

RESEARCH PAPER

Statistical Investigation on Market Cointegration and Causality of Price Signals among Selected Markets of Major Oilseeds in Andhra Pradesh

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ABSTRACT

Present study made an attempt to understand the market Cointegration and causality of price signals among the selected markets (Adoni, Kurnool and Yemmiganur) of Major oilseeds (Groundnut, Castor and Sunflower) in Andhra Pradesh. For this, secondary time series data on market prices had been collected during the period from January 2011 to April 2023 from Agriculture Market Intelligence Centre, Lam Guntur and various selected tools namely Johansen Method of Cointegration, Vector Error Correction Model (VECM) and Engle Granger causality test were also been employed. It was resulted with conclusion of stable price cointegration across the selected markets of Groundnut, Castor and Sunflower in the long run relation through Johansen's Cointegration test. Where from VECM estimates on Groundnut prices, Error Correction Term (ECT) was identified as negative and significant for Adoni and Kurnool market only, which confirmed that these series would be return to its previous long run equilibrium with the price adjustment (speed of recovery) from short run disequilibrium to long run equilibrium by 29.1% and 23.3% per month respectively. Granger Causality test revealed that there existed long run bi-directional causality for markets of Kurnool and Yemmiganur i.e., price transmission would occur in both directions for Groundnut and castor.

HIGHLIGHTS

- ① Analysis of monthly price data (2011–2023) for groundnut, castor and sunflower across the selected markets of Andhra Pradesh (Adoni, Kurnool and Yemmiganur) were studied.
- ① Johansen cointegration test confirmed long-run price integration among the selected markets for all three oilseed crops, indicating strong market linkage and price transmission.
- ① Vector Error Correction Model (VECM) revealed price adjustment speeds of 29.1% (Adoni) and 23.3% (Kurnool) for groundnut, 42% (Adoni) for castor and 20.6% (Adoni) for sunflower, showing varying convergence to long-run equilibrium.
- ① Granger causality analysis showed bi-directional price transmission between several market pairs, particularly Kurnool–Yemmiganur for groundnut and all market pairs for castor.
- ① The study demonstrates strong spatial market integration in Andhra Pradesh oilseed markets, providing insights for price policy, market monitoring and improving market efficiency.

Keywords: Cointegration, causality, Market, price and Oilseeds

Oilseed crops are the second most important determinant of agricultural economy, next only to cereals within the segment of field crops. India is the fourth-largest producer of oilseeds

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globally, accounting for 10% of the world's total production while utilizing 20.8% of the global area under oilseed cultivation. At national level, these were cultivated across 29.16 million hectares and its production was about 37.70 million tonnes with an average yield of 1292 kg/ha. during 2021-22. India produces a diverse range of oilseeds, including groundnut, soybean, sunflower, sesamum, niger seed, mustard, and safflower. According to industry reports, oilseed production in India grew at a compound annual growth rate (CAGR) of 7.7% between 2015-16 and 2020-21, reflecting steady expansion in the sector. The top oilseed-producing states in India are Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal. Additionally, India ranks among the world's leading exporters of oilseed products (IBEF, 2022).

Across the landscape of India-2021, Groundnut was grown in an area of 5.75 million hectares with a production of about 10.11 million tonnes and an average productivity rate of 1795 kg/ha. India's groundnut exports (during April-August 2022) stood at US\$ 223.52 million for the quantity of 177,938.21 MT. Major producing states of India are Gujarat, Rajasthan, Tamil Nadu, Andhra Pradesh and Karnataka. In Andhra Pradesh, groundnut was cultivated in an area of 8.2 lakh hectares with a production of 5.2 lakh tonnes, contributing 5.13% to India groundnut production for the year 2021-22. Castor is also an important non-edible and commercial oilseed crop, which occupies a prominent position in Andhra Pradesh's agricultural landscape. It is the second most important oilseed crop next to groundnut in terms of acreage and economy in the state. India is the leader in global castor production and dominates in international castor oil trade with 92% share of total world's castor oil production. In India, it was cultivated under 7.547 lakh ha and its production was 15.08 lakh tonnes during 2021-22. Similarly, sunflower is one of the most commonly preferred oil seed crops over the others and it was cultivated in an area of 0.28 million ha. with a production of 0.25 million tonnes and productivity of 905 kg/ha., at national level during 2021-22.

MATERIALS AND METHODS

Data

The present study had been conducted on the secondary time series data on market (Adoni, Kurnool and Yemmiganur) prices of the selected oilseeds (Groundnut, Castor and Sunflower) in Andhra Pradesh during the period of January 2011 to April 2023 from the sources namely Agmarknet (agmarknet.gov.in) and Agricultural market intelligence centre (AMIC), Lam-Guntur.

METHODOLOGY

The methodological process was been started with a brief note on stationary and non-stationary time series data followed by testing of unit root i.e. stationarity test.

Test of Stationary: The order of differencing was assessed by performing unit root test. The most widely used test for detecting the unit root (non-stationary) of time series is Augmented Dickey Fuller (ADF) test. In conducting Dickey Fuller (DF) test, it has assumed that the error term is uncorrelated. But in most of cases correlated, hence Dickey-Fuller (1979) had developed another test, known popularly known as the ADF test. This test is conducted by augmenting the regression [e.g.: $(\Delta Y_t = \beta_1 + \delta Y_{t-1} + e_t)$] equation, by adding the lagged values of dependent variable (ΔY_t) . The ADF test consist of estimating, (Gujarathi *et al.* 2012) following regression,

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-i} + e_t$$

Where m is number of lagged difference terms required so that the error term e_t is serially independent. The test can be carried out by performing a $t (= \tau)$ statistic of ' δ ' with dickey fuller table values at 5% and 10% LOS. If absolute $t (= \tau)$ statistic of ' δ ' is greater than its table value, it indicates that the series is Stationary.

Johansen Method of Cointegration

After confirmation of stationarity in the entire price series at the same order of differences, the co-integration of markets was tested by Johansen

maximum-likelihood techniques. In this present context, the long-run price relationship between the markets was employed by conducting the Johansen cointegration test (Johansen and Juselius, 1990). The Johansen procedure examines a vector autoregressive model of Y_t , an $(n \times 1)$ vector of variables that were integrated into the order one [I(1)] time series. This vector autoregressive model can be expressed as an equation where Γ and Π are matrices of parameters, p is the number of lags (selected based on Schwarz information criterion), and ε_t is an $(n \times 1)$ vector of innovations. The presence of at least one cointegrating relationship is necessary for the analysis of the long-run relationship of the prices to be plausible.

To detect the number of co-integrating vectors, Johansen proposed two likelihood ratio tests: trace test and maximum eigenvalue test, shown in Equations where T is the sample size and λ^{\wedge} is the i^{th} largest established correlation. The trace test examines the null hypothesis of r cointegrating vectors against the alternative hypothesis of n co-integrating vectors. The maximum eigen value test, on the other hand, tests the null hypothesis of r co-integrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors.

$$\Delta Y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i Y_{t-i} + \Pi Y_{t-1} + \varepsilon_t$$

$$J_{\text{trace}} = -T \sum_{i=r+1}^n \ln(1 - \lambda_i^{\wedge})$$

$$J_{\text{max}} = -T \ln(1 - \lambda_r^{\wedge} + 1)$$

Vector Error Correction Model

In the study, Vector Error Correction Model-VECM (Johansen, 1988), had been used to analyse the short-run and long-run dynamics in the model. It has two distinct characteristics: first, a VECM is dynamic in the sense that it involves lags of the dependent and explanatory variables; it thus captures the short-run adjustments to changes of particular adjustments into past disequilibria and contemporaneous changes in the explanatory variables. Second, the VECM is transparent in displaying the cointegrating relationship between or among the variables. This study relies on VECM approach which provides relative advantage over conventional ECM, as it is restricted to only a single equation with one variable designated as the dependent variable, explained

by another variable that is assumed to be weakly exogenous for the parameters of interest.

The conventional VECM for cointegrated series can be written as:

$$\Delta Y_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta Y_{t-i} + \sum_{i=1}^{k-1} \delta_i \Delta X_{t-i} + \phi Z_{t-1} + u_t$$

where, Y_t represents the price of a commodity in a particular market and X_t represent the corresponding price of the same commodity in another market and Z_{t-1} is the Error. A negative coefficient of ECT, ϕ is used to determine the speed of adjustment as it measures the speed at which Y returns to equilibrium after a change in X .

Granger Causality Test

In the present study, Granger causality test (Granger, 1987), had been used to detect the causal relationship between the price series in domestic oilseed markets of Andhra Pradesh. A time series X is said to Granger-cause Y if it can be shown, usually through a series of t-tests and F-tests on lagged values of X (and with lagged values of Y also included), that those X values provide statistically significant information about future values of Y .

For example,

$$Y_t = \alpha_1 + \sum_{i=1}^n \alpha_i Y_{t-i} + \sum_{j=1}^m \beta_j X_{t-j} + e_t$$

$$X_t = \alpha_1 + \sum_{i=1}^n \alpha_i X_{t-i} + \sum_{j=1}^m \beta_j Y_{t-j} + u_t$$

for all possible pairs of (X, Y) series in the group. The reported F-statistics are the Wald test statistic

for the joint hypothesis: $(H_0 : \beta_1 = \beta_2 = \beta_3 \dots)$ for each equation. The null hypothesis is that x does not Granger-cause y in the first regression and that y does not Granger-cause x in the second regression (Dey *et al.* 2021).

RESULTS

Initially Univariate Time series data on Prices of Groundnut, Castor and Sunflower crops from selected markets during the period from Jan 2011 to Apr 2023 were verified for the presence of

outliers by Grubb’s test. Later, to know the basic behaviour of data series, descriptive statistics and simple growth rate were employed. The results were presented in Table 1, as discussed. It was confirmed that there were no outliers detected from the Grubb’s test during the period among the selected markets.

From Table 1, it was observed that the prices of groundnut in Adoni during the study period had varied from 2600 to 7202 (₹/Q.) with an average of 4908.01 (₹/Q.). Standard Deviation was recorded as 872.08, which indicated that the prices were dispersed highly over the months. It was also revealed that the data was slightly negative skewed, as skewness was recorded as -0.11. It had registered a simple growth rate (SGR) of almost 0.84% per

month, where for Kurnool and Yemmiganur these were recorded as 69% and 54% respectively.

Similarly, it was also revealed that the average prices of Castor in the selected markets were 4066.56 (₹/Q.), 3931.96 (₹/Q.) and 3947.45 (₹/Q.) respectively. Coefficient of Variation (%) over the markets was almost adjacent to each other, which indicated that the prices were dispersed closely over the markets. Where for Sunflower, simple growth rate (SGR) was calculated as 0.47% per month for Adoni, where for Kurnool and Yemmiganur these were recorded as 45% and 96% respectively. Hence, it was concluded as the prices had positive trend over the period.

Checking for stationary of data series

As per Table 2, Prices of the oilseeds in the

Table 1: Descriptive Statistics for the Prices of Groundnut, Castor and Sunflower in selected Markets

	Groundnut Prices (₹/Q.)			Castor Prices (₹/Q.)			Sunflower Prices (₹/Q.)		
	A	K	Y	A	K	Y	A	K	Y
Mean	4908.01	4359.94	4424.12	4066.56	3931.96	3947.45	3488.99	3553.51	3455.92
Minimum	2600	3017.67	2628.86	2800	2754.81	2797.4	2450	2162.73	2100
Maximum	7202	6174.61	7049.99	6751.2	6252.67	6350.35	5486.1	5382.17	5387.4
Standard deviation	872.08	858.64	932.92	1018.55	945.95	938.94	772.08	738.55	810.91
Skewness	-0.11	0.37	0.46	1.18	1.05	1.07	1.31	1.11	1.09
Kurtosis	-0.46	-0.91	-0.65	0.47	0.21	0.24	0.67	0.39	0.18
CV %	17.77	19.69	21.09	25.05	24.06	23.79	22.13	20.78	23.46
Simple Growth Rate (SGR) %	0.84	0.69	0.54	0.45	0.34	0.4	0.47	0.45	0.96
Outliers detected (Grubbs test)	No	No	No	No	No	No	No	No	No

A: Adoni; K: Kurnool; Y: Yemmiganur

Table 2: Result of ADF Test for the prices of Groundnut, Castor and Sunflower of selected markets

Data type		ADF statistic	Critical value (P value)	Decision
Groundnut				
Adoni	ADF at level	-2.94	0.18	Data Non-Stationary
	ADF at 1 st difference	-6.73	0.01	Data became Stationary
Kurnool	ADF at level	-2.53	0.35	Data Non-Stationary
	ADF at 1 st difference	-6.94	0.01	Data became Stationary
Yemmiganur	ADF at level	-2.9	0.16	Data Non-Stationary
	ADF at 1 st difference	-6.92	0.01	Data became Stationary
Castor				
Adoni	ADF at level	-2.47	0.37	Data Non-Stationary
	ADF at 1 st difference	-4.98	0.01	Data became Stationary
Kurnool	ADF at level	-2.5	0.36	Data Non-Stationary
	ADF at 1 st difference	-6.21	0.01	Data became Stationary
Yemmiganur	ADF at level	-2.59	0.32	Data Non-Stationary
	ADF at 1 st difference	-4.54	0.01	Data became Stationary
Sunflower				
Adoni	ADF at level	-0.69	0.96	Data Non-Stationary
	ADF at 1 st difference	-5.51	0.01	Data became Stationary
Kurnool	ADF at level	-2.53	0.35	Data Non-Stationary
	ADF at 1 st difference	-6.94	0.01	Data became Stationary
Yemmiganur	ADF at level	-1.15	0.91	Data Non-Stationary
	ADF at 1 st difference	-5.08	0.01	Data became Stationary

selected markets namely Adoni, Kurnool and Yemmiganur were confirmed the presence of unit root (nonstationary at level) and became stationary at first difference i.e., I (1). From this, it was inferred that the all markets were integrated of order one and also for suggesting the further test of Cointegration (*Johansen's cointegration test*).

Table 3: Lag Length Selection Criteria

Groundnut	AIC	HQ	SC
1	23.848	23.917	24.019
2	23.815	23.829	23.872
3	23.856	23.996	24.199
4	23.892	24.066	24.321
5	23.940	24.148	24.454
Castor			
1	22.455	22.611	22.688
2	22.533	22.603	22.790
3	22.513	22.625	22.798
4	22.504	22.678	22.932
5	22.513	22.722	23.027
Sunflower			
1	20.855	20.925	21.026
2	20.856	20.960	21.113
3	20.910	21.049	21.253
4	20.923	21.097	21.351
5	20.918	21.127	21.432

Later, the selection for appropriate number of lags in the vector autoregressive model was done to maintain parsimonious nature of the model and also to conduct the further cointegration procedure. For

this, several information criterion namely Akaike Information Criterion (AIC), Schwarz Criterion (SC) and Hannan Quin (HQ) were calculated to compare over different lags as per Dey *et al.* (2021). From Table 3, optimum number of lags was decided as two for Groundnut markets, where it was identified as one for both castor and sunflower markets, due to its minimum values.

Examining cointegration of selected crops among the markets

In the study, Johansen's Cointegration test (through *trace statistics and maximum eigen value methods*) was used to detect the existence of long run relations among the market prices, there by determining the number of cointegrating equations among these markets in the selected oilseeds. As the test particularly used to assure the rejection of Null hypothesis (H_0): $r = 0$ i.e., no cointegration against alternative hypothesis of existence of one or more cointegrations. From Table 4, it was clear from these both tests that there existed more than one (i.e., *Two*) cointegration relationships, which led to the conclusion of stable price cointegration across the oilseed markets in the long run relation. Which also meant, shock in prices of one market, would transmit (influence) the other market prices. Similar kind of result obtained by Paul *et al.* (2015) on Indian onion prices.

In this study, Vector Error Correction model was also built to analyse the short run dynamics of

Table 4: Johansen's Cointegration test for the prices of Groundnut, Castor and Sunflower in the selected Markets

Hypothesized no. of CE(s)	Eigen Value	Trace Statistic	Critical Value (5% LOS)	Max Eigen Statistic	Critical Value (5% LOS)
Groundnut					
None* ($r = 0$)	0.169	57.37*	31.52	27.10*	21.07
At Most 1 * ($r \leq 1$)	0.153	30.28*	17.95	24.20*	14.9
At Most 2 ($r \leq 2$)	0.041	6.08	8.18	6.08	8.18
Castor					
None* ($r = 0$)	0.347	102.92*	31.52	62.38*	21.07
At Most 1 * ($r \leq 1$)	0.241	40.54*	17.95	40.44*	14.9
At Most 2 ($r \leq 2$)	0.00067	0.1	8.18	0.1	8.18
Sunflower					
None* ($r = 0$)	0.296	76.39*	31.52	51.29*	21.07
At Most 1 * ($r \leq 1$)	0.156	25.10*	17.95	24.80*	14.9
At Most 2 ($r \leq 2$)	0.002	0.3	8.18	0.3	8.18

Table 5: Results of VECM for Groundnut, Castor and Sunflower prices of selected markets

	Error Correction Term	Intercept	D (A (-1))	D (A (-2))	D (K (-1))	D (K (-2))	D (Y (-1))	D (Y(-2))
Groundnut								
D (A)	-0.2914 [0.0685]***	315.3749 [78.2554]***	-0.2743 [0.0917]**	-0.1591 [0.0850]	0.6225 [0.1209]***	0.3197 [0.1278]*	-0.2002 [0.0768]*	-0.2209 [0.0754]**
D (K)	-0.2337 [0.0853]*	48.3132 [63.1816]	0.1133 [0.0740]	0.034 [0.0686]	0.0564 [0.0976]	0.0397 [0.1031]	-0.0315 [0.0620]	-0.1628 [0.0609]**
D (Y)	0.1389 [0.0821]	-124.163 [93.7482]	-0.1085 [0.1098]	-0.286 [0.1018]**	0.3859 [0.1448]**	0.2672 [0.1531]	-0.2303 [0.0920]*	-0.3939 [0.0903]***
Castor								
D (A)	-0.423 [0.1370]**	-64.1556 [37.0587]	-0.1836 [0.1138]		0.0674 [0.0976]		0.0516 [0.1138]	
D (K)	0.1985 [0.1296]	47.2952 [35.0386]	-0.1821 [0.1076]		-0.1202 [0.0923]		0.3525 [0.1076]**	
D (Y)	0.4573 [0.1168]***	102.8042 [31.5965]**	-0.2278 [0.0970]*		0.1867 [0.0832]*		-0.0251 [0.0971]	
Sunflower								
D (A)	-0.2063 [0.0574]***	37.8165 [14.3929]**	-0.2078 [0.0822]*		0.0535 [0.0618]		-0.105 [0.0697]	
D (K)	-0.0497 [0.0795]	17.6871 [19.9134]	0.154 [0.1137]		-0.2489 [0.0855]**		0.0511 [0.0965]	
D (Y)	0.3434 [0.0752]***	-2.4188 [18.8345]	-0.1421 [0.1075]		-0.0384 [0.0808]		-0.0082 [0.0913]	

the selected markets, concerned with ensuring the presence of long run equilibrium (cointegration). In this model, Error Correction Term (ECT) was used to indicate the speed of adjustment among the variables before converging to equilibrium in a dynamic model i.e., as per these coefficient values, how quickly variables would return back to equilibrium, to be revealed. From Table 5, the price adjustment (speed of recovery) from short run disequilibrium to long run equilibrium for Groundnut prices in Adoni market was found to be 29.1% per month followed by Kurnool market with 23.3% per month. It was also identified that there was no speed of adjustment for Yemmiganur market as the Error Correction Term (ECT) was positive and non-significant for that market prices of Groundnut.

Short run Cointegration over different markets of Groundnut

For Adoni market, it was concluded as the current month market prices would be influenced by one and two months lagged price of its own and also by Kurnool and Yemmiganur. Similarly for Kurnool market, the current month price of Kurnool market

was influenced by two month lagged price of Yemmiganur only. But for Yemmiganur market, these were influenced by one month lagged price of Kurnool and Yemmiganur itself and two month lagged prices of Adoni, Kurnool and Yemmiganur itself.

Similarly for Castor, the Error Correction Term (ECT) in the VECM (From Table 5) was negative and significant for Adoni only, which indicated the series would return to its long-run equilibrium, with a price adjustment speed of 42% per month. However, ECTs were positive for Kurnool and Yemmiganur, showing no speed of adjustment for these markets. Similar findings were reported by Nautiyal (2021) and Dey et al. (2021) in studies on price dynamics and market integration in India. In the context of short run cointegration: Current month prices of Adoni Market were not influenced by lagged prices of other markets, but where for Kurnool and Yemmiganur Markets, current prices were influenced by one-month lagged prices of other market prices only.

Similarly, ECT for Sunflower market prices was found to be negative and significant only for

Adoni, with a price adjustment speed of 20.6% per month. In terms of short run cointegration: Current prices of Adoni and Kurnool were influenced by its one-month lagged prices only, but in case of Yemmiganur, current market prices were not influenced by lagged prices from other markets.

Equational representation of speed of adjustment

The estimated VECM equations for these three markets were as follows: Here refers to differenced series; APGA, APGK, APGY: represent the adjusted prices of Groundnut for Adoni, Kurnool, and Yemmiganur, respectively. Similarly, APCA, APCK, APCY were Correspond to the adjusted prices of Castor for the same markets. Where APSA, APSK, APSY: Denote the adjusted prices of Sunflower for Adoni, Kurnool, and Yemmiganur, respectively and ECT refers to error correction term. The coefficients which were significant at 5% level are marked as bold.

$$\Delta APGA_t = -0.29ECT_{t-1} + 315.38 - 0.27\Delta APGA_{t-1} - 0.15\Delta APGA_{t-2} + 0.62\Delta APGK_{t-1} + 0.32\Delta APGK_{t-2} - 0.20\Delta APGY_{t-1} - 0.22\Delta APGY_{t-2}$$

$$\Delta APGK_t = -0.23ECT_{t-1} + 48.31 + 0.11\Delta APGA_{t-1} + 0.03\Delta APGA_{t-2} + 0.05\Delta APGK_{t-1} + 0.04\Delta APGK_{t-2} - 0.03\Delta APGY_{t-1} - 0.16\Delta APGY_{t-2}$$

$$\Delta APGY_t = 0.13ECT_{t-1} - 124.16 - 0.10\Delta APGA_{t-1} - 0.28\Delta APGA_{t-2} + 0.38\Delta APGK_{t-1} + 0.26\Delta APGK_{t-2} - 0.23\Delta APGY_{t-1} - 0.39\Delta APGY_{t-2}$$

$$\Delta APCA_t = -0.43ECT_{t-1} - 64.15 - 0.18\Delta APCA_{t-1} + 0.07\Delta APCK_{t-1} - 0.05\Delta APCY_{t-1}$$

$$\Delta APCK_t = 0.19ECT_{t-1} + 47.29 - 0.18\Delta APCA_{t-1} - 0.12\Delta APCK_{t-1} + 0.35\Delta APCY_{t-1}$$

$$\Delta APCY_t = 0.45ECT_{t-1} + 102.80 - 0.23\Delta APCA_{t-1} + 0.19\Delta APCK_{t-1} - 0.02\Delta APCY_{t-1}$$

$$\Delta APSY_t = -0.21ECT_{t-1} + 37.82 - 0.21\Delta APSA_{t-1} + 0.05\Delta APSK_{t-1} - 0.11\Delta APSY_{t-1}$$

$$\Delta APSK_t = -0.05ECT_{t-1} + 17.68 + 0.15\Delta APSA_{t-1} - 0.25\Delta APSK_{t-1} + 0.05\Delta APSY_{t-1}$$

$$\Delta APSY_t = 0.34ECT_{t-1} - 2.42 - 0.14\Delta APSA_{t-1} - 0.04\Delta APSK_{t-1} - 0.01\Delta APSY_{t-1}$$

Table 6: Results of Pairwise Granger Causality Tests for Prices of Groundnut, Castor and Sunflower of selected markets

Market-Pairs	Lags	F-stat.	P-value	Decision	Result
Groundnut					
Kurnool to Adoni	2	14.364	<0.001	Unidirectional	Kurnool Granger cause Adoni
Adoni to Kurnool	2	1.738	0.21	No causality	Adoni doesnot Granger cause Kurnool
Yemmiganur to Kurnool	2	2.858	0.039	Bidirectional	Yemmiganur Granger cause Kurnool
Kurnool to Yemmiganur	2	4.418	0.005		Kurnool cause Yemmiganur
Yemmiganur to Adoni	2	2.367	0.073	No causality	Yemmiganur does not cause Adoni
Adoni to Yemmiganur	2	2.2	0.09	No causality	Adoni does not cause Yemmiganur
Castor					
Kurnool to Adoni	1	5.949	0.0007	Bidirectional	Kurnool Granger cause Adoni
Adoni to Kurnool	1	6.594	0.0003		Adoni Granger cause Kurnool
Yemmiganur to Kurnool	1	7.563	0.0001	Bidirectional	Yemmiganur Granger cause Kurnool
Kurnool to Yemmiganur	1	4.005	0.0013		Kurnool Granger cause Yemmmiganur
Yemmiganur to Adoni	1	6.998	0.0024	Bidirectional	Yemmiganur Granger cause Adoni
Adoni to Yemmiganur	1	3.098	0.0289		Adoni Granger cause Yemmiganur
Sunflower					
Kurnool to Adoni	1	3.9028	0.022	Bidirectional	Kurnool Granger cause Adoni
Adoni to Kurnool	1	7.8305	0.001		Adoni Granger cause Kurnool
Yemmiganur to Kurnool	1	3.916	0.01	Unidirectional	Yemmiganur Granger cause Kurnool
Kurnool to Yemmiganur	1	1.4329	0.235	No causality	Kurnool does not Granger cause Yemmiganur
Yemmiganur to Adoni	1	18.248	<0.001	Bidirectional	Yemmiganur Granger cause Adoni
Adoni to Yemmiganur	1	17.554	<0.001		Adoni Granger cause Yemmiganur

Causality test among selected markets of Oilseeds

The Granger causality helps in establishing the direction of causation (if any) between the variables and thus helps in predicting the value of one variable on the basis of other variable. In the present analysis, optimum lag length was selected based on the minimum AIC and SBC criteria.

From Table 6, it was identified for Groundnut market prices that for there existed long run unidirectional causality from Kurnool to Adoni and long run bi-directional causality between the markets of Kurnool - Yemmiganur only. Similar report was obtained by Suthar *et al.* (2022) in the study on price behaviour of groundnut in major markets of India.

Similarly for castor, long run bi-directional causality was observed between each with other selected market, which indicated that the price transmission would occur in both directions.

But Sunflower markets it was observed that there existed long run bi-directional causality between the markets of Adoni - Kurnool and Yemmiganur -Adoni, Similarly, unidirectional causality was observed for Yemmiganur to Kurnool market and no causal relationship was observed between Kurnool to Yemmiganur market.

CONCLUSION

In the present work, Johansen's Cointegration Test confirmed long-run price integration among selected markets for groundnut, castor and sunflower. In the groundnut markets, the VECM estimates showed that the Error Correction Term (ECT) was negative and significant for Adoni (-29.1%) and Kurnool (-23.3%), indicating price adjustments toward equilibrium, with Kurnool's price influenced by Yemmiganur's two-month lagged price. Granger Causality analysis revealed bi-directional causality between Kurnool and Yemmiganur, unidirectional causality from Kurnool to Adoni and no causality between Yemmiganur and Adoni. Where for castor, ECT was negative and significant for Adoni (42%), showing a faster adjustment rate, while Kurnool's price was affected by one-month lagged prices of Yemmiganur and Adoni. Granger Causality indicated bi-directional relationships among Adoni-Kurnool, Kurnool-Yemmiganur and Yemmiganur-

Adoni. Similarly for sunflower markets, ECT was negative and significant for Adoni (-20.6%), confirming a moderate price adjustment. Granger Causality showed bi-directional transmission between Adoni-Kurnool and Yemmiganur-Adoni, unidirectional causality from Yemmiganur to Kurnool, and no causality between Kurnool and Yemmiganur. In that way, present study helps to identify price linkages between regional oilseed markets, ensuring efficient price transmission and reducing market inefficiencies. It also assists policymakers in monitoring market stability and designing effective trade and price policies.

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