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Article

Price Behaviour and Linkages: A Case Study on Potato

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Abstract: Potato (Solanum tuberosum L.), regarded as the "king of vegetables," is India's fourth most important food crop after rice, wheat, and maize, contributing significantly to nutritional security and farm income diversification. India, the world's second-largest producer with 60.18 million tonnes (2024–25), accounts for ~16% of global output. Despite its strong production base, market integration and price volatility pose major challenges for farmers and consumers alike. This study investigates the spatial integration, price dynamics, and causality among four major potato markets—Agra, Amritsar, Bengaluru, and Chikkaballapura—using weekly wholesale price data from 2015 to 2025. Stationarity was examined through ADF, PP, and KPSS tests, while Johansen's co-integration and Vector Error Correction Model (VECM) were employed to capture long-run equilibrium and short-run price adjustments. Results reveal significant co-integration among the selected markets, with Bengaluru prices responding strongly to Amritsar and Agra, while Chikkaballapura exhibited short-run corrections influenced by terminal markets. Granger causality analysis confirmed both uni- and bidirectional linkages, highlighting Bengaluru–Chikkaballapura interdependence. Findings underscore the necessity of robust cold storage, logistics, and market linkages to mitigate volatility and strengthen farmer incomes. Policy interventions, alongside technological innovations such as aeroponic seed systems, will be critical to ensure stable and sustainable growth of India's potato sector.

Keywords— Potato markets, Price behaviour, Co-integration, VECM, Granger causality, Market integration.

INTRODUCTION

Importance of the crop in the region in terms of output

Potato (Solanum tuberosum L.) popularly known as 'The king of vegetables', has emerged as fourth most important food crop in India after rice, wheat and maize. It is believed that potato was a native of Andes in South America and gradually spread throughout the world. Indian vegetable basket is not complete without Potato. For the reason that, the dry matter, edible energy and edible protein content of potato makes potato nutritionally superior vegetable as well as staple food not only in our nation but also all over the world. Now, it becomes as a part and parcel of breakfast, lunch and dinner globally. Indian potato is the choice of the world for its flavor and satisfies the international quality requirements from the view of disease freeness, shape, size, skin color, flesh and dry matter content.

India is the world's second largest potato producer with 60.18 million tonnes after China which had produced 93.5 million tonnes in 2024-25. These two nations collectively contribute around 1/3 of the world potato production of 383 million tonnes, India's contribution to world output is approximately 15.8%. Potato in India is principally produced as a winter crop and around 20% comes from kharif production. The area under potato as per reports for 2022-23 production period was 2.3 million hectares. Area under potato during 1950-51 to 2015-16 experienced 3.27% compound annual growth rate (CAGR) compared to 4.72 and 1.40% CAGR for production and productivity respectively. Among the main producing states, Uttar Pradesh is in leading position with a production of 20.13 million tonnes followed by West Bengal (14.51 mt) during 2023-24. Karnataka has ranked 11th with 5.89 lakh MT. Even it has been seen that in order to maintain the current

trend of diversification from cereals to horticultural crops, diverting from wheat / barley cultivation to potato cultivation allows to gain better returns by farmers.

Potato is cultivated in India under varied agro climatic conditions. Generally, the potato growing areas in India may be divided into the northern hills, the northern plains, the eastern hills, the plateau and the southern hills. The kharif season with long days is the growing season in the northern hills. In this region, the crop goes through water stress during emergence and early growth stage during the peak bulking stage and it is always subjected to late blight infection. Hence, varieties for this region need to have resistance to late blight, must be capable to endure water stress and the crop duration should be 120 – 150 days. A number of varieties resistant to disease problems are dveloped by Public and private agencies.In plateau tract, two crops i.e. kharif and rabi are harvested in most of the places. The kharif crop faces long duration of day, unpredictable rainfalls, high temperatures, high incidence of early blight and mites. Kufri jyoti and Kufri lauvkar are suitable for this period. The Rabi crop is extremely short duration and early bulking type like Kufri Lauvkar crops well in this season. Kufri jyoti is also cultivated in this season. Once harvested, the potatoes are used for a variety of purposes, and not only as a vegetable for cooking at home. In fact, it is likely that less than 50 percent of potatoes grown worldwide are consumed fresh. The rest are processed into potato food products and food ingredients, fed to cattle, pigs and chickens, processed into starch for industry, and re-used as seed tubers for growing the next season's potato crop.

Further, adding to this, the Government of India established four Agri Export Zones (AEZs) in Punjab, West Bengal, Uttar Pradesh and Madhya Pradesh for potato production and trade improvement. The key aims of the Agri Export Zones established is to give priority to partnership, convergence of organizations, stakeholders aimed at offering a package of facilities for potato export. These AEZs are making efforts in strengthening and creating infrastructure for export of fresh and processed potato products, with the mandate for tackling the export of potato and its products.

Major markets in terms of arrivals

Although potato is not a major vegetable crop of Karnataka, it is used in culinary preparations, chips making and also for seed purpose. Farmers sell potatoes in regulated markets owing to better infrastructure facilities and transparency in trade. The increased arrivals in the market yards have led to considerable improvement in the Agricultural Produce Market Committee (APMC) structure, conduct and performance. The major regulated markets for Potato in Karnataka are Bengaluru, Hubballi, Belgaum, Hassan, Chikkaballapura and Kolar. Bengaluru being a terminal market receives the largest share of arrivals of potato among these markets. The major arrivals of Potato in these markets are during October and March months corresponding to Kharif and Rabi crop harvests. During off-season Potato from other states like Punjab and Uttar Pradesh arrive to Karnataka.

1. Arrival and price pattern in the selected markets

Fig.1: Arrival Pattern of Potato in Selected Markets

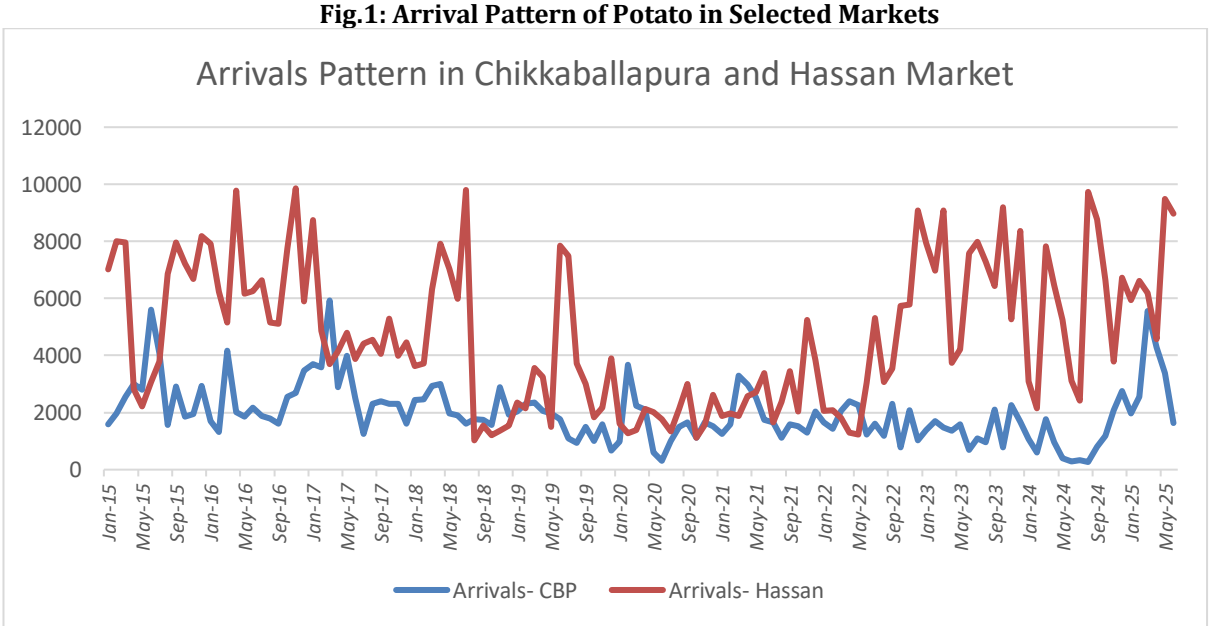
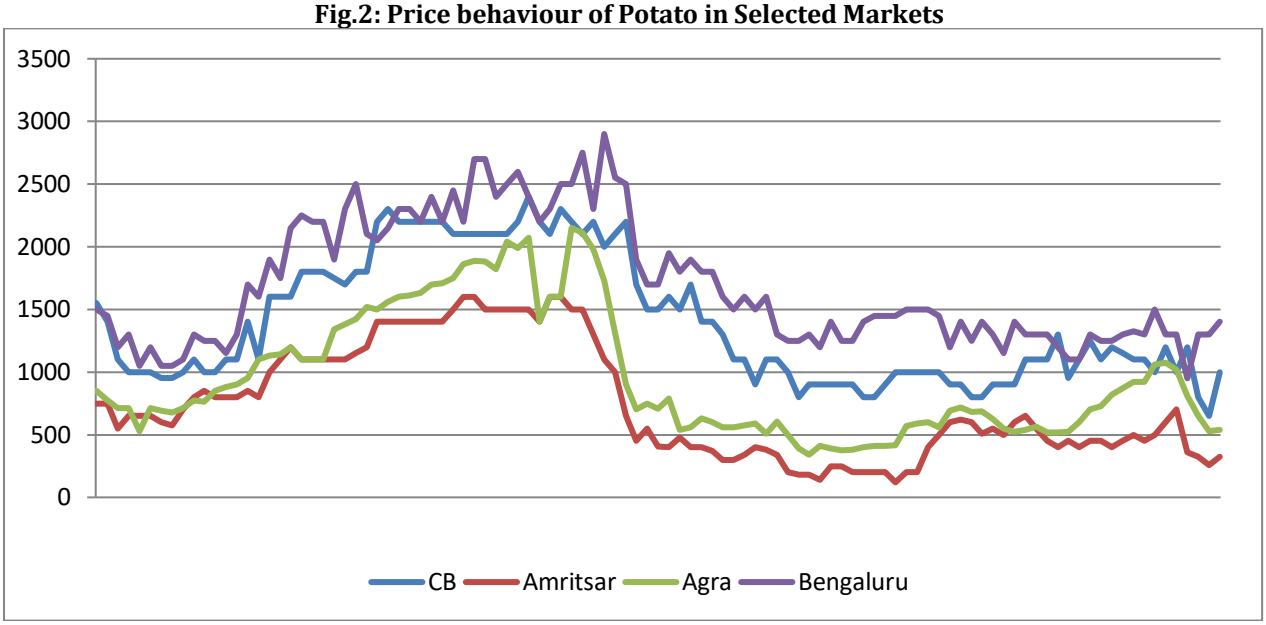


Fig.2: Price behaviour of Potato in Selected Markets



The arrival pattern of potato was studied by considering Amritsar and Chikkaballapura as primary markets for potato arrivals, while Bengaluru and Agra for terminal markets. The Potato arrivals in Agra and Amritsar APMCs from January 2015 to June 2025 have shown considerable seasonality during January to March months, whereas Chikkaballapura and Hassan have lower seasonal pattern in arrivals (Fig.1). Price pattern during the same period have shown uptrend in 2024 as compared to 2025 with less pronounced seasonal pattern (Fig.2).

Price movements are a matter of concern to a large number of people, such as consumers who purchase products, producers who grow them, and regulators who govern markets. Cyclical variation in market prices was found to be irregular in the market. Therefore, there is a requirement to keep a constant eye on the prices and arrivals of the crop so that the farmers are made aware of the fluctuation happening in the prices. (Bhattacharya, 2014).

As per the paper authored by (Isha Sharma, 2023), the research finds that India's potato production and marketing have a cobweb-type demand-supply cycle with the result that prices fluctuate with wide political implications. Price support schemes, strategic stocking, and futures contracting are suggested as a measure to stabilize the price of potatoes.

According to the study conducted by (Ranjit Kumar Paul, 2015) The price signals of agricultural products from markets in various geographic locations are crucial to the economy. The price signals regulate and direct production, marketing and consumption choices in the long run. Thus, in the event that markets are poorly integrated, the price signals get distorted, leading to inefficient utilization of resources and hindering sustainable agricultural development. This article uses an econometric framework for estimating a vector error correction model (VECM) to analyze the spatial market integration and price transmission between major coffee consumption centers of India (viz. Bangalore, Chennai and Hyderabad) utilizing month-wise wholesale prices of coffee seeds.

Data source for co-integration

The price data from four major potato markets in India viz., Agra, Amritsar, Chikkaballapura and Bengaluru from January 2015 to June 2025 was used for analysis. The secondary data on weekly prices of potato from the selected markets of Agra, Amritsar, Chikkaballapura and Bengaluru were pooled from Krishimaratavahini and AGMARKNET websites. E-views software was used to analyse the co-integration among the market prices of potato after performing stationarity tests.

METHODOLOGY

Statistical testing was conducted in three steps. The first one was testing for the order of integration of prices of potato in each market at the levels and after first differencing using the Augmented Dickey-Fuller (ADF), PP and KPSS statistic. Subject to the results of the tests, the second phase is to examine pair-wise Potato market time series prices co-integration using the Johansen's maximum likelihood method. If pair-wise markets co-integration occurs, however, it cannot be presumed that the two markets are in one market (the law of one price). Based on the pair-wise Potato market co-integration outcomes, the third stage employs Vector Error Correction Model (VECM) to identify interaction effects, using the error term from this co-integrating regression as a proxy for the VECM term

to exploit the short run dynamics and causality of the model. The VECM incorporates co-integration relations in the specification so that it constrains long-run behaviour of the endogenous variables to settle at their co-integrating relationships along with the scope for adjustment dynamics in the short run. The co-integration term is referred to as the error correction term because the displacement from long-run equilibrium is corrected over time through a series of partial adjustment in the short run. The required condition for carrying out the co-integration test is that the two price series should have the same order of integration. Maximum Likelihood (ML) co-integration test procedure of Johansen and Juselius (1990) has been utilized to test for market integration.

Testing stationarity

In order to check the stationarity of price series of potato, the Augmented Dickey Fuller, Phillips Perron and KPSS based unit root tests were performed. It could be inferred that Augmented Dickey Fuller test values were less than the critical value at five per cent level given by Mackinnon statistical tables implying that the series were non stationary at their levels confirming the existence of unit root. After taking first difference, all the series became stationary which is obvious as the test statistic values are more than the critical value at five per cent level and are hence free from the consequence of unit root. Since these price series were I (1), further tested for presence of co-integration.

Table 1: Unit root test of selected potato market prices

Series	Original Series			1st differenced series		
	ADF Test Stat	PP	KPSS	ADF Test Stat	PP	KPSS
Agra	-1.27	-1.34	0.41	-6.72	-9.02	0.11
Amritsar	-0.86	-1.13	0.14	-8.55	-8.57	0.14
Bengaluru	-1.82	--2.70	0.47	-17.16	-19.25	0.05
Chikkaballapura	-1.04	-1.27	0.13	-12.63	-12.63	0.12

5% critical values for ADF, PP and KPSS statistics are -2.89, -2.88 and 0.46 respectively

Co-integration among the potato prices in different markets

Johansen's Co-integration test of chosen potato markets for long-run co-integration of four potato markets was conducted. If two series could be co-integrated, there must be at least one co-integration relationship. Co-integration can be influenced by certain facts like transport cost, tariffs, etc. The null hypothesis statement of the existence of r co-integrated relationship versus the alternative hypothesis of r+1 co-integration relationship were tested

The outcome of Johansen's multiple co-integration method in the use of E-views software is depicted in Table 2. Both Rank test and maximum Eigen value reported the existence of at least two co-integration equations at 5 per cent level of significance. Therefore, it is concluded that markets move towards long run equilibrium relationship.

Causality among prices: Testing for pair-wise Granger causality

Engle and Granger (1987), demonstrate that if two series are individually I (1), and co-integrated, there will be a causal relationship in at least one direction. To estimate error correction model, two stages are required for two first order co-integrated vectors. First, the pair-wise Granger Causality test method is employed to understand how much of market prices' influence can be explained through own market prices' past values; then second, to understand if incorporating lagged values of another large market prices will enhance the explanation of price behaviour of the first market.

Table 2: Johansen's co-integration test statistic

No. of CE(s)	Eigen value	Trace Statistic	Critical Value	Prob.	Max-Eigen Statistic	Critical Value	Prob.
None *	0.2025	49.7853	47.8561	0.0326	22.6275	27.5843	0.1899
At most 1	0.1515	27.1579	29.7971	0.0978	16.4341	21.1316	0.2005
At most 2	0.0778	10.7238	15.4947	0.2290	8.1040	14.2646	0.3682
At most 3	0.0259	2.6199	3.8415	0.1055	2.6199	3.8415	0.1055

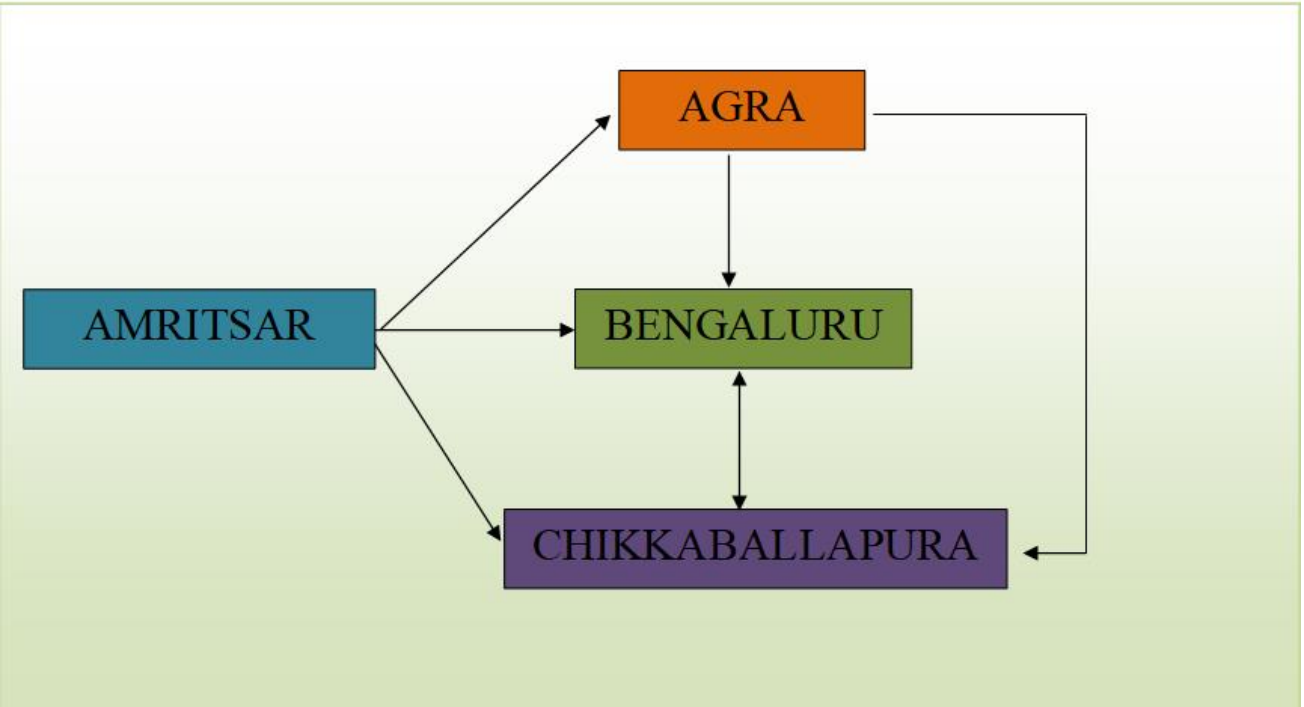
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
** denotes rejection of the hypothesis at the 0.05 level*

The pair-wise Granger causality test was conducted to analyze the influence of one market on the prices of other markets. It may be observed through the significant F-statistics that Chikkaballapura being a major production centre is influenced by other markets as it heavily depends on Amritsar and Agra for seed potato and dispatches

potatoes for consumption to neighbouring Bengaluru market (Table3). Only Bengaluru and Chikkaballapura have exhibited bidirectional causality. Amritsar and Agra market prices have a bearing on the potato prices of Bengaluru and not *vice versa.* Similarly, Amritsar prices had unidirectional influence on Agra market potato prices.

Table 3: Pair-wise Granger causality of potato market prices

Null Hypothesis	F-Statistic	Prob.	Direction
AMRITSAR does not Granger Cause CB	15.6018	1.E-06	→
CB does not Granger Cause AMRITSAR	0.35830	0.6998	
AGRA does not Granger Cause CB	8.4255	0.0004	→
CB does not Granger Cause AGRA	1.0402	0.3572	
BENGALURU does not Granger Cause CB	3.5833	0.0315	↔
CB does not Granger Cause BENGALURU	5.9667	0.0036	
AGRA does not Granger Cause AMRITSAR	1.2696	0.2855	
AMRITSAR does not Granger Cause AGRA	10.7069	6.E-05	→
BENGALURU does not Granger Cause AMRITSAR	0.3641	0.6958	
AMRITSAR does not Granger Cause BENGALURU	10.9603	5.E-05	→
BENGALURU does not Granger Cause AGRA	0.1249	0.8827	
AGRA does not Granger Cause BENGALURU	8.5551	0.0004	→



Potato				Optimum Lag
Market Pairs		ECT		
		1st variable	2nd variable	
Chikkaballapura	Amritsar	-0.1928*	0.0217	One
Chikkaballapura	Agra	-0.2165*	-0.1044	One
Chikkaballapura	Bengaluru	-0.1845*	-0.4869*	One
Amritsar	Agra	0.0278	-0.3480*	One
Amritsar	Bengaluru	0.0189	-0.4823*	One
Agra	Bengaluru	-0.0043	-0.4666*	One

Major Implications

Market information and intelligence are crucial to enable farmers and traders to make informed decisions on crop choice and marketing decisions. The market integration analysis showed that Agra, Amritsar, Bengaluru and Chikkaballapura markets are highly integrated and prices move in unison. Thus, proper price discovery in leading markets is the key determinant for enhancing farmers income. Planting and marketing decisions of farmers need to consider price dynamics and adjustments thereof.

Global Significance: India, producing over 60 million tonnes of potatoes annually, remains the second-largest global producer, contributing ~16% of world output. Along with China, it secures nearly 40% of global supply, reinforcing its strategic importance in the world potato economy.

Regional Concentration: Indian potato cultivation is largely focused in Uttar Pradesh, West Bengal, and Bihar, which collectively produce over 70% of the country's total output. This regional bias means that production shocks experienced by these states can have price implications for the entire nation.

Technological Transformation: Recent efforts such as aeroponics seed systems and the Central Potato Research & Training Centres at Agra, Kushinagar, and Hapur are a shift towards technology-based productivity increases, assuring enhanced quality seeds and greater farmer returns.

Price Behaviour Insights: The prices in Hassan and Chikkaballapur markets are cointegrated, reflecting long-term equilibrium relationships irrespective of regional differences. Hassan registers greater volatility, whereas Chikkaballapur exhibits superior CAGR (~6.2%) compared to Hassan (~3.3%). These relationships capture both supply-demand imbalances as well as storage/marketing inefficiencies across regional markets.

Policy Needs: In order to prevent volatility and stabilize farmer revenues, investment in cold storage, logistics, processing capacity, and market linkages is critical. Sourcing and value chains strengthening will prevent distress selling during gluts and facilitate stable realization of prices.

CONCLUSION

India's potato industry has entered an era of consistent growth in production, regional specialization, and technological upgradation. With increased output and productivity, India not only stabilizes its food economy but also consolidates its international position. Yet price behaviour continues to be a worry: local volatility, cointegration with diverging growth rates, and storage limitations point to systemic inefficiencies. Though Chikkaballapur shows increased price growth, Hassan's market is more volatile, pointing to the uneven quality of price stabilization across regions. Overall, the evidence indicates that future competitiveness of India's potato sector does not only lie in the growth of production but also in minimizing price volatility through improved infrastructure, technology shift, and policy support. To ensure that such measures will make potato cultivation continue to be a profitable and sustainable diversification strategy for farmers while stabilizing consumer markets.

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