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# Cointegration and Price Discovery Mechanism of Major Spices in India

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**Abstract** Price discovery is one of the major functions of the commodity market to hedge sharp price fluctuations, protecting the interests of both farmers and consumers. Production and export of major spices from India is gradually gaining importance in foreign market and also on Indian economy in terms of foreign currency reserve. This study makes an effort to understand the price discovery mechanism by identifying the transmission of price signals between spot and futures market of four major spices (chilli, turmeric, cumin and coriander) that are traded in National Commodity and Derivative Exchange (NCDEX), India using daily price data from October 2015 to April 2017. Among other statistical tools, econometric methods viz., Cointegration test, Granger Causality test, Vector Error Correction Model (VECM) are used in assessing the price behavioural pattern between spot and futures market. Cointegration analysis reveals long run associationship between spot and futures prices in chilli,turmeric, cumin. The study also reveals that both spot and futures market play leading role in the price discovery process and are informationally efficient in reacting to each other. On the other hand uni-directional causality is evident from futures to spot price in case of coriander. It is expected that both the producers and the users of these important spices will be benfitted from such findings and will help them in harvesting better profit by hedging out the uncertainity in the spice market.

***Keywords:*** *agriculture, commodity market, cointegration, econometrics, price discovery, VECM*

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## 1. Introduction

Being agrarian in nature Indian economy provided major emphasis on agricultural production. As a result of which consistent efforts have been made to transform the agriculture scenario of the country through different programmes like High Yielding Varieties (HYV), Green revolution etc., which has transformed India from a food deficient to a food surplus country [1]; hence efficient marketing of agricultural commodities gaining momentum. As a result during the past few decades, especially after “Green Revolution” the country has taken several policy measures to protect the interests of both the producer and consumer [2]. Though future marketing was initiated long back, it took late ninties of last century to make the Forward Markets Commission (FMC) effective.

Unlike industrial production, agricultural production has to depend on the vagaries of weather to a great extent vis-a-vis agricultural commodities experience sharp price fluctuation in international as well as in domestic markets. Futures trading is a technique for price discovery and price risk management and is useful to all sectors of economy, including the farmers and consumers [3,4]. Forward marketing is used as a tool to hedge against sharp price fluctuations. Abnormal price fluctuations adversely affect the farmers (as they realize lower prices of their produce during the harvest season, *i.e.* distress sale) and consumers (as they have to pay higher prices in the lean season to meet their requirements). Futures trading provides mean of appraising the supply and demand conditions and dealing with price risks, over time and distance. Futures trading not only provides price signals to the market of today, but also time ahead. It also provides guidance to farmers and buyers (consumers) of agricultural commodities. For a stable economy in a developing country like India, the foreign exchange reserve at any point of time plays a great role, among the agricultural commodities spices are the major contributors in earning a sizeable amount of foreign currency through its export. As such to have a stable production vis-a-vis marketing the knowledge of the spot and futures prices with their relationship is utmost importance.

Price discovery is the general process used in determining the spot price through futures market. It is very useful for producers as they get a fair idea about the prices likely to prevail in the future and thus allocate their scarce resources accordingly among other commodities to maximize their profit and minimize risk. Consumers can also be benefited from knowing the commodity price in advance. Ali and Gupta (2011) worked on efficiency in agricultural commodity futures markets in India using the cointegration approach. The purpose of their study was in line with the ongoing global and domestic reforms in agriculture and allied sectors. Trade liberalization policy in India has increased exposure of agricultural produce to price and other market risks, which consequently emphasize the importance of futures markets for price discovery and price risk management [5]. Chopra and Bessler (2005) studied the incidence of price discovery for black pepper in the spot market and the nearby and first distant futures markets in Kerala, India [6]. Raghavendra *et al.* (2016) empirically examined the market, which reacts first in India by assessing the relationship between spot and futures prices of agricultural commodities such as soya bean, chana, maize, jeera and turmeric for a period from January 2010 to March 2015 traded in National Commodity and Derivatives Exchange (NCDEX). Their empirical results suggested that the existence of long-run equilibrium relationships between futures and spot prices for all the five agricultural commodities.[7] Allen *et al.* (2016) analyzed cointegrating relationships among agricultural commodity, ethanol and cushing crude oil spot and futures prices. The use of grains for the creation of bio-fuels had sparked fears that these demands are inflating food prices. They analyzed approximately 10 years of daily spot and futures prices for corn, wheat, sugar ethanol and oil prices from Data Stream for the period 19 July 2006 to 2 July 2015. The analysis, featured Engle-Granger pair wise cointegration and Markov-switching VECM and Impulse Response Analysis, confirmed that these markets have significant linkages which vary according to whether they are in low or high volatility regimes [8].

The fundamental objective of price discovery process is to understand whether any new information is first reflected in futures price or it changes the spot price or there exists any significant lag in disseminating market information between spot and futures market. In any efficient market, new information reflects immediately in spot and futures prices simultaneously and this will diminish any arbitrage opportunity. Thus, studies regarding price discovery and market integration are gaining momentum day by day.

Among the various agricultural commodities being traded in NCDEX spices are one of these having tremendous importance in foreign exchange earning also. India is the largest producer and exporter of spices in the world with around 180 spice products reaching over 150 countries, contributing 80% of world production and 60% of world exports.Chilli, turmeric, cumin and coriander are among the top spices that are traded in the commodity market. During 2015-2016, these four spices account for 3.53 million tons of production, which is 52% of overall spices produced in India. Chilli, turmeric and cumin are the top 3 spices exported from India; cumulatively 5.73 lakh tones have been exported during 2015-16 with a share of 41.5%.

Thus, the knowledge of the price discovery mechanism with respect to these fours spices play havoc role in the Indian spice market. As such, this study is an attempt to examine the price discovery mechanism of four traded spices (turmeric, chilli, cumin and coriander) to unearth the relationship between spot and futures market prices using econometric tools such as cointegration techniques, vector error correction model (VECM) and others. Both spot and futures market prices are studied to specify whether there exist any uni-directional (i.e. which market will react first) or bi-directional effect between the markets, which in turn helps to understand the market information dissemination process in a proper way.

# 2. Material and Methods

## 2.1. Data

The present study is based on daily spot and futures price data of turmeric, chilli, cumin and coriander collected from NCDEX (*www.ncdex.com*) from October 2015 to April 2017.

## 2.2. Methodology

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

### 2.2.1. Test for Stationarity

A time series is said to be stationary if its mean and variance are constant over time and the value of covariance between two time periods depends only on the distance or gap or lag between the two time periods and not on the actual time at which the covariance is computed.

On the other hand a non-stationary time series data will have time varying mean or variance or both. Although our interest lies in stationary time series data but generally in econometric analysis we encounter non-stationary data. For testing the stationarity of time series data, Augmented Dickey-Fuller (ADF) test and Phillips-Perron test (PP test), as described below, have been used.

Let,

$$Y_t = \rho Y_{t-1} + u_t \ (-1 \le \rho \le 1), \tag{1}$$

where $u_t$ is a white noise [3] error term.

In presence of unit root i.e. when $\rho$=1, the series is non-stationary. But unfortunately we can't simply regress $Y_t$ on $Y_{t-1}$ and find out if estimated ρ is equal to 1 or not because in estimation by OLS technique, the hypothesis that ρ=1 by the usual *t* test is biased in presence of unit root. Thus we arrange the previous equation (1) as follows:

$$Y_t - Y_{t-1} = \rho Y_{t-1} - Y_{t-1} + u_t = (\rho - 1) Y_{t-1} + u_t, \tag{2}$$

which can also be written as:

$$\Delta Y_t = \delta Y_{t-1} + u_t. \tag{3}$$

Where $\delta = (\rho - 1)$ and Δ is the first difference operator. In practice instead of estimating Eq. (1) we rather test the null hypothesis $\delta = 0$ against the alternative hypothesis $\delta < 0$ in Eq. (3). If $\delta = 0$, then $\rho = 1$, i.e. we have a unit root and the time series under consideration is non stationary.

#### 2.2.1.1. Augmented Dickey-Fuller Test

For testing stationarity, Augmented Dickey-Fuller [9] method is applied where study variable $Y_t$, can be expressed in following manner:

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \delta Y_{t-1} + \sum_{i=1}^{m} \beta_i \Delta Y_{t-i} + \epsilon_t, \qquad (4)$$

where, $Y_t$ is a vector to be tested for cointegration, $t$ is time or trend variable, $\Delta Y_t = Y_t - Y_{t-1}$ and $\in_t$ is white noise error term, $\alpha_0$ is constant and $\alpha_1$ is the coefficient of trend. The null hypothesis that $\delta = 0$ signifying presence of unit root, *i.e.*, the time series is non-stationary and the alternative hypothesis is $\delta = 0$ signifying the time series is stationary, therefore, rejecting the null hypothesis. The required test statistics is

$$DF_\tau = \frac{\delta - 1}{SE(\delta)}.$$

The value of the test statistic computed and compared with relevant critical values for Dickey-Fuller test.

#### 2.2.1.2. Phillips-Perron Test

The ADF test assumes the homogeneity in the error term where as in presence of non homogeneity and any interdependence or any non parametric behavior, PP test is preferred. Phillips and Perron [10] propose an alternative (non-parametric) method of controlling for serial correlation when testing for a unit root. The PP test is based on the statistic:

$$\check{t}_\alpha = t_\alpha \sqrt{\left(\frac{\gamma_0}{f_0}\right)} - \frac{T\left(f_0 - \gamma_0\right)\left(se\left(\hat{\alpha}\right)\right)}{2\sqrt{f_0}\, s}.$$

Where $\hat{\alpha}$ is the estimate, and $t_\alpha$ is the $t$-ratio of α, $se\left(\hat{\alpha}\right)$ is coefficient standard error, and $s$ is the standard error of the test regression. In addition, $\gamma_0$ is a consistent estimate of the error variance (calculated as, $\frac{(T-k)s^2}{T}$ where $k$ is the number of regressors and T the sample size). The remaining term, $f_0$, is an estimator of the residual spectrum at frequency zero.

### 2.2.2. Vector Autoregressive (VAR) Process

The time series being non-stationary with identical order of integration, we need to identify the optimal lag length for an unrestricted vector auto regressive (VAR) model [9,11] on the basis of suitable information criteria viz. LR statistic, FPE (Final Prediction Error), Akaike Information Criteria (AIC), Schwartz Information Criteria (SIC) and HQ(Hannan-Quinn). In addition to that a simple VAR model also helps to establish short run dynamics between both the price series when a cointegrating relationship is not found. A VAR is a simple extension of the AR (P) framework and is given by:

$$Y_t = \delta + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_k Y_{t-k} + u_t, \qquad (5)$$

where, $u_t \sim IN(0, \Sigma); Y_t = \left(Y_{1t}, Y_{2t}, \ldots, Y_{nt}\right)'$ is $(n \times 1)$ random vector of endogenous variables, each of the $A_i$ is an $(n \times n)$ matrix of parameters, δ is a fixed $(n \times 1)$ vector of intercept terms. Finally, $u_t = \left(u_{1t}, u_{2t}, \ldots, u_{nt}\right)'$ is a n-dimensional white noise or innovation process, i.e., $E(u_t) = 0, E(u_t, u_t') = \Sigma$ and $E(u_t, u_s') = 0$ for $s \neq t$. The covariance matrix Σ is assumed to be non-singular.

### 2.2.3. Johansen Method of Cointegration

With the prior knowledge of the identical order of integration and appropriate lag length the Johansen's cointegration test [5,9,11,12] procedure is employed to find whether there exists a long run equilibrium between the two price series. Suppose that $Y_t$ is an $(n \times 1)$ vector and non-stationary, i.e. I (1) variables, then the unrestricted vector auto regression (VAR) of $Y_t$ up to 'k' lags can be specified as:

$$Y_t = \sum_{i=1}^{k} \Pi_i Y_{t-i} + u_t. \qquad (6)$$

For k > 1, this VAR in the levels always can be written

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Pi_i \Delta Y_{t-i} + u_t. \qquad (7)$$

The matrix $\Pi$ of order $(n \times n)$ can be written in terms of the vector or matrix of adjustment parameters $\alpha$ and the vector or matrix of cointegrating vector $\Pi = \alpha\beta'$.

If the matrix $\Pi$ equals a matrix of zeroes, that is, $\Pi = 0$ then the variables are not cointegrated and the relationship reduces to the vector auto regression in the first differences.

$$\Delta Y_t = \sum_{i=1}^{k-1} \Pi_i \Delta Y_{t-i} + u_t. \qquad (8)$$

One way is to test whether the rank of $\Pi$ is zero, that is whether, $Rank(\Pi) = 0$ against the $Rank(\Pi) \neq 0$ and in fact $Rank(\Pi)$ = the number of cointegrating vectors. The number of cointegrating vectors is less than or equal to the number of variables $n$ and strictly less than $n$ if the variables have unit roots.

Basically the Johansen tests are called the maximum eigen value test and the trace test. For both test statistics, the initial Johansen test is a test of the null hypothesis of no cointegration against the alternative of cointegration. The tests differ in terms of the alternative hypothesis.

First of all the test of the maximum (remaining) eigenvalue is a likelihood ratio test. The test statistic is

$$LR(r_0, r_0 + 1) = -T \ln\left(1 - \lambda_{r_0+1}\right), \qquad (9)$$

where $LR(r_0, r_0 + 1)$ is the likelihood ratio test statistic for testing whether rank $(\Pi)$=$r_0$ versus the alternative hypothesis that rank $(\Pi)$=$r_0 + 1$.

Again, the trace test is a test whether the rank of the matrix $\Pi$ is $r_0$. The null hypothesis is that rank $(\Pi)$=$r_0$. The alternative hypothesis $r_0 < rank(\Pi) \leq n$ is that, where n is the maximum number of possible cointegrating vectors. For the succeeding test if this null hypothesis is rejected, the next null hypothesis is that $rank(\Pi) = r_0 + 1$ and the alternative hypothesis is that $r_0 + 1 < rank(\Pi) \leq n$.

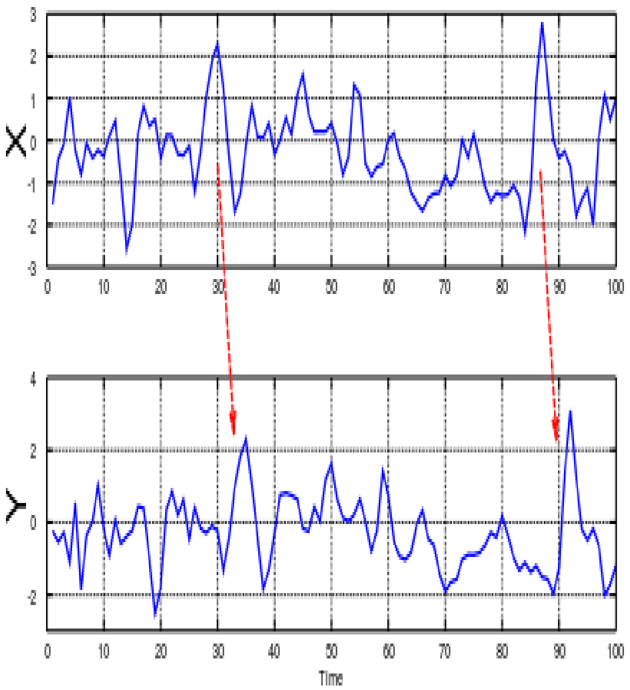
The likelihood ratio test statistic is:

$$LR(r_0, n) = -T\sum_{i=r_0+1}^{n} \ln(1-\lambda_i), \tag{10}$$

where, $LR(r_0, n)$ is the likelihood ratio statistic for testing whether rank $(\Pi)=r$ versus the alternative hypothesis that rank $(\Pi) \le n$.

#### 2.2.4. Granger Causality Test

The time series being cointegrated Granger causality test [9,13] is carried out to examine the direction of causality. 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 $Y$




(**Note:** When time series X Granger-causes time series Y, the patterns in X are approximately repeated in Y after some time lag (two examples are indicated with arrows). Thus, past values of X can be used for the prediction of future values of Y).

**Figure 1.** Causality diagram (X causing Y)

For example,

$$\begin{aligned} Y_t &= \alpha_1 + \alpha_1 Y_{t-1} + \ldots \\ &+ \alpha_i Y_{t-i} + \beta_1 X_{t-1} + \ldots + \beta_i X_{t-i} + e_t, \end{aligned} \tag{11}$$

$$\begin{aligned} X_t &= \alpha_1 + \alpha_1 X_{t-1} + \ldots \\ &+ \alpha_i X_{t-i} + \beta_1 Y_{t-1} + \ldots + \beta_i Y + u_t, \end{aligned} \tag{12}$$

for all possible pairs of $(x, y)$ series in the group. The reported F-statistics are the Wald test statistic for the joint hypothesis:

$$\beta_1 = \beta_2 = \ldots = \beta_l,$$

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.

#### 2.2.5. Vector Error Correction Model (VECM)

Once the price series are cointegrated, Vector Error Correction Model (VECM) [11,14] is estimated to examine the lead-lag relationship between two price series with the short-run and long-run dynamics in the model; it has two distinct characteristics: first, an ECM is dynamic in the sense that it involves lags of the dependent and explanatory variables; it thus captures the short-run adjustments from past disequilibria and contemporaneous changes in the explanatory variables to equilibrium. Second, the ECM is transparent in displaying the cointegrating relationship between or among the variables. A VEC Model is synonymous to a VAR model to understand the long run deviation of the study variable, including constant, Error Correction Term (ECT) and the lagged terms. The VECM can be written as:

$$\begin{aligned} \Delta SP_t &= C_1 + \sum_{k=1}^{n} \alpha_{1i} \Delta SP_{t-k} \\ &+ \sum_{k=1}^{n} \beta_{2i} \Delta FP_{t-k} + u_{1t}, \end{aligned} \tag{13}$$

$$\begin{aligned} \Delta FP_t &= C_2 + \sum_{k=1}^{n} \beta_{1i} \Delta FP_{t-k} \\ &+ \sum_{k=1}^{n} \alpha_{2i} \Delta SP_{t-k} + u_{2t}, \end{aligned} \tag{14}$$

where, $SP_t$ and $FP_t$ are spot and future market prices of turmeric prices at time t, $u_{1t}$ and $u_{2t}$ are white noise disturbance terms and $C_1$ and $C_2$ represents ECTs of respective equations. The ECT expresses the long-run causal effects, while the coefficients of lagged explanatory variables give an indication of short-run adjustments. The coefficient of ECT must be negative and significantly different from zero. The negative ECT implies that if there is a deviation from the existing and long-run equilibrium, there would be an adjustment back to long-run equilibrium in subsequent periods. If the markets are cointegrated then one price is found to Granger cause the other. Hence, enables us to identify which market(s) play leading role in price discovery.

## 3. Results & Discussion

Daily spot and futures price movement of four studied spices in India viz., turmeric, chilli, cumin and coriander are presented in Figure 2 (a) to Figure 2 (d). From the plots one can observe that the futures price and the spot price of the selected agricultural commodities are moving in the same direction. So, there might be a chance that the spot price being influenced by the futures price. Moreover, except cumin all the crops, both the spot and futures price series exhibit downward movement during the study period.

### 3.1. Descriptive Statistics

Descriptive statistics helps in examining the past behaviour or the nature of the given data series; they describe the data and are typically distinguised from the inferential statistics. Descriptive statistics have been presented in Table 1. From Table 1, one can observe that the mean spot price is higher than that of corresponding future price in all the four crops. This most probably indication of incorporation of more amd more market information between the declaration of future price and realization spot price latter on infavour of the producers.Higher CV in futures price series depicts it's more disperse behavior than spot price on all spices except for coriander where spot price shows more dispersion than futures price. For turmeric and cumin both the price series show platy-kurtic behavior where as in chilli and coriander express leptokurtic nature. Thus one can say that the prices of turmeric and cumin remained almost stable throughout the period whereas those of chili and corriander changed. Finally, for degree of asymmetry of the distribution around their respective means say all the prices, except futures and spot prices of coriander and future price of turmeric is negatively skewed. Thereby indicating that changes in prices whatever have taken place are during latter period.

## 3.2. Testing for Stationarity of Data

Both ADF and PP test accepts the null hypothesis that series has unit root. Table 2 shows the result of unit root and confirm that both the spot and futures price are non stationary and they possess 1st order of integration i.e. I(1) for all spices except for coriander where both the price series at level (without 1st differencing) exhibit near stationary pattern although after first differencing i.e. I(1) they attain complete stationarity.

An appropriate VAR lag order based on several criteria viz. LR statistic, FPE, AIC, SIC and HQ is selected for subsequent analysis. The results are given in Table 3 which confirms that lag order 2 is suitable for all the crops except cumin where lag of order 3 is found best.

## 3.3. Johansen Co-Integration Test

The results (Table 4) of the Johansen Cointegration test under both Trace and Maximum eigen value statistic with their corresponding p-values confirm rejection of null hypothesis ($H_0$): $r = 0$ i.e., presence of no cointegrating equation at 5% level of significance for all the spices except for coriander is evident.

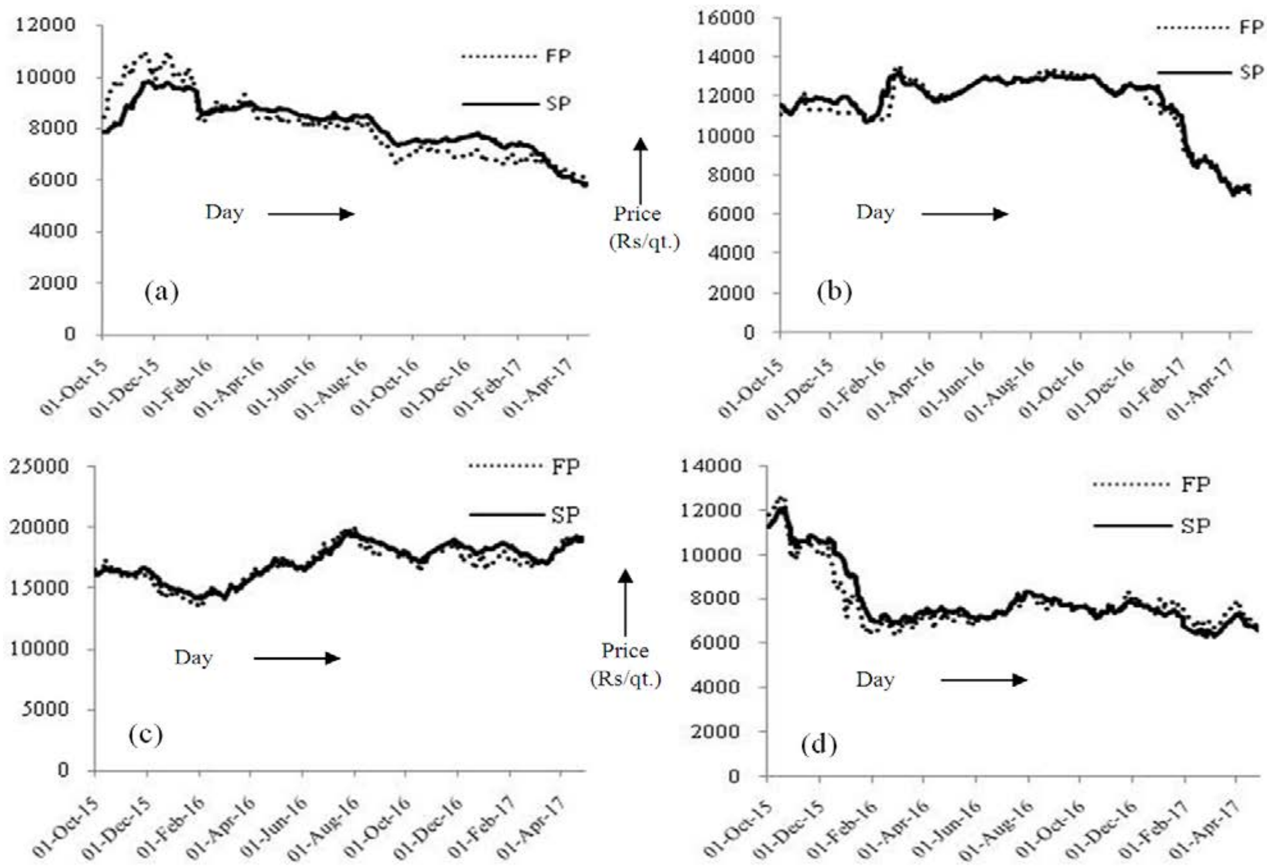



**Figure 2.** Daily plot of futures and spot prices of (a) Turmeric, (b) Chilli, (c) Cumin and (d) Coriander

**Table 1. Descriptive Statistics**

| | Turmeric | | Chili | | Cumin | | Coriander | |
|---|---|---|---|---|---|---|---|---|
| Measures | FP | SP | FP | SP | FP | SP | FP | SP |
| Mean | 8127.86 | 8153.69 | 11587.71 | 11637.62 | 16912.87 | 17123.43 | 7817.81 | 7943.86 |
| Median | 8156.00 | 8355.50 | 12028.00 | 12148.33 | 17090.00 | 17310.26 | 7505.00 | 7480.05 |
| Max. | 11032.0 | 9823.8 | 13592.0 | 13237.5 | 20125.0 | 19575.7 | 12688.0 | 12162.2 |
| Min. | 6086.00 | 5800.00 | 7094.00 | 7000.00 | 13470.00 | 14112.50 | 6454.00 | 6341.35 |
| SD | 1315.29 | 935.47 | 1646.81 | 1627.64 | 1556.26 | 1472.52 | 1250.17 | 1321.22 |
| Skewness | 0.50 | -0.35 | -1.20 | -1.57 | -0.30 | -0.42 | 2.05 | 1.64 |
| Kurtosis ($\beta_2$) | 2.21 | 2.85 | 3.64 | 4.38 | 2.58 | 2.15 | 7.11 | 4.73 |
| CV(%) | 16.18 | 11.47 | 14.21 | 13.98 | 9.20 | 8.60 | 15.99 | 16.63 |

Note: FP: futures price and SP: spot price (in INR/100kg).

**Table 2. ADF and PP test results**

| | | ADF Test Statistic | p-value | PP Test Statistic | p-value |
|---|---|---|---|---|---|
| | ***Level*** | | | | |
| Turmeric | Spot Price | 0.69 | 0.99 | 0.44 | 0.98 |
| | Future Price | -0.47 | 0.89 | -0.65 | 0.85 |
| Chilli | Spot Price | 1.20 | 0.99 | 0.83 | 0.99 |
| | Future Price | 1.24 | 0.99 | 0.76 | 0.99 |
| Cumin | Spot Price | -0.95 | 0.77 | -1.05 | 0.73 |
| | Future Price | -1.27 | 0.64 | -1.23 | 0.66 |
| Coriander | Spot Price | -2.66 | 0.08 | -2.36 | 0.15 |
| | Future Price | -3.14 | 0.025 | -3.09 | 0.03 |
| | ***First Difference*** | | | | |
| Turmeric | Spot Price | -12.31*** | 0.00 | -13.04*** | 0.00 |
| | Future Price | -15.65*** | 0.00 | -15.65*** | 0.00 |
| Chilli | Spot Price | -13.73*** | 0.00 | -14.35*** | 0.00 |
| | Future Price | -16.27*** | 0.00 | -16.46*** | 0.00 |
| Cumin | Spot Price | -10.39*** | 0.00 | -16.98*** | 0.00 |
| | Future Price | -19.33*** | 0.00 | -19.39*** | 0.00 |
| Coriander | Spot Price | -12.78*** | 0.00 | -12.80*** | 0.00 |
| | Future Price | -15.11*** | 0.00 | -15.13*** | 0.00 |

Note: *** means significant at p = 0.01.

**Table 3. Lag order selection**

| | ***Turmeric*** | | | | |
|---|---|---|---|---|---|
| Lag | LR | FPE | AIC | SIC | HQ |
| 0 | NA | 3.91e+11 | 32.367 | 32.390 | 32.376 |
| 1 | 2380.168 | 3.02e+08 | 25.200 | 25.269 | 25.227 |
| 2 | 33.304* | 2.79 e+08* | 25.123* | 25.237* | 25.168* |
| 3 | 6.645 | 2.80 e+08 | 25.126 | 25.286 | 25.190 |
| 4 | 1.284 | 2.86 e+08 | 25.146 | 25.351 | 25.228 |
| Lag | ***Chilli*** | | | | |
| 0 | NA | 3.91e+11 | 32.367 | 32.390 | 32.376 |
| 1 | 2380.168 | 3.02e+08 | 25.200 | 25.269 | 25.227 |
| 2 | 33.304* | 2.79 e+08* | 25.123* | 25.237* | 25.168* |
| 3 | 6.645 | 2.80 e+08 | 25.126 | 25.286 | 25.190 |
| 4 | 1.284 | 2.86 e+08 | 25.146 | 25.351 | 25.228 |
| Lag | ***Cumin*** | | | | |
| 0 | NA | 5.63e+11 | 32.732 | 32.754 | 32.74 |
| 1 | 2084.066 | 1.12e+09 | 26.516 | 26.583 | 26.543 |
| 2 | 46.89 | 9.99e+08 | 26.398 | 26.512* | 26.443 |
| 3 | 20.784* | 9.61e+08* | 26.359* | 26.518 | 26.422* |
| 4 | 0.435 | 9.83e+08 | 26.381 | 26.585 | 26.463 |
| 5 | 1.824 | 1.00e+09 | 26.399 | 26.649 | 26.450 |
| Lag | ***Coriander*** | | | | |
| 0 | NA | 2.66e+11 | 31.982 | 32.004 | 31.99 |
| 1 | 2531.459 | 1.70e+08 | 24.625 | 24.692 | 24.652 |
| 2 | 43.263* | 1.53 e+08* | 24.521* | 24.633* | 24.566* |
| 3 | 2.519 | 1.55 e+08 | 24.537 | 24.693 | 24.599 |
| 4 | 9.227 | 1.55 e+08 | 24.533 | 24.733 | 24.612 |

Note: * indicates lag order selected by the criteria.
Note: LR selects the value within accepted boundary region, whereas other criteria FPE, AIC, SIC and HQ selects the minimum value.

**Table 4. Johansen Cointegration test results**

| **Spice** | $H_0$ | **Trace statistic** | **p-value** | **Max. Eigen statistic** | **p-value** |
|---|---|---|---|---|---|
| Turmeric | $r = 0$ | 17.76 | 0.022** | 15.80 | 0.028** |
| | $r \leq 1$ | 1.96 | 0.160 | 1.96 | 0.160 |
| Chilli | $r = 0$ | 17.55 | 0.024** | 16.86 | 0.019** |
| | $r \leq 1$ | 0.69 | 0.405 | 0.69 | 0.405 |
| Cumin | $r = 0$ | 19.97 | 0.009*** | 18.27 | 0.010*** |
| | $r \leq 1$ | 1.70 | 0.190 | 1.70 | 0.190 |
| Coriander | $r = 0$ | 30.97 | 0.0001*** | 22.47 | 0.002*** |
| | $r \leq 1$ | 8.50 | 0.004*** | 8.50 | 0.003*** |

Note: *** significant at p= 0.01 and ** significant at p= 0.05.

## 3.4. Granger Causality Test

This test helps to understand which price determines the other or bi-directional impact on each other. For turmeric, chilli and cumin the presence of bi-directional impact rather causality of the both price series on each other is evident whereas for coriander it's a one-way causal linkage from futures market to spot market prices i.e. information gets reflected first in the future prices and then it transmitted to spot market prices. The following table supports the impact of both the price series in price discovery mechanism for the first three spices.

**Table 5. Granger causality test results**

| **Spice** | **Null Hypothesis** | **F-Statistic** | **Prob.** | **Direction** |
|---|---|---|---|---|
| Turmeric | FP does not Granger cause SP | 6.26 | 0.0022*** | FP→SP |
| | SP does not Granger cause FP | 2.89 | 0.057* | SP→FP |
| Chilli | FP does not Granger cause SP | 3.75 | 0.024** | FP→SP |
| | SP does not Granger cause FP | 12.18 | 8.e-06*** | SP→FP |
| Cumin | FP does not Granger cause SP | 18.14 | 6e-11*** | FP→SP |
| | SP does not Granger cause FP | 4.11 | 0.007*** | SP→FP |
| Coriander | FP does not Granger cause SP | 6.56 | 0.001*** | FP→SP |
| | SP does not Granger cause FP | 2.07 | 0.13 | |

Note: ***: significant at p = 0.01, **: significant at p = 0.05 and * : significant at p = 0.10

## 3.5. Estimates of Vector Error Correction Model

Vector Error Correction Model (VECM) is employed for checking the presence of any long-run associationship between the two price series and its lagged coefficients are analysed for understanding the short-run dynamics. Turmeric, chilli and cumin show the cointegrating behavior with a single cointegrating equation. For coriander where cointegration is not evident, a simple VAR model is sufficient in describing the short-run relationship between spot and futures price series. The most important aspect of Table 6 is negative and significant error correction term (ECT) of spot price, which implies presence of long-run causality [7,15] running from futures to spot price, also well supported by the Granger causality test (Table 5). The VECM estimates for the three spices suggest, a daily price adjustment of 1.2% and 0.5% of futures price from short-run disequilibrium to attain long-run equilibrium for turmeric and cumin respectively [11]. In contrary to above the ECT of futures price show significant behaviour for chilli, implies short run impact from spot to futures. The short-run dynamics for turmeric and chilli seems quite similar as the subsequent lag of spot price shows significant impact to determine its counter part and itself. The subsequent lag of futures price shows significant behaviour in determining spot price in short-run which is well supported by significant nature of ECT.

For cumin, couple of lags of spot price determine the futures and single lag (second) of spot impacts itself. Couple of lags of futures also helps in determining spot prie and itself in short run.

**Table 6. VECM estimates of Turmeric, chilli and cumin**

| | Turmeric | | Chilli | | Cumin | |
|---|---|---|---|---|---|---|
| Error Correction Equation | D(FP) | D(SP) | D(FP) | D(SP) | D(FP) | D(SP) |
| C (Coint. Eq) | 0.0068 [0.688] | -0.012 [-2.613] ** | 0.079 [3.489]*** | -0.0158 [-0.877] | 0.0231 [0.676] | -0.005 [-3.061]*** |
| D (FP (-1)) | -0.029 [-0.396] | 0.056 [1.641]* | 0.066 [1.138] | 0.104 [2.253]** | -0.135 [-1.912]* | 0.152 [4.492]*** |
| D (FP (-2)) | 0.024 [0.346] | 0.042 [1.248] | 0.0819 [1.419] | 0.032 [0.691] | -0.257 [-3.504]*** | -0.059 [-1.671]* |
| D (FP (-3)) | - | - | - | - | 0.016 [0.233] | 0.006 [0.178] |
| D (SP (-1)) | 0.377 [2.366]** | 0.166 [2.248]** | 0.159 [2.165]** | 0.199 [3.377]*** | 0.323 [2.372]** | -0.062 [-0.946] |
| D (SP (-2)) | -0.096 [-0.623] | 0.027 [0.372] | 0.023 [0.319] | 0.117 [1.99]** | 0.317 [2.33]** | 0.173 [2.646]*** |
| D (SP (-3)) | - | - | - | - | -0.05 [-0.406] | 0.009 [0.159] |
| C (Residual) | -8.56 [-0.972] | -4.874 [-1.189] | -7.632 [-1.109] | -7.20 [-1.189] | 6.09 [0.4] | 6.189 [0.845] |

Note: Values in [] show t-statistic values; ***: significant at p = 0.01, **: significant at p = 0.05 and * : significant at p = 0.10; 'D': difference value of the price series.

### 3.6. A VAR Framework for Coriander

In case of coriander, study fails to establish any cointegration between the couple of price series. The VAR estimates (Table 7) for coriander helps to infer that in the short-run scenario the lagged term of both the price series has significant impact in determining the subsequent value of the other. In addition to that for coriander a clear causality from the futures price to spot price is evident as suggested by the Granger causality test (Table 5).

**Table 7. VAR estimates of Coriander**

| Error Correction Equation | FP | SP |
|---|---|---|
| FP (-1) | 1.085 [15.556]*** | 0.128 [3.276]*** |
| FP (-2) | -0.127 [-1.86]* | -0.100 [-2.619]*** |
| SP (-1) | 0.243 [2.029]** | 1.182 [17.583]*** |
| SP (-2) | -0.227 [-1.974]** | -0.216 [-3.354]*** |
| C (Residual) | 188.700 [3.258]*** | 43.290 [1.332] |

Note: Values in [ ] show t-statistic values; ***: significant at p = 0.01, **: significant at p = 0.05 and *: significant at p = 0.10.

## 4. Conclusion

Futures market of agricultural commodity does play an efficient role in terms of price risk management, price discovery, price fluctuation, commodity delivery system and others. This study enables us to understand the transmission of price signal i.e. which market reacts first to any new information by assessing the relationship between the spot and futures market of the selected spices (chilli, turmeric, cumin and coriander) using econometrics methods like Johansen's cointegration test, Granger Causality test, Vector Error Correction Model (VECM) etc. Cointegration analysis reveals long run associationship between spot and futures prices, except for coriander where only one-way causal linkage from futures to spot market is observed. Thus, for coriander price discovery first takes place in futures market then leads to spot market. The empirical findings for chilli, turmeric and cumin state both spot and futures market play leading role in the price discovery and both markets react simultaneously to any new information. The results obtained expected to understand the information flow across the market, which in turn will help in price formulation and market investment strategies by the producers as well as user and will also help in risk mitigating due to market volatility.

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