomato in prices was noticed in Pimpalgaon market among the months as compared to Mumbai, Nagpur, Nashik and Pune. The overall significant negative correlation between arrivals and prices of tomato in Nagpur market was noticed. It indicated that arrivals and prices of tomato have moved in opposite direction in Nagpur market during the study period. The volatility shocks in the prices of tomato are quite persistence for long time in all selected markets except Pune market. The prices of tomato are co-integrated. It indicated that pair of markets moves together and efficiently functioning, competitive and closely associated. The market pair Nagpur-Pimpalgaon have bidirectional causality and Mumbai-Nagpur, Mumbai-Nashik, Mumbai-Pimpalgaon, Mumbai-Pune, Nagpur-Nashik, Pune-Nagpur, Pimpalgaon-Nashik and Pune-Pimpalgaon have a unidirectional causality. It is concluded that very high price volatility of tomato present in Mumbai, Nagpur, Nashik and Pimpalgaon markets. It should be minimized and needs to protect price security for farming community.

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