Agricultural Economics Research Review
Vol. 27 (No.2) July-December 2014 pp 289-298
DOI: 10.5958/0974-0279.2014.00032.9

Cointegration, Causality and Impulse Response Analysis in Major Apple Markets of India[§]

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Abstract

The study has investigated market integration across five major wholesale apple markets, viz. Ahmedabad, Bengaluru, Delhi, Hyderabad and Kolkata, of the country by adopting Johansen's multivariate cointegration approach. The study has confirmed the presence of cointegration, implying the long-run price association among the markets. To get the additional evidence as to whether and in which direction price transmission is occurring between the market pairs, Granger causality test has been used, which has confirmed Delhi to be the price-determining market. Hyderabad has been found comparatively more efficient as it has depicted most bidirectional causal relations with other markets. The market pairs: Ahmedabad — Kolkata and Bengaluru — Kolkata have not shown any causal relation between them. The impulse response functions were also conducted which have confirmed the results of cointegration and Granger causality, but the magnitude of price transmission has been found relatively low in some market pairs that are spatially integrated. The major implication of the study is for the designing of a network of agricultural wholesale markets across the country at almost equal distance from each other to enhance the market integration and better price transmission among them.

Key words: Apple markets, cointegration, Granger causality, price transmission, impulse response functions

JEL Classification: C01, C22, Q13

Introduction

The literature on efficiency of agricultural markets has revealed that there are several impediments to the efficient functioning of these markets in the developing economies like India. The continuing debate concerning the appropriate agricultural marketing policies, government intervention in the marketplace, determinants of agricultural marketing efficiency, and the need to estimate the effects of these determinants have made it necessary for the researchers to either modify the traditional techniques or develop methods that would enable analysis of market competence. An intrusion by the government in marketing may be justified if it remedies the nearby imperfections and does not augment distortions in the market functioning. To monitor whether the government strategy has perked up market functioning or not, is a complex phenomenon in the actual sense. However, one way to throw some light on this issue is to analyze the market performance by studying market integration (Mukhtar and Javed, 2007). This market integration can be measured in terms of the strength and speed of price transmission between markets across various regions of the country (Ghafoor *et al*., 2009). The degree to which consumers

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§ The paper is a part of the M.Phil. thesis entitled "Cointegration, Causality and Price Transmission Analysis in Major Apple Markets of India" of the first author, submitted to the Centre for Economic Studies, Central University of Punjab, Bathinda, in 2014 under the guidance of second author.

and producers would benefit, depends on how domestic markets are integrated with world markets and how different regional markets are integrated with each other (Varela *et al.*, 2012).

Although several studies have been done empirically using cointegration techniques which concern the market integration of agricultural commodities in India (Ghosh, 2003; 2011; Kar *et al.,* 2004; Jha *et al.,* 2005; Yogisha, 2005; Jayasuriya *et al.,* 2007; Shenoy, 2008; Acharya *et al.,* 2012; Reddy *et al.,* 2012; Sekhar, 2012), only a little work has been carried out on the empirical evaluation of apple market integration. The study by Deodhar *et al.* (2006) on market integration across the wholesale apple markets in India has found that the markets are not integrated, but the main drawback of this study was the selection of period for the study. The selected study period had witnessed the lowest domestic apple production in India for the past two decades and imports of apple were also lowest due to 100 per cent tariff rates on apple till 1999. On the other hand, Kar *et al.* (2004) have reported that the Chennai, Delhi and Mumbai wholesale apple markets are well integrated. Similarly, Vasisht *et al.* (2008) have found that the prices of fruits and vegetables in major wholesale markets of India were highly volatile, but the less-perishable commodities like apple were found to have the presence of long-run association across some of the state level markets. The controversy of these past studies leaves a little justification whether or not apple markets are integrated in India.

While there is much emphasis on the area and production of apples in India, relatively little is known about how price transmission takes place in the domestic apple markets. This information is important for apple producers and other players in apple value chain since it influences their marketing decisions (buying and selling), which in turn, influences the assessments related to logistical matters and ultimately the export potential of apples from India. The apple producers are incapable to precisely base their marketing decisions on the price information they obtain from the markets in India (Kavitha, 2005). Producers do not have awareness on the concrete flow of information and products across the apple markets. Consequently, apple farmers are unable to specialize and benefit from the gains of trade (Deodhar *et al.*, 2007). They do not allocate the resources efficiently and the produce may be sent to markets having over-supply and lower prices, instead of moving to the markets with shortage facilities and higher prices (Kavitha, 2005). On the other hand, the increasing demand for imported apples indicates a growing consumption pattern and shift of consumers' preference from domestic to foreign produce, and thus witnessing a threat to the domestic industry, especially since 1999 when the tariffs on most of the agricultural commodities were either completely removed or lowered to allow import of foreign produce, including apples. Against this backdrop, the present study has analyzed the market integration using the Johansen's cointegration method, determination of Granger causal directions and the spatial price movements using impulse response functions (IRF) among the major wholesale apple markets of India.

Data and Methodology

The data on monthly average wholesale apple price (in ₹/ 100 kg) in Ahmedabad, Bengaluru, Delhi, Hyderabad and Kolkata markets from January, 2003 to December, 2013 were taken from the National Horticulture Board, Government of India. All the series were transformed into natural log-form to eliminate variations in movement due to level differences. The analytical techniques used in the study are described below.

Augmented Dickey-Fuller (ADF) Unit Root Test

An implicit assumption in Johansen's cointegration approach is that the variables should be non-stationary at level, but stationary after first differencing. The Augmented Dickey-Fuller test is utilized to check the order of integration by using the model (1):

$$\Delta Y_t = \alpha + \delta T + \beta_1 Y_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta Y_{t-1} + \varepsilon_t \quad \ldots(1)$$

where, $\Delta Y_t = Y_t - Y_{t-1}$, $\Delta Y_{t-1} = Y_{t-1} - Y_{t-2}$, and $\Delta Y_{t-2} = Y_{t-2} - Y_{t-3}$, etc., ε_t is pure white noise term, α is the constant-term, T is the time trend effect, and p is the optimal lag value which is selected on the basis of Schwartz information criterion[1] (SIC). The null hypothesis is that β_1, the coefficient of Y_{t-1} is zero.

[1] An index was used as an aid in choosing between the competing models. It is defined as: $-2L_m + m \ln n$, where n is the sample size, L_m is the maximized log-likelihood of the model and m is the number of parameters in the model.

The alternative hypothesis is: $\beta_1 < 0$. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary[2] (Gujarati, 2010).

Cointegration Analysis Using Johansen Methodology

The Johansen procedure examines a vector auto regressive (VAR) model of Y_t, an (n × 1) vector of variables that are integrated of the order one— I (1) time series. This VAR can be expressed as Equation (2):

$$\Delta Y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i Y_{t-1} + \Pi Y_{t-1} + \varepsilon_t \qquad ...(2)$$

where, Γ and Π are matrices of parameters, p is the number of lags (selected on the basis of Schwarz information criterion), ε_t is an (n × 1) vector of innovations. The presence of at least one cointegrating relationship is necessary for the analysis of long-run relationship of the prices to be plausible. To detect the number of co-integrating vectors, Johansen proposed two likelihood ratio tests: trace test and maximum eigen value test, shown in Equations (3) and (4), respectively.

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \qquad ...(3)$$

$$J_{\max} = -T \ln(1-\hat{\lambda}_r + 1) \qquad ...(4)$$

where, T is the sample size and $\hat{\lambda}_i$ is the i^{th} largest canonical correlation. The trace test examines the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. The maximum eigen value test, on the other hand, tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of $r+1$ cointegrating vectors (Hjalmarsson and Osterholm, 2010).

Granger Causality Test

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). It is an F-test of whether changes in one price series affect another price series. Taking the causality relationship between Delhi and Ahmedabad wholesale apple markets as an example, the test was based on the following pairs of OLS regression equations through a bivariate VAR:

$$P\ln D_t = \sum_{i=1}^{m} \alpha_i P\ln D_{t-i} + \sum_{i=1}^{m} \beta_j P\ln A_{t-j} + \varepsilon_{1t} \quad ...(5)$$

$$P\ln A_t = \sum_{i=1}^{m} \Upsilon_i P\ln A_{t-i} + \sum_{i=1}^{m} \delta_j P\ln D_{t-j} + \varepsilon_{2t} \quad ...(6)$$

where, D and A are Delhi and Ahmedabad markets, P ln stands for price series in logarithm form and t is the time trend variable. The subscript stands for the number of lags of both variables in the system. The null hypothesis in Equation (5), i.e. H_0:$\beta_1 = \beta_2 = ... = \beta_j$=0 against the alternative, i.e., H_1: Not H_0, is that $P\ln A_t$ does not Granger cause $P\ln D_t$. Similarly, testing H_0: $\delta_1 = \delta_2 = ... = \delta_j = 0$ against H_1: Not H_0 in Equation (6) is a test that P ln D_t does not Granger cause P ln A_t. In each case, a rejection of the null hypothesis will imply that there is Granger causality between the variables (Gujarati, 2010).

Impulse Response Functions

Granger causality tests do not determine the relative strength of causality effects beyond the selected time span. In such circumstances, causality tests are inappropriate because these tests are unable to indicate how much feedback exists from one variable to the other beyond the selected sample period (Rahman and Shahbaz, 2013). The best way to interpret the implications of the models for patterns of price transmission, causality and adjustment are to consider the time paths of prices after exogenous shocks, i.e. impulse responses (Vavra and Goodwin, 2005). The impulse response function traces the effect of one standard deviation or one unit shock to one of the variables on current and future values of all the endogenous variables in a system over various time horizons (Rahman and Shahbaz, 2013). In this study, we have used the generalized impulse response function (GIRF) originally developed by Koop *et al*. (1996) and suggested by Pesaran and Shin (1998). The GIRF in the case of an arbitrary current shock, δ, and history, ω_{t-1} is given in Equation (7).

$$GIRF_Y(h, \delta, \omega_{t-1}) = E[Y_{t+h} | \delta, \omega_{t-1}] — E[y_{t+h} | \omega_{t-1}] \quad \text{for } n = 0, 1, ... \qquad ...(7)$$

Results and Discussion

The summary statistics of monthly wholesale prices of fresh delicious apples for the period January,

[2] Non-stationary means that the mean and variance of the time series are unstable throughout the period and the auto-covariance is varying by the time change.

Table 1. Summary statistics of monthly wholesale prices for fresh delicious apples in selected markets for the period January, 2003 to December, 2013

(in ₹/100 kg)

Market	Observations (No.)	Monthly wholesale price			Standard deviation
		Minimum	Maximum	Mean	
Ahmedabad	132	2998	11567	5945	1900
Bengaluru	132	2817	12667	6510	2165
Delhi	132	2332	9223	5086	1625
Hyderabad	132	2966	11738	6144	1994
Kolkata	132	2566	11092	5719	1822

2003 to December, 2013 are presented in Table 1. A perusal of Table 1 reveals that the minimum values of the average price varied from ₹ 2,332/100 kg in Delhi market to ₹ 2,998/100 kg in Ahmedabad market, while the maximum values of the average price varied from ₹ 9,223/100 kg in Delhi market to ₹ 12,667/100 kg in Bengaluru market during the study period. The average prices were found to be ₹ 5,945/100 kg in Ahmedabad, ₹ 6,510/100 kg in Bengaluru, ₹ 5,086/100 kg in Delhi, ₹ 6,144/100 kg in Hyderabad and ₹ 5,719/100 kg in Kolkata. The standard deviation in price was found to be maximum in the Bengaluru wholesale market (₹ 2,165) and minimum in Delhi wholesale market (₹ 1,625) from January, 2003 to December, 2013.

Unit Root Test Results

The results of the Augmented Dickey-Fuller (ADF) unit root test applied at level and first difference to the logarithmically transformed prices of apple are given in Table 2. The empirical evidence suggests that price series had unit root problem at their level form. The null hypothesis of the unit root at level form cannot be rejected for all price series as the absolute values of the ADF statistics are well below the 5 per cent critical values of the test statistics. Thus, it is concluded that all the price series are non-stationary at their level forms. In order to test the level or number of unit roots in the data, a unit root test of first difference was conducted, which showed the number of unit roots to be equal to one, since the data became stationary after the first difference as absolute values of the ADF statistics were now greater than the 5 per cent critical values of the test statistics. With the proof that the price series were non-stationary and integrated of the order 1, test for cointegration among the selected apple markets using Johansen's maximum likelihood approach was applied.

Table 2. ADF unit root test results for wholesale prices of apple (including intercept and trend as exogenous)

Market	At level/first difference	T-cal.	(Prob.*)	Remarks
Ahmedabad (A)	ln A	-3.331	(0.0659)	Non-stationary
	Δln A	-8.977**	(0.0000)	Stationary
Bengaluru (B)	ln B	-2.779	(0.2075)	Non-stationary
	Δln B	-10.87**	(0.0000)	Stationary
Delhi (D)	ln D	-2.715	(0.2324)	Non-stationary
	Δln D	-9.143**	(0.0000)	Stationary
Hyderabad (H)	ln H	-2.612	(0.2757)	Non-stationary
	Δln H	-11.04**	(0.0000)	Stationary
Kolkata (K)	ln K	-3.213	(0.0854)	Non-stationary
	Δln K	-9.113**	(0.0000)	Stationary

Notes:
1. The asterisks ** indicate that unit root at level or in the first differences were rejected at 1 per cent as well as at 5 per cent significance. The (prob.*) denotes MacKinnon (1996) one-sided *p*-values.
2. 'ln' denotes wholesale price in logarithmic form and Δ ln denotes the price series in logarithm form after first difference.

Table 3. Overall cointegration in major apple markets of India

H_0	H_A	Statistics	C.V. (5%)	Prob.**
		Trace test		
$r = 0$	$r \geq 1$	157.57*	69.818	0.0000
$r \leq 1$	$r \geq 2$	99.211*	47.856	0.0000
$r \leq 2$	$r \geq 3$	52.676*	29.797	0.0000
$r \leq 3$	$r \geq 4$	25.699*	15.494	0.0010
$r \leq 4$	$r = 5$	9.6165	11.841	0.5328
		Maximum eigen-value test		
$r =0$	$r \geq 1$	58.364*	33.876	0.0000
$r \leq 1$	$r \geq 2$	46.534*	27.584	0.0001
$r \leq 2$	$r \geq 3$	26.976*	21.131	0.0067
$r \leq 3$	$r \geq 4$	20.083*	14.264	0.0054
$r \leq 4$	$r = 5$	9.6165	9.8414	0.5172

Note:*denotes rejection of the null hypothesis at 5 per cent level of significance.

Cointegration Test Results

The results of Johansen's maximum likelihood tests (maximum eigen-value and trace test) are given in Table 3. To check the first null hypothesis that the variables were not cointegrated ($r = 0$), trace and eigen-value statistics were calculated, both of which rejected the null hypotheses as maximum eigen-value and trace test statistics values were higher than 5 per cent critical values and accepted the alternative of one or more cointegrating vectors. Similarly, the null hypotheses: $r \leq 1$, $r \leq 2$ and $r \leq 3$ from both statistics were rejected against their alternative hypotheses of $r \geq 1$, $r \geq 2$ and $r \geq 3$, respectively. The null hypothesis $r \leq 4$ from both the tests (trace test and maximum eigen-value test) were accepted and their alternative hypotheses ($r = 5$) were rejected as the trace value and maximum eigen-value were well below than their corresponding critical values at 5 per cent level of significance. Both these tests confirmed that all the five selected apple markets had 4 cointegrating vectors out of 5 cointegrating equations, indicating that they are well integrated and price signals are transferred from one market to the other to ensure efficiency. Thus, Johnson cointegration test has shown that even though the selected wholesale apple markets in India are geographically isolated and spatially segmented, they are well-connected in terms of prices of apple, demonstrating that the selected apple markets have long-run price linkage across them.

Pair-wise Cointegration Results

A pair-wise cointegration that was also performed across the markets, the results of which are given in Table 4. This test showed that the each market pair, viz., Ahmedabad–Bengaluru, Ahmedabad–Delhi, Ahmedabad–Hyderabad, Bengaluru–Delhi, Bengaluru –Hyderabad, Delhi–Hyderabad, Delhi–Kolkata and Hyderabad–Kolkata, had one cointegrating equation, implying that these market pairs are cointegrated and there exists long-run price association between them. On the other hand, the market pairs: Ahmedabad–Kolkata and Bengaluru–Kolkata had no cointegrating vector(s), implying that there does not exist any cointegration between them and thus, no long-run price association exists between these two market pairs.

Granger Causality Test

After finding cointegration among different apple markets, granger causality was also estimated between the selected pairs of apple markets in India. The granger causality shows the direction of price formation between two markets and related spatial arbitrage, i.e., physical movement of the commodity to adjust the prices difference (Ghafoor *et al*., 2009). The results of granger causality tests are presented in Table 5 which shows that all the four F-statistics for the causality tests of wholesale prices in Delhi market on other markets are statistically significant. The null hypothesis of no granger causality was rejected in each case for Delhi market. Besides, Hyderabad had three, Bengaluru and Ahmedabad had two each and Kolkata had one F-statistics statistically significant on other market prices.

According to the granger causality test, there were unidirectional causalities between the market pairs: Bengaluru–Hyderabad, Delhi–Ahmedabad, Delhi–Bengaluru and Delhi–Kolkata wholesale markets, meaning that a price change in the former market in each pair granger causes the price formation in the latter market, whereas the price change in the latter market is not feed backed by the price change in the former market in each pair. From Table 6, it can be seen that there exists bidirectional causality between Ahmedabad–Bengaluru, Ahmedabad–Hyderabad, Delhi–Hyderabad and Kolkata–Hyderabad market pairs. In these cases, the former market in each pair granger causes the wholesale price formation in the latter market which in turn provides the feedback to

Table 4. Pair-wise cointegration in major apple markets

Market pair	H_0	H_A	Trace test		Maximum eigen-value test		Cointegrating
			Statistic	C.V. (5%)	Statistic	C.V. (5%)	equations (CE)
lnA-lnB	$r = 0$	r ³ 1	19.127*	15.494	15.780*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	3.3462	3.8414	3.3462	3.8414	
lnA-lnD	$r = 0$	$r \geq 1$	17.491*	15.494	14.334*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	3.1577	3.8414	3.1577	3.8414	
lnA-lnH	$r = 0$	$r \geq 1$	27.047*	15.494	24.485*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	2.5611	3.8414	2.5611	3.8414	
lnA-lnK	$r = 0$	$r \geq 1$	14.203	15.494	11.745	14.264	NONE
	$r \leq 1$	$r \geq 2$	2.4574	3.8414	2.4574	3.8414	
lnB-lnD	$r = 0$	$r \geq 1$	15.502*	15.494	14.373*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	3.1289	3.8414	3.1289	3.8414	
lnB-lnH	$r = 0$	$r \geq 1$	22.369*	15.494	19.509*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	2.8601	3.8414	2.8601	3.8414	
lnB-lnK	$r = 0$	$r \geq 1$	11.227	15.494	8.4363	14.264	NONE
	$r \leq 1$	$r \geq 2$	2.7910	3.8414	2.7910	3.8414	
lnD-lnH	$r = 0$	$r \geq 1$	23.868*	15.494	21.366*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	2.5013	3.8414	2.5013	3.8414	
lnD-lnK	$r = 0$	$r \geq 1$	46.617*	15.494	43.944*	14.264	1 CE
	$r \leq 1$	$r \geq 2$	2.6735	3.8414	2.6735	3.8414	
lnH-lnK	$r = 0$	$r \geq 1$	29.595*	15.494	27.293*	14.264	1 CE
	r £ 1	r ³ 2	2.3019	3.8414	2.3019	3.8414	

Note:*denotes rejection of the null hypothesis at 5 per cent level of significance.

the former market as well. Further, two market pairs, Ahmedabad–Kolkata and Bengaluru–Kolkata, have no direct causality between them, indicating that neither Ahmedabad nor Bengaluru market granger causes the price formation in Kolkata, nor the Kolkata market granger causes the price formation in Ahmedabad and Bengaluru markets. In other words, there is no long-run price association between these market pairs (Figure 1).

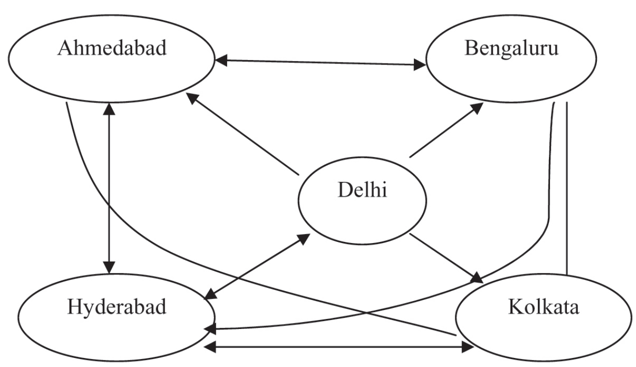

Figure 1. Granger causality directions between the market pairs

Impulse Response Functions

The results of impulse response functions, given in Appendix Figures A-1 to A-5, show how and to what extent a standard deviation shock in one of the apple markets affects the current as well as future prices in all the integrated markets over a period of twelve months. It can be seen that when a standard deviation shock is given to any market, the responses of all other markets disappear between 5 and 6 months. A shock originating from the Delhi wholesale market is more or less transmitted to all other major apple markets in the country, but a shock originating from any other apple market is relatively less transmitted to the Delhi market. This implies that the Delhi market has dominance in price determination in other markets of the country. A noteworthy point in Appendix Figure A-3 is that the wholesale prices in Kolkata and Bengaluru markets are inversely related to prices in the Delhi market up to initial three months, but thereafter follow a pattern similar to other response curves to a shock originating in Delhi market wholesale prices. On the other hand, the results of Hyderabad

Table 5. Pair-wise Granger causality in major apple markets

Null hypothesis	F-statistics	Prob.	Granger cause	Direction
lnA does not Granger cause lnB	5.2319	0.0006**	Yes	Bidirectional
lnB does not Granger cause lnA	12.2433	0.0238**	Yes	
lnD doesnot Granger cause lnA	7.30541	0.0454**	Yes	Unidirectional
lnA does not Granger cause lnD	11.007	0.4512	No	
lnH does not Granger cause lnA	7.3230	0.0077**	Yes	Bidirectional
lnA does not Granger cause lnH	7.4360	0.0073**	Yes	
lnK does not Granger cause lnA	20.628	0.00001	No	None
lnA does not Granger cause lnK	2.0601	0.1536	No	
lnD does not Granger cause lnB	13.257	0.0003**	Yes	Unidirectional
lnB does not Granger cause lnD	18.593	0.00002	No	
lnH does not Granger cause lnB	2.5829	0.1105	No	Unidirectional
lnB does not Granger cause lnH	10.139	0.0018**	Yes	
lnK does not Granger cause lnB	26.175	0.000001	No	None
lnB does not Granger cause lnK	2.9877	0.0863	No	
lnH does not Granger cause lnD	7.8370	0.0059**	Yes	Bidirectional
lnD does not Granger cause lnH	15.914	0.0001**	Yes	
lnK does not Granger cause lnD	23.106	0.000004	No	Unidirectional
lnD does not Granger cause lnK	7.1983	0.0083**	Yes	
lnK does not Granger cause lnH	13.862	0.0003**	Yes	Bidirectional
lnH does not Granger cause lnK	5.9439	0.0161**	Yes	

Notes: The lags of the dependent variable used to obtain white-noise residuals were determined using the Schwarz Information Criterion (SIC).

** denotes rejection of the null hypothesis at 5 per cent level of significance.

market impulse response confirm that the price transmission from Hyderabad to other markets and vice versa occur in large proportions. Unlike Delhi, Hyderabad and Ahmedabad markets, a shock given to the Kolkata and Bengaluru markets is transmitted to a lesser extent to other markets, implying that Kolkata and Bengaluru are relatively market followers and do not play a significant role in national apple markets of the country.

Concluding Remarks and Policy Suggestions

The study has examined cointegration, causality and price transmission in major apple markets of India. The results of overall cointegration test have indicated that different wholesale apple markets in the country are well-integrated and have long-run price association across them. The market pair-wise cointegration test has confirmed that the pairs of Ahmedabad–Kolkata and Bengaluru–Kolkata markets do not have any price association between them. Granger causality tests have also indicated that unlike in other market pairs, Ahmedabad–Kolkata and Bengaluru–Kolkata markets have no causality direction on price formation between them. The results of impulse response functions, on the other hand, have confirmed that the speed as well as magnitude of a shock given to Kolkata and Bengaluru markets are relatively less transmitted to other markets, thus revealing that Kolkata and Bengaluru markets are trend followers and not trend setters. One of the reasons for their subservient role could be the existence of sea ports like Haldia, Mormugao, New Mangalore, Ennore and Chennai ports, where foreign produce arrives first. Consequently, the imported apple markets have enlarged in several south Indian cities, including Bengaluru. Therefore, a positive standard deviation shock in the domestic apple prices forces the consumers to shift from low-quality domestic apples to high quality imported apples around the sea port and thus the rise in domestic prices is relatively less reflected in the Kolkata and Bengaluru markets. Therefore, quality improvement in domestic fruit is a meaningful implication reflected in the Kolkata and Bengaluru markets. On the other hand, Hyderabad market has been found comparatively competent. This may be due to its geographical position— the centre-most among the selected apple markets of the country. Therefore, the price signals in Hyderabad market are quickly transmitted to other markets and vice versa. It implies that the geographical situation and optimal distance between the market places hold the mutual forces on commodity movements and price formation. It is, therefore, suggested that the network of agricultural wholesale markets should be well-designed so as to keep equal distance from each other. It will not only boost a direct inter-market competition, but will also control the massive marketing margins of agricultural commodities. The produce can be transported to the deficit areas thereby providing benefits to both consumers and producers.

Acknowledgment

The authors are thankful to the anonymous referee for providing helpful suggestions.

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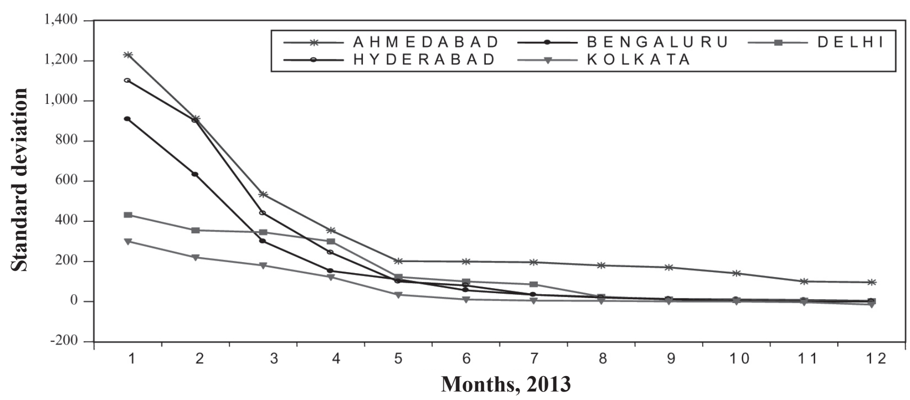
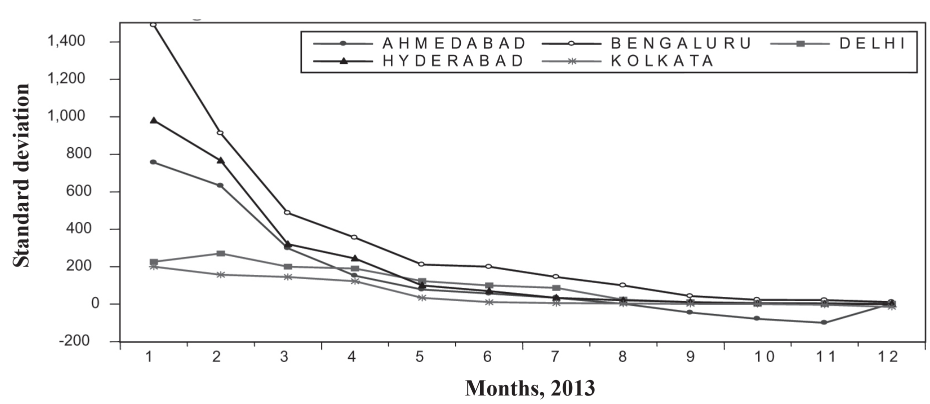
Received: March, 2014; Accepted June, 2014

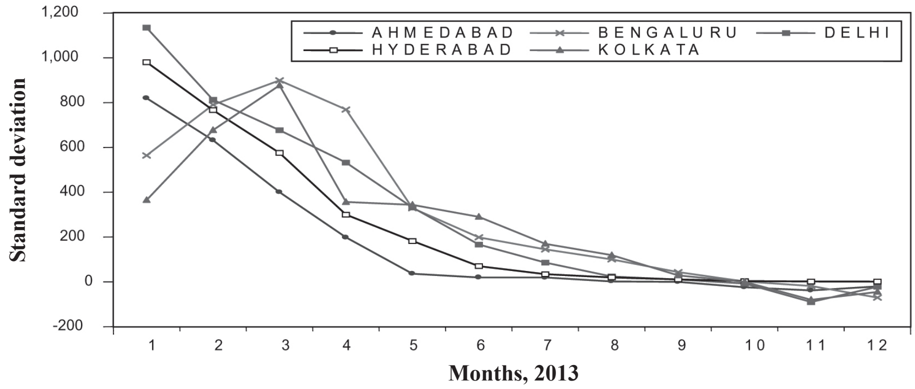
Appendices



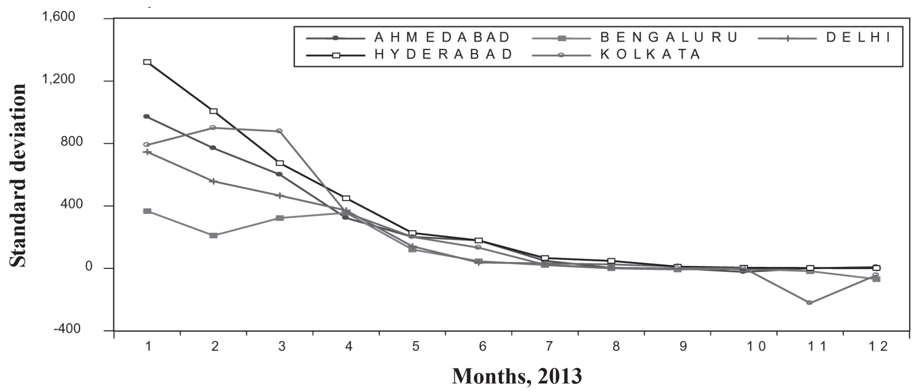
Appendix Figure A-1. Response of selected markets to a generalized standard deviation shock in Ahmedabad market



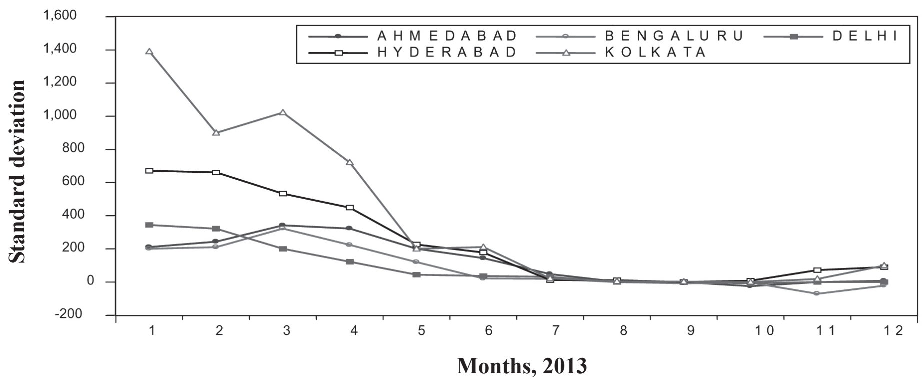
Appendix Figure A-2. Response of selected markets to a generalized standard deviation shock in Bengaluru market



Appendix Figure A-3. Response of selected markets to a generalized standard deviation shock in Delhi market



Appendix Figure A-4. Response of selected markets to a generalized standard deviation shock in Hyderabad market



Appendix Figure A.5. Response of selected markets to a generalized standard deviation shock in Kolkata market