Co-integration and causality analysis of "castor" (*Ricinuscommunis*oil)markets in India

Abstract

Castor (*Ricinus communis L.*) is a major industrial oilseed crop. Because of its numerous uses in the manufacturing of a wide range of industrial uses, castor oil has risen significantly in importance in the global economy. The study examined market integration in major Castor markets in India, including Dhanera, Patan, Kurnool, and Yemmiganur. The co-integration analysis conducted revealed a high level of market integration, as evidenced by the significant positive and negative values of weekly Castor prices across all markets. Unit root tests indicated that the markets were non-stationary, but became stationary when analyzed at the first difference. Further analysis using Johansen's tests identified three cointegrating equations among the markets. The results of the Vector Error Correction Model (VECM) demonstrated long-term price influences between markets. Specifically, Dhanera was found to be influenced by its own price, as well as by prices in Patan and Yemmiganur. Patan, on the other hand, was influenced by its own price, as well as by prices in Dhanera and Yemmiganur. Additionally, Kurnool and Yemmiganur were influenced by prices in neighboring markets.

Key words: castor, co-integration, unit root test (ADF), vector error correction, Johansen Test

1. Introduction

Castor is an industrial non-edible oil seed crop. It grows well on dry terrain and can be rather successful in situations with little fertility and little rainfall. India is referred to as an oilseed crop paradise, accounting for 10.0% of global oilseed production and 19.0% of the world's total oilseed acreage. India is the world's second-largest oilseed producer in terms of output and ranks second in terms of productivity (Kalpana M, et al., 2023).

In recent years, the significance of the Castor crop in India has grown substantially, as it contributes a substantial amount of foreign exchange to the country. Castor oil plays a dominant role in this trade, India is the single largest castor producer, accounting for more than 80 percent of the world's castor supply in terms of both quantity and value(Srinivasan, G., et.al., 2021). It is the second most traded commodity internationally, following pepper, and is the fourth commodity for which future trading is permitted. Currently, the global demand for Castor oil is in line with the available supply. Major consumers of Castor seed include China, the European

Union, and Brazil. India stands as the largest exporter of Castor oil, holding a 70% share of the international market, followed by China and Brazil (Ramoliya, R. K., 2022).

The production of castor seeds in India is anticipated to increase by 9% in the 2023–24 season through October. The Castor Crop Survey 2023–24 from the Solvent Extractors' Association of India (SEA) projects that India would produce 20.54 lakh tons of castor seed in 2023–24 as opposed to 18.81 lakh tons in 2022–23. The amount of castor oil and seed meal exported between April and September of last year was 3.14 lakh tones and 1.54 lakh tones, respectively; during the same period this year, the amounts grew to 3.16 lakh tones and 1.82 lakh tones, respectively. China (2.85 lakh tones), the Netherlands (0.91 lakh tones), France (0.64 lakh tones), the United States (0.53 lakh tones), and Japan (0.18 lakh tones) are the main importers of castor oil from India. (November 2023; Castor Outlook)

The reported area under castor in 2023–24 was 9.52 lakh ha (23.53 lakh acres), compared to 9.31 lakh ha (23.02 lakh acres) in 2022–2023 for the same period. Gujarat leads all states in castor area (7.15 lakh ha; 17.67 lakh acres), followed by Rajasthan (1.84 lakh ha; 4.55 lakh acres), Andhra Pradesh (0.40 lakh acres; Odisha (0.04 lakh acres); and Karnataka (0.02 lakh acres). The first preliminary projections from the Central Government state that 16.69 lakh tons of castor will be produced nationwide in 2023–2024. Gujarat (13.35 lakh tones), Rajasthan (3.12 lakh tones), Andhra Pradesh (0.11 lakh tones), Odisha (0.04 lakh tones), and Karnataka (0.02 lakh tones) are the five states in India that produce the most of the castor seeds.

In Gujarat, the Patan market's output rose by 15 to 20 percent in 2021; Similar production levels are expected in other areas. More than two lakh metric tons of seeds were produced in Rajasthan. The contributions from Telangana, Andhra Pradesh and other regions totaled about one lakh metric tons. From Gujarat, 12.5 lakh metric tons were produced. During the January 24, 2020 Castor conference in Palanpur, Gujarat, the estimated production for incoming crops varied from 15.50 to 16 lakh metric tons. Production in the Bhuj area is predicted to treble due to the area's larger land and strong yield(Bhatt, Y., & Jit, P, 2022).

India's castor exports amount to 10.92 million tons annually, generating revenue of 10,692 crore rupees. If the current consumption trend continues, India is projected to earn an additional 270.24 million rupees from castor exports by 2025. This demonstrates the significant potential for growth in India's castor export industry in the coming years. (Yamanura, & Kumar, R. M., 2020).Castor oil, which is rich in triglycerides known as ricinolein and found in 40–60% of castor seed, is used as a lubricant in high-speed engines and aircraft. Hydrogenated castor oil is utilized in soaps, printing inks, ointments, waxes, cosmetics, hair dressings, and disinfection treatments. In addition, castor oil has medical and lighting applications. It is also utilized in veterinary medicine. (Pari, L., et.al., 2020)

Market integration refers to the interconnectedness of various marketplaces, where goods flow in proportion to one another. This concept serves as a measure of the relationship between multiple markets and the extent of price movement between them. In well-integrated markets, prices tend to be similar, largely influenced by the cost of transporting goods between them. Understanding market integration is essential for grasping the correlation between diversity and market interaction, offering valuable insights into how different markets interact and influence one another. (Venkannanavara, M. M., & Kerur, N. M, 2021).This study examines co-integration in major castor markets in India, measuring the long-term relationship between time series variables. By analyzing co-integration, valuable insights into market interconnectedness and dynamics are gained. The research aims to provide a comprehensive analysis of co-integration among these markets, shedding light on factors driving price movements. Understanding these relationships can help market participants make informed decisions and manage risk exposure. This study adds to existing literature on co-integration in commodity markets and provides insights for policymakers, investors, and stakeholders in the castor industry.

2. Methodology

2.1 Data and study area

This study utilized secondary data to examine the integration of Castor markets. Incomplete price transmission can lead to biased incentives for farmers, impacting decision-making and agricultural productivity. Analyzing price movements in related markets helped assess the efficiency of the marketing system for the selected crop in the region.To select markets for the study, purposive sampling was employed. Four markets were chosen based on their size and production levels: Adoni and Yemmiganur in Kurnool, Andhra Pradesh, and Dhanera and Patan in Gujarat. Castor seed monthly prices were obtained from the government website (http://agmarknet.gov.in/).The study focused on analyzing the integration among Castor markets by examining average weekly modal prices from January 2015 to December 2023.

2.2 Market Integration Analysis

The concept of market integration elucidates the connection between prices in two geographically distinct markets. When markets are integrated, it signifies that they function as a unified system.

Agricultural markets that are geographically isolated can become interconnected when their prices show similar trends over a prolonged period. When studying market integration, it is important to consider the time it takes for prices to spread across markets and related commodities. Factors such as differences in product preferences, perishability, and restrictions on interstate travel can influence the integration of regional markets.In this study, co-integration and error-correction methodology were utilized to analyze the integration among specific Castor markets. The following steps outline the market integration analysis.

2.2.1 testing for a unit root, I (1), in each series;

2.2.2 testing for the number of co-integrating vectors in the system;

2.2.3 estimating and testing for the co-integrating relationship in the framework of a vector error correction model;

2.2.1 Test for unit root

It is necessary to verify that each price series is non-stationary and integrating in the same order before doing a cointegration test. This required utilizing tests like the Augmented Dickey Fuller (ADF) test to check for non-stationary in the variable. A stationary series has autocorrelations that are constant over time, a constant mean and variance, and other characteristics that are unaffected by time. The first differences in the series are examined for stationary if it is determined that the series is non-stationary. The order of integration I (d) is the number of times (d) a series is differenced to make it stationary. (Dolai, R. K., & Mondal, D., 2023).

The ADF test considers the null hypothesis that a given series has a unit root i.e., it is non-stationary the test is applied by running the regression of the following form

$$\Delta y_t = (\rho - 1) y_{t-1} + u_t = \delta y_{t-1} + u_t \qquad (1)$$

Where, Δ is the first difference operator. This model can be estimated and testing for a unit root is equivalent to testing δ= 0 (where δ = ρ - 1). Since the test is done over the residual term rather than raw data, it is no possible to use standard t-distribution to provide critical values. Therefore, this statistic has a specific distribution simply known as the Dickey – Fuller table.

A time series analysis and, more importantly, error correction equations require the determination of the order of integration of each variable, as each variable involved in the estimation of these models must be a first differently stationary series. If the coefficient δ is not statistically different from zero, it implies that the series have a unit root, and therefore the series is non-stationary. The unit root test for augmented-dickey fuller (ADF) is applied (Dickey D. A. and Fuller W. A, 1981). A t-test is used to evaluate the null hypothesis of non-stationary data. In the event when the estimated variable is considerably negative, the null hypothesis is rejected.

The critical values for this test are negative and larger than the standard t values. If the computed value (at level) is smaller than the critical‘t’ statistics, accept the null hypothesis of non-stationary series. In this case, the individual series may be integrated of order 1or 2, i.e., I (1) (or) I (2) and may be more than this order. Once the variable are checked for stationary and are of same order, integration between them can be tested using methods such as Augmented Dickey Fuller test (or) Johansen Maximum likelihood test in a bivariate as well as multivariate frame work of the estimated value of error term exceeds critical values at one per cent, five per cent and 10 per cent levels of significance, the conclusion would be that the residual term is stationary and hence the two individual series, through non-stationary are co-integrated in the long run.

2.2.2 Johansen Test

A linear combination of the commodity price time series may be stationary, suggesting a long-run equilibrium relationship between them, even though the individual time series may not be stationary on levels (Engle and Granger, 1987). Two non-stationary series are deemed to be co-integrated if their linear combination becomes stationary. The purpose of the cointegration test is to determine whether or not the residual term of the regression between the two-time series in question is stationary. The test begins with the assumption that two variables must share the same intertemporal characteristics in order for there to be a long-run equilibrium relationship between them. (Dolai, R. K., & Mondal, D., 2023).

The Johansen Juselius Maximum Likelihood approach is used in addition to the ADF test. Because it addresses endogeneity and simultaneity issues that other co-integration procedures in bivariate models fail to address, this test is thought to be superior to others. When cointegration is examined between more than two variables, it is also significant. In this technique, the hypothesis of co-integration vector's existence is formulated on a group of non-stationary series, and the test statistics for the hypothesis of a given number of co-integration vectors and their weights are derived by applying the hypothesis of reduced rank of the long-run impact matrix likelihood ratio and the maximum likelihood test. Inference regarding linear restrictions on the co-integration vectors and their weights is carried out using standard chi square methods (Johnsen and Juselius,1990 and Johansen,1988). First, the order of integration is the same for each time series of prices, and then test for co integration. Only variables of the same order of integration qualify for the pair wise co integration relationships the specific linear combination tested are the residual from a static co integration regression such as

$$Y_t = \beta_1 + \beta_2 X_1 + Z_t \qquad (2)$$

Where Y_1 and X_1 are two price series in levels and Z_t is the residual term Testing for co integration implies testing stationary of the residual term Z_t

2.2.3 Vector error correction mechanism

It is quite possible for random walks to be related to each other so that a regression of one random walk on the other has a stationary error term. For example, let

$$\Delta X_1 = \varepsilon$$

$$\Delta Y_1 = \mu$$

and let y_t+$x_t$be stationary. The simplest example is that y_t= -x_t+v. That is, let one random walk be the negative of the other- along allowing for some error. Then the sum is simply a random error with no unit root or autocorrelation.

If the combination of unit root variables is not unit root, then there must be some relation between them. This is true if and only if statement. If you find co integration then a relationship exists, if not it does not. Therefore, if you are interested in establishing that a relationship exists between unit root variables, this is equivalent to establishing co integration. That relationship is called the co integrating vector, which for our example is (1, 1) since the sum is stationary.

The equations can be written in the following form to capture all relationships and avoids unit roots.

$$\Delta X_t = \alpha_1(\beta_1 Y_{t-1} + \beta_2 X_{t-1}) + \varepsilon_t + \vartheta_t \qquad (3)$$

$$\Delta Y_t = \alpha_2(\beta_1 Y_{t-1} + \beta_2 X_{t-1}) + \mu_t + \vartheta_t \qquad (4)$$

This is called a vector error correction model. The error comes from the co integrating relationship. The betas contain the co integrating equation and the alphas the speeds of adjustment. Co integration analysis was carried out using EViews 7.0.0.1.rar.

3.Results and discussion

3.1 Augmented Dickey Fuller (ADF) unit root test

The ADF results for unit roots are displayed in Table 1, demonstrating the non-stationarity of all castor markets at the 1% level. Nevertheless, all markets remain stationary at their starting difference. At the one percent significance level, the test statistics were less than the crucial values due to their calculation and lack of unit root effects for each market. Consequently, there's a risk that the selected markets will merge.

Table 1. Augmented Dickey Fuller unit root test

Markets	Augmented Dickey Fuller test statistics		
	Level	First difference	Critical value (P)
Dhanera	-1.953819***	-23.75717***	
	(0.3076)	(0.0000)	
Patan	-1.826753***	-12.95896***	
	(0.3675)	(0.0000)	-3.440634 (0.01)
Kurnool	-2.185637***	-31.73120***	-2.865969 (0.05)
	(0.2119)	(0.0000)	-2.569187 (0.10)
Yemmiganur	-1.975446***	-32.49530***	
	(0.2978)	(0.0000)	

*Note.**** indicates significance at 1% level. P indicates mackinnon one-sided p-values

3.2 Johansen's Co integration test

There are three co-integrating equations among the markets that were chosen, according to the results of the Johansen's Co integration test for both the maximal Eigen value and the trace statistic, which are shown in Tables 2 and 3. A long-term link between the chosen castor markets is confirmed by the Johansen cointegration test result. To find out how much the markets are integrated, we must use a vector error correcting approach.

Table 2. Johansen's Co integration test (trace test)

Hypothesized no. of CE(s)	Eigen value	Trace statistic	Critical value (0.05 level)	Probability
None*	0.104883	137.5473	47.85613	0.0000**
At most 1*	0.062714	68.96129	29.79707	0.0000**
At most 2*	0.039723	28.87040	15.49471	0.0003**

At most 3	0.006088	3.780175	3.841466	0.0519*

*Note.*Trace test indicates 3 co integrating eqn(s) at the 0.05 level. * 5%, ** 1% denotes rejection of the hypothesis at significant level.

Table 3. Johansen's Co integration test (Maximum Eigen value test)

Hypothesized no. of CE(s)	Eigen value	Max-Eigen statistic	Critical value (0.05 level)	Probability
None*	0.104883	68.58602	27.58434	0.0000**
At most 1*	0.062714	40.09088	21.13162	0.0000**
At most 2*	0.039723	25.09023	14.26460	0.0007**
At most 3	0.006088	3.780175	3.841466	0.0519*

*Note.*Max-eigenvalue test indicates 3 co integrating eqn(s) at the 0.05 level. * 5%, ** 1% denotes rejection of the hypothesis at significant level.

3.3 Vector Error Correction Mechanism

Table 4. Estimates for short run price integration in selected markets

Cointegrating Eq:	CointEq1	CointEq2	CointEq3
Dhanera (-1)	1.000000	0.000000	0.000000
Patan (-1)	0.000000	0.000000	1.000000
Kurnool (-1)	0.000000	1.000000	0.000000
Yemmiganur (-1)	-1.169727	-1.124438	-1.245620
	(0.05580)	(0.02651)	(0.06169)
	[-20.9646]	[-42.4095]	[-20.1918]
C	140.6225	313.5367	375.5279

Since different castor markets are integrated in the long run. Hence, VECM was employed to know the speed of adjustments among the markets for long run equilibrium.

As evidenced by the level of significance and the quick speed of adjustment, the data displayed in Table 4 demonstrate that all of the markets—Dhanera, Patan, Kurnool, and Yemmiganur—came to a short-term equilibrium. The coefficient values suggest that in the Dhanera market, 50 weeks in the Patan market, 8 weeks in the Kurnool market, and 8 weeks in the Yemmiganur market, any price disruption would be repaired within a month.

In the long run, the significant Vector Error Correction estimates of selected castor markets exhibited both positive and negative coefficients. The results presented in table 5 shows thatdhanera castor market, was one week (0.096) lagged own price and significant at five per cent and one week (-0.087) lagged patan market price was significant at five per cent level of significance. It reveals that in the long run, dhanera market price was influenced by its own market price and also by patan market price. In case of patan castor market, two week (-0.167) lagged own price was significant and dhanera market one week (-0.207) lagged price was significant and two week (0.109) lagged dhanera market price was significant at five per cent level of significance and yemmiganur market one week (0.092) lagged price was significant at five per cent. It reveals that, in the long run patan market price was influenced by its own market price and also by dhanera marker price and yemmiganur market price.

In case of kurnool market, VCEM estimated that one week (-0.244) lagged own price was significant and in dhanera market one week (0.378) and two week (0.163) lagged price was significant at five per cent level of significance and in patan market, one week (-0.97) lagged price was significant at five per cent level of significance. It reveals that in the long run, Kurnool market price was influenced by its own market price and also dhanera and patan market price. In case of yemmiganur castor market, estimated that one week (-0.178) lagged own price was significant at and in patan market, one week (0.205) lagged price significant. It reveals that in the long run, yemmiganur market price was influenced by its own market price and also by patan market price. It can be summarized that all the selected markets viz., Dhanera, Patan, Kurnool and Yemmiganur were influenced by their own weekly lags and also by the other market prices.

Table 5. Test Results of Vector Error Correction Model for selected markets

Error Correction:	D(DHANERA)	D(PATAN)	D(KURNOOL)	D(YEMMIGANUR)
CointEq1	-0.092030	0.290238	0.036859	0.107829
	(0.03047)	(0.02985)	(0.03665)	(0.03233)
	[-3.01995]* **	**[9.72170]*** **	[1.00582]	**[3.33571]*** **
CointEq2	0.046961	-0.289922	0.024865	-0.021594
	(0.02845)	(0.02787)	(0.03421)	(0.03018)
	[1.65071]	**[-10.4025]*** **	[0.72684]	[-0.71557]
CointEq3	0.081203	0.068215	-0.152299	0.150746
	(0.02702)	(0.02647)	(0.03250)	(0.02867)
	[3.00481]* **	**[2.57660]*** **	**[-4.68654]*** **	**[5.25871]*** **
D(DHANERA(-1))	0.096477	-0.207433	0.378631	-0.008746
	(0.04816)	(0.04718)	(0.05791)	(0.05108)
	[2.00339] **	**[-4.39682]*** **	**[6.53833]*** **	[-0.17121]
D(DHANERA(-2))	0.058053	0.109895	0.163022	-0.016112
	(0.04853)	(0.04755)	(0.05836)	(0.05148)
	[1.19618]	**[2.31138] ** **	**[2.79338] *** **	[-0.31297]

D(PATAN(-1))	-0.087761 (0.03623) **[-2.42231] ****	0.051090 (0.03549) [1.43942]	-0.097113 (0.04357) **[-2.22904] ****	0.205663 (0.03843) **[5.35146] *****
D(PATAN(-2))	0.069510 (0.03674) [1.89204]	-0.167925 (0.03599) **[-4.66573]*****	0.027385 (0.04418) [0.61988]	-0.049319 (0.03897) [-1.26557]
D(KURNOOL(-1))	0.004018 (0.03802) [0.10568]	-0.050352 (0.03725) [-1.35185]	-0.244008 (0.04572) **[-5.33713] *****	-0.033421 (0.04033) [-0.82870]
D (KURNOOL (-2))	-0.013479 (0.03482) [-0.38712]	0.047819 (0.03411) [1.40181]	-0.072503 (0.04187) [-1.73156]	0.043605 (0.03694) [1.18058]
D (YEMMIGANUR (-1))	0.077186 (0.04017) [1.92142]	0.092479 (0.03935) **[2.34987] ****	-0.004152 (0.04831) [-0.08594]	-0.178237 (0.04261) **[-4.18279] *****
D(YEMMIGANUR (-2))	0.031403 (0.03623) [0.86666]	0.021771 (0.03550) [0.61331]	-0.051673 (0.04357) [-1.18590]	0.023340 (0.03844) [0.60724]
C	3.134707 (4.74115) [0.66117]	4.873346 (4.64477) [1.04921]	4.330421 (5.70131) [0.75955]	4.057541 (5.02918) [0.80680]

Note. **( )** indicates standard error. [ ] indicates t statistic. *** indicates significance at 1% level. ** indicates significance at 5%

Detailed results from co integration analysis through vector error correction model at one per cent and five per cent level is consolidated in the table 6.

Table 6. Consolidated table from the results of Vector Error Correction Mechanism

Dhanera	Patan	Kurnool	Yemmiganur
Dhanera(-1)	Dhanera(-1 and -2)	Dhanera(-1 and -2)	Patan(-1)
Patan(-1)	Patan(-2)	Patan(-1)	
	Yemmiganur(-1)	Kurnool(-1)	Yemmiganur(-1)

Note.() indicates lagged time period in terms of week: each column under specific headings indicates the markets co integrated with the boldly indicated markets.

Conclusion

The results of the unit root test reveal that all castor markets display non-stationary at the one percent level. However, upon examining their first difference, it is evident that all markets are stationary, indicating the presence of a unit root. The Johansen cointegration test further validates the existence of a long-term relationship among the chosen castor markets, signifying their integration in the long run.In summary, the analysis demonstrates that the selected markets - Dhanera, Patan, Kurnool, and Yemmiganur - are influenced by their respective weekly lags as well as the prices of other markets.

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