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SPATIAL INTEGRATION AND PRICE BEHAVIOUR ANALYSIS OF MAJOR POTATO WHOLESALE MARKETS IN GUJARAT

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ABSTRACT

In this age of market information and intelligence, price behaviour analysis of agricultural commodities is crucial for optimizing returns of farmers and to hedge them from associated price fluctuations. Unintegrated markets are the precursors of market failures leading to discrepancies in both supply and demand. The purpose of this study is to examine market integration and price transmission mechanism under a unified testing strategy for potato in four major wholesale consumption markets of Gujarat viz. Ahmedabad, Bharuch, Rajkot, and Surat. Monthly wholesale prices (Rs/quintal) for fourteen years (2007-08 to 2020-21), yielding a total of 168 observations, were analyzed. The findings revealed the highest elasticity of price transmission between Rajkot and Surat (0.96), while the lowest between Ahmedabad and Rajkot markets (0.84). Besides, error correction model confirmed that on average 27 per cent to 44 per cent of the short-run price fluctuations in the markets get corrected within a month. Granger causality further confirmed bidirectional price influence in all the market pairs except for Ahmedabad-Rajkot pair. As significant improvements in transportation and storage infrastructure in Gujarat might have led to high price integration in the markets, the study opines the need for taking price integration advocacy to the farmers' end directly through calibrated training programmes for enabling them to take improved planting, storage and marketing decisions.

Keywords: *Market integration; direction; potato prices*

INTRODUCTION

In food security terms, market prices serve as proxy for both food availability and food access. In the era of agricultural information literacy, price behaviour analysis of agricultural commodities attains prominence and can be touted as a key criterion of the last-mile delivery by both public and private extension mechanism (Ganga, 2020). The strength of market integration and the speed of price transmission mechanism are revealed through price analysis. Developed infrastructure including storage structures, effective transportation, and reasonable credit, insurance and other institutional linkages are the hallmarks of integrated markets (Goletti *et al*., 1995). Such integrated markets would lead to enhanced food supply, less price risks, and limited scope for market entry barriers. On the flip-side, integration and transmission failures will end up in localized or regional food insecurity or famines as the distant markets (with scarcity) may lack the ability to respond to the emerging price signals of isolated markets (with surplus).

Though it may not be possible to conduct price analysis on all agricultural commodities in India for want of time series data for a considerable time period, such attempts in major food commodities at least may signal in shortages, surpluses or efficient distribution of resources for the benefit of farmers to tackle the ever-changing market and marketing conditions. One such important food commodity is potato which is the most popular crop in India as apart from being used as a vegetable, it is also greatly demanded by the country's ever growing food industry. It is no coincidence that the crop occupies 21 per cent share in the gross value output of vegetables in 2019-20 at 2004-05 prices (NHB, 2020; Raval *et al.,* 2021).

In India, potato crop gets cultivated in diverse agro-climatic conditions and the states of West Bengal, Bihar, Uttar Pradesh and Gujarat together account for more than 80 per cent of its production. As of the triennium ending (TE) 2019-20, the country accounted for 21.92 lakh ha area under the crop with a production of 438 lakh metric tonnes (MT), which is the second largest production in the world (14.6%) next only to China (49.5%). Coming to Gujarat state, potato gets majorly cultivated in the North Gujarat region in the districts of Banaskantha, Sabarkantha and Mehsana. During TE 2019-20, all the three districts together comprised 1.12 lakh ha producing 29.62 lakh MT. A number of good integrated pack houses, air cargo complex and gamma

irradiation projects have been established in Gujrat for promoting value addition as well as export prospects of horticultural crops including potato. In addition, the state hosts a large number of cold chain units of which 70-80 per cent are used exclusively for the storage of potatoes. Thereby, it is no coincidence that all the leading national and multinational manufactures of processed and value-added products in potato are located in Gujarat ensuring the possibility of fair remuneration to the farmers to specialize in quality potato production.

OBJECTIVES

(1) To determine the presence of long-run integration among the selected potato wholesale markets

(2) (To detect short-run price disequilibria among market pairs and estimate their convergence to the long-run path

(3) To diagnose the direction of price flow among the integrated markets

METHODOLOGY

Only the potato consumption markets were taken into account in the present study. The degree of integration existing between markets can be readily translated to the efficient availability and utilization of market related infrastructure in moving the produce from surplus (production centres) to deficit (consumption centres) regions. The monthly data on average wholesale modal prices of potato from four major consumption markets comprising 168 observations between January 2007-08 and December 2020-21 in Gujarat *viz*. Ahmedabad, Bharuch, Rajkot and Surat were employed in the present study. Though Deesa wholesale market in Banaskantha district is the largest market occupying more than 55 per cent of the potato volume transactions in the state, it was not selected as it happens to be a production market. The markets in the study were selected on the basis of their consumption nature and these four markets together constituted more than one-fourth (27%) of daily transactions of marketable potato in Gujarat wholesale markets. The price data were sourced from Agmarknet (www.agmarknet.nic.in) for the stated period.

Tools of analysis

The market integration cum price transmission analysis was attempted using a unified testing strategey comprising the tests of unit root, lag selection, co-integration, error correction and Granger causality in their order.

Unit root test

Any two wholesale markets are considered to be integrated when there is existence of long-run equilibrium inbetween. However, two price-series need to be stationary at first to establish any such relationship since econometric relation between the time-series has the presence of trend components (Davidson and Mackinnon, 1993). A stationary series with a constant mean and a constant finite covariance structure does not vary systematically with time and tends to return frequently to its mean value and fluctuates around it within a more or less constant range. In this study, the price series of wholesale markets were first checked for stationarity by using Augmented Dicky-Fuller (ADF) unit-root test of the following form (Gujarati, 2009):

$$\Delta Y_{it} = \alpha + \beta_i T + \delta_i Y_{i\,-1} + b_i \sum_{i-1}^{p} \Delta Y_{i\,-1} + e_t \qquad \textbf{(1)}$$

Where:

Y_{it} = Price of a commodity in a given market 'i' at a time't';

ΔY_{t-i} = $Yt_{-1} - Y_{t-2}$ (t-i – lagged prices and Δ – differenced series);

T = Time trend;

α = Drift parameter;

β_i, δ_i and b_i = Coefficients; and

ε_t = Pure white noise error-term.

In this model, the ADF tests the null hypothesis that the price series (Y_{it}) has a unit root and price series are not stationary. This is done by calculating t-statistics for $\delta_i = 0$ in equation (1). If the value of the ADF statistics (δ) is less than the critical value at the conventional significance level (usually at 5 per cent significance) then the series (Y_{it}) is said to be stationary and *vice-versa.*

Lag selection test

Deriving optimal length is an essential part of co-integation analysis. The two most commonly used lag length selection criteria are the Akaike Information Criteria (AIC) and the Schawartz Information Criteria (SIC) with the following specifications as given below.

AIC = T ln (sum of squared residuals) + 2n **(2)**

SIC = T ln (Sum of squared residuals) + nln (T) **(3)**

Where: n = number of parameters estimated; and T = number of usable observations

Augmented Engle-Granger test

The concept of co-integration and the methods for estimating a co-integrated relation (Engle and Granger, 1987) provide a framework for estimating and testing long run equilibrium relationships between stationary integrated variables. If two prices in spatially separated markets (or different levels of the supply chain) *p1t* and *p2t* contain stochastic trends and are integrated at levels (I = 0), then the prices are said to be co-integrated if:

$$P_{1t} = \beta P_{2t} = u_t \quad \textbf{(4)}$$

Where β is referred as the co-integrating vector whereas equation (5) is said to be the co-integrating regression. The above relationship was estimated using *inter alia* Ordinary Least Squares (OLS) analysis as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{jt} + e_t \quad \textbf{(5)}$$

Where:

Y_{it} = Price of potato in the market 'i' at a time't';

X_{jt} = Price of potato in the market 'j' at a time't';

β_0 = Constant term;

β_1 = Long-run elasticity of price transmission; and

ε_t = Error-term.

If both the series were found to be stationary at levels (I = 0), then the classical regression model [as given in equation (6)] would hold good for estimating the long-run equilibrium and the β coefficient itself is sufficient to represent the elasticity of price transmission.

Error correction model

Even after confirming the existence of a long-term equilibrium in the market pairs (as shown in Equation 6), there exists possibility for short-run disequilibrium, due to which, the price change in one market may not get transmitted immediately to the other market and takes some time for such transmission. Accordingly, the speed of short-run adjustment to the long-run equilibrium was estimated by using the Error Correction Model (ECM) as given below.

$$\Delta Y_{t-i} = \alpha_0 + \alpha_1 \Delta X_{t-i} + \alpha_2 e_{t-1} + \varepsilon_t \quad \textbf{(6)}$$

Where:

ΔY_{t-i} = $Y_{t-1} - Y_{t-2;}$

α_0 = Constant term;

$\alpha_{1,} \alpha_2$ = Speed of price transmission;

ΔX_{t-i} = $X_{t-1} - X_{t-2}$;

e_{t-1} = Lagged error term of the co-integration model; and

ε_t = White noise error-term.

In this manner, the speed of adjustment towards the long-run path was ascertained as otherwise the integration between the market pairs may not be perfect. In the above equation (6), the magnitude of α_2 explains the speed at which the price approaches equilibrium and it is expected to be negative, so that the equilibrium is restored in the long-run.

Granger causality test

According to Granger causality, if a signal *X* "Granger causes" (or "G-causes") a signal *Y*, then present and past values of *X* may contain information that helps predict future *Y*. At the same time, it is important to note that Granger causality measures precedence and information content but does not by itself indicate causality. Following Gujarati *et al*. (2009), the causality test was attempted by the equation given below:

$$\Delta Y_i = \beta_0 + \beta_1 Y_{i(t-1)} + \beta_{2(t-1)} + \sum_{k=1}^{m} \delta_k \Delta y_{i(t-k)} \sum_{h-1}^{n} \alpha_h \Delta y_{j(t-h)} + \varepsilon_t \quad \textbf{(7)}$$

Where:

Y_{it} = market 'i' at time 't';

Y_{jt} = market 'i' at time 't'; and

m and n = number of lags determined by SIC.

The null hypothesis is that a market 'X' does not Granger-cause market 'Y'.

RESULTS AND DISCUSSION

The daily average wholesale prices of potato for the period January 2007-08 to December 2020-21 is given in Table 1. As it could be seen from the table, there are limited price variations among the markets as the average price was found to be high in Bharuch market (Rs. 970/qtl) and low in Surat market (Rs. 883/qtl) with the difference being only around 10 per cent. Similarly, the maximum and minimum prices were also found to be more or less the same across the markets. Marketable potato production among farmers, limited scope in expanding area beyond the traditional belt and steady demand from the agro-processing sector might be the key determinants for the prices to remain stable among all the markets.

Table 1: Descriptive statistics of monthly potato price series in major wholesale markets of Gujarat state between January 2007-08 to December 2020-21 (n=168)

Particulars	Major potato wholesale markets in Gujarat (Consumption centres)			
	Ahmedabad	Bharuch	Rajkot	Surat
Mean	963.043	970.23	896.99	883.52
Median	850.00	883.00	846.43	817.86
Maximum	2514.29	2057.143	2325.00	2345.00
Minimum	321.43	275.00	310.72	307.15
Std. Dev.	401.39	392.18	389.55	379.99
Observations	168	168	168	168

Price association among selected potato markets

Apart from descriptive statistics of the data, a zero-order correlation matrix was also attempted to identify the relationship between potato prices in major wholesale markets of Gujarat and the same is presented in Table 2. As it can be seen from the table, a very strong and positive association (ranging between 0.89 to 0.94) has been noticed among potato prices of all the selected markets, which indicates that prices tend to move together across markets. The coefficient 'r' values were also found to be significant at 1 % level. As potato has been one of the highly volatile commodities during the recent years in most parts of the country, such association may tend to have implications to stabilize the prices at local or regional levels.

Table 2: Zero Order Correlation Matrix of monthly wholesale prices in major potato markets of Gujarat between January 2007-08 and December 2020-21

Particulars	Major potato wholesale markets in Gujarat			
	Ahmedabad	Bharuch	Rajkot	Surat
Ahmedabad	1.00			
Bharuch	0.94	1.00		
Rajkot	0.93	0.89	1.00	
Surat	0.94	0.93	0.91	1.00

Note: All the values were found to be significant at 1 % level.

Potato price linkages among selected markets

Unit root

As a first step to determine the price transmission mechanism in potato, an Augmented Dickey-Fuller (ADF) unit root test applied to ascertain the stationarity of the monthly price series obtained from major potato wholesale consumption markets across Gujarat state. The stationarity of price indices was tested before establishing the causal relationships across the markets. The results of the unit root tests rejected the null hypothesis of the presence of unit root as the potato prices were considered stationary at level itself *i.e.,* these were integrated at order zero (I = 0) for all the markets. In similar terms, Sidhu *et al*. (2010) observed price series of cabbage and onion to be stationary at level itself.

Table 3: ADF unit root test of potato market prices in Gujarat state

Market price series (in log)	At level ~ (I = 0)	t-Statistic	p-value	Remark
Ahmedabad (AH)	ln AH	-3.55***	0.0072	Stationary
Bharuch (BH)	ln BH	-2.96**	0.0394	Stationary
Rajkot (RJ)	ln RJ	-3.44**	0.0136	Stationary
Surat (SU)	ln SU	-2.77*	0.0634	Stationary

Note: (1) ***, **, and * indicate significance at 1 %, 5 % and 10 %, respectively. (2) McKinnon critical values of ADF statistic (p-value) under the assumption of both constant and time trends in the series are -3.45 (1 %), -2.87 (5 %) and -2.57 (10 %). (3) Unit root test assumes both constant and time trends.

Lag selection

Attaining stationarity in the price series or obtaining it in the same order ~ I(d) may alone not be sufficient to establish market integration. The order of lag of the variables included in the model also needs to be ascertained. Accordingly, Akaike Infirmation Criteria (AIC), Schwarz Information Criteria (SIC) and Hannan and Quinn Information

Criteria (HQIC) values were used to ascertain the lags. The findings furnished in Table 4 show minimum values of SIC and HQIC at the first lag itself whereas values of AIC were found minimum only at the third lag. Considering the other two criteria, further market integration analysis was worked out with an optimal lag length of 1.

Table 4: Lag length criteria for potato market prices in Gujarat state

Lag	LogL	LR	FPE	AIC	SIC	HQIC
0	-11159.12	NA	7.67e+17	52.53232	52.57046	52.54739
1	-10358.91	1581.580	1.91e+16	48.84195	49.03264*	48.91728*
2	-10331.19	54.26879	1.81e+16	48.78679	49.13003	48.92239
3	-10304.64	51.48914	1.72e+16*	48.73711*	49.23289	48.93297
4	-10290.72	26.71682	1.74e+16	48.74692	49.39526	49.00305
5	-10275.87	28.24270	1.75e+16	48.75231	49.55319	49.06870
6	-10270.29	10.50427	1.84e+16	48.80134	49.75477	49.17800
7	-10250.54	36.78927	1.81e+16	48.78373	49.88972	49.22066
8	-10233.90	30.69943*	1.80e+16	48.78071	50.03924	49.27790

Note: * indicates lag order selected by the criterion; and

Co-integration analysis

The elasticity of price transmission was estimated by fitting a double log regression model and the elasticities were obtained directly as all the markets were found to be stationary at level (*i.e.,* I=0). Accordingly, Table 5 presents a matrix with the price transmission coefficients for each of the market pair combinations. As it could be seen from the table, all the six market pairs were found to be integrated in the long-run equilibrium with a certain degree of price transmission from one to another. Among all the market pairs, the highest elasticity of price transmission was found to be in Surat-Rajkot pair (0.958) followed by Bharuch-Surat (0.895), Bharuch-Rajkot (0.873) and the lowest being in Ahmedabad-Bharuch market pair (0.843). In other words, on an average more than 85 per cent of the price change was found getting transmitted from one market to the other.

This way, the co-integration between market pairs confirms the existence of long-run equilibrium. Shinoj *et al*. (2008) used a similar approach and established the long-run integration between major fish markets in India. It is crucial for the markets to be integrated of the same order for the cointegration to take place. It is almost normal for all the agricultural commodity markets not to be integrated at level (I=0) but only after first or second differencing (I ≠ 0) in which case Engle Granger regression model alone would not be sufficient to diagnose any long-term integration unlike the present favourable situation.

Table 5: Elasticity of price transmission between various domestic market pairs

Markets	Bharuch	Rajkot	Surat
Ahmedabad	0.843*** (4.10)	0.840*** (6.08)	0.863*** (8.10)
Bharuch		0.873*** (6.98)	0.895*** (5.77)
Rajkot			0.958*** (11.61)

Notes: 1. *** denotes significance at 1 %;
2. Figures inside parenthesis indicate t-values;
3. The price series are of the same order of integration.

Error Correction Model

The presence of co-integration in the model has established the existence of long-run equilibrium among the market pairs. At the same time, there may be the possibility of short-term disequilibrium among the markets in which the prices between the market pairs fluctuate for a short-while and may not get transmitted from one market to the other. Such short-run dynamics of co-integrated equation was modeled through the error correction model in the study and the findings are presented in the following equations:

1. Ahmedabad – Bharuch : $\Delta \ln AM = 0.0004 + 0.336\ \Delta \ln BH - 0.274^{**} e_{t-1}$

2. Ahmedabad – Rajkot : $\Delta \ln AM = 0.0004 + 0.451\ \Delta \ln RJ - 0.339^{**} e_{t-1}$

3. Ahmedabad – Surat : $\Delta \ln AM = 0.0004 + 0.464\ \Delta \ln SU - 0.393^{**} e_{t-1}$

4. Bharuch – Rajkot : $\Delta \ln BH = 0.0001 + 0.491\ \Delta \ln RJ - 0.407^{**} e_{t-1}$

5. Bharuch – Surat : $\Delta \ln BH = 0.0001 + 0.437\ \Delta \ln SU - 0.470^{**} e_{t-1}$

6. Rajkot – Surat : $\Delta \ln RJ = 0.0005 + 0.572\ \Delta \ln SU - 0.445^{**} e_{t-1}$

As the beta coefficients of the lagged error term (e_{t-1}) in the model capture the short-run equilibrium between the market pairs, the equations confirm the presence of co-integration in the short-run. Besides, the coefficient of the error correction term (i.e. lagged error term) was negatively significant for all market pairs. This confirms that the market prices are integrated in the long-run and the variations due to external shocks that may occur in the short run also get adjusted and converge towards the long-run equilibrium path. For instance, between Ahmedabad-Bharuch market pair 27 per cent of the short-term fluctuations were found to be getting corrected within a month's time at 5 per cent level of significance. The corresponding speed of adjustment was found highest for Bharuch-Surat (47 per cent) followed by Rajkot-Surat (44 per cent) and Bharuch-Rajkot (40 per cent). All the coefficients of speed of adjustment were significant at 5 per cent level of significance.

Granger causality

The Granger causality test was employed to understand the direction of price formation between market pairs. At the same time, the associated spatial arbitrage *i.e*., physical movement of commodity to adjust the prices difference (Venujayakanth *et al*., 2017) can also be ascertained using this test as displayed in Table 6.

Table 6: Pair-wise Granger Causality in major potato markets of Gujarat

Market pair	Null hypothesis	Lag	F-statistics	p-value	Granger cause	Direction
Ahmedabad (AH) – Bharuch (BH)	AH does not Granger Cause BH	1	26.17	0.00*	YES	Bi-directional
	BH does not Granger Cause AH	1	35.12	0.00*	YES	
Ahmedabad (AH) – Rajkot (RJ)	AH does not Granger Cause RJ	1	1.06	0.30	NO	Uni-directional
	RJ does not Granger Cause AH	1	95.91	0.00*	YES	
Ahmedabad (AH) – Surat (SR)	AH does not Granger Cause SJ	1	15.28	0.00*	YES	Bi-directional
	SJ does not Granger Cause AH	1	44.10	0.00*	YES	
Bharuch (BH) – Rajkot (RJ)	BH does not Granger Cause RJ	1	7.41	0.00*	YES	Bi-directional
	RJ does not Granger Cause BH	1	61.17	0.00*	YES	
Bharuch (BH) – Surat (SJ)	BH does not Granger Cause SJ	1	33.56	0.00*	YES	Bi-directional
	SJ does not Granger Cause BH	1	56.25	0.00*	YES	
Rajkot (RJ) – Surat (SJ)	RJ does not Granger Cause SJ	1	102.35	0.00*	YES	Bi-directional
	SJ does not Granger Cause RJ	1	5.20	0.00**	YES	

Note: (1) The lags of the dependent variable used to obtain white-noise residuals were determined using the Schwartz Information Criteria (SIC); (2) *, ** denote rejection of the null hypothesis at 1 % and 5 % significance levels respectively.

As shown in Table 6, the F-statistics of the causality tests of wholesale prices of all the markets pairs were statistically significant, except for the Ahmedabad-Rajkot market pair. Only the Rajkot market was found influencing the price change in Ahmedabad market and not *vice-versa*. As Ahmedabad entirely happens to be a consumption market when compared to Rajkot, the probable influence of the former influencing the prices of the latter may be absent. Otherwise, a price change in any market is transmitted to the market pair bi-directionally. Thereby, null hypothesis of no granger causality was rejected in all other market pairs. Thereby, it has been determined that integration has also led to bi-directional price flow among markets. This is a welcome phenomenon as such signals may help farmers in decision-making.

CONCLUSION

Spatial integration of markets tends to exist, when prevailing prices of one market equals that of the other plus transportation and other costs, *inter-alia,* utilized to transact the commodity in-between. In this study, the major wholesale potato consumption markets of Gujarat (*viz.* Ahmedabad, Bharuch, Rajkot and Surat) were found to be well integrated both under long-run and short-run equilibria. This provides critical evidence to the existence of adequate provision of public goods in the state such as infrastructure, transportation and the presence of large number of buyers leading to perfect competition in the potato markets. The findings revealed that the price-series were found to be stationary at level (I=0) itself with an optimal lag length of one. Further analysis showed that on an average, 85 per cent of price transmission was observed between all the six market pairs with mostly bi-directional causality in the long-run. For the shorter version of it, the existence was empirically proved with the lagged error terms being significantly negative. Subsequently, the price convergence of the short-run disintegration to the long-run path was found to be between 27 and 47 per cent. It is suggested that market integration can be further enhanced provided the market price information system is backed up with institutional support for combating any incidence price asymmetricity beyond enabling farmers in making better planting, storage and marketing decisions.

IMPLICATIONS

The findings of the study can equip potato farmers in the decision-making of whether to store the harvested produce or go after its immediate liquidation. Further, the price signals emanating from market integration may boost the bargaining capacity of the producers while dealing with traders, contract farming companies, processors, and other stakeholders in the value chain.

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CONFLICT OF INTEREST

There is no conflict between author.

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