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An econometric analysis of market integration in Telangana maize markets

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Abstract

This study tests long-run spatial market integration between price pairs of maize in five major markets *viz*., Badepally, Karimnagar, Siddipet, Nagarkurnool and Warangal of the Telangana State by adopting important econometric tools like Johansen's multivariate co integration approach, Augmented Dickey-Fuller (ADF), Granger causality test and Vector Error Correction Model (VECM). The study has confirmed the presence of co integration, implying the five years price association among the markets. To get the additional evidence as to whether and in which direction price transmission is occurring between the market pairs, Granger causality test has been used, which has confirmed Badepally to be the price-determining market. Badepally has been found comparatively more efficient as it has depicted most bidirectional causal relations with other markets. The Vector Error-Correction Model (VECM) shown the selected markets of maize are employed to know the speed of adjustments for the prices of maize among selected markets, for short run and long run equilibrium of prices. The results show that Badepally market influence prices in the other three major markets i.e., Warangal, Siddipet and Karimnagar.

Keywords: Market integration, maize, co integration, granger causality, VECM

Introduction

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated in about 164 countries having wider diversity of soil, climate, biodiversity and management practices. United States of America is the largest producer of maize contributing nearly 29.96% of the total production in the world. Other important growing countries are China, Brazil, Argentina, India, Mexico, Ukraine, Indonesia and South Africa.

In India, maize is grown throughout the year. It is predominantly a kharif crop with 87 per cent of the area under cultivation in the season. Maize is the third most important cereal crop in India after rice and wheat. It accounts for around 10 per cent of total food grain production in the country. During 2024-25, area under maize was 120.91 lakh hectares as compared to 112.41 lakh hectares during 2023-24. Major maize growing states in India are Madhya Pradesh, Karnataka, Maharashtra, Rajasthan, Bihar, Uttar Pradesh, Telangana, Tamil Nadu and Gujarat. According to the final advance estimates 2024-25, Government of India Maize crop is estimated at 434.09 lakh tonnes as compared to 376.65 lakh tonnes in 2023-24. The leading states of final advance estimates in 2024-25. Madhya Pradesh 66.42 lakh tone followed by Karnataka 61.90 lakh tonnes, Bihar 54.68 lakh tonnes, Maharastra 47.49 lakh tonnes, Telangana 33.92 lakh tonnes, West Bengal 28.36 lakh tonnes, Rajasthan 26.78 lakh tonnes, Tamil Nadu 26.63 lakh tonnes and Andhra Pradesh 21.48 lakh tonnes. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. In Telangana, during 2024-25 area under maize was 5.79 lakh hectares as against 4.90 lakh hectares during 2023-24. Major maize growing districts in Telangana include Siddipet, Nagarkurnool, Rangareddy, Vikarabad, Mahabubnagar, Kamareddy, Nizamabad, Karimnagar and Jagtial contributing nearly 85% of total maize production. According to Final Advance Estimates of Production of Food grains for 2024-25, Maize production estimate was 33.92 lakh tonnes in Telangana State.

An indirect means of analyzing market efficiency is to test for market integration. Three types of market integration are identified in the literature, inter-temporal, vertical and spatial. Inter temporal market integration relates to the arbitrage process across periods. Vertical market integration is concerned with stages in marketing and processing channels. Spatial integration is concerned with the integration of spatially distinct markets i.e., if price changes in one market are fully reflected in alternative market then these markets are said to be spatially integrated. The concept of market integration has normally been applied in studies involving spatial market inter-relatedness. Market integration is a central issue in many contemporary debates concerning the issues of market liberalization. Market integration is perceived as a precondition for effective market reform in developing countries. The high degree of market integration means the markets are quite competitive and provide little justification for extensive and costly government intervention designed to improve competitiveness to enhance market efficiency. Markets that are not integrated may convey inaccurate picture about price information that might distort production decisions and contribute to inefficiencies in markets, harm the ultimate consumer and lead to low production and sluggish growth.

In India, there exist several studies, which have analyzed market integration in food grain crops such as wheat, rice etc. (Ghosh, 2003; Ghosh, 2011; Ghoshray and Ghosh, 2011; Acharya, *et al.*, 2012; Ghosh, 2012; Sekhar, 2012) [5, 6, 7, 1,.]. The existing literature on market integration in horticultural crops is quite scanty (Basu, 2006; Beag and Singla, 2014; Wani, *et al.*, 2015) [2, 3, 9], while no such studies except Sendhil*et al.*, (2014) [10] and Reddy *et al.* (2012) [11] exist in onion, which analyze market integration and price transmission in spatially separated markets. Both the studies were conducted in pre-2011 period during which the prices of onion were generally stable and as such impact of price shocks in one market was not visible in other markets. The formulation of valid study on the market integration in onion has potential application for the development of agricultural markets. Against this backdrop, the existing study analyses market integration in onion and its price transmission analysis in selected markets of India. We find a substantial body of research literature on the issue of agricultural markets integration in the developing countries (Goletti and Babu, (1994) [16], Dercon (1995) [15], Baulch, B. (1997) [13], Dawson and Dey (2002) [14], Jha*et al.*, (2005) and Bakhshoodeh and Sahraeiyan (2006)) [12]. Tahir Mukhtar and Muhammad Tariq Javed. 2007 [17].

Materials and Methods

For price integration, simple bivariate correlation coefficients measure price movements of a commodity in different markets. This is the simplest way to measure the spatial price relationships between two markets. Early inquiries on spatial market integration, for example Lele (1967) [18] and Jones (1968) [19] have used this method. However, this method clearly has some limitations, as it cannot measure the direction of price integration between two markets. The cointegration procedure measures the degree of price integration and takes into account the direction of price integration. This econometric technique provides more information than the correlation procedure, as it allows for the identification of both the integration process and its direction between two markets.

Market Integration Test

Market integration is tested using the cointegration method, which requires that

Two variables, say P_{it} and P_{jt} are non-stationary in levels but Stationary in first differences i.e. $P_{it} \sim I(1)$ and $P_{jt} \sim I(1)$.

There exists a linear combination between these two series,

Which is stationary i.e. υ_{it} (=P_{it} α $\hat{\beta}P_{it}$) $\sim I(0)$.

So the first step is to test whether each of the univariate series is stationary. If they are both I (1) then we may go to the second step to test cointegration. The Engle and Granger (1987) procedure is the common way to test cointegration.

Unit root test

The regression analysis of non-stationary time series produces spurious results, which can be misleading (Ghafoor, *et al.*, 2009) [20]. The most appropriate method to deal with non-stationary time series for estimating long-run equilibrium relationships is cointegration, which necessitates that time series should be integrated of the same order. Augmented Dickey- Fuller (ADF) and Phillips-Perron test (PP) is used to verify the order of integration for each individual series. The ADF test, tests the null hypothesis of unit root for each individual time series. The rejection of the null hypothesis indicates that the series is non-stationary and *vice-versa* (Dickey and Fuller, 1981). The number of the appropriate lag for ADF is chosen for the absence of serial correlation using Akaike Information Criterion (AIC). The ADF test is based on the Ordinary Least Squares (OLS) method and requires estimating the following model.

$$\Delta lnP_t = \alpha_0 + \delta_1 t + \gamma lnP_{t-1} + \sum_{j=1}^{q} \vartheta_j \Delta lnP_{t-j} + \varepsilon_t$$

Where, P the price in each market, Δ is the difference parameters (i.e., $\Delta P1 = P_t - P_{t-1}$, $P_{t-1} = P_{t-1} - P_{t-2}$ and $P_{n-1} = P_{n-1} - P_{n-2)}$ and so on, α_0 is the constant or drift, t is the time or trend variable, q is the number of lags length and ε_t is a pure white noise error term.

Johansen Cointegration

The maximum likelihood (ML) method of cointegration is applied to check long-run wholesale prices relation between the selected markets of India (Johansen, 1988; Johansen and Juselius, 1990) [21, 22]. The starting point of the ML method is vector autoregressive model of order (k) and may be written as:

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

Where, (n*1) denotes the vector of non-stationary or integrated at order one, i.e., I (1) prices series. The procedure for estimating the cointegration vectors is based on the Vector error correction model (VECM) representation given by:

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

Where,

Γ_i= -(I-Π$_i$-….,T); i=1,2,….k-1

Π = − (I-Π, −………Π$_k$)

Both Γi and Πi are the n*n matrixes of the coefficient conveying the short and long run information respectively, μ is a constant term, t is a trend, and ε_t is the n-dimensional vector of the residuals that is identical and independent distributed. The vector ΔP_t is stationary P_t is integrated at order one I(1) which will make unbalance relation as long as Π matrix has a full rank of k. In this respect, the equation can be solved by inversing the matrix Π^{-1} for Pt and as a linear combination of stationary variable. The stationary linear combination of the Pt determines by the rank of Π matrix. If the rank r of the matrix Π r=0 the matrix is the null and the series underlying is stationary. If the rank of the matrix Π is such that 0 < rank of (Π) = r < n then there are n × r cointegrating vectors. The central point of the Johansen's procedure is simply to decompose Π into two n × r matrices such that Π=αβ'. The decomposition of Π implies that the β'Pt are r stationary linear combination.

Johansen and Juselius, (1990) [22] proposed two likelihood ratio test statistics (Trace and Max Eigen test statistics) to determine the number of cointegrating vectors as follows:

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

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

Where, r is the number cointegrated vector, $\widehat{\lambda}_1$ is the eigen value and $\widehat{\lambda}_{r+1}$ is the$(r+1)^{th}$ largest squared eigen value obtained from the matrix Π and the T is the effective number of observation. The trace statistics tested the null hypothesis of r cointegrating vector(s) against the alternative hypothesis of n cointegrating relations. The Max Eigen statistic tested the null hypothesis (r =0) against the alternative $(r + 1)$.

Vector Error Correction Model (VECM)

If price series are I (1), then one could run regressions in their first differences. However, by taking first differences, we lose the long-run relationship that is stored in the data. This implies that one needs to use variables in levels as well. Advantage of the vector error correction model (ECM) is that it incorporates variables both in their levels and first differences. By doing this, VECM captures the short-run disequilibrium situations as well as the long-run equilibrium adjustments between prices. Even if one demonstrates market integration through cointegration, there could be disequilibrium in the short-run i.e. price adjustment across markets may not happen instantaneously. It may take some time for the spatial price adjustments. VECM can incorporate such short-run and long-run changes in the price movements.

A VECM formulation, which describes both the short-run and long-run behaviors of prices, can be formulated as:

$$\Delta P_{it} = \gamma_1 + \gamma_2\Delta P_{jt} - \pi\hat{\upsilon}_{it-1} + v_{it}. \qquad (4)$$

In this model, γ_2 is the impact multiplier (the short -run effect) that measures the immediate impact tha t a change in P_{jt} will have on a change in P_{it}. On the other hand, π is the feedback effect or the adjustment effect that shows how much of the disequilibrium is being corrected, that is the extent to which any disequilibrium in the previous period effects any adjustment in the P_{it} period of course $\hat{\upsilon}_{t-1} = P_{it-1} - \hat{p}_1 - \hat{p}_2 P_{ji-1}$ and therefore from this equation we also have ρ_2 being the long-run response.

Granger Causality Test

If a pair of series is cointegrated then there must be Granger causality in at least one direction, which reflects the direction of influence between series (in our case prices). Theoretically, if the current or lagged terms of a time-series variable, say P_{it}, determine another time-series variable, say P_{it}, then there exists a Granger causality relationship between $P_{jt}$and P_{it}, in which P_{it} is Granger caused by P_{it}. Bessler and Brandt (1982) firstly introduced this test into research on market integration to determine the leading market.

From the above analysis, the model is specified as follows:

$$\Delta P_{it} = \theta_{11}\Delta P_{it-1} + \ldots + \theta_{1n}\Delta P_{it-n} + \theta_{21}\Delta P_{jt-1} + \ldots \theta_{2n}\Delta P_{jt-n} - \gamma_1(P_{it-1} - \alpha P_{jt-1} - \delta) + \varepsilon_{1t}$$

$$\Delta P_{jt} = \theta_{31}\Delta P_{jt-1} + \ldots + \theta_{3n}\Delta P_{it-n} + \theta_{41}\Delta P_{it-1} + \ldots \theta_{4n}\Delta P_{it-n} - \gamma_2(P_{it-1} - \alpha P_{jt-1} - \delta) + \varepsilon_{2t}$$

The following two assumptions are tested using the above two models to determine the Granger causality relationship between prices.

$\theta_{21} = \ldots = \theta_{2n} = \cdots = \gamma_1 = 0$ (No causality from P_{jt} to P_{it})

$\theta_{41} = \ldots = \theta_{4n} = \cdots = \gamma_2 = 0$ (No causality from P_{it} to P_{jt})

Results and Discussion

Our price data consist of monthly modal prices of maize (Rs/qtl) in five major markets *viz*. Badepally, Nagarkurnool, Karimnagar, Siddipet and Warangal of the Telangana State using monthly maize prices over the period from January 2020 to December 2024. The data was taken from the websites of agriculture marketing government of Telangana http://tsmarketing.in/ and https://agmarknet.gov.in/. The maize modal price trend of all the selected markets is presented in Fig. 1, which shows the symmetric behavior in the movement of prices in all the selected markets except Warangal, the maximum modal price of 2880.00 Rs/ quintal prevailed in Nagarkurnool and the minimum price was found in Nagarkurnool 1193.00 Rs/ quintal followed by Karimnagar 1228 Rs/ quintal.

Descriptive Statistics

The summary statistics indicate that maize prices have been highly volatile in Nagarkurnool, followed by Warangal, as shown by their high coefficients of variation. The Badepally market, being the largest producer of maize in Telangana, experiences price fluctuations primarily influenced by the demand in other markets. Among the markets, the highest average prices for maize were observed in Siddipet, whereas the lowest average prices were recorded in Karimnagar and Badepally. Present in (Table 1).

Table 1: Summary Statistics of the monthly modal Prices for Maize in major markets for Telangana State from the period January, 2020 to December, 2024 (in `/100 kg)

	Badepally	Nagarkurnool	Karimnagar	Siddipet	Warangal
Mean	1893.55	1916.18	1843.48	1923.95	1914.53
Median	1898.00	2008.00	1825.50	2035.00	2011.50
Maximum	2410.00	2880.00	2510.00	2549.00	2629.00
Minimum	1316.00	1238.00	1228.00	1193.00	1257.00
Std. Dev.	322.20	401.23	359.10	361.60	391.45
CV	17.02	20.94	19.48	18.79	20.45

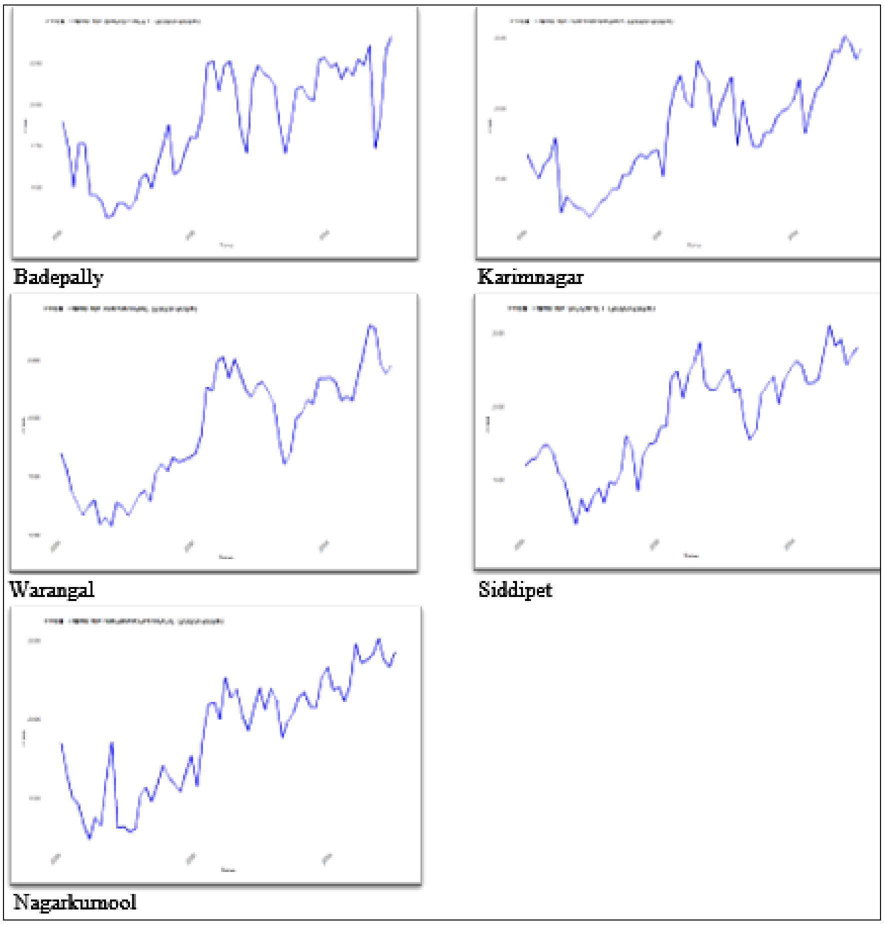

Fig 1: Price behavior (`Rs/quintal) of Maize crop in major selected markets in Telangana State.

Order of the Integration

In order to check the stationarity of price series of maize, the standard ADF and PP unit root tests, are applied to determine the order of integration. The unit root test regression implies that regressing the first difference of a series with its one period lag and several lags (as suggested by the various lag length criterion) of the first differenced series. The null hypothesis of ADF and PP tests is accepted or rejected based on the critical value and corresponding probability value. If the test statistics is smaller in absolute terms than the critical values and the corresponding probability value is greater than 5% level, the series is said to be non-stationary. The results of the ADF and PP test values are below the critical value at 5% level of significance indicating the non existence of unit root test. This implies that the Maize price series are non stationary at level in Badepally, Karimnagar, Siddipet and Warangal, only one market is stationary at level i.e., Nagarkurnool market. Remaining four markets i.e., Badepally, Karimnagar, Siddipet and Warangal are stationary at first difference I (1).

Table 2: ADF and PP Tests for Unit Root in the modal prices of maize

Augmented Dickey-Fuller test results at level				Phillips-Perron test results at level		
	t-Statistic	Prob.*	Remarks	t-Statistic	Prob.*	Remarks
Badepally	-2.85	0.22	Non-stationary	-22.08	0.03	Non-stationary
Nagarkurnool	-3.60	0.04	Stationary	-38.90	0.01	Stationary
Karimnagar	-2.00	0.57	Non-stationary	-17.40	0.09	Non-stationary
Siddipet	-2.48	0.37	Non-stationary	-13.52	0.30	Non-stationary
Warangal	-2.41	0.40	Non-stationary	-13.30	0.31	Non-stationary

Augmented Dickey-Fuller test results after differencing				Phillips-Perron test results after differencing		
ΔBadepally	-4.08*	0.01	Stationary	-46.41*	0.01	Stationary
Nagarkurnool	-3.60*	0.04	Stationary	-38.90*	0.01	Stationary
ΔKarimnagar	-4.16*	0.01	Stationary	-68.05*	0.01	Stationary
ΔSiddipet	-4.76*	0.01	Stationary	-55.48*	0.01	Stationary
ΔWarangal	-4.55*	0.01	Stationary	-45.45*	0.01	Stationary

Notes: * denote significance at 1% levels of significance and Δ denote the first difference of the time series.

Co-integration Analysis

Johansen's Co-integration test for selected maize markets for the long-run co-integration was performed. If two series are potentially co-integrated, at least one co-integration relationship exists. Co-integration may be affected by some facts, such as transportation cost, tariffs, and so on. The two tests, i.e., trace and max Eigen statistics of Johansen's approach based on the vector autoregressive model (VAR) were put into the application to analyze the cointegrating vectors between the selected maize markets. The results of Johansen's maximum likelihood tests (maximum eigen-value and trace test) are reported in Table 3. The first null hypothesis of maximum eigen-value and trace test, tests the no cointegration (r = 0) against the alternative hypothesis (r ≥ 1) of at least one cointegrated equation prevailed in the VAR system. Both, the maximum eigen-value and trace test reject the null hypothesis of no cointegration. The rejection/acceptance of the null hypothesis is decided by the trace max- eigen test statistic values against their critical value and corresponding probability value which is less than test statistic in the first null hypothesis. Similarly, the null hypotheses from r ≤ 1 to r ≤ 2 for both the statistics were rejected against their alternative hypotheses from the r ≥ 1 to r ≥ 3 as their critical values are less than the test statistics and the corresponding probability values are also less than 0.05. This implies that Johansen co-integration test indicate that the maize markets in Telangana exhibit significant long-run co-integration. There are three co-integrating relationships among the five markets, suggesting that they are closely linked and move together over time. These findings have important implications for understanding the market integration and price transmission mechanisms in the region. Policymakers, traders, and stakeholders can use this information to design strategies that promote market efficiency and stability, ensuring that price changes in one market are reflected across others in a predictable manner.

Table 3: Johansen's Co-integration Test Results of five major Maize Market prices in Telangana State

Hypothesized No. of CE(s)	H_0	H_1	Eigen value	Trace Statistics results			Max-Eigen Statistics results		
				Trace Statistics	0.05 Critical Value	P-Value	Max-Eigen Statistic	0.05 Critical Value	P-Value
None	r =0	r≥1	0.435	120.45*	88.80	0.000	50.43*	43.60	0.001
At most 1	r≤1	r≥2	0.281	70.12*	63.00	0.023	38.77*	37.55	0.042
At most 2	r≤2	r≥3	0.082	45.32*	42.34	0.038	35.18*	31.24	0.037
At most 3	r≤3	r≥4	0.059	20.14	25.32	0.256	14.10	23.62	0.421
At most 4	r≤4	r=5	0.047	5.18	12.25	0.612	12.96	12.96	0.775

Notes: in represent the natural logarithm and * denote the rejection of null hypothesis at 5% level of significance

Table 4 shows the results of bivariate Trace and Maximum Eigen-value tests. For all the Maize markets pairs, the first null hypothesizes of r=0 are rejected as the critical value is less than both from the trace and max Eigen statistics, and corresponding probability value is also less than 5% level of significance. Some market pairs (e.g., Badepally-Nagarkurnool, Nagarkurnool-Siddipet, Nagarkurnool-Warangal and Karimnagar-Nagarkurnool) do not show further co-integration at r≤1, r≥2. Markets like Siddipet-Warangal, Badepally- Karimnagar, Badepally-Warangal, Karimnagar - Siddipet, Karimnagar - Warangal and Badepally-Siddipet exhibit the strongest co-integration relationships, reflecting high interdependence. Hence, it can be concluded that only most of the Maize markets (like Badepally-Nagarkurnool, Nagarkurnool-Siddipet, Nagarkurnool-Warangal and Karimnagar-Nagarkurnool) are the Telangana state are efficiently functioning. Moreover, the Johansen's Trace and Maximum Eigen-value tests signify that the modal prices in these maize markets are competitive. In the competitive markets, the movements of the prices are closely associated. The study has conformity with most of the regional research work, which also revealed that the major maize markets are efficiently functioning and prices are well transmitted and cointegrated (Reddy *et al.*, 2012; Sendhil *et al.*, 2014; Rajendran, 2015) [11, 10,]. The null hypotheses for both the trace and trace max Eigen statistics are no cointegration equation against the alternative hypothesis of at least one cointegration equation are rejected in all the cases. The acceptance and rejection of the null hypothesis are based on the critical test value and corresponding probability value.

Table 4: Pair-wise Johansen co-integration test results for the modal prices of Maize

Hypothesized No. of CE(s)	H_0	H_1	Eigen value	Trace Statistics results			Max-Eigen Statistics results		
				Trace Statistics	0.05 Critical Value	P-Value	Max-Eigen Statistic	0.05 Critical Value	P-Value
Badepally-Karimnagar	r =0	r≥1	0.602	90.24*	15.49	0.00	52.60*	14.26	0.00
	r≤1	r≥2	0.483	37.63*	3.84	0.00	37.63*	3.84	0.00
Badepally-Nagarkurnool	r =0	r≥1	0.551	48.04*	15.49	0.00	45.75*	14.26	0.02
	r≤1	r≥2	0.038	2.24	3.84	0.13	2.24	3.84	0.13
Badepally-Siddipet	r =0	r≥1	0.598	85.32*	15.49	0.00	51.96*	14.26	0.00
	r≤1	r≥2	0.443	33.35*	3.84	0.00	33.35*	3.84	0.00
Badepally-Warangal	r =0	r≥1	0.620	79.35*	15.49	0.00	55.21*	14.26	0.00
	r≤1	r≥2	0.345	24.14*	3.84	0.00	24.14*	3.84	0.00
Karimnagar-Nagarkurnool	r =0	r≥1	0.501	42.32*	15.49	0.00	39.71*	14.26	0.01
	r≤1	r≥2	0.044	2.61	3.84	0.10	2.61	3.84	0.10
Karimnagar-Siddipet	r =0	r≥1	0.586	79.85*	15.49	0.00	50.34*	14.26	0.00
	r≤1	r≥2	0.404	29.50*	3.84	0.00	29.50*	3.84	0.00
Karimnagar-Warangal	r =0	r≥1	0.547	66.55*	15.49	0.00	45.23*	14.26	0.00
	r≤1	r≥2	0.312	21.32*	3.84	0.00	21.32*	3.84	0.00
Nagarkurnool-Siddipet	r =0	r≥1	0.437	35.21*	15.49	0.00	32.80*	14.26	0.00
	r≤1	r≥2	0.041	2.40	3.84	0.00	2.40	3.84	0.12
Nagarkurnool-Warangal	r =0	r≥1	0.350	27.47*	15.49	0.00	24.60*	14.26	0.00
	r≤1	r≥2	0.049	2.87	3.84	0.09	2.87*	3.84	0.09
Siddipet-Warangal	r =0	r≥1	0.583	70.78*	15.49	0.00	49.95*	14.26	0.00
	r≤1	r≥2	0.306	20.83*	3.84	0.00	20.83*	3.84	0.00

Granger causality test

After confirming the integration of price series, we have performed pair-wise Granger causality test for five major maize markets to comprehend causal relation between them. The result of the Granger causality analysis presented in Table 5 explicates that bidirectional causality market pairs is Nagarkurnool-Badepally. In these cases, the former market in each pair granger causes the modal price formation in the latter market, which in turn provides the feedback to the former market as well. Unidirectional causality markets pairs are Badepally-Karimnagar and Siddipet -Karimnagar. It means that a price change in the former market in each pair granger cause the price formation in the latter market, where as the remaining markets are shown no causality. It means the price change in the latter market is not feed backed by the price change in the former market. The Granger causality test reveals that most market pairs are not causally linked, reflecting localized pricing or inefficiencies in price transmission. However, specific unidirectional and bi-directional relationships highlight potential key nodes in the price network. Efforts to improve price linkages could enhance overall market efficiency for maize.

Tables 5: Market pair wise results of the Granger Casualty test

Lagged Periods	Markets Pairs	F-Statistic	P-Value	Decision of null hypothesis	Remarks
1	Karimnagar- Badepally	0.29986	0.8765	Reject	No causality
	Badepally-Karimnagar	5.94089**	0.0006	Do not reject	Unidirectional
2	Nagarkurnool-Badepally	3.70493**	0.0107	Do not reject	Bi-directional
	Badepally-Nagarkurnool	2.99169**	0.0123	Do not reject	
3	Siddipet-Badepally	0.88198	0.4822	Reject	No causality
	Badepally-Siddipet	2.45039	0.0593	Reject	No causality
4	Warangal-Badepally	0.24848	0.9091	Reject	No causality
	Badepally-Warangal	1.61622	0.1863	Reject	No causality
5	Nagarkurnool-Karimnagar	0.29162	0.8819	Reject	No causality
	Karimnagar-Nagarkurnool	2.00455	0.1096	Reject	No causality
6	Siddipet-Karimnagar	3.24478**	0.0200	Do not reject	Unidirectional
	Karimnagar-Siddipet	1.10474	0.3657	Reject	No causality
7	Warangal-Karimnagar	1.80124	0.1448	Reject	No causality
	Karimnagar-Warangal	2.36490	0.0667	Reject	No causality
8	Siddipet-Nagarkurnool	0.31240	0.8682	Reject	No causality
	Nagarkurnool-Siddipet	2.14959	0.0898	Reject	No causality
9	Warangal-Nagarkurnool	1.82731	0.1398	Reject	No causality
	Nagarkurnool-Warangal	0.99217	0.4214	Reject	No causality
10	Warangal-Siddipet	1.72947	0.1597	Reject	No causality
	Siddipet-Warangal	1.49758	0.2185	Reject	No causality

Note: ** represents the level of significance at 5% level

Short run and long run behavior of market prices

Since the Johansen's multiple co-integration test results showed that the selected maize markets having long run equilibrium relationship and there exists co-integration between them. Hence the Vector Error Correction model (VECM) among the selected markets of maize is employed to know the speed of adjustments for the prices of maize among selected markets, for short run and long run equilibrium of prices. The results of VECM are presented in Table 6.

The estimates of the Vector Error Correction Model revealed that the co-integration equation values for Karimnagar and Warangal indicate that these markets rapidly attain short-run equilibrium. The one-month lagged price in the Badepally market significantly influences the current prices in Badepally, Siddipet, and Karimnagar. Similarly, the one- and two-month lagged prices in the Karimnagar market affect the current prices in the Warangal market. In Nagarkurnool and Siddipet, the one- and two-month lagged prices impact their respective current prices. Furthermore, the one-month lagged price in the Warangal market influences the current prices in Karimnagar, while the two-month lagged price impacts the current prices in Nagarkurnool.

Table 6: Vector Error Correction Model for Maize prices for Major five selected markets

Error Correction:	Badepally	Karminagar	Nagarkurnool	Siddipet	Warangal
CointEq1	[-0.63624]	[-4.45606]	[-1.37699]	[0.30154]	[3.35872]
BADEPALLY(-1))	[-2.44850]	[4.88190]	[0.73270]	[1.97871]	[-0.22676]
BADEPALLY(-2))	[-2.76975]	[4.38932]	[-0.31621]	[0.56784]	[0.56639]
KARMINAGAR(-1))	[0.63595]	[0.75698]	[1.30905]	[0.06145]	[-2.66890]
KARMINAGAR(-2))	[0.19579]	[0.80508]	[0.71819]	[0.15995]	[-2.84031]
NAGARKURNOOL(-1))	[1.15743]	[0.37694]	[-3.32393]	[-0.37438]	[0.28648]
NAGARKURNOOL(-2))	[-1.42376]	[0.74257]	[-2.06533]	[0.53365]	[-0.68218]
SIDDIPET(-1))	[0.75472]	[-1.63049]	[-0.91036]	[-4.37897]	[0.95996]
SIDDIPET(-2))	[-0.53888]	[-1.06244]	[-0.10116]	[-2.91824]	[1.32896]
WARANGAL(-1))	[-1.16564]	[-3.31112]	[-0.92989]	[0.76574]	[-0.91197]
WARANGAL(-2))	[-1.23225]	[-1.64625]	[-2.00958]	[1.10380]	[-1.54914]
C	[-0.11491]	[0.45277]	[0.86258]	[0.21879]	[-0.15249]

This study examined the spatial market integration and price behavior of maize markets in Telangana State through co-integration analysis, utilizing modal monthly price data from January 2020 to December 2024. The findings revealed that all major maize markets in Telangana are highly integrated in terms of price movements. Agricultural markets play a pivotal role in enhancing agricultural marketing and production efficiency. A critical issue in analyzing policy reforms related to national agricultural markets is the degree to which domestic agricultural commodity markets respond to price changes. The overall performance of agriculture depends not only on production or supply efficiency but also on marketing efficiency, particularly the effectiveness of agricultural markets and price signals. Spatial market integration reflects the extent to which geographically distant markets (e.g., between regions) share common long-term price or trade information for a homogeneous commodity.

The results of ADF unit root test indicated that price series are stationary in first differencing logarithm i.e., Badepally, Siddipet, Karimnagar and Warangal markets and except one market i.e., Nagarkurnool found to be integrated zero order I (0). Results of Johansen's co integration test showed the price series as co integrated. The results of the granger causality test indicated that in the long -run there was a two direction relationship between market prices. There is bidirectional causality affected on maize prices of Nagarkurnool-Badepally. While unidirectional causality shown in the Badepally-Karimnagar, Siddipet-Karimnagar. Results of Vector Error Correction Model (VECM) showed that Karimnagar and Warangal markets shown short run equilibrium rapidly. The one-month lagged price in the Badepally market significantly influences the current prices in Badepally, Siddipet, and Karimnagar. Similarly, the one- and two-month lagged prices in the Karimnagar market affect the current prices in the Warangal market. In Nagarkurnool and Siddipet, the one- and two-month lagged prices impact their respective current prices. Furthermore, the one-month lagged price in the Warangal market influences the current prices in Karimnagar, while the two-month lagged price impacts the current prices in Nagarkurnool. It clearly shown that there is huge scope for increasing maize prices in the India and Telangana State. Because of the projected 20-30% increase in feed demand and the rising ethanol demand driven by the government's 20% ethanol blending target by 2030 will significantly boost maize consumption in India. The present prices of Maize crop in India and Telangana State maize modal prices are on par with the Minimum support prices.

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