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Research Article
STUDY OF PRICE DYNAMICS AND COINTEGRATION IN MAJOR INDIAN CHILLI MARKETS

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Abstract: Understanding agricultural commodity price relationships is important as it helps producers to improve their awareness regarding production costs and ultimately aids in income determination. The present study empirically examines the dynamic interrelationships among the chilli wholesale prices in the Byadgi, Khammam, and Guntur markets. Johansen cointegration tests revealed that, no cointegrating relationships among the selected markets. All the markets studied exhibited unidirectional causality. The vector autoregression (VAR) model indicated that the chilli market prices are majorly influenced by their own past prices. The magnitude of the response shock on the selected market prices was captured by impulse response function analysis.

Keywords: *Cointegration, VAR, Impulse response function analysis*

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Introduction
In a market-driven economy, the pricing mechanism is expected to transmit information to determine the flow of marketing activities. Price signals guide and regulate production, consumption, and marketing decisions over time, form, and place. Recent advances in time series analysis, specially cointegration analysis, allow ascertaining the causes of price differences in inter-regional or spatial markets, which has become an important econometric tool to better understand markets. Market integration can be measured in terms of the strength and speed of price transmission between markets across various regions of a country [1]. Cointegration implies Granger (1988) [2] causality between the variables, meaning that if two markets are integrated, the price in one market would commonly be found to cause the price in the other market, and/or vice versa [3]. Therefore, Granger's causality provides additional evidence as to whether and in which direction price transmission is occurring between two markets. Although several studies have been carried out empirically using cointegration techniques which studied different agricultural markets in India [4-6], however, a little work has been carried out in the way of empirically evaluating chilli market integration in southern India.

Chilli, commonly referred to as the "wonder spice", is one of the most important commercial spice crops used extensively worldwide. India is the world's largest producer, consumer, and exporter of chilli. As per 3rd advance estimates, chilies are grown on approximately 8.52 lakh hectares of area, yielding 1.57 million tonnes in India for the year 2021-22 (agricoop.nic.in), with the majority consumed domestically. Almost 90% of the country's chilli is cultivated in the states of Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka and West Bengal. Nearly 30 percent of the country's chilli production is being exported to different countries. During 2019–20, chilli accounted for 43 percent of India's total spice exports. In the last three years, the average export of chilli has been around 4 lakh tons, which is the highest since 1993-94. Considering the sustainable source of foreign exchange earnings for the Indian economy, it is therefore important to analyse the countries' major chilli marketing systems so that the country chilli production as well as exports are efficiently managed.

The presence of perfect market integration and price transmission are critical phenomena to consider for efficient marketing system management in which the new information is confounded into markets simultaneously when they are cointegrated. This type of system has considerable significance for deriving maximum gains for producers, consumers, and middlemen in the marketing chain [7-14]. The present study aims to understand the causal relationships and dynamic interactions among major chilli markets in southern India namely Guntur, Byadgi and Khammam, by employing a series of econometric tests. First, Unit root tests are employed to examine the presence of non-stationarity in the price series. Besides the traditional VAR analysis, this study incorporates impulse response analysis to investigate the dynamic interactions between markets. Granger causality tests are applied to examine the causal structures among the study markets. The outcome of this study would provide valuable information on the degree of integration and efficiency of markets.

Material and Methods
Vector Autoregressive (VAR) Process
Let us consider a univariate time series P_t, t=1,2,3,…,T arising from the model

$$P_t = \delta + \emptyset_1 P_{t-1} + \emptyset_2 P_{t-2} + \cdots + \emptyset_k P_{t-k} + u_t \quad (1)$$

Where, u_t~IN(0,σ), is a sequence of uncorrelated error terms and $\emptyset_i$, i=1,2,…,k are the constant parameters. This is a sequentially defined model; P_t is generated as a function of its own past values. This is a standard autoregressive process or AR(k), where k is the order of the autoregression.

If a multiple time series P_t of n endogenous variables is considered, the extension of (1) will give the VAR(k) model (VAR model of order k), *i.e*., it is possible to specify the following data generating procedure and model P_t as an unrestricted VAR involving up to k lags of P_t and can be expressed as,

$$P_t = \delta + A_1 P_{t-1} + A_2 P_{t-2} + \cdots + A_k P_{t-k} + u_t \quad (2)$$

where, $P_t = (P_{1t}, P_{2t}, \dots, P_{nt})'$ is (n×1) random vector, each of the Ai is an (n×n) matrix of parameters, δ is a fixed (n×1) vector of intercept terms.

Finally, $u_t = (u_{1t}, u_{2t}, \ldots, u_{nt})$ is a n-dimensional white noise or innovation process, *i.e.*, $E(u_t) = 0$, $E(u_t, u_t') = \sum$ and $E(u_t, u_s') = 0$ for s≠t. The covariance matrix $\sum$ is assumed to be non-singular.

Cointegration Process

Cointegration analysis is used to assess whether long-run equilibrium relationships exist between markets which specified as:

$$P_t^1 = \alpha_o + \alpha_1 P_t^2 + \varepsilon_t \quad (3)$$

where, P_t^1 is the price of a commodity in one market and P_t^2 is the price in another market. If ε_t is stationary, then market prices are said to be cointegrated. The cointegration analysis reflects the long-run movement of price, although in the short run they may drift apart. Johansen's (1988) multivariate cointegration approach was used to examine cointegration between two market prices. Before leading to cointegration test, it is mandatory to perform stationarity test. The following form of Augmented Dickey-Fuller (ADF) unit root test was performed to check stationarity of the series.

$$\Delta P_t = \alpha + \beta t + \gamma P_{t-1} + \sum_{j=1}^{\rho} \delta j \, \Delta P_{t-j} + \varepsilon_{it} \quad (4)$$

where, P_t is a vector to be tested for cointegration, t is time or trend variable, ΔP_t is the first difference, $\Delta P_{(t-j)}$ are changes in lagged values, and ε_{it} is the white noise. The parameter of interest in the ADF model is γ. The null hypothesis that, H_0:γ=0; signifying unit root, states that the time series is non-stationary while the alternative hypothesis, H_1:γ<0, signifies that the time series is stationary, thereby rejecting the H_0.

Johansen's Cointegration Tests

A cointegrated system can be written as:

$$\Delta P_t = \mu + \sum_{i=1}^{\rho-1} \Gamma_i P_{t-1} + \prod P_{t-1} + \varepsilon_t \quad (5)$$

where, P_t denotes an (n×1) vector of I(1) prices, Γ_i = -(I - $\prod_1$ - ... - $\prod_t$); i=1, 2…., ρ - 1; ρ is the lag order of auto-regressive process, $\prod$ = -(I - $\prod_1$ - ... - $\prod_\rho$). Each of ∏i is an n×n with rank (0≤r<n), which is the rank of linear independent cointegration relations in the vector space of matrix; ε_t is white noise error term. There are two types of test ratios *viz*., trace test and maximum eigenvalue test. The null hypothesis for the trace test is that the number of cointegration vectors is r = r* against the alternative that r > r*. On the other hand, the null hypothesis for the "maximum eigenvalue" test is as for the trace test but the alternative is r = r* + 1 [5,6].

Engle-Granger causality

In order to evaluate the nature of the relationship between chilli market prices, Granger causality tests (1988) were employed. The purpose of Granger causality is to assess the predictive power of a single variable on other variables in the system. Presence of Granger causality offers insights into the nature of commodity returns and can be used as a basis for predicting time series models. For a bivariate system of stationary time series {At} and {Pt}, the variable A is said to Granger cause P if we can better forecast P using lagged values of A, even after lagged P variables are taken into account.

Following Musunuru (2017) [15], consider a VAR (k) model for A and P, which can be represented as:

$$A_t = \emptyset_1 + \sum_{i=1}^{k} \alpha_{1i} A_{t-i} + \sum_{i=1}^{k} \beta_{1i} P_{t-i} + \varepsilon_{1t} \quad (6)$$

$$P_t = \emptyset_2 + \sum_{i=1}^{k} \alpha_{2i} A_{t-i} + \sum_{i=1}^{k} \beta_{2i} P_{t-i} + \varepsilon_{2t} \quad (7)$$

The test for Granger causality from A to P is an F test for the joint significance of α_{21}, …., α_{2p}. Similarly, the test for Granger causality from P to A is for the joint significance of β_{11}, …., β_{1p}.

Results and Discussion

Data

The present study is based on data from various secondary sources like Krishimaratavahini, Agmarknet, and the records of APMC Guntur. The sample analyzed in this study utilizes month-wise wholesale prices of dry/ red chillies in important chilli market yards in India, such as Guntur, Byadgi, and Khammam. There is a total of 134 data points in each series, with data available from the month of January 2011 to February 2022. The time plot for each price series is displayed in [Fig-1]. [Table-1] summarises the simple descriptive statistics and variability of prices in various markets in terms of coefficient of variation. A perusal of [Table-1] indicates that, the maximum price was observed in the Byadgi market in September 2021, whereas the minimum price was observed in the Khammam market in November 2002. The results reveal the variability as explained by the coefficient of variation ranges between 29.81 and 39.31%, respectively, in the Guntur and Byadgi markets.

Table-1 Descriptive Statistics of Dry chilli prices in Selected Markets

Statistics	Markets		
	Byadgi	*Khammam*	*Guntur*
Mean	8582.92	5661.25	8326.34
Minimum	3427.02	2059.53	3200.00
Maximum	18167.70	12557.00	14403.61
Standard Deviation	3374.10	2102.92	2481.71
Kurtosis	0.81	0.83	-0.21
Skewness	1.17	0.67	0.35
CV (%)	39.31	37.15	29.81

Table-2 ADF Test for Level and Differenced Series of Dry chilli prices in Selected Markets

Markets	Level		Differenced		Order of Integration
	Statistics	P- Value	Statistics	P- Value	
Byadgi	-2.859	0.218	-5.983	<0.001	I(1)
Khammam	-2.390	0.203	-7.022	<0.001	I(1)
Guntur	-2.757	0.213	-4.908	<0.001	I(1)

The hypothesis that the price series are non-stationary is tested using the augmented Dickey-Fuller (ADF) test. The ADF test confirms the presence of unit root in the price series. However, after first differencing, all the series were found to be stationary and, therefore, were integrated of order one, *i.e*., I(1). The conformation that each level series is of I(1) allowed to proceed for Johansen's cointegration test. The result of the stationarity test is reported in [Table-2].

To test the cointegration, the next step is to calculate the optimum number of lags for endogenous variables in the model. This is done by using vector autoregressive (VAR) lag order selection criteria presented in [Table-3]. There are five criteria of selection, all of which are efficient and equally important. [Table-3] shows that out of five criteria, two, *i.e*., HQ and SC, show the use of one lag for model. On the other hand, FPE and AIC suggest a lag of six for study. To avoid complexities, an optimum lag of one was selected for the analysis.

Table-3 VAR lag order selection criteria

Lag	LR	AIC	FPE	HQ	SC
0	NA	47.714	5.82 e+20	47.753	47.832
1	748.386	42.722	3.58e+18	42.832*	42.993*
2	32.592	42.678	3.45e+18	42.870	43.152
3	29.893	42.684	3.45e+18	42.957	43.336
4	21.574	42.701	3.51e+18	43.058	43.582
5	27.497	42.749	3.69e+18	43.191	43.834
6	15.302	42.663*	3.39e+18*	43.189	43.978
7	23.828*	43.737	3.67e+18	43.343	44.230
8	18.701	42.829	4.05e+18	43.518	44.526

Table-4 Results of Cointegration Test

H_0: Rank = r	Maximum Eigenvalue		Trace Test	
	Statistic	5% Critical Value	Statistic	5% Critical Value
H_0: r = 0	46.57	22.00	130.67	34.91
H_0: r ≤ 1	24.75	15.67	74.10	19.96
H_0: r ≤ 2	15.37	9.24	41.35	9.24

Cointegration Analysis

Johansen's cointegration test was applied to examine whether the selected chilli market prices share the same stochastic trend and, consequently, whether a stable long-run linkage exists between them. The Johansen's test reports two tests for cointegration: the trace test (designed to test the presence of r cointegrating vectors) and the max-eigenvalue test (designed to test the hypothesis of r cointegrating vectors in r+1 cointegrating vectors). [Table-4] shows the results of trace and eigenvalue test statistic, with a five percent critical value. The test results unveil that there is no cointegration among the study variables, as indicated by the higher calculated value than the critical value at five percent level of significance. The cointegration results reveal that only short-run dynamic interactions exist and there is no stable, long-run equilibrium relationship among chilli market price.

As per the Johansen's cointegration test results, reported in [Table-4], imply the short-run dynamics exist between chilli market prices. Hence, the chilli prices could be better modeled through the vector auto regression (VAR) system than the vector error correction model (VECM). The VAR model is estimated by using the same lag length (lag =1) which was employed in the previous cointegration test. [Table-5] shows the results of the VAR model estimates. From the table, it is evident that all the chilli market prices are positively related to their own lags. Likewise, Byadgi is related to the first lag of Khammam and Guntur.

Table-5 Vector Auto Regressive Model (VAR) Parameters Estimation

Byadgi market as dependent variable				
	Estimate	Std. Error	t value	P-value
Byadgi (l_1)	0.22	0.0814	2.6540	0.008951**
Khammam (l_1)	0.21	0.0549	3.8010	0.000222**
Guntur (l_1)	-0.09	0.0436	-2.0150	0.046006*
Const.	54.37	70.93	0.7670	0.444755
Khammam market as dependent variable				
	Estimate	*Std. Error*	*t value*	*P-value*
Byadgi (l_1)	0.155665	0.130718	1.191	0.236
Khammam (l_1)	-0.212869	0.09851	-2.161	0.0328*
Guntur (l_1)	0.079224	0.070044	1.131	0.26
Const.	30.349704	113.863653	0.267	0.79
Guntur market as dependent variable				
	Estimate	*Std. Error*	*t value*	*P-value*
Byadgi (l_1)	-0.08121	0.16585	-0.49	0.625
Khammam (l_1)	-0.05426	0.11187	-0.485	0.628
Guntur (l_1)	0.18876	0.05853	3.225	0.00164*
Const.	68.55391	144.46707	0.475	0.636

Granger Causality Test

Granger causality means the direction of price formation between two markets and related spatial arbitrage, *i.e.*, physical movement of the commodity to adjust for these price differences. Pairwise Granger causality tests are conducted to understand the causal relations among the markets, and the results are summarised in Table 6. A unidirectional causal influence from Byadgi prices to Khammam and Guntur prices is observed at one percent and five percent level of significance respectively. This implies that the Byadgi market Granger causes price formation in the Khammam and Guntur markets, but they do not provide any feedback to the Byadgi base market. Likewise, Khammam Granger cause for Guntur prices. Similarly, Khammam Granger cause Guntur prices. This result is confirmed by previous VAR results in [Table-5], where past values of Khammam and Guntur market prices influence current values of chilli in Byadgi market. Furthermore, changes in Guntur rates influence Khammam chilli prices.

Impulse Response Graph of Chilli Prices

A ten-period impulse response function analysis was conducted in order to analyse the magnitude of the response shock on the selected chilli market prices. The results are presented in [Fig-2]. The impulse response function shows how a shock to one variable affects itself and the other variables in the VAR system over time while holding all other external effects constant. The responses of Byadgi to unexpected orthogonal shocks to the other market prices are given in the first row of [Fig-2]. From the figure, it is evident that Byadgi reacts positively to unexpected shocks to Khammam and responds negatively to shocks to Guntur. This initial reaction is short-lived and lasts only up to 4 months. The responses of Guntur to the orthogonal shocks are given in the second row of the figure. Guntur responds negatively to an unexpected shock to Byadgi and Khammam. Finally, the third row gives the responses of Khammam to the orthogonal shocks. Khammam reacts positively to a shock to Byadgi; and reaction is short lived and lasts only up to 4 months. However, the negative shock effect is short lived for Guntur.

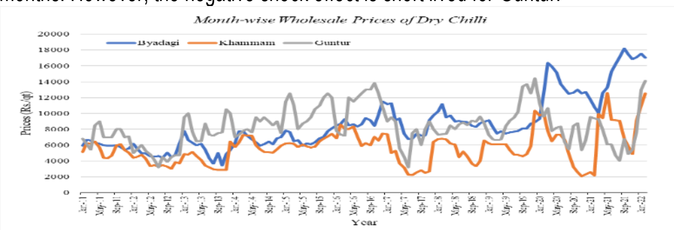

Fig-1 Time-series plot of Dry Chilli prices in selected markets

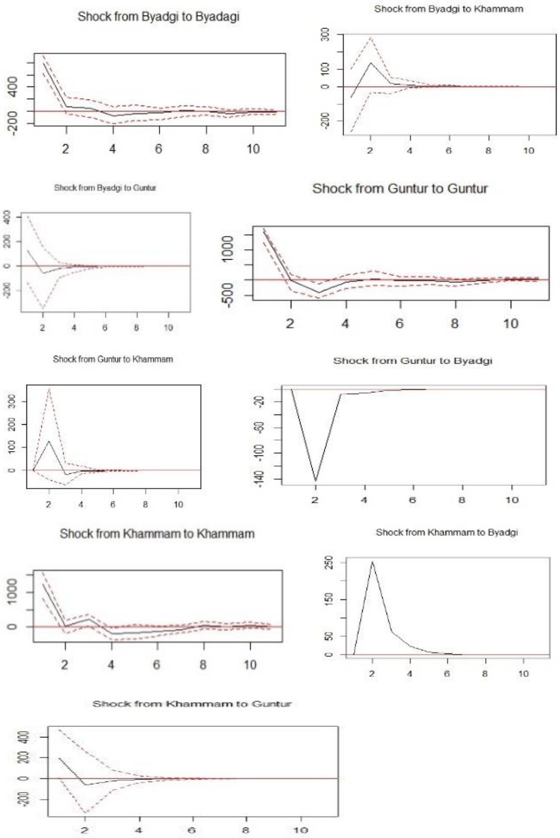

Fig-2 Impulse Response Graph of Chilli Prices

Table-6 Pairwise Granger Causality Test between selected chilli market price series

Markets	F statistics	Pr (>F)	Direction
Byadgi → Khammam	3.6350	0.0025**	Unidirectional
Khammam → Byadgi	1.9310	0.8166	
Byadgi → Guntur	2.2110	0.0469*	Unidirectional
Guntur → Byadgi	0.7957	0.5752	
Khammam → Guntur	2.4048	0.0317*	Unidirectional
Guntur → Khammam	1.0044	0.4260	

Table-7 Variance Decomposition of Chilli Price Series

Period	*Byadgi Market Prices Explained by*		
	Byadgi (%)	Khammam (%)	Guntur (%)
1	100	0	0
2	88.871	8.431	2.698
3	88.479	8.843	2.678
4	88.421	8.899	2.680
5	88.416	8.904	2.680
6	88.415	8.905	2.680
Period	*Khammam Market Prices Explained by*		
	Byadgi (%)	Khammam (%)	Guntur (%)
1	0.231	99.769	0
2	1.304	97.726	0.970
3	1.322	97.688	0.990
4	1.326	97.684	0.990
5	1.326	97.684	0.990
6	1.326	97.684	0.990
Period	*Guntur Market Prices Explained by*		
	Byadgi (%)	Khammam (%)	Guntur (%)
1	0.581	1.439	97.980
2	0.705	1.587	97.709
3	0.721	1.605	97.674
4	0.723	1.607	97.670
5	0.723	1.608	97.669
6	0.723	1.608	97.669

Variance Decomposition of Chilli Prices

The variance decomposition of chilli prices shows that how much proportion of variation in one market prices affected due to its own shock against the shock in other market prices and likewise for the variation in rest of markets.

The first panel of [Table-7] reports the percentage variation in chilli prices of the Byadgi market, explained by its own lagged values and by the lagged values of Khammam and Guntur market prices. Byadgi price variations explained by Guntur are not as pronounced as those in the Khammam market, which rise over time. The results indicate that only around 2.678% to 8.905% of the variations in Byadgi prices are explained by these markets. As per the second panel, Khammam price variations explained by Guntur prices are also very small as compared to Byadgi causes, which range from 0.231 to 1.236 percent. Similarly, Guntur prices explained by Byadgi are low-slung when compared to Khammam prices, where these markets explain 0.581 to 1.605 percent of the variation.

Conclusion

The study aims to show whether Byadgi, Khammam, and Guntur market chilli prices are interrelated by employing a series of econometric tests. The results of the Granger causality tests show that a unidirectional relationship exists between Khammam and Guntur, and between Byadgi and Khammam, and Guntur prices. When the Johansen approach is considered for the presence of long-run interrelations, empirical results showed that there is no cointegration among the studied market prices and consequently confirmed the existence of only short-run dynamics between these chilli prices. The impulse response functions based on VAR models confirm that the chilli wholesale prices respond to shocks originating from other markets.

Application of research: Price relations between markets

Research Category: Price Dynamics and Market Co-integration

Abbreviations: VAR- Vector Auto Regression

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Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: APMC Guntur

Cultivar / Variety / Breed name: Chilli

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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