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Market Integration and Price Volatility in Tea Market of India

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***Abstract*:** This paper examine the transmission and spatial integration analysis between tea producing (Guwahati, Kolkata and Chennai) and consuming (Mumbai, Delhi and Bhopal) markets using monthly price data from April 2005 to March 2020. Correlation analysis, Johansen co-integration test, Vector Error Correction Model and Granger causality were used for the analysis. Instability in the price series was measured by Cuddy Della-Valle index. The maximum instability in tea prices was in March in Guwahati market (18.48%)andthe seasonality index revealed that farmers got nearly average prices throughout the year.Johansen co-integration test revealed that all the selected markets were well integrated in the long run. Bhopal market was found to be the key market which influenced the price of all other markets by Granger Causality test. ARCH family model was found to be best fitted for estimating price volatility in the key market.

***Keywords*:** ARCH, Co-integration, Granger causality, Instability, Volatility

India was the market leader at the international level with regard to production and consumption of tea till 2005. India was the world's second largest tea producer, with 1360.81 million kgs produced (Statista 2020). The tea market in India is huge with tens of thousands of tea gardens spread around the nation, including such popular varieties as Darjeeling and Assam. More than half of the tea produced in India remains in the country for consumption, effectively making this a country of a billion tea drinkers (World Atlas 2022). Tea occupies an important role in the Indian economy not only due to its capacity to earn foreign exchange, but also because it impacts the livelihoods of scores of people employed directly and indirectly by the industry. Tea prices were on the rise since July due to supply issues, which were considered as a requisite for the sustenance of the sector. Domestic tea prices from January to November period at auctions especially South India, was higher by Rs. 28.96 per kg at Rs. 130/kg, while North Indian price was up by Rs. 54.75 at Rs. 207.59 as compared to same period last year. However, in the last few auctions sales, there was a free fall in prices and quantity sold (Kumar S, 2020). In the first auction held in May, prices surged by over 52 per cent to Rs. 217.12 per kg in Guwahati. (Tea board of India 2020). In a similar auction in Siliguri, prices surged by around 39 per cent to Rs. 204.25 per kg. By mid-May, prices in Guwahati rose by 61 per cent to Rs. 217.12 per kg. Buyer demand has been extremely strong, which pulled up prices significantly (Rakshit 2020). Although there is geographical dispersion of markets, prices across different market centres exhibit long-run spatial linkages, suggesting that all the exchange locations are integrated and that prices provide relevant market signals (Ghosh 2010). The extent of integration gives signals for efficient resource allocation, which is considered essential for ensuring greater market efficiency, price stability and food security (Muhammad and Mirza 2014). Test of integration also plays a key role in determining the geographical level at which agricultural price policy should be targeted, at least in the short-run to ensure regular availability of food and price stability (Jha et al 2005). Therefore, the present paper attempts to understand the co-movement of prices among different domestic markets for tea crop in India. It also aims to estimate the volatility exhibited by the prices in the selected markets to provide suitable policy suggestions for pricing policy.

MATERIAL AND METHODS

The monthly time series data on prices and arrivals of tea for the period January 2009 to August 2020 were used for the present study obtained from Agmarknet portal of Ministry of Agriculture and Farmers Welfare, GoI. The study investigated market integration across six major wholesale markets, Guwahati (Assam), Kolkata (West Bengal), Chennai (Tamil Nadu), Mumbai (Maharashtra), Delhi and Bhopal (Madhya Pradesh). These markets were selected on the basis of location as well volume of produce handled. Guwahati, Kolkata and Chennai are located in tea producing area, whereas Mumbai, Delhi and Bhopal are located in the consuming area.

Analytical framework: Different analytical tools such as seasonality analysis, unit root test, Johansen co-integration test, Granger's causality analysis, vector error correction model and ARCH family model were used to examine the market behaviour. The analysis of data was performed by using E-views 9 and R software.

Instability analysis: The coefficient of variation (C.V.) is usually employed to estimate instability in time series data. However, a limitation of C.V. is that it over-estimates the level of instability in the time series data characterised by long term trends (Paul et al. 2013, Nimbrayan and Bhatia 2019). This limitation is overcome by the Cuddy-Della Valle index (CDVI) suggested by Cuddy and Della Valle (1978) which corrects the coefficient of variation.

$$CDVI = CV\sqrt{1-r^2}$$

where, r^2=coefficient of determination

Seasonality index: The range in seasonality was estimated by using the method suggested by Ali (2000):

$S_i = (I_h - I_l)$

S_i = Seasonal indices

I_h = Highest value of seasonal index

I_l = lowest value of seasonal index

Test for stationarity: The first step in the time series analysis, before testing for co-integration and Granger causality, is to examine the stationarity of each individual time series selected for the analysis. Augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller 1979) was considered to examine the stationarity. The test was applied to check the order of integration by using the model:

$$\Delta P_t = \alpha_0 + \delta_1 t + \beta_1 P_{t-1} + \sum_{j=0}^{q} \beta_1 \Delta P_{t-1} + \varepsilon_t$$

Where,

P = the price in each market,

Δ= difference parameter (i.e., $\Delta P_1 = P_t - P_{t-1}$, $\Delta P_{t-1} = P_{t-1} - P_{t-2}$ and $\Delta P_{n-1} = P_{n-1} - P_{n-2}$)

α_0 = constant or drift

t = time trend variable

q = number of lag length and

ε_t = pure white error term,

The null hypothesis is that β_1 (the coefficient of P_{t-1}) is zero. The alternative hypothesis is: $\beta_1 < 0$. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary (Gujarati 2004).

Johansen's co-integration method: Co-integration explains the extent of deviation from the long run equilibrium relationship by the non-stationary series. Once it was confirmed that all of the price-series were stationary at the level or at same order of differences, the maximum likelihood (ML) method of co-integration was applied to check long run wholesale price relation between the selected markets (Johansen 1988, Johansen and Juselius 1990). Maximum likelihood ratio test statistic is proposed to test number of co-integrating vectors. The null hypothesis of atmost 'r' co-integrating vectors against a general alternative hypothesis of more than 'r' co-integrating vectors is tested by trace statistics. The number of co-integrating vectors indicated by the tests is an important indicator of the extent of co-movement of prices. An increase in the number of co-integrating vectors implies an increase in the strength and stability of price linkages.

Vector error correction model: The co-integration analysis reflects the long-run movement of two or more series, although in the short-run they may drift apart. Once the series are found to be co-integrated, then the next step is to find out the short run relationship along with the speed of adjustment towards equilibrium using error correction model, represented by equations:

$$\Delta \ln X_t = \infty_0 + \sum \beta_{1i} \Delta \ln Y_{t-1} + \sum \beta_{2i} \Delta \ln X_{t-1} + \gamma ECT_{t-1}$$

$$\Delta \ln X_t = \beta_0 + \sum \infty_{1i} \Delta \ln X_{t-1} + \sum \alpha_{2i} \Delta \ln Y_{t-1} + \gamma ECT_{t-1}$$

where, ECT_{t-1} is the lagged error correction term; X_t and Y_t are the variables under consideration transformed through natural logarithm; and X_{t-i} and Y_{t-i} are the lagged values of variables X and Y. The parameter γ is the error correction coefficient that measures the response of the regressor in each period to departures from equilibrium. The negative and statistically significant values of γ depict the speed of adjustment in restoring equilibrium after disequilibria and if it is positive ad zero, the series diverges from equilibrium.

Granger causality test: After undertaking co-integration analysis of the long run linkages of the various variables, and having identified they are linked, an analysis of statistical causation was conducted. The Granger causality test conducted within the framework of a VAR model is used to test the existence and the direction of long run causal price relationship between the markets (Granger, 1969). F-test is used to check the significance of changes in one price series affect another price series. Also, this test identifies the key market, i.e., the market which influences the price of all other markets.

Measuring price volatility: ARCH family Model: Once the key market is identified, volatility of price series of that market is checked by testing the presence of heteroskedasticity through ARCH test. If heteroskedasticity has found in price series, then to deal with this, the popular and non-linear model is the autoregressive conditional heteroscedastic (ARCH) model, proposed by Engle (1982). The model was generalized by Bollerslev (1986) in the form of Generalized ARCH (GARCH) model for parsimonious representation of ARCH. In the GARCH model, the conditional variance is also a linear function of its own lags. As in ARCH, this model is also a weighted average of past squared residuals, but it has declining weights that never go completely to zero. Apart from these two models, there are other models such as TARCH, EGARCH and PARCH. The best fit model was selected out of these models based on AIC and SIC values. The forecasting performance of fitted models is assessed with respect to two traditional accuracy measures, viz., the root mean square error (RMSE) and the mean absolute percentage error (MAPE).

RESULTS AND DISCUSSION

Seasonality and instability analysis: The CDVI index showed that the prices are stable and had no fluctuation in prices throughout the year and seasonality index was almost around one in each month which means that the farmers receive nearly average prices through the year (Table 1).

Correlation analysis: The correlation coefficients between the markets were highly significant and ranged from -0.846 to 0.896. This also implies that price differential in the markets is not more than transportation cost and hence, the markets are said to be efficient (Table 2).

Augmented Dickey-Fullar test (ADF): As correlation analysis provides only rough estimates on price movements. To avoid spurious results there is a need to check whether the variables are stationary or not. (Guleria et al 2022). The ADF based unit root test procedure was applied to check whether the price series is stationary at their level, followed by their differences. So, the price series is stationary at first difference which means zero mean and zero variance. The t-statistic value for all the markets is significant implying that these series were stationary and free from consequences of unit root (Table 2). Therefore can proceed with co-integration

Johansen co-integration test: The integration among selected tea markets was analysed through the Johansen co-integration test (Table 3). Unrestricted co-integration rank test (Eigen value and trace statistic) indicated the presence of at least six co-integrating equations at 5 per cent level of significance. This indicated that tea prices in the selected market were having long run equilibrium and also implies

Table 1. Instability and seasonality in Tea price in selected markets

Month	Guwahati			Kolkata			Chennai			Mumbai			Delhi			Bhopal		
	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI
January	24.78	15.42	1.02	12.62	4.72	1.01	15.06	9.52	1.01	20.79	10.88	1.00	17.69	4.82	1.00	28.44	11.34	0.98
February	24.26	15.21	1.01	13.06	4.62	1.00	15.13	9.22	1.01	19.96	10.37	1.01	17.94	5.63	1.00	26.98	10.64	0.99
March	24.74	18.48	1.02	12.97	4.62	1.00	14.20	8.11	1.01	20.50	10.71	1.00	18.28	6.18	1.00	27.23	14.41	1.02
April	28.24	12.96	0.96	13.54	4.76	0.99	9.83	5.82	0.99	20.66	10.99	1.00	18.40	6.02	1.01	27.23	14.41	1.02
May	28.72	11.99	0.97	13.52	4.69	0.99	9.79	5.71	0.99	20.48	10.86	1.00	18.00	5.97	1.01	27.23	14.41	1.01
June	26.82	12.23	1.00	13.46	5.36	1.01	9.98	5.84	0.99	20.13	10.66	0.99	17.90	5.19	1.00	27.03	14.65	1.02
July	25.44	11.31	1.00	13.86	5.52	1.01	10.18	5.99	0.99	19.72	10.57	0.99	18.34	4.91	1.00	25.84	14.29	1.04
August	23.65	10.46	1.01	13.86	5.52	1.00	10.26	6.05	0.99	19.47	10.29	1.00	18.63	3.85	0.99	24.17	11.41	1.03
September	21.41	12.91	1.02	14.14	5.14	1.00	11.20	6.59	1.00	16.60	8.13	1.01	17.63	3.70	1.00	24.99	11.03	1.02
October	21.41	12.91	1.02	12.46	5.15	1.01	12.27	7.30	1.00	16.59	9.30	1.01	16.35	3.81	1.01	25.13	11.09	1.01
November	21.05	14.58	1.02	12.53	4.90	1.01	12.63	7.72	1.00	17.18	10.21	1.01	16.33	4.24	1.00	25.95	11.50	1.00
December	21.20	15.47	1.02	12.53	4.90	1.00	14.18	8.96	1.00	15.52	9.34	1.02	15.91	4.32	1.00	25.95	11.50	0.99

CV-Coefficient of Variation (%), CDVI- Cuddy-Della Valle index and SI-Seasonality Index

Table 2. Correlation coefficients of monthly tea prices between selected markets

	Guwahati	Kolkata	Chennai	Mumbai	Delhi	Bhopal
Guwahati	1.000					
Kolkata	0.712*	1.000				
Chennai	-0.388*	0.736*	1.000			
Mumbai	0.592*	0.819*	-0.711*	1.000		
Delhi	0.773*	0.911*	0.742*	0.896*	1.000	
Bhopal	0.581*	0.859*	-0.846*	0.745*	0.801*	1.000

*indicates p<0.05

Table 3. ADF test to check the stationary of the data

Markets	t-Statistic	p value
Guwahati	-5.65	0.00
Kolkata	-13.09	0.00
Chennai	-7.96	0.00
Mumbai	-9.38	0.00
Delhi	-7.45	0.00
Bhopal	-3.39	0.01

*MacKinnon (1996) one sided p-values The whole data was Stationary

strength and stability of price linkages between selected tea markets.

Vector error correction model: Vector Error Correction Model (VECM) was employed to know the speed of adjustments among the markets for long run equilibrium among the selected markets. The number of lags in the VECM was taken to be two as the Akaike Information Criterion (AIC) was lowest at this order (2) in the system for all the selected markets i.e., Guwahati, Kolkata, Chennai, Mumbai, Delhi and Bhopal. The results of error correction terms were interpreted in order to study the nature of market (stable/unstable/random), endogeneity and the movement towards the long run equilibrium, i.e., efficiency of the market. Thereafter, the short-term causality in the prices of selected markets included in the system, i.e., which market impacts the price of other market was also explained.

$\Delta \ ln\ Guwahati_t = -0.11\ ECT_{t-1}\ -0.71\Delta ln\ Guwahati_{t-1} + 0.74\ \Delta Kolkata_{t-1} - 0.87\ \Delta lnMumbai_{t-1} + -0.005\ \Delta ln\ Delhi_{t-2} + 0.04\ \Delta Chennai_{t-1}$

$\Delta\ ln\ Kolkata_t = -0.04\ ECT_{t-1}\ -0.69\Delta ln\ Kolkata_{t-1}\ -0.02\ \Delta Mumbai_{t-2} + 0.87\ \Delta lnMumbai_{t-1} + -0.005\ \Delta ln\ Delhi_{t-2} + 0.04\ \Delta Chennai_{t-1} -0.03\Delta ln\ Guwahati_{t-1}$

$\Delta\ ln\ Bhopal_t = -0.66\ ECT_{t-1}\ -0.13\Delta ln\ Chennai_{t-1}\ -0.03\ \Delta Guwahati_{t-2} + 0.18\ \Delta lnKolkata_{t-2} + -0.30\ \Delta ln\ Mumbai_{t-2}$

$\Delta\ ln\ Chennai_t = -0.05\ ECT_{t-1}\ -0.23\Delta ln\ Mumabi_{t-1}\ -0.15\ \Delta Bhopal_{t-1} + 0.08\ \Delta Guwahati_{t-2} + -0.08\ \Delta ln\ Kolkata_{t-2}$

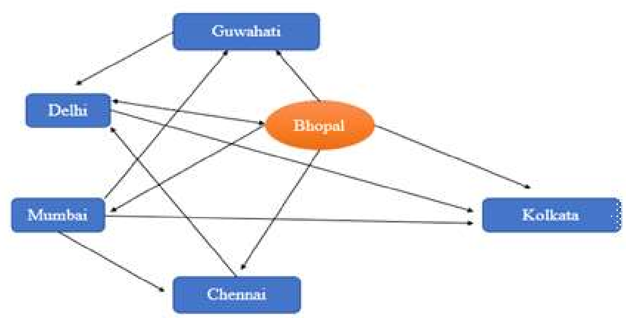
$\Delta\ ln\ Delhi_t = -0.09\ ECT_{t-1}\ -0.23\Delta ln\ Delhi_{t-1}\ -0.04\ \Delta Guwahati_{t-1} + 0.01\ \Delta Kolkata_{t-2} + -0.03\ \Delta ln\ Mumbai_{t-2} + 0.01\ \Delta Bhopal_{t-2}$

$\Delta\ ln\ Mumbai_t = -0.29\ ECT_{t-1}\ -0.22\Delta ln\ Bhopal_{t-2}\ -0.28\ \Delta ln\ Chennai_{t-1} + 0.17\ \Delta ln\ Delhi_{t-1} + -0.02\ \Delta ln\ \Delta Guwahati_{t-1} + 0.15\ \Delta ln\ Kolkata_{t-1} -0.39\ \Delta ln\ Mumabi_{t-1}$

Guwahati, Kolkata and Chennai were found to be dependent on the other markets, the speed of adjustment is low in general i.e., 11, 4 and 5 per cent respectively. This is probably due to the reason that only one-way transaction exists between the markets and said to be producing markets which supplies the produce to the other markets. However, in the Bhopal, Mumbai and Delhi markets, the speed of adjustment is found to be higher i.e., 66 per cent and 29 per cent and 11 per cent respectively. As, Bhopal market is found to be consuming market the stored quantity might be released due to faster error correction mechanism takes place. Similar results were observed by Saxena and Chand (2017).The tea prices in Guwahati market were affected by the prices in Kolkata, Mumbai and Chennai market with lag of one month as well as that of Delhiprices with two lags. Kolkata market affected by the price of Bhopal and Guwahati at lag of one-month Mumbai and Chennai market affect Kolkata market with two lags. However, prices in Bhopal market were affected by Chennai with one month lag and two-month lag of Guwahati, Kolkata and Mumbai prices.

Granger Causality test: Among the selected tea markets, the tea price of Bhopal market showed bidirectional causality transmission with tea price of Delhi market (Fig. 1). The Bhopal market itself influenced the price of Mumbai, Chennai, Kolkata and Guwahati markets which shows the unidirectional relationship between them. Guwahati market uni-directionally influenced the price of Delhi market. Mumbai market uni-directionally influenced Chennai, Kolkata and Guwahati markets. Bhopal market was a key market which influenced the price of tea crop in all other selected markets.

Testing the ARCH effect in the key market: The Box-Jenkins approach has a basic assumption that the residuals



Single arrow shows unidirectional relationship and double arrow shows bidirectional relationship

Fig. 1. Unidirectional and bidirectional relationship between markets

Table 3. Johansen cointegration test (trace) of price variation in tea markets

Null hypothesis	Eigen value	Trace statistic	Critical value	Prob.**
None *	0.298147	171.6785	95.75366	0.00
At most 1 *	0.202394	124.2383	69.81889	0.00
At most 2 *	0.197901	93.93554	47.85613	0.00
At most 3 *	0.18836	64.38543	29.79707	0.00
At most 4 *	0.144382	36.4198	15.49471	0.00
At most 5 *	0.109399	15.52508	3.841466	0.0001

Trace statistics indicates six cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

remain constant over time. Thus, the ARCH – Lagrange multiplier (LM) test was carried out on the square of the residuals and to test whether residuals do in fact remain constant. The results of the test given in table 6 revealed the presence of ARCH effect in price series of Bhopal (key) market.

Fitting of GARCH model: The GARCH model was fitted on the Bhopal market priceseries and then forecasting ability was tested. From all ARCH family models, the GARCH model was identified to be the best fit on the basis of minimum value of AIC and SIC (Table 6).

The capture volatility present in the tea price series quite well as evident from the significant value of coefficient of squared of residual term at lag one in the variance equation. The average price of tea in each month will be around Rs. 102.09 per kg (antilog of 2.009) (Table 7). Forecasting ability

Table 5. ARCH - LM test for price series of Bhopal market

Lags	F-statistic	P value
1	-0.011	p<0.001
2	-0.015	p<0.001
3	0.036	p<0.001
4	-0.015	p<0.001
5	0.121	p<0.001
6	-0.016	p<0.001

Table 6. Selection of best fit model

ARCH family model	Akaike information criterion (AIC)	Schwarz information criterion (SIC)
ARCH	6.357	6.399
GARCH	5.581*	5.666*
TARCH	5.609	5.673
EGARCH	6.811	6.853

*indicates model selected for the estimating price volatility

Table 4. Pair-wise granger causality test of selected tea markets

Null Hypothesis:	F-Statistic	Prob.
CHENNAI does not Granger Cause BHOPAL	0.041	0.960
BHOPAL does not Granger Cause CHENNAI	11.239	0.000
DELHI does not Granger Cause BHOPAL	5.271	0.006
BHOPAL does not Granger Cause DELHI	4.705	0.010
GUWAHATI does not Granger Cause BHOPAL	0.453	0.637
BHOPAL does not Granger Cause GUWAHATI	10.568	0.000
KOLKATA does not Granger Cause BHOPAL	1.225	0.297
BHOPAL does not Granger Cause KOLKATA	7.686	0.001
MUMBAI does not Granger Cause BHOPAL	0.626	0.537
BHOPAL does not Granger Cause MUMBAI	2.802	0.064
DELHI does not Granger Cause CHENNAI	0.166	0.847
CHENNAI does not Granger Cause DELHI	2.465	0.089
GUWAHATI does not Granger Cause CHENNAI	0.489	0.614
CHENNAI does not Granger Cause GUWAHATI	0.712	0.493
KOLKATA does not Granger Cause CHENNAI	0.119	0.888
CHENNAI does not Granger Cause KOLKATA	0.220	0.803
MUMBAI does not Granger Cause CHENNAI	2.921	0.057
CHENNAI does not Granger Cause MUMBAI	0.392	0.676
GUWAHATI does not Granger Cause DELHI	6.967	0.001
DELHI does not Granger Cause GUWAHATI	1.230	0.296
KOLKATA does not Granger Cause DELHI	0.374	0.689
DELHI does not Granger Cause KOLKATA	2.268	0.108
MUMBAI does not Granger Cause DELHI	1.242	0.292
DELHI does not Granger Cause MUMBAI	1.196	0.306
KOLKATA does not Granger Cause GUWAHATI	2.157	0.120
GUWAHATI does not Granger Cause KOLKATA	0.793	0.455
MUMBAI does not Granger Cause GUWAHATI	3.285	0.041
GUJRAT does not Granger Cause MUMBAI	0.604	0.548
MUMBAI does not Granger Cause KOLKATA	5.058	0.008
KOLKATA does not Granger Cause MUMBAI	0.908	0.406

Table 7. Mean and variance equation for GARCH Model

Variable	Coefficient	Std. Error	Z-Statistic	p value
Mean equation				
Intercept	2.009*	0.13	15.456	0.000
Variance equation				
GARCH	0.592*	0.024	24.222	0.000
ϵ^2_{-1}	0.974*	0.237	4.108	0.000
R-squared	-0.016	Sum squared residuals		76.351
Adjusted R-squared	-0.0089	Log likelihood		-38.685
RMSE	7.411	MAPE		11.51

*p<0.05

of the model was judged on the basis of value of root mean square error (RMSE) and mean absolute per cent error (MAPE). In the present study, the value of RMSE and MAPE has been found to be 7.411 and 11.51. Low value of MAPE has been assured the high forecasting ability of the fitted model (Gabriel 2012).

CONCLUSION

The tea price remained stable in the selected markets. In January to March and September to December, low to medium instability was observed. During these months, farmers received a better price than usual. The correlation analysis revealed that market prices moved together and were highly integrated, implying that the price differential in the selected markets was not greater than the transportation cost. This signalled that the markets are efficient. The price series in the selected markets were stationary and co-integration test indicated that the tea prices in the selected markets had long run relationship. The speed of adjustment was highest in Bhopal market (66 per cent) followed by Mumbai (29 per cent) and Guwahati (11 per cent). Granger causality revealed that Bhopal market was the key market which influenced the price of the other selected markets. For checking price volatility, GARCH model was used which revealed that the average price of tea in each month will be around Rs. 102.09 per kg. However, priority should be given to Guwahati, Kolkata and Chennai markets where lower chance of correction of any disequilibrium. More farmers should be encouraged to participate in future trading and contract farming so as to reduce the variation in arrivals and prices.

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