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Spatio-temporal integration of tomato markets in Karnataka state: An econometric analysis

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ABSTRACT

The present study attempts to examine existence of spatio temporal cointegration of major tomato markets in Karnataka state. Based on the arrivals, Mysore, Bangalore, Kolar and Chintamani markets were selected. The weekly wholesale modal prices were collected for the period of two years (2014 to 2016) from Agmarknet. Error correction and Johansen cointegration analysis was performed to examine the presence of cointegration between markets. The result indicated that Mysore, Kolar and Chintamani markets are cointegrated. The coefficient of error correction term signaling the speed of adjustment of disequilibrium between spatially separated markets was higher in case of Kolar and Chintamani market (52%) and was lower in case of Kolar and Mysore market (40%). The reason for faster rate of adjustment in case of Kolar and Chintamani is due to proximity (33 kms), availability of grading facility, and scientific storage facility in case of Kolar market.

***Keywords*: Error correction model, Johansen cointegration analysis, tomato markets**

In developing economies, markets are confronted with hurdles which impair their efficient functioning. The major hurdles are inadequate infrastructure, poor access to market information, restriction imposed by the state government on movement of goods between regions. If markets are not well integrated then it could result in erroneous price signals leading to inefficient allocation of resources, unequal distribution of marketed surplus ultimately hindering social welfare. Law of one price postulated that integrated markets are an indicator of absence of market imperfections and inefficiencies. Market integration stabilizes price, allocate resource efficiently and correct market imperfections. If markets are well integrated then government can focus on stabilizing market price in impetus market and the same signal will be transmitted to the rest of markets. Spatial market integration refers to smooth transmission of price signals and information across spatially separated markets. The nature and extent of spatial integration in developing economies like India is of immense importance for drawing most advantageous market related policies (Ravallion, 1986). Tomato is an important vegetable crop cultivated in an area of 64325 hectares with annual production of 2031152 tons in Karnataka state. Tomato plays a vital role in up-liftment of farming community through its prolific yield potential. Majority of farmers in the state mainly depend on this crop for cash income. Its inherent price volatility has put both farming community and government under severe trouble. Hence, attempt should be made to stabilize prices. For which knowledge of price transmission in spatially separated markets and extent of integration is crucial. Therefore, present study has been attempted to empirically estimate the degree of integration in major markets of tomato in Karnataka state.

MATERIALS AND METHODS

Data

Spatial integration of tomato market in Karnataka was estimated considering four major markets *viz*., Mysore Bandiplaya market (38.95%), Chintamani market (14.07%), Kolar market (25.61%) and Bangalore market (5.61%) based on their share in total arrivals (Table 1). Altogether these markets constituted 84.24 per cent of the total arrivals in the state. Data pertinent to weekly modal wholesale prices were collected 1/1/2014 to 31/6/2016 from AGMARKNET.

Tests of stationarity

1) Graphical analysis: Prior to empirical tests, it is advisable to plot the time series to get initial clue about the nature of time series. Time series with upward or downward trend could be suspected for the presence of random walk or unit root or non stationarity. In the presence of trend, mean of the time series remains invariant.

2)Autocorrelation function (ACF) and correlogram: Sample autocorrelation function is the ratio of sample covariance at lag k to sample variance. A plot of sample autocorrelation against k lags is known as sample correlogram. Sample autocorrelations at various lags hover around zero in case of stationary process. In case of non stationary process, sample autocorrelation coefficients are significant even upto several lags. Autocorrelation coefficient starts at a very high value at lag 1 and declines very slowly. To compute ACF upto one third to one quarter length of time series will be considered. Statistical significance of all the autocorrelation coefficients upto certain lags is tested using Q statistic developed by Box and Pierce.

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Sample autocorrelation function at lag k $(\rho\hat{k})$, $\rho\hat{k} = \frac{\gamma_{\hat{k}}}{\gamma_{\upsilon}}$

$\gamma\hat{k}$ = *sample covariance at lag k*

$\gamma_{\hat{O}}$ = *sample variance*

Q statistic developed by Box and Pierce

$$Q = n\sum_{k=1}^{m}\rho_{\hat{k}}^{2}$$

$\rho\hat{k}$ = sample autocorrelation coefficient, n = sample size, m= lag length

3) Unit root test/ test of random walk: It is an empirical test of stationarity (non stationarity) of a stochastic process. A stochastic process may possess unit root or random walk of different form *i.e.*, pure random walk, random walk with drift and random walk with drift around a stochastic trend. The presence of unit root in a stochastic process is determined using Dickey–Fuller test (DF), Augmented Dickey Fuller test (ADF) and Phillips-Peron test (PP). The DF test is estimated in three different forms and the procedure of the same is detailed below.

$\Delta Y_t = \delta Y_{t-1} + U_t$ when Y_t is a is a random walk

$\Delta Y_t = \beta_1 + \delta Y_{t-1} + U_t$ when Y_t is a random walk with drift

$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + U_t$, when Y_t is a random walk with drift around a stochastic trend

In each case, the formulated null hypothesis is $\delta = 0$ *i.e.*, there is a unit root or time series under consideration is non stationary. The alternative hypothesis is $\delta < 0$ inferring that time series is stationary. For the stated null hypothesis, the estimated 't' value of the coefficient of Y_{t-1} follows tau statistic. The error term (U_t) is assumed to be uncorrelated in DF test, in case if they are correlated, then Dickey and Fuller has suggested for deployment of Augmented Dickey Fuller test. ADF test is DF test augmented with lagged values of dependent variable (ΔY_t) to overcome the problem of serial correlation in error term. In the present study, ADF test was employed to determine presence of unit root in case of price series.

$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \sum_{t=1}^{m}\alpha_1 \Delta Y_{t-1} + \varepsilon_t$ is assumed to be white noise, ΔY_{t-1} lagged values of dependent variable.

In case of ADF test also the null hypothesis $\delta = 0$ *i.e.*, there is a unit root or time series under consideration is non stationary is made. ADF test also follows the same asymptotic distribution as that of DF statistic, so the same critical values (tau statistic) holds good.

Cointegration: Two variables are said to be co-integrated if they have long run equilibrium relationship. Regression of a unit root time series on another unit root time series results in spurious regression. Such regression model is of no use in econometric sense unless their residual/ error term is stationary. Stationarity of error term of such regression confirms the presence of long run equilibrium relationship between them.

Tests for cointegration: The presence of cointegrating relationship between time series was determined performing below mentioned tests

1) Conventional method: The extent to which prices in spatially separated markets move together reflects the degree of integration. Correlation of prices prevailing across markets is an indicator of pricing efficiency exhibiting the degree of interrelationship in price movements. Uma Lele defined interrelationship between price movements in two markets as market integration. The degree of correlation between prices in selected markets is considered as indicator of the extent to which two markets are integrated. A high degree of correlation coefficient indicates greater degree of integration atleast in terms of pricing of the product. If correlation is one then markets are said to be perfectly spatially integrated. If correlation coefficient between prices is 0.9 or more then it is interpreted as high degree of inter market price relationship because in such case 81 per cent of the total variation in the prices of one market is associated with that in another market and rest 19 per cent may be due to transportation, market information and data bottlenecks.

2) Conducting DF or ADF unit root test on the residuals estimated from the co-integrated regression/ Engel- Granger (EG) or Augmented Engel Granger (AEG) test

Estimate regression equation between non stationary time series and such a regression is termed as cointegrating regression. The residual obtained from the cointegrating regression equation is tested for the presence of unit root or non stationarity using ADF test. If residual of the cointegrating regression is I(0) *i.e.*, stationary, then such regression is said to be non spurious signaling the presence of long run equilibrium relation or co-integration between those variables.

3) Cointegrating Regression Durbin Watson test (CRDW)

An alternative and quicker method of finding cointegration between time series is through CRDW test. The critical values for CRDW test was given by Sargan and Bhargava. CRDW test is based on Durbin- Watson 'd' statistic obtained from the co-integrating regression. The null hypothesis to test the presence of cointegration or unit root is d = 0 rather than standard d = 2 since d = 2(1- $\hat{\rho}$). In the presence of unit root, the estimated value of ρ will be 1 and corresponding 'd' will be zero. Around 10000 simulations from 100 observations were formed to test the null hypothesis (d = 0) at different level of significance (1%, 5% and 10%) using critical values. The obtained critical values at different level of significance are 0.511, 0.386 and 0.322, respectively. Thus, if the'd' value of cointegrating regression is less than 0.511, the null hypothesis of cointegration will be rejected at 1 % significance level or vice versa.

4) Error correction model (ECM)

If two time series are co-integrated then there exists long run equilibrium relationship on one hand and short run disequilibrium on other hand. The error term of the cointegrating regression could be regarded as equilibrium error capable of tying short run behavior to long run value. ECM is represented as $\Delta P_{1t} = \beta_0 + \beta_1 \Delta P_{2t} + \beta_3 u_{t-1} + \in_t$ where, denotes first difference operator, $\in$ is the random error term, u_{t-1} is the one period lagged value of the error term from the cointegrating regression, P_{1t} and P_{2t} are prices of tomato in two different markets. In ECM equation ΔP_{1t} depends on ΔP_{1t} and equilibrium error term. If error term is non zero, then the model is out of equilibrium. If it takes positive value then equilibrium cannot be restored. Hence, error term is expected to take negative value to correct disequilibrium. The coefficient of lagged error correction term indicates the time required for restoring equilibrium, connoted as speed of adjustment coefficient.

5) Johansen cointegration model

Johansen (1988) and Johansen and Juselius (1990) developed a multivariate cointegration method, a robust technique for testing long run equilibrium relationship between stationary price variables. It constructs a test statistic called the likelihood ratio (LR) to determine number of cointegrating vectors in a cointegrating regression. Trace and maximum eigen value test statistic are used for the above purpose. The former statistic test the null hypothesis of 'r' cointegrating vectors, where r = 0,1,2,…..n-1, it is computed as

$$\text{LR tr} \left(\frac{r}{n}\right) = -T\sum_{t=r+1}^{n} \log(1-\lambda)$$

The later test the null hypothesis of cointegrating vectors against the alternative of r+1 cointegrating vectors for r = 0,1,2……n-1. This test statistic is computed as

$$\text{LR max} \left(\frac{r}{n}+1\right) = -T \log(1-\lambda)$$

n = number of variables in the system, λ = max eigen value, T= sample size

Johansen cointegration test is widely used since it treats all the variables as explicitly endogenous and takes care of endogenity problem by providing an estimation procedure that does not require arbitrary choice of a variable for normalization.

RESULTS AND DISCUSSION

Conventional measure of cointegration

The perusal of Table 1a provides the information on the bi-variate correlation between the price series of the selected market pairs of tomato in Karnataka state. The correlation coefficient ranged between 0.88 in case of Chintamani-Bangalore to 0.925 in case of Mysore-Bangalore market pairs. The correlation coefficients were found to be significantly high across different market pairs indicating the presence of high degree of market integration. According to conventional correlation measure of cointegration all the selected tomato markets were found to be integrated. But in reality, conventional measure loses its econometric plausibility if price series under consideration are non stationary because correlation between non stationary time series will be spurious. Hence, an attempt has been made to use modern approaches to determine the existence of market integration after giving due consideration for inherent non stationary property of price series.

Examination of stationarity based on graphical approach, autocorrelation function and correlogram

Time series plot of various market prices provided initial clue about the likely nature of the price series. The perusal of Fig 1-3 showed the upward trend of market prices indicating the changing mean over time in case of Mysore market, Chintamani market and Kolar market. The upward trend confirms non stationarity of price series or presence of unit root in price series. In case of Bangalore market, apparent trend is not visible (Fig 4). Hence, it is difficult to suspect presence of unit root.

Sample autocorrelation functions were computed for 50 lags considering 1/3rd length of price series across all the markets. Correlogram of wholesale price series in case of Mysore market, Chintamani market and Kolar market tapered gradually excepting Bangalore market reiterating the presence of unit root or non stationarity Fig (5-8) .

Augmented Dickey Fuller unit root test

The results of ADF unit root test of wholesale price series prevailing in Mysore, Kolar, Chintamani and Bangalore tomato markets at level I(0) and first difference I(1) is presented in Table 2. The ADF test was conducted with null hypothesis of non stationarity or presence of unit root in price series against stationarity of price series as an alternative hypothesis. The null hypothesis of non stationarity in price series at level could not be rejected for all the markets excepting Bangalore at 5 per cent level of significance. Non stationary price series are subjected for first differencing and tested for the presence of unit root or stationarity. After first differencing, all the price series become stationary and is reflected in significant test statistic (tau) of ADF test at 5 per cent level. From ADF test, it could be inferred that tomato prices in Mysore, Kolar and Chintamani markets are integrated of same order I(1). The price series which are integrated of same order could be subjected for cointegration analysis to examine the degree of integration.

CRDW test of cointegration

Cointegration between price series was also assessed based on Cointegrating Regression Durbin Watson test. Cointegrating regression equation was estimated for following market pairs *i.e*., prices in Mysore market was regressed on prices in Kolar market (eq 1), prices in Mysore market was regressed on prices in Chintamani market (eq 2) and prices in Kolar market was regressed on prices in Chintamani market (eq 3). The overall significance of estimated regression models were reflected in significant 'F' statistic. The explanatory power of cointegrating regression models expressed in terms of adjusted coefficient of determination was 79.69 %, 85% and 82% in case of eq 1, eq 2 and eq 3, respectively. In CRDW test, the null hypothesis of d = 0 was tested across three cointegrating regressions. The null hypothesis was tested considering critical values at different significance level. The critical value at 1 % level of significance was 0.511. Durbin Watson statistic in three cointegrating regressions was in the order of 0.97, 1.02 and 1.04. These values were compared with critical value of 0.511 at 1 per cent significance level. Since'd' value in all the cointegrating regressions were more than 0.511, the null hypothesis of cointegration among market pairs could not be rejected. The results of CRDW test reiterates the existence of cointegrating relation between selected markets.

Cointegration regression between selected pairs of tomato market in Karnataka

Mysore = 286.98 + 1.05 Kolar

(4.29) (24.76) R^2 = 0.79

Durbin Watson 'd' = 0.97 ………………(1)

Mysore = 176.83 + 1.13 Chintamani

(3.01) (30.05) R^2 = 0.85

Durbin Watson 'd' = 1.02 ………………(2)

Kolar = 61.83 + 0.94 Chintamani

(1.14) (27.01) R^2 = 0.82

Durbin Watson 'd' = 1.04 ………………(3)

Cointegration analysis based on Johansen's test

Johansen cointegration test is based on principle of maximum likelihood estimation. The prerequisite for Johansen test is selection of optimum number of lags to know the Gaussian error terms. The optimal lag length of 2 lags was selected for the considered price series based on Akaike Information Criteria and Schwarz Information Criteria (Table 3). The results of Johansen cointegration relationship between selected tomato markets are presented in Table 4. The cointegration test is based on two test statistic *viz*., trace statistic and maximum eigen value estimated for the purpose of testing null hypothesis of 'r' cointegrating vectors against alternative hypothesis of 'r+1' cointegrating vectors. The null hypothesis of r = 0 (absence of cointegrating vectors or lack of cointegration) was rejected at 1 percent level of significance across market pairs such as Mysore& Kolar, Kolar & Chintamani and Mysore and Chintamani. But the null hypothesis of r = 1 could not be rejected based on trace statistic and maximum eigen value at 5 percent level of significance across above mentioned market pairs. This result clearly indicated the presence of cointegration or long run equilibrium relation between markets. The likely reasons for cointegration are proximity, existence of infrastructural facilities in these markets.

Estimation of speed of adjustment coefficient

From the results of Engel granger test, CRDW test and Johansen cointegration test, price series under consideration were found to be co-integrated. This further prompts researcher to determine Error correction mechanism (ECM). ECM is a means of reconciling short run behavior of a price with its long run behavior. The result of error correction model is presented in Table. The coefficients of the variable " Kolar in eq (4), "Chintamani in eq (5), "Chintamani in eq (6) represents short run changes in dependent variable " Mysore in eq (4), "Mysore in eq (5), "Kolar in eq (6). The coefficient of error term is crucial and is capable of reconciling disequilibrium. The coefficient of error term was statistically significant and negative in all the three ECM models reflecting the capability of restoring equilibrium. The error term otherwise called speed of adjustment coefficient expressed in percentage indicates the rate at which disequilibrium could be reconciled. The speed of adjustment coefficient was highest in case of Kolar and Chintamnai market pair (52%) and lowest in case of Mysore and Kolar market pair (40%). If speed of adjustment coefficient is 52 per cent, it means that any deviation or disequilibrium in prices of Kolar market due to prices in Chintamani market in previous period

Table 1: Major tomato markets in Karnataka state

Major Tomato Markets	Arrivals (Tons)	% Share
Mysore	629920	38.95
Kolar	414162	25.61
Chintamani	227588	14.07
Bangalore	90772	5.61
Total arrivals in the state	16,17,341	

Table 1a: Bivariate correlation matrix of tomato price series in selected markets of Karnataka

	Mysore	Kolar	Chintamani	Bangalore
Mysore	1.000	0.893**	0.924**	0.925**
Kolar	0.893**	1.000	0.908**	0.898**
Chintamani	0.924**	0.908**	1.000	0.888**
Bangalore	0.925**	0.898**	0.888**	1.000

Table 2: ADF test of unit root

Markets/ ADF test	At level		After first difference	
	Tau statistic	P value	Tau statistic	P value
Mysore	-3.18	0.086	-3.73	0.019
Kolar	-3.28	0.069	-9.74	0.001
Chintamani	-3.15	0.093	-3.56	0.030
Bangalore	-3.81	0.015		

Table 3: Optimum lag selection to perform Johansen's cointegration test

Lags	Log likelihood	AIC	BIC	HQC
1	-2907.04	43.94	44.26*	44.07
2	-2892.38	43.85*	44.37	44.06*

Table 4: Summary of Johansen's cointegration test for selected market pairs of tomato

Market pairs	Rank	Trace statistic	P value	L max statistic	P value
Mysore - Kolar	0	53.26	0.0001	42.54	0.0001
	1	10.72	0.09	10.72	0.09
Mysore - Chintamani	0	38.92	0.0006	27.71	0.001
	1	10.57	0.10	10.57	0.10
Kolar- Chintamani	0	46.74	0.0001	36.48	0.0001
	1	10.25	0.12	10.25	0.12

Table 5: Speed of adjustment coefficient/ Error correction coefficient between selected market pairs

Market pairs	Speed of adjustment coefficient (%)
Mysore- Kolar	39.85
Kolar – Chintamani	52.00
Mysore – Chintamani	49.00

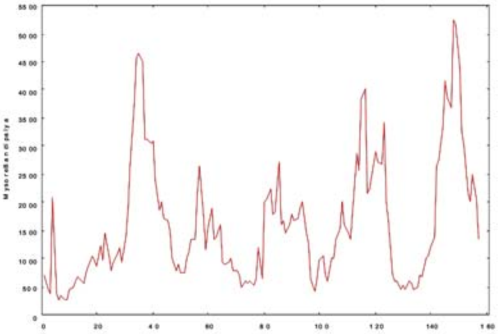

Fig. 1: Time series plot of tomato price in Mysore market

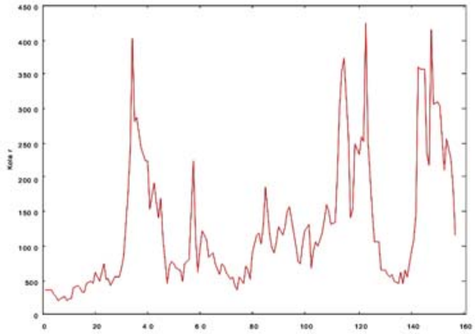

Fig. 2: Time series plot of tomato price in Kolar market

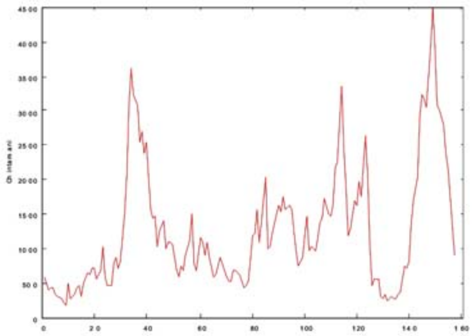

Fig. 3: Time series plot of tomato price in Chintamani market

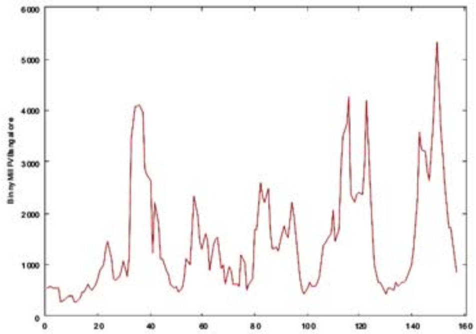

Fig. 4: Time series plot of tomato price in Bangalore market

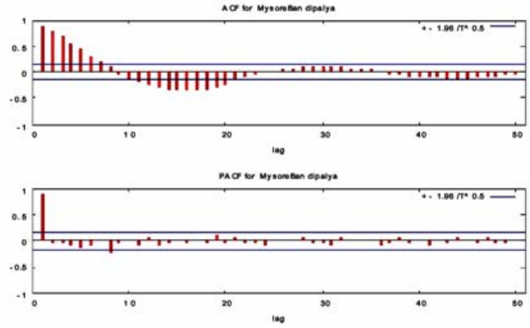

Fig. 5: Correlogram of tomato price series in Mysore market

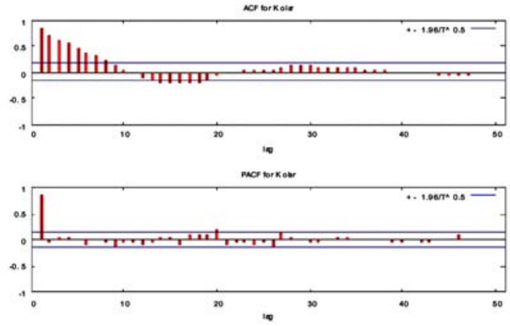

Fig. 6: Correlogram of tomato price series in Kolar market

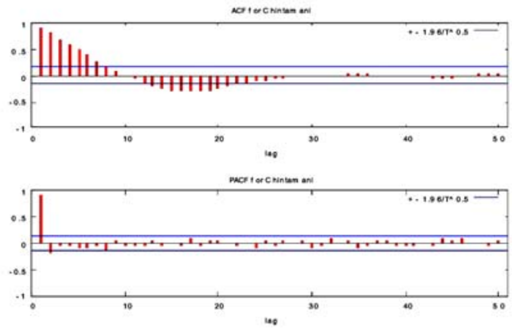

Fig. 7: Correlogram of tomato price series in Chintamani market

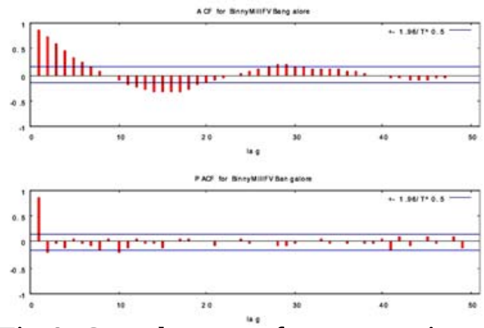

Fig. 8: Correlogram of tomato price series in Bangalore market

will be reconciled at the rate of 52 per cent every week (Table 5). The reason for faster rate of adjustment in case of Kolar and Chintamani is due to proximity (33 kms), availability of grading facility, and scientific storage facility in case of Kolar market. The speed of adjustment coefficient was lowest in case of Mysore and Kolar and it is mainly because of travel distance of 233 km.

Error correction models

$$\Delta \text{ Mysore} = 1.10 + 0.67\, \Delta \text{ Kolar} - 0.39\, e_{t-1} \quad \ldots (4)$$
$$(0.03) \qquad (10.75) \qquad (-6.21)$$

$$\Delta \text{ Mysore} = 1.88 + 0.91\, \Delta \text{ Chintamari} - 0.49\, e_{t-1} \quad .. (5)$$
$$(0.06) \qquad (11.42) \qquad (-7.13)$$

$$\Delta \text{ Kolar} = 2.60 + 0.85\, \Delta \text{ Chintemant} - 0.52\, e_{t-1} \quad \ldots (6)$$
$$(0.09) \qquad (11.27) \qquad (-7.39)$$

The conventional correlation method indicated that all the major markets of tomato in Karnataka state are spatially integrated with a high degree of price correlation. The degree of integration was higher in case of Mysore- Bangalore and Mysore- Chintamani. In contrast, modern method of cointegration analysis indicated that Bangalore market is not having integration with other tomato markets. This contrasting result is accredited to inefficiency of correlation approach to account for inherent non stationarity in the price series, resulting in spurious correlation. Modern methods indicated that Mysore, Kolar and Chintamani tomato markets are spatially integrated. The existence of disequilibrium in markets could be corrected in long run at the rate of speed of adjustment coefficient. The speed of adjustment of disequilibrium was highest in case of Kolar and Chintamani market (52%) followed by Mysore and Chintamani market (49%). The reasons for quick adjustment are existence of necessary market infrastructure such as grading, scientific storage, good road connectivity, banking facility, boarding facility to farmers in Mysore and Kolar markets. Government intervention in improving the degree of market integration is imperative to achieve equitable, efficient and stable markets for tomato. Necessary infrastructure should be created in Chintamani market and infrastructure related to value addition should be created in Kolar and Chintamani market to stabilize volatile market prices of tomato.

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