**Spatial Market Integration among the major Robusta Coffee Growing Regions in India: An Econometric Analysis**

**Abstract**

Coffee occupies a prime position among the plantation crops in India and it is one of the key contributors to the Indian foreign exchange earnings. The price integration among the different markets indicates the interdependence of prices and speed of a price transmission between different markets. located in various regions. The present study examined the movement of Robusta farm gate coffee prices, transmission of price signals and information across the major Robusta coffee producing regions of the country. The study revealed that, the farm gate coffee prices in major Robusta producing regions were well co-integrated with each other, which shows that Robusta coffee prices were transmitted from one region to the other, and also moving together in the long-run, that indicates the existence of transparent price discovery, dissemination and risk transfer among the markets in major Robusta coffee producing regions in India.

**Keywords:** Robusta coffee, Indian foreign exchange, International market, biodiversity hotspots

**Introduction**

Coffee is recognized as one of the most popularly consumed beverages and it stands out as the most widely traded tropical agricultural commodity in the world. As per the International Coffee Organization (an intergovernmental organization at international level), Coffee is being produced in about 55 countries of which 50 countries produce coffee on commercial scale. Primarily, there are two species of coffee being cultivated in the world, namely: Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*).

India is the seventh largest producer of coffee in the world with the production of about 3.60 lakh tonnes, which accounts for about 3.52 per cent of the global coffee production in the year 2023-24 (Database on Coffee, 2023). However, India is the 5th largest producer of Robusta coffee in the world with the share of about 5.70 per cent in global Robusta coffee production (USDA Coffee Annual Report, 2024). India predominantly produces Robusta Coffee, which accounts for about 70 per cent of India’s total coffee production. Coffee is an export-oriented commodity, nearly 70 per cent of the production is being exported to more than 120 countries across the world. Indian Robustas are known for its high quality in the international market and fetches highest premium in the international market. In India, coffee is cultivated under the two-tiered shades in the Western Ghats, which is one of the most important biodiversity hotspots in the world.

Coffee is cultivated in about 4.90 lakh hectares in India (Database on Coffee, 2023), mainly confined to the southern states of the country *viz.,* Karnataka, Kerala and Tamil Nadu, which form the traditional areas (TAs), about 96 per cent of the coffee comes from these three states, which make them as the major coffee producing states in the country.

Karnataka is the largest producer of coffee in India with a share of 70.62 per cent in country’s total production followed by Kerala (20.46 %) and Tamil Nadu (5.36%). The remaining production comes from the Non-Traditional Areas (NTAs) *viz.,* Andhra Pradesh and Odisha and North-Eastern Regions (NERs) which is about 4 per cent of the country’s total coffee production (Database on Coffee, 2023). The major coffee growing districts in India are Kodagu, Chikkamagaluru, Hassan and Wayanad. These four districts accounts for about 87% of the country’s total coffee production. Hence, majority of the coffee trading activities are confined to these districts.

Kodagu district predominantly produces Robusta coffee, which accounts for about 85 per cent of the Kodagu’s total coffee production and rest is Arabica. While, in Chikkamagaluru Arabica and Robusta Coffee produced in the proportion of 45 per cent and 55 per cent, respectively. In Sakaleshpura, Arabica and Robusta coffee produced in the proportion of 43 per cent and 57 per cent, respectively. Whereas, almost all the coffees produced in Wayanad district are Robusta coffees.

In coffee growing regions, coffee growers subject coffee beans for primary processing immediately hours after the harvest. Coffee Farmers then sell primary processed coffees *viz.,* Cherry or Parchment to curers or agents of curers at farm gate. However, the farm gate coffee prices mainly depend on the prices in futures market *viz.,* Intercontinental Exchange, New York for Arabica Coffee and Intercontinental Exchange, Europe for the Robusta Coffee. Earlier studies (ICO, 2018; Pradeepa and Arun, 2021; Melawanki et al., 20245) mainly examined the interdependence of coffee futures and spot prices. However, these studies have not shed lights on interdependence of farm gate coffee prices among the different coffee growing regions. Against the backdrop, the present study has been undertaken to examine the movement of farm gate coffee prices, transmission of price signals and information across the major coffee producing regions *viz.,* Chikkamagaluru, Madikeri, Sakaleshpura and Wayanad.

**Methodology**

The Methodology adopted uses econometric tests to examine the extent of relationship between farm gate coffee prices in major coffee producing regions in India in long run. The analysis was carried out based on monthly observations of four types of coffee prices *viz.,* Robusta cherry, Robusta parchment, Arabica cherry and Arabica parchment from January 2013 to February 2023. All the prices are given in Indian Rupee per 50 Kg bag. The study was based on the secondary data sourced from the Coffee Board.

**Correlation Analysis:** this measure was used to estimate the degree of association between the farmgate coffee prices in major coffee producing regions. Correlation co-efficient between monthly farmgate coffee prices in selected coffee growing regions was estimated to determine the inter-relationship between them.

$r=\frac{Σ\_{i-1}^{n}(X\_{i}-\overbar{X})(Y\_{i}-\overbar{Y})}{\sqrt{Σ\_{i=1}^{n}\left(X\_{i}-\overbar{X}\right)^{2 } Σ\_{i-1}^{n}(Y\_{i}-\overbar{Y })^{2}}}$ ------------ (Eq. 1)

Where, n is the number of data points (observations).

Xi and Yi are the individual data points of variables Xand Y respectively.

 $ \overbar{X} $and $\overbar{Y }$ are the means (averages) of X and Y

The correlation coefficient ‘r’ ranges between -1 and +1. r = +1 indicates a perfect positive linear relationship, r = −1 indicates a perfect negative linear relationship, r = 0 indicates no linear relationship (absence of a linear relationship does not imply independence). The sign of ‘r’ indicates the direction of the relationship: positive ‘r’ means as X increases, Y tends to increase, and vice-versa for negative ‘r’.

**Augmented Dickey-Fuller (ADF) Test:** the farmgate coffee prices were tested for stationarity using Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981), with a trend. The ADF test was used to test the null hypothesis of non-stationarity against an alternative of stationarity of the price data under consideration. The following forms of ADF equations were used for the estimation by ordinary least square method.

$Δy\_{t}=α\_{t}+β\_{t}y\_{t-1}+Σ\_{i=1}^{k}​γ\_{i }​ Δy\_{t-1}+ε\_{t}$ ----------- (Eq. 2)

Where, ‘t’ is the time trend, ‘k’ is the number of lags chosen in the model, Δyt​ is the differenced time series, yt−1​ = lagged level of the time series, α, β, γ, δ are the parameters to be estimated and $ε\_{t}$ is the error term.

If the price series under study found to be non-stationary, the first differenced of the series are tested for stationarity. Further, the order of stationarity with in each market was examined by estimating,

ΔPt = Pt – Pt-1 ------------ (Eq. 3)

Where, P = price

 Phillips and Perron (1987) have developed a more comprehensive theory of unit root test. The Phillips-Perron (PP) test is a statistical test used to check for stationarity in a time series and is commonly applied to test for unit roots, similar to the ADF test. The Phillips-Perron (PP) unit root tests differ from the ADF tests in the way to deal serial correlation and heteroscedasticity in the errors. The null hypothesis for the PP test is that the series has a unit root (i.e., it is non-stationary). The basic model used in the test is:

$y\_{t}= α+ β\_{t}+ ρy\_{t-1}+ ε\_{t}$ ----------- (Eq. 4)

Where, $y\_{t}$ is the time series being tested, $α$ is the intercept, $β\_{t}$ is the deterministic time trend, $ρ$ is the coefficient of the lagged dependent variable and $ε\_{t}$ is the error term.

The Phillips-Perron test statistic is based on the t-statistic of the coefficient ρ from the model:

$t\_{ρ}= \frac{\hat{ρ}-1}{SE(\hat{ρ})}$ ------------ (Eq. 5)

Where, $\hat{ρ}$ is the is the estimated value of the coefficient ρ and SE ($\hat{ρ}$) is the standard error of the estimate of ρ.

Johansen’s Cointegration Test: this test was used to examine the existence of long run equilibrium relationship between the farmgate coffee price series. The procedure introduced by Johansen (1991), the null hypothesis of no cointegration will be tested against the alternative of one cointegrating equation. Johansen co-integration test uses the Vector Autoregressive (VAR) method, in which all cointegrated series are assumed endogenous. The Johansen tests are likelihood-ratio tests as it relies on maximum likelihood method, there are two test statistics *viz.,* 1) Trace test and 2) Maximum Eigenvalue test.

Under the Trace test, the null hypothesis is based on the assumption of no co-integration equation, which needs to be rejected to establish co-integration between the time series variables. The trace test statistic is given by,

$J\_{trace}= -T Σ\_{i=r+1}^{n}ln⁡(1-\hat{λ}\_{i})$ ----------- (Eq. 6)

 Here, T = sample size and $\hat{λ}\_{i} $= ith largest canonical correlation.

The Maximum Eigen value test starts from the null hypothesis of no cointegration equation and tests against a different alternative. The results of rejecting the null hypothesis using the maximum eigenvalue, is slightly different from the trace test. Though both forms are based on the assumption of no cointegration in their null hypothesis, rejecting the null based on the maximum eigenvalue implies that there is just a single possible combination of the non-stationary variables to yield in a stationary process. The corresponding test statistic for the maximum eigenvalue is given below.

 $J\_{max}= -T ln⁡(1-\hat{λ}\_{r+1})$ ----------- (Eq. 7)

The trace test examines the null hypothesis of ‘r’ cointegrating vectors against the alternative hypothesis of ‘n’ cointegrating vectors. The maximum eigenvalue test on the other hand, tests the null hypothesis of ‘r’ cointegrating vectors against the alternative hypothesis of ‘r +1’ cointegrating vectors.

**Granger Causality Test:** this test is used to study the influence/direction of causation in coffee price discovery. In case of two time-series price variables, variable is said to Granger-cause another variable if the later variable can be better predicted using the histories of both the variable rather than using only one variable.

The presence as well as causality direction of long-run market price relationship was evaluated by using the Granger causality test directed within vector autoregressive (VAR) model. It is a probabilistic account of causality using empirical data sets to find the patterns of causality. An Autoregressive Distributed Lag (ADL) model used for the Granger- causality test had been specified below,

$X\_{1}= Σ\_{i=1}^{m}a\_{i}Y\_{t-i}+Σ\_{j=1}^{m}β\_{i}X\_{t-j}+ε\_{1t}$ ------------- (Eq. 9)

$Y\_{1}= Σ\_{i=1}^{n}λ\_{i}Y\_{t-i}+Σ\_{j=1}^{n}δ\_{j}X\_{t-j}+ε\_{2t}$------------ (Eq. 10)

Here, ‘X’ and ‘Y’ are the price series of different markets, ‘t’ is the time period and ‘ $ε\_{1t}$’ and ‘$ε\_{2t}$’ are the error terms.

 To test the pattern of causality between two variables, F-test was used with null hypothesis: Lagged ‘X’ does not Granger cause ‘Y’ and alternative hypothesis: Lagged ‘X’ granger cause ‘Y’. The significance of F statistic is tested with the p-value.

Residual sum of squares (ESSr) is recorded after estimating the restricted model. Granger Causality test is performed by calculating the F-statistic and comparing it to the F-critical value at five per cent level of significance. The F statistic computed as follows:

$F=\frac{(ESS\_{r }-ESS\_{u})/m}{ESS\_{u}/(n-1-m)}$ ------------- (Eq. 11)

Where, m = optimal lag length

 n = number of observations

 m and (n-1-m) are the degrees of freedom.

**Results and Discussion:**

Four types of coffee were used *viz.,* Robusta Cherry, Robusta Parchment Arabica Cherry and Arabica Parchment were to analyse the integration in spatially dispersed major coffee producing regions. The results of the study are segregated for each type of coffee and given below;

 **Robusta Cherry**

In case of Robusta cherry, the results of the correlation analysis of monthly farmgate coffee prices across the major coffee growing regions considered under the study tending towards unity and the values are significant at one per cent indicating that the coffee growing regions are well integrated with each other. Further, the results of the study revealed that, farm gate coffee prices in all the regions were highly correlated with each other with correlation coefficient value ranging from 0.90 to 0.98. The highest correlation coefficient of 0.98 was found between Madikeri and Wayanad, which may be due to the close proximity between the regions and both the regions produces Robusta coffee predominantly. The correlation coefficients were found to be highly significant across the different pairs.

**Table 1: Bivariate correlation matrix for the prices of Robusta cherry in major coffee producing regions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Regions** | **Chikkamagaluru** | **Sakaleshpura** | **Madikeri** | **Wayanad** |
| **Chikkamagaluru** | 1 |  |  |  |
| **Sakaleshpura** | 0.90\*\*\* | 1 |  |  |
| **Madikeri** | 0.98\*\*\* | 0.91\*\*\* | 1 |  |
| **Wayanad** | 0.97\*\*\* | 0.90\*\*\* | 0.98\*\*\* | 1 |

\*\*\*Significant at one per cent level

Source of the data: Coffee Board

**Figure 1: Bivariate correlation scatter plots of Robusta cherry prices in major coffee producing regions**

The monthly price series of farmgate coffee prices are subjected to stationarity tests, namely Augmented Dicky Fuller (ADF) and the Philip Perron (PP) tests. Table 2 displays the estimated test statistics values at level and following the first difference. The results revealed that, the non-stationarity null hypothesis could be accepted due to the existence of a unit root in both Robusta cherry farmgate coffee price series. However, the alternative hypothesis of stationarity of the price series has been accepted at first difference. In case of Robusta cherry, all the price series are integrated of the same order (integrated of order 1), which can also be denoted as I (1).

**Table 2: Results of ADF and PP test for the prices of Robusta cherry in major coffee producing regions**

|  |  |  |
| --- | --- | --- |
| **Regions** | **At Level** | **After first difference\*\*** |
| **ADF** | **P value** | **PP** | **Critical value** | **ADF** | **P value** | **PP** | **Critical value** |
| **Chikkamagaluru** | -0.64 | 0.97 | 1.72 | -2.88 | -4.97 | 0.01 | -11.29 | -2.88 |
| **Sakaleshpura** | -0.59 | 0.98 | -1.86 | -2.88 | -6.14 | 0.01 | -17.59 | -2.88 |
| **Madikeri** | -0.21 | 0.99 | 2.57 | -2.88 | -5.67 | 0.01 | -10.93 | -2.88 |
| **Wayanad** | -0.46 | 0.98 | 1.76 | -2.88 | -5.50 | 0.01 | -12.74 | -2.88 |

\*\* Significant at five per cent

Given that all the farmgate coffee price series are stationary and integrated in the same order, all the price series have been tested for the existence of long run equilibrium using Johansen’s cointegration test. This test is very sensitive to the lags hence Akaike Information Criteria (AIC) was used for the optimum lag lengths selection. The null hypothesis of both Trace and Maximum Eigenvalue tests; no integration (r = 0) against the alternative hypothesis (r ≥1) of at least one co-integrating equation prevailed in the VAR system has been tested. The test statistic value against critical values determines the rejection or acceptance of the null hypothesis.

The results of Johansen’s co-integration test of major coffee-producing regions proceeded in two parts *viz.*, Trace statistic and Maximum Eigenvalue statistic, which are shown in Table 3. The estimated Trace and Maximum eigen value tests statistics were higher than critical values at five per cent level of significance. Therefore, the null hypothesis of absence of co-integration has been rejected and accepted the alternative hypothesis of existence of one or more co-integrating vectors.

The strength of co-integration depends upon the number of co-integrating equations. A minimum of one co-integrating equations implies that the regions are well integrated with the price transmissions across the regions to ensure efficiency. Both Trace test and Maximum eigen value indicated the presence of at least three co-integrating equations at five per cent level of significance, this indicated that coffee prices in major producing regions were having stable long-run equilibrium relationship. Thus, they share a common stochastic factor and react to the same set of information. The results insinuated that, although the regions are geographically isolated and spatially separated, they are closely linked with each other with regard to Robusta Cherry farmgate coffee prices.

**Table 3: Unrestricted cointegration rank (Trace) test for the Robusta cherry prices in major Robusta coffee producing regions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Hypothesized****No. of CE(s)** | **H0** | **HA** | **Trace Statistic** | **Maximum Eigenvalue statistic** |
| **Estimated value** | **Critical values at 5 per cent** | **Estimated value** | **Critical values at 5 per cent** |
| None\* | r = 0 | r ≥ 1 | 107.75 | 53.12 | 49.79 | 28.14 |
| At most 1\* | r ≤ 1 | r ≥ 2 | 57.96 | 34.91 | 29.95 | 22.00 |
| At most 2\* | r≤ 2 | r ≥ 3 | 28.01 | 19.96 | 20.24 | 15.67 |
| At most 3 | r ≤ 3 | r ≥ 4 | 7.77 | 9.24 | 7.77 | 9.24 |

Note: 1. Trace test indicate three cointegrating equations at five per cent level of significance

 2.\* denotes rejection of the null hypothesis at five per cent level of significance

The pairwise co-integration test (both bivariate Trace test and Maximum Eigen value test was performed across the regions and their results are presented in Table 5. Correlation analysis gave a rough idea of integration among selected regions. While, pair wise co-integration among major coffee producing regions gives a clear picture and better understanding of integration of prices between the regions.

**Table 4: Results of Pairwise co-integration test of Robusta cherry prices in major coffee producing regions**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Region Pair** | **H0****Null Hypothesis** | **HA****Alternative****Hypothesis** | **Trace test** | **Maximum eigen value statistics** | **No.****of CE(s)** |
| **Trace****Statistics** | **Critical****Values** | **Maximum****Eigen values** | **Critical****Values** |
| **Chikkamagaluru-****Madikeri** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 27.16\*2.89 | 19.969.24 | 24.27\*2.89 | 15.679.24 | 1 CE |
| **Chikkamagaluru-****Sakaleshpura** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 59.42\*1.78 | 19.969.24 | 57.64\*1.78 | 15.679.24 | 1 CE |
| **Chikkamagaluru-****Wayanad** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 30.93\*2.31 | 19.969.24 | 28.62\*2.31 | 15.679.24 | 1 CE |
| **Madikeri-****Sakaleshpura** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 57.17\*3.09 | 19.969.24 | 54.09\*3.09 | 15.679.24 | 1 CE |
| **Madikeri –****Wayanad** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 26.94\*1.93 | 19.969.24 | 25.00\*1.93 | 15.679.24 | 1 CE |
| **Sakaleshpura-****Wayanad** | r = 0r ≤ 1 | r ≥ 1r ≥ 2 | 66.67\*2.28 | 19.969.24 | 64.39\*2.28 | 15.679.24 | 1 CE |

Note: 1. Trace and Maximum eigen value test indicate one cointegrating equation at five per cent level of significance

 2.\* denotes rejection of the null hypothesis at five per cent level of significance

 **Granger Causality Test**

Granger Causality was studied between the coffee prices at different regions after the co-integration among the coffee prices in main coffee-producing regions was established. Granger Causality test is a statistical tool that is employed to examine the direction of the co-movement connection between the prices of coffee in the main producing regions. Granger's causality demonstrates the direction of price transmission and associated arbitrage between two locations. This method ascertains the cause-and-effect relationship among the two time series data using the F-test. Using the Granger Causality approach, the null hypothesis of absence of causal relationship between the chosen pairs of large producing regions is tested.

The results of pairwise Granger Causality test in major coffee producing regions are presented in the Table 5 revealed that there was a bidirectional influence on prices of Chikkamagaluru and Sakaleshpura, Chikkamagaluru and Madikeri, Chikkamagaluru and Wayanad, Sakaleshpura and Madikeri and Madikeri and Wayanad. Bidirectional Causalities between region pairs implies that the price change in former region in each pair granger cause the price transmission in the latter region and vice-versa. Besides, there was a unidirectional influence on prices of Sakaleshpura and Wayanad i.e., price increase in Wayanad has been transmitted to Sakaleshpura, but Sakaleshpura price does not influence Wayanad prices because, Wayanad predominantly grows Robusta coffee and the Wayanad district solely contributes 25 per cent to the country’s Robusta coffee production.

**Table 5: Results of Pairwise Granger causality test for prices of Robusta cherry in major coffee producing regions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Null Hypotheses** | **F-stat** | **P value** | **Gran- ger cause** | **Direction** |
| Chikkamagaluru does not Granger cause SakaleshpuraSakaleshpura does not Granger cause Chikkamagaluru | 3.63 | 6.69e-3 | Yes | Bidirectional |
| 3.27 | 0.012 | Yes |
| Chikkamagaluru does not Granger cause MadikeriMadikeri does not Granger cause Chikkamagaluru | 5.53 | 0.019 | Yes | Bidirectional |
| 5.09 | 0.025 | Yes |
| Chikkamagaluru does not Granger cause WayanadWayanad does not Granger cause Chikkamagaluru |  6.02 | 2.78e-3 | Yes | Bidirectional |
| 8.60 | 2.43e-4 | Yes |
| Sakaleshpura does not Granger cause MadikeriMadikeri does not Granger cause Sakaleshpura | 5.57 | 2.67e-4 | Yes | Bidirectional |
| 7.03 | 2.29e-5 | Yes |
| Sakaleshpura does not Granger cause WayanadWayanad does not Granger cause Sakaleshpura | 2.02 | 0.0921 | No | Unidirectional |
| 15.57 | 2.45e-11 | Yes |
| Madikeri does not Granger cause WayanadWayanad does not Granger cause Madikeri | 6.85 | 1.27e-7 | Yes | Bidirectional |
| 13.28 | 3.27e-6 | Yes |

Wayanad

Madikeri

Sakaleshpura

Chikkamagaluru

**Figure 2: Pictorial representation of Granger causality test for the prices of Robusta cherry across major coffee producing regions**

**Robusta Parchment**

**Correlation analysis**

 The correlation coefficient of two major coffee producing regions *viz.,* Chikkamagaluru and Sakaleshpura is 0.95 which indicates that the regions are highly integrated.

 Source of data: Coffee Board

**Figure 3: Bivariate correlation scatter plot of Robusta parchment prices in major coffee producing regions**

**ADF and PP test for stationarity**

The monthly price series of coffee is subjected to stationarity tests, namely Augmented Dicky Fuller and the Philip Perron tests. Table 7 displays the estimated test statistics values at level and following the first difference. The results revealed that the non-stationarity null hypothesis could be accepted due to the existence of a unit root in every coffee price series. However, the alternative hypothesis of stationarity of the price series is accepted at first difference. In case of Robusta parchment, all the price series are integrated of the same order (integrated of order 1), which can also be denoted as I (1).

**Table 6: Results of ADF and PP test for the prices of Robusta parchment in major coffee producing regions**

|  |  |
| --- | --- |
| **Regions** | **At Level** |
| **ADF** | **P value** | **PP** | **Critical value** |
| **Chikkamagaluru** | -2.1617 | 0.5092 | -0.8758 | -2.8832 |
| **Sakaleshpura** | -1.2113 | 0.9017 | 0.3684 | -2.8832 |
| **Regions** | **After first difference\*\*** |
| **ADF** | **P value** | **PP** | **Critical value** |
| **Chikkamagaluru** | -5.1215 | 0.01 | -13.1225 | -2.8832 |
| **Sakaleshpura** | -5.3220 | 0.01 | -9.4444 | -2.8832 |

\*\* Significant at five per cent level of significance

**Johansen’s Cointegration Test**

The results of Johansen’s co-integration test of major coffee producing regions proceeded in two parts *viz.,* Trace statistic and Maximum Eigen value statistic, shown in Table 8 and Table 9, respectively. Trace test statistic and Maximum eigen value test statistic rejected the null hypothesis of absence of co-integration. Maximum Eigen statistic and Trace test statistics were found higher than critical values at five per cent level of significance. Therefore, the alternative hypothesis of one or more co-integrating vectors is accepted.

The strength of co-integration depends upon the number of co-integrating equations. A minimum of one co-integrating equations implies that the regions are well integrated with the price transmissions across the regions to ensure efficiency. Both Trace test and Maximum eigen value test indicated the presence of one co-integrating equations at five per cent level of significance. This indicated that, coffee prices in major producing regions of India were having stable long-run equilibrium relationship. Thus, they share a common stochastic factor and react to the same set of information. Also, the results insinuated that, although the regions are geographically isolated and spatially separated, they are closely linked with each other with regard to Robusta parchment prices.

**Table 7: Unrestricted cointegration rank (Trace) test for the Robusta parchment prices in major coffee producing regions**

|  |
| --- |
| **Trace test**(Price series: Chikkamagaluru, Sakaleshpura) |
| **Hypothesized****No. of CE(s)** | **H0** | **HA** | **Trace Statistic** | **Critical values at 5 per cent** |
| None\* | r = 0 | r ≥ 1 | 39.06 | 19.96 |
| At most 1 | r ≤ 1 | r ≥ 2 | 1.41 | 9.24 |

 Note: 1. Trace test indicate one cointegrating equation at five per cent level of significance

 2.\* Denotes rejection of the null hypothesis at five per cent level of significance

**Table 8: Unrestricted cointegration rank (Eigenvalue) test for the Robusta parchment prices in major coffee producing regions**

|  |
| --- |
| **Maximum Eigen value test**(Price series: Chikkamagaluru, Sakaleshpura) |
| **Hypothesized****No. of CE(s)** | **H0** | **HA** | **Maximum Eigen Statistics** | **Critical values at 5 per cent** |
| None\* | r = 0 | r ≥ 1 | 37.65 | 15.67 |
| At most 1 | r ≤ 1 | r ≥ 2 | 1.41 | 9.24 |

Note: 1. Maximum eigenvalue test indicate one cointegrating equation at five per cent level of significance

 2.\* denotes rejection of the null hypothesis at the five per cent level of significance

**Granger Causality Test**

The results of pairwise Granger Causality test in major coffee producing regions are presented in the Table 9 showed that there was a bidirectional influence on prices of Chikkamagaluru and Sakaleshpura. Bidirectional causalities between region pairs implies that the price change in former region in each pair granger cause the price transmission in the latter region and *vice-versa*.

**Table 9: Results of Pairwise Granger causality test for prices of Robusta parchment in major producing regions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Null Hypotheses** | **F-stat** | **P value** | **Gran-ger cause** | **Direction** |
| Chikkamagaluru does not Granger cause SakaleshpuraSakaleshpura does not Granger cause Chikkamagaluru | 3.59 | 0.03 | Yes | Bidirectional |
| 7.99 | 4.32e-4 | Yes |

Sakaleshpura

Chikkamagaluru

**Figure 4: Pictorial representation of Granger causality test for the prices of Robusta parchment across major coffee producing regions**

**Conclusion**

Findings of the study proved that, the presence of cointegration between the farmgate prices of Robusta coffee in major coffee producing regions, indicating that the price series share common stochastic factor and react to the same set of market information. The correlation coefficient results revealed that all the major coffee producing regions were highly correlated with each other. This shows that the regions are well integrated and price signals are transferred from one region to the other to ensure transparency and efficiency. Johansen’s pair-wise cointegration was revealed that, even though the major Robusta coffee producing regions are geographically isolated and spatially segmented, they are well-connected in terms of farm gate prices, demonstrating that the they have long-run price relationship between them. The results of the pairwise Granger test between the major producing regions revealed that, there was a bidirectional influence on the prices of Chikkamagaluru and Sakaleshpura, Chikkamagaluru and Madikeri, Chikkamagaluru and Wayanad, Sakaleshpura and Madikeri and Madikeri and Wayanad. Only Sakaleshpura and Wayanad regions have unidirectional causality where, the price change in Wayanad granger causes the price formation in Sakaleshpura but not *vice-versa*. For the benefit of the coffee stakeholders, Coffee Board is publishing the international and domestic coffee prices in Coffee Board official website on daily basis.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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