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ARTICLE

Market Integration and Price Forecasting of Apple in India

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ABSTRACT

The current study seeks to explore the degree of market integration through co-integration analysis on the wholesale weekly prices of three commercial varieties of Apple (American, Delicious and Moharaji) and their two important commercial grades (Special and Super) collected from five regional fruit markets of India during September, 2005 to February, 2013. The results reveal that apple markets are perfectly integrated, and the Delhi market is the dominant one. In the short run, a disequilibrium ranges from 2.1 to 96.9 per cent among all the varieties and grades of the selected fruits. However, the study finds no cointegration within two pairs of markets (Delhi-Srinagar and Bangalore-Kolkata) for the American Super variety and within one pair (Bangalore-Kolkata) for Moharaji Special. The Granger Causality Test reveals 39 and 18 bi-directional and uni-directional causations respectively under different market situations. Further, Vector Error Correction Model (VECM) results reveal a combination of positive and negative coefficients, though positive coefficients exceed the negative coefficients.

Keywords: Apple, Market integration, Cointegration, Forecasting, India

JEL Classification: Q11, Q13, C 53

I

INTRODUCTION

The form, time and place utilities regulate production, consumption and also help making efficient marketing decisions (Kohl and Uhl, 1998). These decisions are guided by price signals which determine the flow of marketing activities and provide directions for disposal of the supplies. The inter-regional markets located at distant places from the place of production and the resultant price differences provide an important feedback on understanding the market. The State of Jammu and Kashmir (J&K) produces more than 65 per cent of apple in the country of which more than 90 per cent is exported to other states of the country. Therefore, it is primarily the state of J&K which holds the key for any strategy to develop apple production and trade in the country. The marketing of apple in general is characterised by insufficient and inefficient transportation infrastructure, lack of information on arrivals from apple producing states in a particular market and demand from various states in a particular period, resulting in inefficient allocation of resources (Tahir and Riaz, 1997) and reduced farm gate prices accrue to the growers due to distressed sale of apple through contractual arrangements with pre-harvest contractors before fruit set or pre-harvest or immediately after harvest. This kind of disposal of fruit occurs because apple

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cultivation is capital intensive, and the growers have limited income. The uncertainty about future prices has all through been a concern for producers and consumers. It has been observed that price discovery and price risk management are the two important functions performed by advance contracts (Thomas, 2003 and Ahuja, 2006). It could, therefore, be perceived that a fairly good idea of prices at a future date would facilitate producers' rational market decisions (especially regarding choice of market(s) and quantum of produce to be dispatched) for profit maximisation. Against this backdrop, market integration and price forecasting would help in stabilising the prices by removing the market imperfections like monopolies and monopsonies and attain market efficiency (Mushtaq *et al*., 2008). Spatial market integration "is the smooth transmission of price signals and information across spatially separated markets" (Golleti *et al*., 1995; p. 185) or is the "measure of the extent to which demand and supply in one location are transmitted to another" (Negassa *et al*., 2003). If two markets are integrated, they will experience identical price shocks/changes (Barrett, 1996). It has been reported that econometric models underperform when compared with uni-variate, no-change or other naïve prediction devices of forecasting (Mills, 1999).While the poor performance of econometric models for forecasting has been reported by Clements *et al*., (1995, 1998, 1999), others (Granger, 1981, 1986; Granger *et al.*, 1983; Engle and Granger, 1987; Johansen, 1988, 1995 and 1996; Banerjee *et al.*, 1993; Harris, 1995) formulated the basis for cointegration analysis followed by 'equilibrium-correction' models which were used by a large number of researchers in agricultural economics (Kulendran, 1996; De Mello, 2001; De Mello *et al.*,2001; De Mello and Fortuna, 2005; Li *et al.*, 2006; De Mello and Nell, 2005 and Zhou *et al.*, 2007) in one or the other frame to reduce forecast failures. These researchers considered these methodologies as an improvement over previously available methods for forecasting. Given this backdrop, the present study uses VAR and VECM models to forecast apple prices in different markets.

The study of nature and extent of market integration is more important where the markets are spatially dispersed. Keeping in view the importance of the information on prices in different markets for the producer and market functionaries to take profit oriented marketing decisions, the present study is undertaken to empirically estimate the degree of integration of various markets for apple and also to forecast the future prices of this fruit to help the growers to take efficient decisions with regard to marketing of their produce and allocation of resources.

II

METHODOLOGY

2.1 *Data Base*

Apple is available in the market from September to December every year and January and February in the following year which means that the fruit is available for almost six months in a year in the market. It is pertinent to note here that the apple from the state of Jammu & Kashmir comes from all the directions like north, south, east and west and reaches different secondary wholesale markets from the places of the produce. The fruit is transported to these markets located in different parts of the country individually. Therefore, the data for the prices available from the government designated market functionaries of a particular market were collected directly from the designated market sources. Apple is marketed in about ten major secondary wholesale markets in the country. However, five markets (Delhi, Mumbai, Kolkata, Bangalore, and Srinagar) were selected on the basis of the highest volume of apple receipts. Part of the data on wholesale prices from 2005 to 2013 of three important commercial varieties viz., American, Delicious and Moharaji and their two commercial grades (Super and Special), were collected from the functionaries of fruit and vegetable mandies of the selected markets during the financial year 2013-14 under the ICAR sponsored project on market intelligence; another part of the data was collected during the financial year 2014-15 under the UGC sponsored Rajiv Gandhi Chair in contemporary studies on livelihood and food security and later processed to suit the present study. The data was averaged to obtain weekly wholesale prices. In the end, we had continuous data set from September to February every year for each identified market by variety and across grades involving six varieties x grade combinations. Thus the weekly data averaged for 155 weeks was considered sufficient enough to suit the analytical techniques chosen for the analysis of the data. In addition, secondary data from the state development departments of Horticulture, Horticulture Planning and Marketing, Statistics and Economics, Government of J&K, and other published sources was also collected through a specially designed schedule prepared in accordance with the objectives of the study. Following analytical techniques were used to analyse the data. A brief description of the methodology used in the present study is given below:

2.2 *Vector Error Correction Model*

The cointegration analysis reflects the long-run movement of price indices, although in the short run they may drift apart. Johansen's (1988) Multivariate Cointegration approach was used to examine cointegration between two price indices. Before conducting the cointegration test, it is mandatory to perform the stationarity test. Augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller, 1979) was performed in this study to verify stationarity in both the series.

A co-integrated system can be written as:

$$\Delta y_t = \sum_{i=1}^{k} \Gamma_i \Delta y_{t-i} + \alpha\beta' y_{t-k} + \varepsilon_t \quad ....(1)$$

where y_t is the price series, Δy_t is the first difference i.e., ($\Delta y_t = y_t - y_{t-1}$), and the matrix $\alpha\beta'$ is n x n with rank ($0 \leq r < n$), which is the rank of cointegration. The

Johansen's method of cointegration employs a restricted maximum likelihood method. If we assume that $\Pi = \alpha\beta'$. The rank of Π can be obtained by using λ_{trace} statistic. The test statistic can be given as:

$$\lambda_{trace} = -T\sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i)\ \forall\, r = 0, 1, \dots, n-1 \qquad ....(2)$$

where, T is the total number of observations, $\hat{\lambda}_i$'s are estimates of the Eigen values. Now the null and alternative hypotheses for testing the cointegration rank, are, $H_0{:}\ rank\ of\ \Pi = r$ and $H_1{:}\ rank\ of\ \Pi > r$ respectively, where r is the number of cointegrating vectors. This test is carried out under the condition that the cointegrating equation has only an intercept (no trend) and the original price series is non-stationary.

In the present investigation, VECM model was also used for forecasting the apple price in different markets. The forecast accuracy was measured in terms of relative mean absolute prediction error (RMAPE) which was computed by using the following formula

$$\text{RMAPE} = 1/h\sum_{i=1}^{h}\left\{\left|y_{t+i}-\hat{y}_{t+i}\right|/y_{t+i}\right\}\times 100,\ h\ \textit{is the forecast horizon.}$$

The analysis was done using SAS Software Package Version 9.3.

III

RESULTS AND DISCUSSION

The study analyses the price changes in five different markets in India. The criteria for selecting these markets was geographical location like local, northern, western, southern and eastern markets and the volume of transactions. In addition, availability of data too was important for selecting the markets. Price variability is the major component of market risk for both producers and consumers (Schumpeter 1999). Government of India at the national level plays an important role in regulating agriculture prices in India through various market intervention mechanisms. However, these strategies are mostly taken up for agricultural commodities, especially some food grains, most of which are not perishable like fruits and vegetables (Jha and Srinivasan, 1999; Gulati *et al.*, 2000; Ramaswamy, 2002; Chand, 2003). Usually under this particular commodity group, hill and mountainous states are mostly the losers, despite significant potential for pushing growth in agriculture beyond predicted values. It is noteworthy to mention here that more than 90 per cent of the market surplus in fruits and more than 60 per cent of vegetables are sold in open market arrangements in these states. Under such a scenario, the discovery of price behaviour under various market situations becomes important for risk management. The paper looks into this issue by verifying cointegration among the markets. It also examines the possibility of causal linkages among different markets.

3.1 *Market Efficiency*

The evaluation of market efficiency by co-integration analysis recognises that the time series of prices for various markets are usually non-stationary variables (Shen and Wang, 1990; Fortenbery and Zapata, 1993; Wang and Ke, 2005) and if these series are found to be non-stationary then it becomes necessary to test them for co-integration, which is a pre condition for market efficiency and un-biasness (Kellard *et al.*, 1999). Also non-integration among markets implies market in-efficiency. Augmented Dicky Fuller (ADF) test was applied at level and first difference to check the stationarity of this series. The results of unit root test for three commercial varieties with two grades in selected markets are presented in Table 1. The results reveal that the null of the unit root cannot be rejected for all the price series. Therefore, we conclude that all the price series in selected markets are non-stationary.

TABLE 1. AUGMENTED DICKEY-FULLER UNIT ROOT TESTS ON MARKET PRICES OF SELECTED APPLE VARIETIES/GRADES/MARKETS

	American special				American super			
	Level		Ist difference		Level		Ist difference	
Market	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Delhi	-0.38	0.5444	-12.37	< 0.0001	-0.36	0.5537	-10.51	< 0.0001
Mumbai	-0.73	0.3993	-11.94	< 0.0001	-0.57	0.4690	-12.14	< 0.0001
Bangalore	-0.52	0.4890	-14.15	< 0.0001	-0.31	0.5739	-12.26	< 0.0001
Kolkata	-0.12	0.6407	-14.20	< 0.0001	-0.23	0.6029	-11.58	< 0.0001
Srinagar	-0.20	0.6124	-13.98	< 0.0001	0.23	0.7760	-10.37	< 0.0001
	Delicious special				Delicious super			
Market	Level		Ist difference		Level		Ist difference	
	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau
Delhi	-0.29	0.5790	-7.48	< 0.0001	0.60	0.8457	-9.02	< 0.0001
Mumbai	-0.25	0.5966	-12.38	< 0.0001	0.60	0.8439	-11.04	< 0.0001
Bangalore	-0.59	0.4586	-10.43	< 0.0001	0.64	0.8526	-9.33	< 0.0001
Kolkata	-0.07	0.6572	-10.39	< 0.0001	0.60	0.8455	-10.69	< 0.0001
Srinagar	-0.30	0.7721	-8.55	< 0.0001	-0.14	0.6332	-10.40	< 0.0001
	Moharaji special				Moharaji super			
Market	Level		Ist difference		Level		Ist difference	
	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau
Delhi	-0.60	0.4552	-11.56	< 0.0001	-0.52	0.4873	-9.91	< 0.0001
Mumbai	-0.28	0.5821	-11.86	< 0.0001	-0.02	0.6747	-10.78	< 0.0001
Bangalore	-0.30	0.5771	-12.27	< 0.0001	-0.12	0.6405	-11.82	< 0.0001
Kolkata	-0.68	0.4205	-13.83	< 0.0001	-0.30	0.5781	-16.04	< 0.0001
Srinagar	-0.45	0.5195	-11.21	< 0.0001	-0.47	0.5112	-11.22	< 0.0001

Note: P-value less than 0.05 indicates that the corresponding series is stationary at 5 per cent level of significance.

The data is put to test for cointegration applying Johansen's method of reduced rank regression using Vector Error Correction model. Akaike Information Criteria (AIC) and Schwarz Bayesian Criteria (SBC) are used to select the best model for the data under consideration. On the basis of minimum AIC and SBC values presented in Table 2, it is found that for all the markets, VAR model of order one is the best.

TABLE 2. SELECTING THE ORDER OF THE VAR MODEL

Order (1)	Varieties (2)	AIC (3)	SBC (4)
01	American special	40.36	40.95
01	American super	41.40	42.00
01	Delicious special	39.68	40.26
01	Delicious super	39.81	40.40
01	Moharaji special	38.75	39.34
01	Moharaji super	39.82	40.41

3.2 *Cointegration among Markets*

The results on the trace test (Table 3) determine the number of cointegrating vectors. The figures reveal that there are four cointegrated vectors at 5 per cent level of significance and suggest that even if there is geographical dispersion of markets, the prices are integrated. These observations are in agreement with those of Mushtaq *et al., (*2008). The foregone discussion suggests that even though the markets are integrated, there could still be disequilibrium in the short run due to the price adjustments across the markets, which might not happen instantaneously or simultaneously.

TABLE 3. JOHANSEN'S CO-INTEGRATION TEST FOR SELECTED APPLE VARIETIES / GRADES/ MARKETS

H0: Rank = r (1)	H1: Rank > r (2)	Trace (3)	5 per cent critical value (4)	H0: Rank = r (5)	H1: Rank > r (6)	Trace (7)	5 per cent critical value (8)
	American Special				American Super		
0	0	189.3682	68.68	0	0	156.3235	68.68
1	1	116.9853	47.21	1	1	97.0499	47.21
2	2	69.9798	29.38	2	2	50.3921	29.38
3	3	35.4966	15.34	3	3	15.7039	15.34
4	4	3.3917	3.84	4	4	3.0316	3.84
	Delicious Special				Delicious Super		
0	0	139.3693	68.68	0	0	153.7985	68.68
1	1	76.6338	47.21	1	1	89.1840	47.21
2	2	48.7269	29.38	2	2	41.3204	29.38
3	3	22.5312	15.34	3	3	20.3269	15.34
4	4	1.4607	3.84	4	4	1.1255	3.84
	Moharaji Special				Moharaji Super		
0	0	222.3119	68.68	0	0	175.3437	68.68
1	1	154.6401	47.21	1	1	116.9200	47.21
2	2	91.2670	29.38	2	2	68.7853	29.38
3	3	33.4054	15.34	3	3	28.9788	15.34
4	4	3.0348	3.84	4	4	3.0483	3.84

3.4 *Estimates of Vector Error Correction Model Parameters*

The VECM model is estimated to know how far away the prices from the equilibrium level are and to account for this kind of adjustment Vector Error Correction Model could be an appropriate tool that takes into account the kind of adjustment in the short and long run disequilibrium of prices in the distantly located markets. The results presented in Table 4 (adjustment coefficients) reveal disequilibrium in the prices to the tune of 5.6 to 54.8; 11.5 to 96.9; 4.8 to 32.5; 2.1 to 37.1; 20.4 to 45.8 and 22.3 to 47.1 per cent respectively in American Special, American Super, Delicious Special, Delicious Super, Moharaji Special and Moharaji Super. The results of the VECM model show that most of the estimated coefficients are positive for the selected markets. These coefficients measure the ability of the prices for adjustment to deviation from the long run equilibrium, which could be removed in every period of one week.

TABLE 4. RESULTS OF VECTOR ERROR CORRECTION MODEL OF SELECTED APPLE VARIETIES/ GRADES/ MARKETS AND MARKETS

Markets (1)	Coefficient (2)	T Value (3)	P-Value (4)	Markets (5)	Coefficient (6)	T Value (7)	P-Value (8)
	American special				American super		
Delhi	-0.111	-0.90	0.3674	Delhi	0.367	2.15	0.0329
Mumbai	-0.056	-0.43	0.6659	Mumbai	-0.969	-3.66	0.0003
Bangalore	-0.293	-5.60	0.0001	Bangalore	-0.901	-3.10	0.0023
Kolkata	0.548	4.57	0.0001	Kolkata	0.890	4.31	0.0001
Srinagar	0.087	1.87	0.0635	Srinagar	0.115	0.87	0.3865
	Delicious special				Delicious super		
Delhi	-0.131	-1.07	0.1444	Delhi	0.073	1.21	0.2265
Mumbai	0.048	0.39	0.6995	Mumbai	0.371	5.61	0.0001
Bangalore	0.265	2.01	0.0460	Bangalore	0.091	1.25	0.2114
Kolkata	0.325	3.63	0.0004	Kolkata	0.155	2.07	0.0401
Srinagar	-0.093	-1.31	0.1939	Srinagar	0.021	0.04	0.9685
	Moharaji special				Moharaji super		
Delhi	-0.358	-4.25	0.0001	Delhi	-0.282	-3.00	0.0032
Mumbai	-0.308	-2.97	0.0035	Mumbai	-0.223	-2.12	0.0353
Bangalore	0.349	3.70	0.0003	Bangalore	0.303	2.66	0.0086
Kolkata	0.458	4.27	0.0001	Kolkata	0.471	4.06	0.0001
Srinagar	0.204	2.33	0.0214	Srinagar	0.295	3.69	0.0003

3.5 *Causality in Various Markets/Varieties and Grades*

The co-integration tests performed indicate only the existence of long run relationship among the prices of the selected apple varieties, their grades and the five markets. The direction of the relationship among price series and market is equally important for which Granger Causality Tests are performed. The results presented in Table 5 and summarised in Table 6, show no flow of information in American super between Delhi and Srinagar and Bangalore and Srinagar, also in Moharaji between Bangalore and Kolkata indicating that the Delhi and Bangalore prices may cause undue increase in the prices of American Super and Moharaji special respectively. The uni-directional causality is revealed in the Delhi market which lead to the prices for American Special in Bangalore, Kolkata, Srinagar; as regards American Super, it lead to the prices in Mumbai and Kolkata markets. In Delicious Special, Delhi market lead to the prices in Mumbai, Bangalore and Kolkata; Mumbai lead prices in Bangalore, and Bangalore in Kolkata, while as under Moharaji Special and Moharaji Super, Bangalore lead to Srinagar and Kolkata. These uni-directional relationships where prices of one market lead to the prices of other market without having a reciprocal impact on the prices would imply that the market for such varieties / grades is not very efficient in terms of influencing the prices of the other markets and also would increase prices in such markets. Similarly the bi-directional causation was observed in American Special wherein Delhi lead to Mumbai, Mumbai to Kolkata, Srinagar and Bangalore to Kolkata. Similarly under American Super, Delhi lead to the prices in Banglore; Mumbai to Bangalore, Kolkata, Srinagar; Bangalore and Kolkata lead to Srinagar. Under Delicious Special, Delhi lead to Srinagar, Mumbai to Kolkata, Srinagar; Bangalore to Kolkata and Srinagar and Kolkata to Srinagar. In the Moharaji Special and Super, Delhi lead to Mumbai, Bangalore, Kolkata and Srinagar; whereas Mumbai lead to Delhi, Kolkata, Srinagar and Kolkata lead to Srinagar. It should be noted here that the Granger causality results may vary for different number of lags or time horizon included in the models. The compromise is between bias and power. If we use few lags, it results in a biased test due to residual auto-correlation. On the other hand, if we have large number of lags, possibly there may be spurious rejections of null hypothesis. If the Granger causality model has p lags of each of the two variables, then optimum value of p can be chosen based on minimum AIC or BIC values. In the present investigation, it is found that the AIC values are minimum at 3 to 5 lags. Accordingly, specific lag length was used for testing the causality. This implies that the markets by and large have enough ability to predict subsequent prices among them. The results of the study are, therefore, quite useful to various stakeholders like producers, traders, commission agents and policy makers. The results will be helpful in formulating well-designed policies on market intervention schemes for an open commodity market in apple.

3.6 *Performance of the Forecast Model*

To assess the accuracy in the fitted VECM model, RMAPE is computed. Out of total data available, last ten observations are kept aside for validation purposes. Here we compute the RMAPE for the last ten observations for different markets and varieties and the same is reported in Table 7. A perusal of figures reveals that the percentage error for all the cases is less than 10 per cent indicating the superiority of the model in forecasting the prices of the selected Apple varieties/grade wise/ market wise.

TABLE 5. GRANGER CAUSALITY TEST STATISTICS FOR SELECTED APPLE VARIETIES/GRADES/MARKETS

Null hypothesis	No. of lags	American special			American super		
		χ^2	Pr $>\chi^2$	Rel	χ^2	Pr $>\chi^2$	Rel
(1)	(2)	(2)	(3)	(4)	(2)	(3)	(4)
D does not cause M	3	4.51	0.0336	↔	3.60	0.0579	→
M does not cause D		7.52	0.0061		10.88	0.0010	
D does not cause B	3	3.71	0.0542	→	6.85	0.0089	↔
B does not cause D		11.73	0.0006		12.24	0.0005	
D does not cause K	4	3.79	0.0515	→	0.77	0.3793	→
K does not cause D		15.75	< 0.0001		21.19	<.0001	
D does not cause S	4	1.75	0.1864	→	1.63	0.2017	—
S does not cause D		10.46	0.0012		2.99	0.0840	
M does not cause B	4	3.40	0.0652	→	7.36	0.0067	↔
B does not cause M		9.45	0.0021		9.90	0.0016	
M does not cause K	4	7.09	0.0078	↔	6.50	0.0108	↔
K does not cause M		7.23	0.0072		11.86	0.0006	
M does not cause S	4	8.40	0.0038	↔	13.52	0.0002	↔
S does not cause M		6.03	0.0141		6.94	0.0084	
B does not cause K	4	23.54	< 0.0001	↔	9.23	0.0024	↔
K does not cause B		10.92	0.0010		13.76	0.0002	
B does not cause S	3	6.08	0.0137	↔	3.35	0.0672	—
S does not cause B		8.81	0.0030		1.34	0.2478	
K does not cause S	3	12.67	0.0004	↔	4.37	0.0366	↔
S does not cause K		11.50	0.0007		4.94	0.0263	
Null hypothesis		**Delicious special**			**Delicious super**		
		χ^2	Pr $>\chi^2$	Rel	χ^2	Pr $>\chi^2$	Rel
D does not cause M	3	3.75	0.0529	→	0.08	0.7752	→
M does not cause D		19.42	<.0001		46.16	< .0001	
D does not cause B	3	0.24	0.6218	→	3.00	0.0833	→
B does not cause D		8.30	0.0040		8.42	0.0037	
D does not cause K	4	0.03	0.8567	→	1.76	0.1845	→
K does not cause D		13.55	0.0002		22.49	< .0001	
D does not cause S	3	11.81	0.0006	↔	6.04	0.0140	↔
S does not cause D		12.54	0.0004		10.71	0.0011	
M does not cause B	4	4.41	0.0357	→	18.36	< .0001	→
B does not cause M		3.08	0.0791		1.43	0.2319	
M does not cause K	4	6.05	0.0139	↔	26.75	< .0001	↔
K does not cause M		4.66	0.0309		6.80	0.0091	
M does not cause S	4	20.81	< .0001	↔	10.08	0.0015	↔
S does not cause M		14.13	0.0002		8.75	0.0031	
B does not cause K	3	3.33	0.0678	→	5.04	0.0247	↔
K does not cause B		3.74	0.0533		4.40	0.0360	
B does not cause S	3	5.77	0.0163	↔	7.24	0.0071	↔
S does not cause B		11.83	0.0006		8.22	0.0041	
K does not cause S	3	9.96	0.0083	↔	4.19	0.0405	↔
S does not cause K		15.70	< .0001		10.05	0.0015	
Null hypothesis		**Maharaji special**			**Maharaji super**		
		χ^2	Pr $>\chi^2$	Rel	χ^2	Pr $>\chi^2$	Rel
D does not cause M	3	17.17	< .0001	↔	12.67	0.0004	↔
M does not cause D		15.82	< .0001		16.00	< .0001	
D does not cause B	3	15.33	< .0001	↔	14.11	0.0002	↔
B does not cause D		07.76	0.0053		04.51	0.0336	
D does not cause K	3	05.39	0.0202	↔	03.86	0.0495	↔
K does not cause D		17.84	< .0001		18.88	< .0001	
D does not cause S	3	18.46	< .0001	↔	04.93	0.0265	↔
S does not cause D		19.14	< .0001		13.73	0.0002	

Table 5 (*Contd.*)

TABLE 5. (CONCLD.)

Null hypothesis (1)	No. of lags (2)	American special χ^2 (2)	Pr $>\chi^2$ (3)	Rel (4)	No. of / American super χ^2 (2)	Pr $>\chi^2$ (3)	Rel (4)
D does not cause S	3	18.46	< .0001	↔	04.93	0.0265	↔
S does not cause D		19.14	< .0001		13.73	0.0002	
M does not cause B	3	15.80	< .0001	↔	06.16	0.0131	↔
B does not cause M		05.03	0.0249		07.07	0.0078	
M does not cause K	4	05.47	0.0194	↔	06.02	0.0142	↔
K does not cause M		08.85	0.0029		10.90	0.0010	
M does not cause S	4	03.97	0.0462	↔	12.21	0.0005	↔
S does not cause M		11.06	0.0009		15.11	0.0001	
B does not cause K	4	00.53	0.4676	—	01.39	0.2386	→
K does not cause B		02.57	0.1092		03.89	0.0485	
B does not cause S	5	03.80	0.0513	→	06.45	0.0111	→
S does not cause B		03.48	0.0622		00.41	0.5240	
K does not cause S	5	06.44	0.0112	↔	08.87	0.0029	↔
S does not cause B		12.85	0.0003		06.76	0.0093	

Note: D = Delhi, M = Mumbai, B = Bangalore, K = Kolkata, S = Srinagar. ↔ Denotes bidirectional relationship, → denotes unidirectional relationship and — denotes no relationship.

TABLE 6. CATEGORISATION OF APPLE VARIETIES, GRADES AND MARKETS AS PER CO-INTEGRATION AND CAUSALITY TESTS

Causality Cointegration (1)	American Apple: American special (2)	American super (3)	Delicious Apple: Delicious special (4)	Delicious super (5)	Moharaji Apple: Moharaji special (6)	Moharaji super (7)
No Co-integration		D-S B-S			B-K	
Cointegration with unidirectional causation	D-B D-K D-S M-B	D-M D-K	D-M D-B D-K M-B B-K	D-M D-B D-K M-B	B-S	B-S B-K
Cointegration with bi-directional causation	D-M M-K M-S B-K D-S K-S	D-B M-B M-K M-S B-S K-S	D-S M-K M-S B-S K-S	D-S M-K M-S B-K B-S K-S	D-M D-B D-K D-S M-D M-K M-S K-S	D-M D-B D-K D-S M-D M-K M-S K-S

Note: D = Delhi, M = Mumbai, B = Bangalore, K = Kolkata, S = Srinagar.

TABLE 7. VARIETY AND GRADE WISE APPLE PRICE FORECAST PERFORMANCE IN SELECTED MARKETS

	Percentage Relative Mean Absolute Prediction Error (RMAPE)					
(1)	Delicious special (2)	Moharaji special (3)	American special (4)	Delicious super (5)	Moaharaji super (6)	American super (7)
Delhi	9.5	7.3	5.7	8.4	7.2	8.4
Mumbai	5.5	7.0	8.3	9.1	8.5	9.6
Bangalore	7.2	9.9	7.6	7.0	8.7	4.6
Kolkata	4.5	6.2	8.6	9.5	8.3	6.5
Srinagar	8.3	8.7	9.2	6.3	8.8	7.9

IV

SUMMARY AND CONCLUSION

The study has made an attempt to investigate the strength of the spatial market integration of five potential apple markets of India using co-integration and error correction models on the weekly wholesale prices of apple collected from September 2005 to February 2013. The results have revealed that the selected markets are strongly cointegrated and converge on the long run equilibrium. The results further suggest that even if there is geographical dispersion of markets, the prices are linked together indicating that all the market locations are in the same economic market system. However, in the short run, market prices do deviate from their equilibrium but converge in few weeks.

The results of the Granger-Casualty Test reveal a number of 5 bi-directional causations among different markets in Delicious Special, 6 each in American Special, American Super, Delicious Super and 8 in both the varieties of Moharaji Special and Super. Further, the number of uni-directional causations are in the order of 2 each in American Super; Moharaji Special and Super; 4 each in American Special and Delicious Super and 5 in Delicious Special across the selected markets. However, no causation is revealed in 2 markets (Delhi-Srinagar and Bangalore-Srinagar) in American super and in one market (Bangalore-Kolkata) in Moharaji special. The Delhi market is the most dominant market as the prices in this market are found to cause the prices of most of the markets under study. The results have revealed disequilibrium of 2.1 to 96.9 per cent among all the varieties and grades of the fruits selected, which could be removed in each period in the identified markets. It further implies that following a shock to the market resulting in disequilibrium, the economic forces would take a few weeks to restore equilibrium. The forecast model applied to the study revealed that there is less than 10 per cent deviation in the prices forecasted from the actual market prices, confirming the validity of the model used for forecasting. The foregone discussion therefore, suggests that the market integration and forecasts of prices in different markets will be a guiding principle for selecting the most efficient/remunerative market and accordingly the policy makers, marketers, the producers will find it most useful and can use the results to their benefit.

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ANNEXURE I. ADJUSTMENT COEFFICIENTS OF VECM

Markets (1)	CI-R-1 (2)	CI-R-2 (3)	CI-R-3 (4)	CI-R-4 (5)	CI-R-1 (6)	CI-R-2 (7)	CI-R-3 (8)	CI-R-4 (9)
	American Special				American Super			
Delhi	-0.111	-0.008	-0.126	-0.104	0.367	0.151	0.079	0.114
Mumbai	-0.056	0.034	0.178	-0.114	-0.969	-0.062	0.033	0.014
Bangalore	-0.293	0.083	-0.044	0.157	-0.901	-0.210	-0.023	-0.007
Kolkata	0.548	-0.015	-0.046	0.062	0.890	0.171	-0.214	0.009
Srinagar	0.087	-0.065	0.123	0.132	0.115	0.070	0.38	0.002
	Delicious Special				Delicious Super			
Delhi	-0.131	-0.103	-0.084	-0.008	0.073	-0.164	-0.027	0.004
Mumbai	0.048	0.216	0.095	0.006	0.371	0.360	-0.031	0.000
Bangalore	0.265	-0.049	0.062	0.029	0.091	0.136	0.069	0.007
Kolkata	0.325	-0.083	0.216	-0.029	0.155	0.393	-0.014	0.008
Srinagar	-0.093	0.099	-0.133	-0.010	0.021	0.045	0.005	-0.012
	Moharaji Special				Moharaji Super			
Delhi	-0.358	-0.045	-0.156	-0.002	-0.282	-0.143	-0.146	0.006
Mumbai	-0.308	-0.070	-0.064	0.004	-0.223	0.057	0.129	-0.001
Bangalore	0.349	-0.024	0.041	-0.009	0.303	0.078	-0.001	-0.019
Kolkata	0.458	0.137	-0.065	-0.001	0.471	0.304	-0.109	0.007
Srinagar	0.204	-0.018	0.099	0.003	0.295	-0.002	0.102	0.005

CI-R indicates cointegrating relationship.