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## Price volatility and spot-futures relationship in the Indian castor seed market

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### Abstract

**Abstract:** The study examined the volatility and relationship between spot and futures prices of castor seed in India using monthly data for the period July 2004 to December 2024. The analysis was based on secondary data on spot and futures prices, with ARCH and GARCH models and volatility indices used to examine price volatility. The relationship between spot and futures prices was analysed using covariance, correlation, Augmented Dickey-Fuller (ADF) test, Johansen's cointegration test, Vector Error Correction Model (VECM) and Granger causality test. The results indicated that recent price shocks significantly influenced volatility in both spot and futures markets, while the persistence of past volatility was limited. Futures prices exhibited relatively higher volatility than spot prices in most years. Spot and futures prices showed a strong positive correlation and were found to share a stable long-run equilibrium relationship. The VECM results indicated significant adjustment of spot prices towards long-run equilibrium, while the Granger causality test revealed a unidirectional flow of information from futures prices to spot prices. The findings suggest that the castor futures market plays an important role in the price formation process and provides useful price signals to the spot market.

**Keywords:** Castor, spot price, futures price, price volatility, arch-garch, cointegration, vecm, granger causality

### Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop with significant commercial importance to India. India is a leading producer of castor seed and a major player in the global castor oil trade, which has wide applications in pharmaceuticals, lubricants, paints, coatings and other industries. Gujarat is the major castor-producing state, contributing more than three-fourths of the country's production. In 2025-26, the state accounted for 13.61 lakh tonnes out of India's estimated production of 17.86 lakh tonnes. The export-oriented nature of the castor oil industry and the concentration of cultivation among small and marginal farmers make price fluctuations an important concern for the sector. In India, castor seed futures are traded on the National Commodity and Derivatives Exchange (NCDEX), providing market participants with a means of managing price risk and obtaining forward price signals. During 2025-26, castor futures recorded a traded volume of 19.16 lakh tonnes, equivalent to about 1.07 times the reported annual production (NCDEX, 2026).

The close relationship between spot and futures prices is important for understanding price movements in the castor market. Examining the volatility of both markets and their price relationship can help assess how information flows between spot and futures markets and the role of futures prices in the price formation process. Therefore, the study aimed to examine the volatility in spot and futures prices of castor seed in India and to assess the relationship between the two markets.

### Data source and research methodology

The study was based on secondary data on monthly spot and futures prices of castor seed for the period July 2004 to December 2024, comprising 246 observations. Futures price data were obtained from the National Commodity and Derivatives Exchange (NCDEX), while spot price data were obtained from the Directorate of Marketing and Inspection (DMI), Ministry of

Agriculture and Farmers Welfare, Government of India, for Banaskantha district of Gujarat. Banaskantha was considered for the spot market analysis due to its importance in castor production and trade, with Deesa being the designated basis centre for the NCDEX castor seed futures contract.

### Volatility analysis

The volatility of spot and futures prices was examined using ARCH and GARCH models, along with volatility indices to assess the variation in price volatility over the study period.

### Arch(Q) model

The ARCH(q) model was used to capture the effect of past squared shocks on the current volatility of castor prices.

$$h_t = \alpha_0 + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2$$

### Garch(P,Q) model

The GARCH(p,q) model was used to capture both the effect of past shocks and the persistence of conditional volatility in castor prices.

$$h_t = \alpha_0 + \sum_{i=1}^p \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^q \beta_j h_{t-j}$$

Where,

$h_t$ : Conditional variance (volatility) of the castor price at time  $t$

$\alpha_0$ : Constant term representing baseline level of volatility

$\alpha_i$ : Coefficient measuring the effect of past squared shocks on current

volatility

$\varepsilon_{t-i}^2$ : Squared error (shock) of the castor price series at lag  $i$

$\beta_j$ : Coefficient measuring the effect of past conditional volatility on current volatility

$p$ : Number of lags of past squared shocks included in the model

$q$ : Number of lags of past conditional variance included in the model

$i$ : Index representing the lag of the squared error term

$j$ : Index representing the lag of the conditional variance term

### Volatility index

The volatility index was used to measure and compare the extent of price variability in spot and futures markets over the study period.

$$\text{Volatility} = \text{STDEV} \left( \ln \frac{\text{Settle } P_t}{\text{Settle } P_{t-1}} \right) * \sqrt{T}$$

Where,

$\text{Settle } P_t$ : Settlement Price of futures (or spot) contract on day  $t$

$\text{Settle } P_{t-1}$ : Settlement Price of futures (or spot) contract on the previous trading day ( $t-1$ )

$T$ : Number of trading periods in a year used for annualization

$t$ : Current time period or trading day

### Analysis of spot-futures price relationship

The relationship between spot and futures prices was examined using covariance, correlation, Augmented Dickey-Fuller (ADF) test, Johansen cointegration test, Vector Error Correction Model (VECM), and Granger causality test.

### Covariance

The covariance between spot and futures prices was estimated to measure the extent to which the two price series vary together.

$$\text{Cov}(X, Y) = \frac{\sum [(x_i - \bar{X})(y_i - \bar{Y})]}{n - 1}$$

Where,

$X_i$ : Spot price of castor for the  $i^{th}$  observation.

$Y_i$ : Futures price of castor for the  $i^{th}$  observation.

$\bar{X}$ : Mean of the castor spot prices.

$\bar{Y}$ : Mean of the castor futures prices.

$n$ : Total number of paired observations of spot and futures prices.

$i$ : Index representing the  $i^{th}$  observation.

### Correlation coefficient

The correlation coefficient was used to measure the strength and direction of the association between spot and futures prices.

$$r_{xy} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2} \sqrt{\sum (y_i - \bar{y})^2}}$$

Where,

$x_i$ : spot prices for the  $i^{th}$  observation

$y_i$ : futures prices for the  $i^{th}$  observation

$\bar{x}$ : Mean of spot prices

$\bar{y}$ : Mean of futures prices

$r_{xy}$ : correlation coefficient between spot and futures prices

### Augmented dickey-fuller (ADF) test

The Augmented Dickey-Fuller (ADF) test was used to examine the stationarity of the spot and futures price series.

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \delta_1 \Delta Y_{t-1} + \dots + \delta_p$$

Where,

$\Delta Y_t$ : First difference of the castor price series at time  $t$

$Y_{t-1}$ : Lagged value of the castor price series at time  $t - 1$

$\alpha$ : Constant (intercept term)

$\beta$ : Coefficient of the deterministic time trend

$\Gamma$ : Coefficient of the lagged level variable

$\delta_1$ : Coefficient of the  $i^{th}$  lagged first-difference term

$\Delta Y_{t-1}$  :  $i^{\text{th}}$  lagged first difference of the castor price series

$P$  : lag order of the autoregressive process

$T$  : Time period of the observation

### Johansen cointegration test

Johansen's cointegration test was used to determine the existence of a long-run equilibrium relationship between spot and futures prices.

$$\Delta Y_t = \pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \epsilon_t$$

Where,

$Y_t$  : Vector of variables at time  $t$  (e.g., spot and future prices)

$Y_{t-1}$ : Lagged vector of variables (previous time period values)

$\Gamma_i$  : Coefficients that show short run adjustments for each lag

$\Delta Y_{t-i}$ : Differenced values of the variables for lag (to make the series stationary)

$\epsilon_t$  : Error term or residuals at time  $t$ , capturing random shocks or noise

$k$ : Number of lags included in the model

$\pi$ : Long-run coefficient matrix that captures the long-run equilibrium relationship among castor spot and futures prices

$\Gamma_i$ : Short-run coefficient matrix representing the short-run adjustments associated with the  $i^{\text{th}}$  lag

$\epsilon_t$ : Error term (innovation) at time  $t$ , representing random shocks not explained by the model

### Vector error correction model (VECM)

The Vector Error Correction Model (VECM) was used to examine the short-run dynamics and adjustment of spot and futures prices towards their long-run equilibrium.

$$\Delta S_t = \alpha_1 (S_{t-1} - \beta F_{t-1}) + \sum_{i=1}^k \gamma_i \Delta S_{t-i} + \sum_{j=1}^k \delta_j \Delta F_{t-j} + \epsilon_t$$

Where,

$\Delta S_t$  = Change in spot price at time  $t$

$\Delta F_t$  = Change in futures price at time  $t$

$S_{t-1}$  = Lagged spot price at time  $t-1$

$F_{t-1}$  = Lagged futures price at time  $t-1$

$\beta$  = Long-run cointegrating coefficient between spot and futures prices

$S_{t-1} - \beta F_{t-1}$  = Long-run equilibrium error (cointegration term)

$\alpha_1$  = Speed of adjustment coefficient (rate at which disequilibrium is corrected)

$\gamma_i$  = Coefficients for lagged changes in spot prices (short-run dynamics)

$\delta_j$  = Coefficients for lagged changes in futures prices (short-run dynamics)

$\epsilon_t$  = Error term

### Granger causality test

The Granger causality test was used to determine the direction of causality and information flow between spot and futures prices.

Spot Price Equation

$$Y_t = \alpha_0 + \sum_{i=1}^p \alpha_i Y_{t-i} + \sum_{j=1}^q \beta_j X_{t-j} + \epsilon_t$$

Futures Price Equation

$$X_t = \gamma_0 + \sum_{i=1}^p \gamma_i X_{t-i} + \sum_{j=1}^q \delta_j Y_{t-j} + \mu_t$$

Where,

$Y_t$  : Spot price of castor at time  $t$

$X_t$ : Futures price of castor at time  $t$

$\alpha_0, \gamma_0$ : Intercepts in the respective spot and futures price equations

$\alpha_i$ : Coefficients of lagged spot prices ( $Y_{t-i}$ ) in the spot price equation

$\beta_j$ : Coefficients of lagged future prices ( $X_{t-j}$ ) in the spot price equation

$\gamma_i$ : Coefficients of lagged future prices ( $X_{t-i}$ ) in the futures price equation

$\delta_j$ : Coefficients of lagged spot prices ( $Y_{t-j}$ ) in the futures price equation

$p$ : Number of lags of the dependent series

$q$ : Number of lags for the other series

$\epsilon_t, \mu_t$ : Error terms in the respective equations

## Results and Discussion

### Volatility of spot and futures prices

The estimated GARCH (1,1) model was used to examine the conditional volatility of castor spot and futures prices. The results are presented in Table 1.

**Table 1:** GARCH (1,1) Estimates for Spot and Futures Price Volatility

| Series        | Parameter                          | Coefficient | Std. Error | Z-statistic |
|---------------|------------------------------------|-------------|------------|-------------|
| Spot price    | $\alpha$ : RESID (-1) <sup>2</sup> | 1.0095***   | 0.2839     | 3.5558      |
|               | $\beta$ : GARCH (-1)               | -0.0253     | 0.1480     | -0.1709     |
| Futures price | $\alpha$ : RESID (-1) <sup>2</sup> | 0.9837***   | 0.2868     | 3.4300      |
|               | $\beta$ : GARCH (-1)               | -0.0362     | 0.0947     | -0.3826     |

**Note :** \*\*\* significant at 1 per cent level. Variance equation: GARCH = C (2) + C (3) \* RESID (-1)<sup>2</sup> + C (4) \* GARCH (-1)

The ARCH coefficients for both spot (1.0095) and futures (0.9837) prices were positive and statistically significant at the 1 per cent level, indicating that recent price shocks had a significant effect on current volatility. However, the GARCH coefficients for spot (-0.0253) and futures (-0.0362) prices were statistically insignificant, indicating limited persistence of past volatility. The results suggest that volatility in both markets was primarily influenced by recent shocks rather than prolonged volatility persistence.

The annual volatility indices of castor spot and futures prices were estimated to compare the variation in price volatility across

**Table 2:** Annual Volatility Index of Spot and Futures Prices of Castor (%)

| Year  | Spot  | Futures | Year | Spot  | Futures |
|-------|-------|---------|------|-------|---------|
| 2004* | 13.72 | 22.18   | 2015 | 19.00 | 25.48   |
| 2005  | 17.03 | 18.94   | 2016 | 19.04 | 26.97   |
| 2006  | 13.25 | 19.25   | 2017 | 19.12 | 28.63   |
| 2007  | 19.05 | 8.25    | 2018 | 20.8  | 26.19   |
| 2008  | 22.27 | 29.88   | 2019 | 25.58 | 22.32   |
| 2009  | 24.95 | 22.49   | 2020 | 15.93 | 19.72   |
| 2010  | 17.54 | 16.5    | 2021 | 13.25 | 19.36   |
| 2011  | 33.09 | 25.53   | 2022 | 13.89 | 15.18   |
| 2012  | 32.04 | 39.74   | 2023 | 13.6  | 21.53   |
| 2013  | 16.81 | 26.92   | 2024 | 9.49  | 17.52   |
| 2014  | 14.76 | 25.73   |      |       |         |

**Note:** \*Volatility for 2004 is based on 5 months of data (August-December 2004) as NCDEX castor trading began in July 2004

The volatility indices showed considerable variation across the study period. Spot price volatility was highest in 2011 (33.09 per cent), while futures price volatility was highest in 2012 (39.74 per cent). In most years, futures prices exhibited higher volatility than spot prices, although the pattern varied across individual years. Towards the end of the study period, volatility declined in both markets, reaching 9.49 per cent for spot prices and 17.52 per cent for futures prices in 2024. Overall, the futures market

exhibited relatively higher price variability during most of the study period.

#### Relationship between spot and futures prices

The descriptive statistics of spot and futures prices were estimated to examine their central tendency and variability during the study period and are presented in Table 3.

**Table 3:** Descriptive statistics of spot and futures prices of castor

| Statistic             | Spot Prices | Futures Prices |
|-----------------------|-------------|----------------|
| Mean (Rs./quintal)    | 3848.77     | 3965.04        |
| Median (Rs./quintal)  | 3800.04     | 3975.50        |
| Maximum (Rs./quintal) | 7364.77     | 7480.00        |
| Minimum (Rs./quintal) | 1371.13     | 1425.00        |
| Std. Dev.             | 1529.47     | 1557.10        |
| CV(%)                 | 39.74       | 39.27          |
| Skewness              | 0.32        | 0.28           |
| Kurtosis              | 2.50        | 2.40           |

The mean spot and futures prices were ₹3,848.77 and ₹3,965.04 per quintal, respectively, with futures prices recording a slightly higher average. The coefficient of variation was 39.74 per cent for spot prices and 39.27 per cent for futures prices, indicating broadly similar variability in the two markets. The maximum

and minimum prices also indicate significant variation over the study period.

Covariance and correlation analysis was carried out to examine the degree and direction of association between spot and futures prices, with the results presented in Table 4.

**Table 4:** Covariance and Correlation between Spot and Futures Prices

| Series Pair                         | Obs. | Covariance | Correlation Coefficient (r) |
|-------------------------------------|------|------------|-----------------------------|
| Log Price levels (LNFUT, LNSPOT)    | 246  | 0.1881     | 0.9923                      |
| (First Differences) DLNFUT, DLNSPOT | 245  | 0.0020     | 0.547466                    |

The spot and futures prices exhibited a very strong positive correlation of 0.9923 in levels, indicating a close association between the two markets. However, the correlation between their first differences was lower at 0.5475, suggesting that short-run price movements were comparatively less closely related.

The positive association in both cases indicates that the two price series generally moved in the same direction.

The stationarity of the spot and futures price series was examined using the Augmented Dickey-Fuller (ADF) test, and the results are presented in Table 5.

**Table 5:** Augmented Dickey-Fuller Unit Test Results

| Series  | Specification       | ADF statistic (Level) | ADF statistic (1 <sup>st</sup> difference) |
|---------|---------------------|-----------------------|--------------------------------------------|
| Spot    | Intercept           | -1.3455 (0.6086)      | -10.8328*** (0.0000)-                      |
|         | Intercept and trend | -2.7562 (0.2152)      | -10.8109*** (0.0000)                       |
| Futures | Intercept           | -1.3483 (0.6072)      | -14.9590*** (0.0000)                       |
|         | Intercept and trend | -2.5965 (0.2824)      | -14.9290*** (0.0000)                       |

**Note :** \*\*\* significant at 1 per cent level; figures in paranthesis are MacKinnon (1996) p-values. Lag length of 5 selected automatically based on AIC

The ADF test results indicate that both spot and futures price series were non-stationary at levels, as the null hypothesis of a unit root could not be rejected. However, both series became

stationary after first differencing, with the test statistics significant at the 1 per cent level under both specifications. Thus, both price series were integrated of order one, I(1), satisfying the requirement for testing cointegration.

Since both spot and futures price series were integrated of order one, Johansen's cointegration test was employed to examine the

existence of a long-run equilibrium relationship between the two markets.

**Table 6:** Johansen's Co-Integration Test Estimates

| Hypothesised No. of CE(s)      | Eigenvalue | Statistic  | 5% Critical Value |
|--------------------------------|------------|------------|-------------------|
| <b>Trace test</b>              |            |            |                   |
| None*                          | 0.1074     | 29.0840*** | 15.4947           |
| At most 1                      | 0.0060     | 1.4732     | 3.8415            |
| <b>Maximum eigenvalue test</b> |            |            |                   |
| None*                          | 0.1074     | 27.6108*** | 14.2646           |
| At most 1                      | 0.0060     | 1.4732     | 3.8415            |

**Note:** \* denotes rejection of the null hypothesis at the 5 per cent level; \*\*\* significant at 1 per cent level; p-values based on MacKinnon-Haug-Michelis(1999)

Both the trace and maximum eigenvalue tests rejected the null hypothesis of no cointegration at the 1 per cent level, while the hypothesis of at most one cointegrating relationship was not rejected. This confirms the existence of one cointegrating relationship between castor spot and futures prices, indicating that the two markets maintained a stable long-run equilibrium

relationship during the study period.

The Vector Error Correction Model (VECM) was estimated to examine the short-run adjustment of spot and futures prices towards their long-run equilibrium, and the results are presented in Table 7.

**Table 7:** Vector Error Correction Model : Cointegrating Equation and Error Correction Terms

| <b>Cointegrating equation</b> |                     |                    |
|-------------------------------|---------------------|--------------------|
| LNPOT (-1)                    | 1.0000              |                    |
| LNFUTURES (-1)                | -1.0215*** (0.0166) |                    |
| Constant                      | 0.2079              |                    |
| <b>Error Correction term</b>  | <b>D (Futures)</b>  | <b>D (Spot)</b>    |
| Error Correction Coefficient  | 0.2174*(0.1146)     | -0.1588** (0.0729) |
| t-statistic                   | 1.8964              | -2.1801            |
| Adjusted $R^2$                | -0.0019             | 0.4279             |

**Note :** Standard errors are given in parantheses; \* and \*\* indicate statistical significance at 10 and 5 per cent level, respectively

The estimated cointegrating coefficient of futures prices was -1.0215 and statistically significant at the 1 per cent level, confirming a significant long-run relationship between spot and futures prices. The error correction coefficient for spot prices was -0.1588 and significant at the 5 per cent level, indicating that about 15.88 per cent of the previous period's disequilibrium was corrected through adjustments in spot prices. The adjustment coefficient for futures prices was positive (0.2174)

and significant at the 10 per cent level, indicating a comparatively weaker adjustment towards long-run equilibrium. The results suggest that both markets participate in restoring equilibrium, with a stronger adjustment observed in the spot market.

The Granger causality test was employed to examine the direction of information flow between castor spot and futures prices, and the results are presented in Table 8.

**Table 8:** Pairwise Granger Causality Test Results

| Null Hypothesis                     | Obs | F - Statistic | p-value | Direction of relationship |
|-------------------------------------|-----|---------------|---------|---------------------------|
| Futures does not Granger-cause Spot | 244 | 83.217***     | 4.E-28  | FUTURES SPOT              |
| Spot does not Granger-cause Futures |     | 1.0376        | 0.3559  |                           |

**Note :** \*\*\* denotes rejection of the null hypothesis at the 1 per cent level



The results indicate a unidirectional causal relationship from futures prices to spot prices. The null hypothesis that futures prices do not Granger-cause spot prices was rejected at the 1 per cent level, while the reverse hypothesis could not be rejected. This indicates that past movements in futures prices contain useful information for predicting subsequent movements in spot prices, suggesting that the futures market plays an important role in the price formation process of castor.

## Conclusion

The study examined the volatility and relationship between spot and futures prices of castor seed for the period July 2004 to December 2024. The ARCH-GARCH results indicated that recent price shocks significantly influenced volatility in both markets, while volatility persistence was limited. Futures prices exhibited relatively higher volatility in most years. The spot and futures prices showed a strong positive association and shared a

stable long-run equilibrium relationship. The VECM results indicated significant adjustment of spot prices towards long-run equilibrium, while Granger causality revealed a unidirectional flow of information from futures to spot prices. Overall, the findings suggest that the castor futures market plays an important role in price formation and provides useful price signals to the spot market.

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