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Estimation of Price Cointegration across Major Potato Markets of India – An Application of the Vector Error Correction Model

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Abstract: The present study analyzed the price cointegration between Delhi, Agra, Ahmedabad, Indore, Patna, Kolkata, Burdwan, Coochbehar, Guwahati and Chennai potato markets from January 2015 to December 2021. To identify the presence of long run cointegrating relationship the Johansen cointegration methodology was used. It was found that long-run equilibrium existed between the prices of the selected markets. The short-run price movements were identified through the Vector Error Correction Model (VECM) which revealed that Agra market was the quickest to reestablish equilibrium after any price shock, followed by Burdwan, Chennai and Coochbehar markets. Delhi, Chennai and Coochbehar markets on the other hand were found to be the more efficient in transferring price signals. It was concluded that any relevant policy initiative administered through these markets would perform better in the long run. Also, any effort to influence the price of potato artificially would be void due to the high degree of long run price cointegration across the country. There were evidences of inter-state price transmissions between potato wholesale markets which would also help formulate effective price policies.

Keywords: Cointegration, Vector Error Correction Model, Potato, Price linkage, VECM, Market integration.

INTRODUCTION

The unprecedented population pressure and the associated demand for food pose a challenge to today's food systems globally. FAO forecasts 70% more demand for food in view of global population growth up to 9.7 billion people by the year 2050 (FAO *et al.,* 2017). Potato emerges as a promising crop to feed this expanded population sustainably and nutritiously while also providing livelihood to farmers across the globe. The production of potato is highly climate-specific and is concentrated in the temperate regions of the northern hemisphere of the globe (Devaux *et al.,* 2020). China and India have experienced a steady, almost linear growth in potato production over the last 50 years (Devaux *et al.,* 2020). India has produced over fifty-four million metric tons of potato in 2020-2021, the bulk of the production is concentrated in northern India wherein the states Uttar Pradesh and Gujrat stand highest in area and productivity respectively, West Bengal being a close second in both the parameters (Agricultural statistics at a glance, 2021).

Fresh potato is a thinly traded commodity in global markets and is absent in major international commodity exchanges. It is therefore subject to less price volatility on a global scale (FAO, 2009). However, the price of potato is far more volatile on a national scale as a result of production uncertainties and demand shifts (Katoch and Singh 2020). Recently, horizontal and vertical price linkages are important areas of research in the food markets. The extent to which a price shock at one market/level of value chain affects a price in other markets/value chain level provides an assessment of the functioning of markets. The number of studies on horizontal price linkages in the food markets in the developed world has increased recently; however, it is hard to find studies on how the price transmission mechanism takes place in potato vegetable markets in developing countries. Hence this paper attempts to assess the price transmission mechanism of spatially separated wholesale potato markets in India. Results of this study will assist producers and consumers to realize the gains from long-term comparative advantage and also help governments in developing trade policy.

MATERIAL AND METHOD

Given two or more series are non-stationary at level, if there exists a stationary linear combination between them, the series are called cointegrated (Gujarati, 2012). To estimate the market integration through price transmission, this study uses the weekly wholesale price data from 2015 to 2021 of potato markets. The selection of the market was based on three factorsi) production catchments of potato (area in hectare) ii) unique market profile characteristics (number of sellers concentration) and iii) non-stationarity of price series. Based on these factors, ten major markets were selected for investigation, i.e., Agra (Uttar Pradesh), Ahmedabad (Gujarat), Chennai (Tamil Nadu), Delhi, Guwahati (Assam), Indore (Madhya Pradesh), Kolkata, Burdwan, Coochbehar (West Bengal) and Patna (Bihar). The time series weekly wholesale price data were collected from the market database of the National Horticultural Research and Development Foundation (NHRDF) pertaining to the year 2015 to 2021. The weekly price data for the selected markets is depicted in the form of a line-graph in Fig 1 for better visual representation.

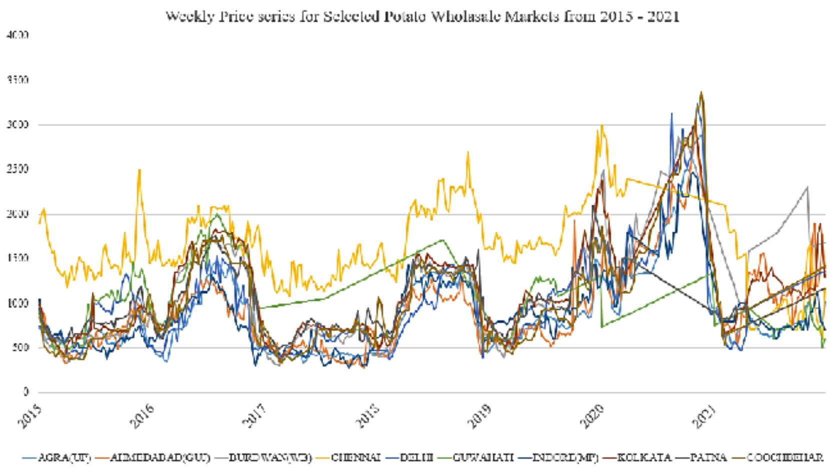

Fig. 1. Weekly price series for selected potato wholesale markets from 2015-2021.

Test for unit root. A time series is called stationary when the mean and variance of the series are time-invariant and the autocorrelation is a function of the distance between two time periods and not the actual periods concerned (Gujarati, 2012). Any cointegration test assumes the non-stationarity of time series. Hence, it is instrumental to check for a unit root in level and the first difference before we can proceed further. For this, this study employed the Phillips Perron test (PP test) for stationarity due to its non-parametric estimation and does not require specifying the level of serial correlation as in ADF.

Johansen test. The cointegration test is based on the truism that for two or more series to be non-stationary, they must possess the same intertemporal characteristics. In this analysis, the Johansen, Juselius Maximum Likelihood method was employed due to its simultaneously handling multiple series while other methods such as Engle-Granger are objectively bi-variate models. It also addresses the endogeneity and simultaneity problems better than a bi-variate framework (Johansen and Juselius, 1990).

Vector Error Correction Model (VECM)

The Johansen cointegration model indicates any long-run relationship between the time series. From the perspective of policy prescription, short-run price linkages between markets are as important as the long-run relationships. Having established a long-run relationship, it is also of critical importance to observe the short-run behaviour of the series concerned, as they drift apart and recalibrate to the long-run equilibrium. The speed of this adjustment has serious implications on the level of efficiency and information mobility across markets. For these reasons, Vector Error Correction Model was built on the data. The short-run cointegrating equations for each cointegrating relationship pertain to the general form of-

$$\Delta Y_t = \sigma + \sum_{i=1}^{k-1} \Upsilon_i \, \Delta Y_{t-i} + \sum_{j=1}^{k-1} \eta_j \, \Delta X_{t-j} + \sum_{m=1}^{k-1} \xi_m \, \Delta R_{t-m} + \lambda ECT_{t-1} + u_t$$

Where ECT is the error correction term and Y, X and R, are cointegrated time series variables of different periods indicated by their suffixes. λ is the error correction coefficient that measures the speed of adjustment. Negative and significant values of λ indicate the speed of restoring previous equilibrium while zero or positive values of the term indicated explosive or divergent behaviour from the equilibrium (Saxena and Chand 2017).

RESULT AND DISCUSSION

Results of the unit root test. Phillips Perron test was performed for the presence of unit root at level and first difference. The PP test is built upon the alternative hypothesis of stationarity. Thus, any p-value less than 0.05 signifies a stationary series. The results of the PP test are presented in Table 1. From the results, it was inferred that all the selected series are integrated of degree one.

Johansen Cointegration test results. To determine the number of cointegrating equations in the data, the Johansen cointegration test was employed through trace statistics and the maximum eigenvalue method. Johansen's cointegration methodology is based on the sequencing of the tests to determine the rank of the matrix formulated on a group of non-stationary series. The null hypothesis of at most r cointegrating vectors with an alternative hypothesis of (r +1) cointegrating vectors are tested at each stage starting with r = 0.

From Table 2 it was depicted that the trace statistics associated with the null hypothesis $r = 0$, $r \leq 1$, and $r \leq 2$ are higher than the corresponding 5% critical values leading to the conclusion that there are four cointegrating relationships between the variables concerned.

Table 3 depicted the results of the maximum eigenvalue rank test of the Johansen cointegration method and indicated that there are three cointegrating vectors based on the MacKinnon-Haug-Michelis p-values obtained for the test statistic.

The trace test and the maximum eigenvalue test conclude different results. It is to note that both the tests are likelihood-ratio type tests but they employ different assumptions for the deterministic part of the data generating process (DGP). Hubrich *et al.*, have noted that the trace test tends to exhibit more distorted sizes compared to the other (Hubrich *et al.*, 2001). Lütkepohl *et al.* (2004) have suggested the use of the trace test over the maximum eigenvalue test in a small sample simulation. Accordingly, this study concluded that among the selected series there are four cointegrating equations and this leads to the conclusion of stable price cointegration across the selected potato markets in the long run.

Table 1: Philips Perron test statistics.

Markets	**Phillips Perron test statistics**	
	At Level	**1st Difference**
Agra	-2.712438 (0.0728)	-11.68627 (0.0000)
Ahmedabad	-2.854834 (0.0518)	-23.62326 (0.0000)
Burdwan	-2.108215 (0.2416)	-15.63132 (0.0000)
Chennai	-2.709097 (0.0734)	-20.09566 (0.0000)
Coochbehar	-2.483640 (0.1203)	-13.32277 (0.0000)
Delhi	-2.806135 (0.0583)	-17.64707 (0.0000)
Guwahati	-2.572070 (0.0997)	-19.89303 (0.0000)
Indore	-2.321159 (0.1658)	-20.42175 (0.0000)
Kolkata	-2.682212 (0.0781)	-15.28654 (0.0000)
Patna	-2.831015 (0.0528)	-20.83195 (0.0000)
Critical values **1% level** -3.447818 | **5% level** -2.869134 |**10% level** -2.570883		

Table 2: Johansen cointegration through trace statistics method.

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace statistics**	**0.05 critical value**	**Prob.**
None *	0.184058	333.1591	239.2354	0
At most 1 *	0.180034	258.7102	197.3709	0
At most 2 *	0.139919	186.062	159.5297	0.0008
At most 3 *	0.106183	130.8956	125.6154	0.0229
At most 4	0.092089	89.81058	95.75366	0.1196
At most 5	0.057646	54.45176	69.81889	0.4422
At most 6	0.04269	32.72075	47.85613	0.5723
At most 7	0.02744	16.75299	29.79707	0.6583
At most 8	0.014781	6.569508	15.49471	0.6282
At most 9	0.003053	1.119275	3.841465	0.2901

Table 3: Johansen cointegration through max. eigenvalue method.

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen value	0.05 critical value	Prob.
None *	0.184058	74.44885	64.50472	0.0043
At most 1 *	0.180034	72.64816	58.43354	0.0012
At most 2 *	0.139919	55.1665	52.36261	0.0251
At most 3	0.106183	41.08497	46.23142	0.1607
At most 4	0.092089	35.35882	40.07757	0.1547
At most 5	0.057646	21.73101	33.87687	0.6284
At most 6	0.04269	15.96776	27.58434	0.6685
At most 7	0.02744	10.18349	21.13162	0.7272
At most 8	0.014781	5.450233	14.2646	0.6843
At most 9	0.003053	1.119275	3.841465	0.2901

Vector Error Correction Model (VECM). The VECM model was built to analyze the short-run behaviour of the selected potato markets concerned with ensuring the presence of long-run cointegration. The results of this model are presented in Table 4 wherein the error correction terms and coefficients of cointegrating equations along with corresponding standard errors and t-statistics are provided.

The concerned discussion is divided into two parts. The first part discussed the error correction term which revealed the speed of adjustment from short-run deviations. Later we formed the short-run cointegrating equations under VECM framework for each market. This illustrated the cointegration and price transmission across the selected markets.

The error correction term. The Error Correction Term (ECT) for Agra, Burdwan, Coochbehar, Chennai and Patna are all negative and significant, which indicates that the series will return to its previous long-run equilibrium. The coefficient of the error correction term, which signifies the speed of adjustment, was highest in Agra and Burdwan markets, respectively 15.9% and 15.37% followed by Chennai and Coochbehar and Patna markets at 14.37%, 13.07% and 9% respectively.

Table 4: Vector Error Correction Estimates.

Error Correction:	D(AGR)	D(AHM	D(BURD	D(CHEN)	D(COB	D(DEL)	D(GWA)	D(INDR_	D(KOL)	D(PAT)
CointEq1	-0.159065	-0.000842	-0.153795	-0.143761	-0.130793	-0.076560	-0.020814	0.063377	-0.033750	-0.099673
	{0.02693}	{0.05429}	{0.03309}	{0.05143}	{0.03395}	{0.04650}	{0.02796}	{0.03675}	{0.03146}	{0.03256}
	[-5.90575]	[-0.01550]	[-4.64797]	[-2.79516]	[-3.85208]	[-1.64645]	[-0.74436]	[1.72432]	[-1.07263]	[-3.06157]
D(AGR(-1))	0.257515	0.079342	0.106333	0.083154	0.223875	0.541568	0.041945	-0.004559	0.123999	0.079675
	{0.05848}	{0.11787}	{0.07184}	{0.11166}	{0.07372}	{0.10096}	{0.06071}	{0.07980}	{0.06831}	{0.07068}
	[4.40381]	[0.67311]	[1.48017]	[0.74469]	[3.03697]	[5.36441]	[0.69093]	[-0.05714]	[1.81516]	[1.12724]
D(AGR(-2))	-0.011927	-0.029562	0.029639	0.236497	0.005716	0.035765	0.069379	0.092694	0.009029	0.018758
	{0.05709}	{0.11509}	{0.07014}	{0.10902}	{0.07197}	{0.09857}	{0.05927}	{0.07791}	{0.06670}	{0.06901}
	[-0.20891]	[-0.25686]	[0.42256]	[2.16921]	[0.07941]	[0.36284]	[1.17050]	[1.18975]	[0.13537]	[0.27181]
D(AHM(-1	0.053285	-0.327946	0.011345	0.085588	0.008599	0.047864	0.002576	0.057202	-0.015140	-0.004737
	{0.02752}	{0.05547}	{0.03381}	{0.05255}	{0.03469}	{0.04751}	{0.02857}	{0.03755}	{0.03215}	{0.03326}
	[1.93628]	[-5.91182]	[0.33556]	[1.62869]	[0.24786]	[1.00743]	[0.09018]	[1.52323]	[-0.47093]	[-0.14240]
D(AHM(-2	0.057562	-0.161784	0.007415	0.006124	0.078561	0.096511	0.016856	0.116807	-0.003234	0.006082
	{0.02704}	{0.05450}	{0.03321}	{0.05163}	{0.03408}	{0.04668}	{0.02807}	{0.03689}	{0.03158}	{0.03268}
	[2.12912]	[-2.96862]	[0.22324]	[0.11862]	[2.30504]	[2.06767]	[0.60053]	[3.16608]	[-0.10239]	[0.18612]
D(BURD(-1))	0.047941	0.018717	0.094357	0.143284	-0.003004	-0.039923	0.089684	0.136923	0.138533	0.014024
	{0.04674}	{0.09421}	{0.05742}	{0.08925}	{0.05892}	{0.08069}	{0.04852}	{0.06378}	{0.05460}	{0.05649}
	[1.02573]	[0.19867]	[1.64332]	[1.60543]	[-0.05099]	[-0.49476]	[1.84831]	[2.14682]	[2.53719]	[0.24823]
D(BURD(-2))	-0.015517	-0.143674	0.101439	0.180305	-0.023806	-0.036963	-0.009903	-0.026901	0.158122	0.093152
	{0.04649}	{0.09372}	{0.05712}	{0.08878}	{0.05861}	{0.08027}	{0.04827}	{0.06344}	{0.05431}	{0.05620}
	[-0.33376]	[-1.53304]	[1.77599]	[2.03091]	[-0.40617]	[-0.46050]	[-0.20518]	[-0.42401]	[2.91128]	[1.65758]
D(CHEN(-1))	0.039456	-0.032709	0.028826	-0.057406	-0.019414	-0.019529	0.043702	-0.019047	-0.028087	0.042946
	{0.02869}	{0.05784}	{0.03525}	{0.05479}	{0.03617}	{0.04954}	{0.02979}	{0.03916}	{0.03352}	{0.03468}
	[1.37504]	[-0.56548]	[0.81772]	[-1.04767]	[-0.53669]	[-0.39421]	[1.46700]	[-0.48642]	[-0.83786]	[1.23819]
D(CHEN(-2))	0.028580	-0.005322	-0.029270	-0.054554	0.015150	0.008712	-0.026801	0.003306	0.010585	0.019880
	{0.02830}	{0.05704}	{0.03476}	{0.05403}	{0.03567}	{0.04885}	{0.02938}	{0.03861}	{0.03306}	{0.03420}
	[1.01006]	[-0.09330]	[-0.84203]	[-1.00965]	[0.42471]	[0.17834]	[-0.91233]	[0.08562]	[0.32022]	[0.58124]
D(COB(-1))	0.201562	0.114147	0.071764	0.009244	0.192566	0.266052	-0.053469	0.072377	0.046029	0.056006
	{0.04281}	{0.08631}	{0.05260}	{0.08176}	{0.05397}	{0.07392}	{0.04445}	{0.05843}	{0.05002}	{0.05175}
	[4.70779]	[1.32260]	[1.36436]	[0.11306]	[3.56776]	[3.59929]	[-1.20291]	[1.23878]	[0.92025]	[1.08220]
D(COB(-2))	-0.097567	-0.059007	-0.001124	0.132302	-0.169595	-0.149720	0.099221	-0.079551	0.039383	-0.063052
	{0.04241}	{0.08548}	{0.05210}	{0.08098}	{0.05346}	{0.07321}	{0.04402}	{0.05787}	{0.04954}	{0.05126}
	[-2.30080]	[-0.69029]	[-0.02158]	[1.63384]	[-3.17250]	[-2.04504]	[2.25378]	[-1.37471]	[0.79498]	[-1.23011]
D(DEL(-1))	0.059880	0.025761	-0.038478	-0.079315	0.056827	-0.175644	-0.031716	0.004355	-0.003287	0.014587
	{0.03417}	{0.06888}	{0.04198}	{0.06525}	{0.04308}	{0.05900}	{0.03548}	{0.04663}	{0.03992}	{0.04130}
	[1.75234]	[0.37398]	[-0.91657]	[-1.21550]	[1.31916]	[-2.97722]	[-0.89400]	[0.09339]	[-0.08233]	[0.35316]
D(DEL(-2))	0.007042	0.054289	0.016456	-0.138427	0.001114	-0.097962	-0.027096	-0.097707	0.038366	-0.018647
	{0.03325}	{0.06702}	{0.04085}	{0.06349}	{0.04191}	{0.05740}	{0.03452}	{0.04537}	{0.03884}	{0.04019}
	[0.21179]	[0.81002]	[0.40288]	[-2.18026]	[0.02658]	[-1.70658]	[-0.78499]	[-2.15348]	[0.98775]	[-0.46397]
D(GWA(-1))	-0.046312	-0.054833	-0.056435	0.011537	0.099177	-0.104275	-0.074127	0.075588	0.094299	0.083592
	{0.05236}	{0.10555}	{0.06433}	{0.09999}	{0.06601}	{0.09040}	{0.05436}	{0.07145}	{0.06117}	{0.06329}

	[-0.88446]	[-0.51950]	[-0.87731]	[0.11538]	[1.50248]	[-1.15348]	[-1.36363]	[1.05787]	[1.54158]	[1.32074]
D(GWA(-2))	-0.000937	0.147289	0.177785	-0.011335	0.152094	0.019951	0.069003	0.030400	0.168759	0.064980
	{0.05215}	{0.10513}	{0.06407}	{0.09959}	{0.06575}	{0.09004}	{0.05414}	{0.07117}	{0.06093}	{0.06304}
	[-0.01797]	[1.40104]	[2.77482]	[-0.11382]	[2.31337]	[0.22158]	[1.27444]	[0.42715]	[2.76988]	[1.03079]
D(INDR(-1))	0.032495	0.089457	-0.152205	0.011151	-0.005796	0.182134	0.036734	-0.079799	0.129479	-0.079535
	{0.04465}	{0.09000}	{0.05485}	{0.08526}	{0.05628}	{0.07708}	{0.04635}	{0.06093}	{0.05216}	{0.05397}
	[0.72783]	[0.99398]	[-2.77495]	[0.13079]	[-0.10298]	[2.36288]	[0.79251]	[-1.30978]	[2.48244]	[-1.47377]
D(INDR(-2))	-0.006449	0.029020	-0.019733	-0.080814	0.026322	-0.095808	0.057887	0.066897	0.055949	-0.053991
	{0.04370}	{0.08810}	{0.05369}	{0.08346}	{0.05509}	{0.07545}	{0.04537}	{0.05964}	{0.05106}	{0.05283}
	[-0.14756]	[0.32941]	[-0.36753]	[-0.96835]	[0.47777]	[-1.26978]	[1.27583]	[1.12171]	[1.09585]	[-1.02205]
D(KOL(-1))	-0.101477	0.315874	0.087499	-0.270399	0.064752	0.081757	-0.051433	-0.026616	0.000539	-0.021998
	{0.05098}	{0.10276}	{0.06263}	{0.09735}	{0.06427}	{0.08801}	{0.05292}	{0.06957}	{0.05956}	{0.06162}
	[-1.99057]	[3.07383]	[1.39712]	[-2.77766]	[1.00757]	[0.92891]	[-0.97181]	[-0.38260]	[0.00906]	[-0.35700]
D(KOL(-2))	-0.046969	0.245778	-0.123923	-0.232562	0.085966	0.069660	-0.060246	0.047974	-0.033638	-0.035829
	{0.05162}	{0.10406}	{0.06342}	{0.09858}	{0.06508}	{0.08913}	{0.05359}	{0.07045}	{0.06031}	{0.06240}
	[-0.90982]	[2.36181]	[-1.95397]	[-2.35912]	[1.32094]	[0.78158]	[-1.12411]	[0.68099]	[-0.55776]	[-0.57417]
D(PAT(-1))	0.075439	0.220388	-0.039141	0.153047	0.131658	0.029622	0.122283	0.178895	0.003494	-0.148888
	{0.04641}	{0.09354}	{0.05701}	{0.08862}	{0.05850}	{0.08012}	{0.04818}	{0.06333}	{0.05421}	{0.05609}
	[1.62563]	[2.35599]	[-0.68655]	[1.72710]	[2.25053]	[0.36974]	[2.53819]	[2.82499]	[0.06445]	[-2.65433]
D(PAT(-2))	0.068082	0.005136	0.036405	0.116789	-0.191271	-0.175618	0.067006	-0.004178	0.014014	-0.010204
	{0.04778}	{0.09631}	{0.05870}	{0.09124}	{0.06023}	{0.08249}	{0.04960}	{0.06520}	{0.05582}	{0.05775}
	[1.42494]	[0.05333]	[0.62021]	[1.28005]	[-3.17556]	[-2.12899]	[1.35084]	[-0.06408]	[0.25107]	[-0.17668]

[AGR= Agra, AHM= Ahmedabad, BURD= Burdwan, COB=COB, CHEN= CHEN, DEL= Delhi, GWA= Guwahati, INDR= Indore, KOL= Kolkata, PAT= Patna, ()= lag length, {}= standard error of the coefficients, []= t-statistic of the coefficients]

Short-run cointegrating equations

Agra Market. The current week's price of Agra market was influenced by one and two weeks lagged price of its own, of Ahmedabad market as well as of Coochbehar market and Kolkata market's weekly price from two weeks ago. The concerned short-run equation under the VECM framework was-

$$\begin{aligned}\Delta AGRA_t = & -0.15\,ECT_{t-1} + 0.25AGRA_{t-1} \\ & - 0.01AGRA_{t-2} \\ & + 0.05AHMEDABAD_{t-1} \\ & + 0.05AHMEDABAD_{t-2} \\ & + 0.2COOCHBEHAR_{t-1} \\ & - 0.09COOCHBEHAR_{t-2} \\ & - 0.1KOLKATA_{t-2}\end{aligned}$$

Ahmedabad market. The current weekly price of the Ahmedabad market was influenced by one week lagged price of itself, the one and two-week lagged price of the Kolkata market and one week lagged price of the Patna market. The concerned short-run equation under the VECM framework was-

$$\begin{aligned}\Delta AHMEDABAD_t & \\ = & -0.32AHMEDABAD_{t-1} \\ & + 0.31KOLKATA_{t-1} \\ & + 0.24KOLKATA_{t-2} + 0.22PAT_{t-1}\end{aligned}$$

Burdwan Market. Current potato weekly price in Burdwan market was influenced by one week lagged price of Guwahati market, one and two weeks lagged price of Indore market and two weeks lagged price of Kolkata market. The market showed a high exogenous influence on the determination of price as it consists of no lagged values of its own as an explanatory variable. The concerned short-run equation under the VECM framework was-

$$\begin{aligned}\Delta BURDWAN_t = & -0.15ECT_{t-1} + 0.17GUWAHATI_{t-2} \\ & - 0.15INDORE_{t-1} \\ & - 0.12KOLKATA_{t-2}\end{aligned}$$

Coochbehar Market. Current weekly potato price in Coochbehar market was influenced by both one and two weeks lagged price of itself, one week lagged price of Agra market, two weeks lagged price of Ahmedabad market, two weeks lagged price of Guwahati market and both one and two weeks lagged price of Patna market. It is to note that the Coochbehar market was cointegrated with 4 other markets which proved it to be more effective and wider in range for price signal transmissions. The concerned short-run equation under the VECM framework was-

$$\begin{aligned}\Delta \mathrm{COOCHBEHAR} = & -0.13ECT_{t-1} + 0.22AGRA_{t-1} \\ & + 0.07AHMEDABAD_{t-2} \\ & + 0.19COOCHBEHAR_{t-1} \\ & - 0.16COOCHBEHAR_{t-2} \\ & + 0.15GUWAHATI_{t-2} \\ & + 0.13PATNA_{t-1} - 0.19PATNA_{t-2}\end{aligned}$$

Chennai market. Current potato weekly price in Chennai market was influenced by two weeks lagged weekly price of Agra market, two weeks lagged weekly price of Burdwan market, two weeks lagged weekly price of Delhi market, and both one and two weeks lagged weekly price of Kolkata market. Here also we can observe an exogenous influence on price determination. Another observation was that three out of four markets which significantly affect the price in the Chennai market appear in two weeks' lagged price and leading to the conclusion of slower price transmission across the selected markets. The concerned short-run equation under the VECM framework was-

$$\begin{aligned}\Delta CHENNAI_t = & -0.14ECT_{t-1} + 0.23AGRA_{t-1} \\ & + 0.18BURDWAN_{t-2} \\ & - 0.13DELHI_{t-2} \\ & - 0.27KOLKATA_{t-1} \\ & - 0.23KOLKATA_{t-2}\end{aligned}$$

Delhi market. Current potato weekly price in Delhi market was influenced by one week lagged price of itself, one week lagged price of Agra market, both one and two weeks lagged price of Coochbehar market, one week lagged price of Indore market and two weeks lagged price of Patna market. The concerned short-run equation under the VECM framework was-

$$\Delta DELHI_t = 0.5AGRA_{t-1} + 0.2COOCHBEHAR_{t-1} - 0.14COOCHBEHAR_{t-2} - 0.17DELHI_{t-1} + 0.18INDORE_{t-1} - 0.17PATNA_{t-2}$$

Guwahati market. The current potato weekly price of Guwahati market was influenced by one week lagged price of Burdwan market, two weeks lagged price of Coochbehar market and the one-week lagged price of Patna market. The concerned short-run equation under the VECM framework was-

$$\Delta GUWAHATI_t = 0.8BURDWAN_{t-2} + 0.9COOCHBEHAR_{t-2} + 0.12PATNA_{t-1}$$

Indore market. The current potato weekly price of Indore market was influenced by one week lagged price of Burdwan market, two weeks lagged price of Delhi market and the one-week lagged price of Patna market. We can observe a high exogenous influence overall on the price determination. The concerned short-run equation under the VECM framework was-

$$\Delta INDORE_t = 0.13BURDWAN_{t-1} - 0.9DELHI_{t-2} + 0.17PATNA_{t-1}$$

Kolkata market. The current potato weekly price of the Kolkata market was significantly influenced by one week lagged price of Agra market, both one and two weeks lagged prices of Burdwan market and two weeks lagged prices of Guwahati market. Here also we can observe a high exogenous influence overall on the price determination. The concerned short-run equation under the VECM framework was-

$$\Delta KOLKATA_t = 0.12AGRA_{t-1} + 0.13BURDWAN_{t-1} + 0.15BURDWAN_{t-2} + 0.16GUWAHATI_{t-2}$$

Patna market. The current potato weekly price of the Patna market was significantly influenced by one week lagged price of itself only which was indicative of both the strongest endogeneity in the price determination among the selected markets and weak cointegration with other markets in the short run. It also indicates that any short-run price shock was absorbed by the market which is indicative of a flexible supply mechanism. The concerned short-run equation under the VECM framework was-

$$\Delta PATNA_t = -0.09ECT_{t-1} - 0.14PATNA_{t-1}$$

we enumerate the mutual effects amongst the selected markets in Table 5.

Table 5: Consolidated table of price transmission from VECM estimates.

AGR	**AHM**	**BURD**	**COB**	**CHEN**	**DEL**	**GWA**	**INDR**	**KOL**	**PAT**
AGR (-1)	AHM (-1)	GUWA (-1)	AGR (-1)	AGR (-1)	AGR (-1)	BURD (-2)	BURD (-1)	AGR (-1)	PAT (-1)
AGR (-2)	KOL (-1)	INDR (-1)	AHM (-2)	BURD (-2)	COB (-1)	COB (-2)	DEL (-2)	BURD (-1)	
AHM (-1)	KOL (-2)	KOL (-2)	COB (-1)	DEL (-2)	COB (-2)	PAT (-1)	PAT (-1)	BURD (-2)	
AHM (-2)	PAT (-1)		COB (-2)	KOL (-1)	DEL (-1)			GWA (-2)	
COB (-1)			GWA (-2)	KOL (-2)	IND (-1)				
COB (-2)			PAT (-1)		PAT (-2)				
KOL (-2)			PAT (-2)						

[AGR= Agra, AHM= Ahmedabad, BURD= Burdwan, COB=COB, CHEN= CHEN, DEL= Delhi, GWA= Guwahati, INDR= Indore, KOL= Kolkata, PAT= Patna, ()= lag length]

SUMMARY AND CONCLUSION

In India, Potato is a political commodity and it is known for high price volatility which seriously affects the profitability of the farmers. This study was conducted to better understand the price relationship amongst selected key potato markets in the country. The empirical results of the study reported that there was cointegration in the weekly prices that concluded a high degree of market integration in major Potato markets. This is consistent with the view that Potato markets in India are quite competitive. Hence, any effort to artificially influence the price would be void in the long run. In the short run, there were deviations from the equilibrium which are corrected at various speeds denoted by the error correction terms (ECTs). Agra and Burdwan markets were quicker to return to long-run equilibria from short-run deviations because of the higher speed of adjustments. Coochbehar, Chennai and Delhi markets are cointegrated with more markets leading to the conclusion that these markets were more efficient in transferring price signals. Guwahati market was influenced by Coochbehar, Burdwan and Patna markets, exhibiting a significant case of inter-state potato price linkage. The study concluded that policies regarding potato marketing administered in West Bengal may have a significant effect on Assam state's potato price after a lag period of two weeks. Results of this study recommended that any policy initiatives on potato-related infrastructure like cold storage, value addition and food parks etc be implemented through these markets to be more effective on a larger scale. Developing a robust potato price information dissemination system using the core principle of cointegration analysis with forecasting methods was found to be effective in short-run price fluctuations in these potato markets.

FUTURE SCOPE

The present study can be extended and enhanced in the future by including the retail price series of the selected markets and thereby testing for cointegration across the supply chain of potato. Based on the cointegration between a wholesale potato market and its retail counterpart, there may or may not be a presence of artificial price influences along the chain of supply which is an important study to be conducted. The study's scope can also be expanded by including potato prices from neighbouring countries as well as by including crops other than potato.

Conflict of Interest. None.

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