# The Relationship Between Major Castor Markets in India: A Co-integration Analysis

**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. Co-integration analysis showed strong market integration, with weekly Castor prices in all markets displaying significant positive and negative values. Unit root tests indicated non-stationarity, but markets became stationary at the first difference. Johansen's tests revealed three co-integrating equations among the markets. VECM results showed long-term price influences between markets, with Dhanera influenced by its own price, as well as prices in Patan and Yemmiganur. Patan was influenced by its own price, as well as Dhanera and Yemmiganur, while Kurnool and Yemmiganur were also influenced by neighbouring market prices.

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

## 1. Introduction

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 tonnes and 1.54 lakh tonnes, respectively; during the same period this year, the amounts grew to 3.16 lakh tonnes and 1.82 lakh tonnes, respectively. China (2.85 lakh tonnes), the Netherlands (0.91 lakh tonnes), France (0.64 lakh tonnes), the United States (0.53 lakh tonnes), and Japan (0.18 lakh tonnes) 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 tonnes), Rajasthan (3.12 lakh tonnes), Andhra Pradesh (0.11 lakh tonnes), Odisha (0.04 lakh tonnes), and Karnataka (0.02 lakh tonnes) are the five states in India that produce the most castor.

In Gujarat, the Patan market's output rose by 15 to 20 percent in 2021; comparable production is anticipated in other regions. In Rajasthan, more than two lakh MT of seeds were produced. Roughly one lakh MT was given by Telangana, AP, and other regions. About 12.5 lakh MT came from Gujarat. At the Castor meeting, which took place in Palanpur, Gujarat, on January 24, 2020, production estimates for incoming crops ranged between 15.50 to 16 lakh MT. Because of the greater acreage and good yield in the Bhuj area, production is expected to quadruple. (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 is the interconnectedness of different marketplaces where goods flow in proportion to one another. It is a measure showing the relationship between multiple markets and the degree of price movement between them. Well-integrated markets have similar prices, influenced primarily by the cost of transporting goods between them. Market integration is crucial in understanding the correlation between diversity and market interaction, providing insights into how different markets interact and influence each other (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 market integration concept explained the relationship between the prices prevailing in two markets that were spatially separated. When markets were integrated, it implied that the markets in the system operated as a single market system.

The agricultural markets that are geographically isolated become integrated when their prices exhibit comparable trends over an extended duration. When examining market integration, one must also take into account the time it takes for prices to spread across markets and associated commodities. Variations in variety preferences, perishability, and restrictions on interstate travel may have an impact on the integration of the regional market.

Co-integration and error-correction methodology were employed in this study to analyze the integration among particular Castor markets. The following steps make up 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-stationarity 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 stationarity 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, $\Delta$ is the first difference operator. This model can be estimated and testing for a unit root is equivalent to testing $\delta = 0$ (where $\delta = \rho - 1$). 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 stationarity 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*

Table 1 presents the ADF results for unit roots, which show that all castor markets are non-stationary at the 1% level. Nevertheless, at their initial disparity, all markets are immobile. The fact that the test statistics were calculated and free from unit root effects for every market was smaller than the critical values at the one percent significance level. As a result, there is a chance that the chosen markets will integrate.

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

**4.Conclusion**

The results of the unit root test reveal that all castor markets display non-stationarity 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.

**References**


1. Ramoliya, R. K. (2022). Growth and instability of major oilseed crops in Gujarat. *International Journal of Agriculture Sciences*, *ISSN*, *14*, 0975-3710.
2. Srinivasan, G., Kumar, S. S., & Marikannan, K. (2021). A STUDY ON CASTOR VALUE CHAIN IN NAMAKKAL DISTRICT OF TAMIL NADU, INDIA. *Plant Archives*, *21*(1), 1849-1851.
3. Castor Outlook, November - 2023, Agricultural Market Intelligence Centre, PJTSAU.
4. Bhatt, Y., & Jit, P. (2022). Estimating and Bridging the Yield Gaps in Oilseeds for Atma Nirbhar Bharat.
5. Yamanura, & Kumar, R. M. (2020). An overview of utility, status, retrospective and prospects of castor: a review.
6. Venkannanavara, M. M., & Kerur, N. M (2021). Co-Integration of Castor Markets in India—An Econometric AnalysisFrontiers in Crop Improvement. Vol 9 2241-2246 (Special Issue-V)
7. Pari, L., Suardi, A., Stefanoni, W., Latterini, F., & Palmieri, N. (2020). Environmental and economic assessment of castor oil supply chain: a case study. *Sustainability*, *12*(16), 6339.
8. Dolai, R. K., & Mondal, D. (2023). Cointegration between Agricultural GDP and Inputs in India: An Empirical Analysis. *Sch J Econ Bus Manag*, *5*, 118-129.
9. Johansen S. and Juselius K. (1990). ‘Maximum likelihood estimation and inference on cointegration- with application to the demand for money’. Oxford bulletin of Economics and statistics, 52, 170-209.

10. Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*, *12*(2-3), 231-254.
11. Dickey D. A. and Fuller W. A, (1981). 'Likelihood ratio statistics for autoregressive time series with a unit root'. Econometrica, 49, 1057-1072.