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Co-Integration of Bajra (Pearl Millet) Markets in Rajasthan

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Abstract

This study examines the integration of bajra markets across five major regional markets in Rajasthan, *viz.,* Alwar, Barmer, Jaipur, Jalore and Jodhpur. These markets were selected based on significant commodity arrivals. The monthly whole sale prices of bajra spanning from January 2019 to December 2023 were analyzed. The unit root tests using the Augmented Dickey-Fuller method revealed that price series in each location were non-stationary at their levels but stationary at their first differences. The co-integration analysis demonstrated price linkages among these regional markets, indicating spatial integration. The Johansen's multiple co-integration tests further suggested the existence of at least two co-integration equations among the selected bajra markets based on likelihood-ratio tests. The Granger causality tests revealed predominantly unidirectional causality among the markets, particularly in Alwar and Jaipur. This suggests that prices in Alwar influence prices in Barmer, Jaipur, Jalore and Jodhpur markets, while Jaipur prices impact Barmer and Jodhpur markets. Alwar emerges as an independent market for bajra prices in Rajasthan. Furthermore, the study indicates long-run price transmission and short-run equilibrium among these markets, as evidenced by vector error correction estimates across different lags. Inclusive, the findings suggest a moderate level of integration among major bajra markets in Rajasthan, highlighting the interconnectedness and interdependence of these regional markets in the context of bajra pricing.

Keywords : Unit root test, Granger causality, Independent market, Price transmission

Bajra, also known as pearl millet, is a staple crop widely cultivated in India, particularly in the arid and semi-arid regions of as Rajasthan with its hot and dry climate is one of the leading states in Bajra cultivation. The crop holds significant importance in the region's agriculture due to its resilience to drought and high temperatures.

Bajra cultivation in Rajasthan typically occurs during the *kharif* season, starting from June and extending to October. The crop requires minimal water and is well-suited to regions with low rainfall and poor soil conditions, making it a crucial choice for farmers in this area. One of the key objectives in studying bajra cultivation in Rajasthan is to explore the co-integration of market prices. Understanding market co-integration involves analyzing the long-term equilibrium relationship between prices of bajra in different markets, particularly considering factors such as demand, supply, transportation costs and Government policies affecting trade.

The specific objective of co-integration analysis of bajra market prices is to identify the interdependencies and long-term trends across various marketplaces within Rajasthan and potentially across other states where bajra is also cultivated. This analysis helps in comprehending the pricing dynamics, market integration and factors influencing price movements. It further aids policymakers, traders and farmers in

making informed decisions related to production, procurement and marketing strategies, thereby contributing to the sustainability and profitability of bajra cultivation in Rajasthan and beyond.

METHODOLOGY

Selection of Markets

The study focuses on major bajra markets in Rajasthan, which collectively contribute over 60 per cent of the state's total bajra production. The markets from this state were purposively selected based on their significant arrivals. The analysis is based on monthly wholesale price data from five major bajra markets, *viz.,* Alwar, Barmer, Jaipur, Jalore and Jodhpur. The data spans from January 2019 to December 2023 and were collected from https://agmarknet.gov.in/.

Market Integration

To sustain the growth rate, it's crucial for farmers to receive remunerative prices, ensuring they obtain a fair share of the consumer rupee spent on bajra and its value-added products. This can only be achieved when there is a high level of marketing efficiency. The analysis of market integration across space and form serves as the primary means to assess marketing efficiency.

In spatially integrated markets, prices are determined simultaneously across various locations, with any price changes in one market being transmitted to others. Markets that lack integration may provide inaccurate price signals, potentially distorting producers' marketing decisions and leading to inefficient product movement. Moreover, traders may exploit such markets, benefiting themselves at the expense of both producers and consumers.

Price Transmission Analysis

The output of price transmission analysis helps to understand the following points - Is there a long-term relationship between the two markets prices, Do prices in market 'A' influence those in market 'B', the reverse or do they both influence each other in there prices, If the price in one market changes how much will it cause the other price to change in short-run within the year and If the price in one market changes how much will it cause the other price to change in the long-run. In the context of two domestic prices, it tells us whether market 'A' is influencing market 'B' or 'B' is influencing 'A' or if both are influencing each other. This causation analysis helps in understanding and describing trends in local prices.

Augmented Dicky Fuller Test

Prior to testing for co-integration, the price series are first tested for their order of integration, since a necessary condition for co-integration is that the series are integrated of the same order. The Augmented Dickey-Fuller (ADF) test is used to test for the order of integration. To test unit root, the ADF test is conducted based on the following regression equation:

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \alpha_i \sum \Delta Y_{t-1} + e_t$$

[t-1 : One month lagged price and A : differenced series].

Y_i denoted the price series of markets (Alwar, Barmer, Jaipur, Jalore and Jodhpur bajra price series).

If the coefficient δ is not statistically different from zero, it implies that the series have a unit root and therefore, the series is non-stationary. To verify that the first differenced price series is indeed stationary, ADF unit root tests are used. The null hypothesis of non-stationary is tested using a t-test. The null hypothesis is rejected if the estimated variable is significantly negative. Once the variables are checked for stationary and are of the same order, integration between them can be tested.

Testing for market integration is central to the design of any agricultural price policy in many developing countries and has been an area of abiding research interest. This literature can be divided into three broad categories. Until recently, two broad approaches had been used to investigate market integration: (i) those devised prior to the use of co-integration techniques, (ii) those using co-integration methods of the Engle-Granger variety and (iii) those using

Johansen maximum-likelihood techniques. To the extent that agricultural prices tested are non-stationary, the latter technique is more appropriate.

Engle-Granger Causality

An Autoregressive Distributed Lag (ADL) model for the Granger causality test was developed following (Engle and Granger, 1987) specification provided below :

$$P^1_t = \alpha + \beta_o T + \sum^J_{j-1} \beta_j P^1_{t-j} + \sum^K_{k-1} h_k P^2_{t-k} + \varepsilon_t$$

where, T is the time trend, ε_t is the error term.

Lags for the ADL model were selected to minimize the Akaike's Information Criterion. Granger causality tests were specified as: l

$$P^1_t = \alpha + \beta_o T + \sum^J_{j-1} \beta_j P^1_{t-j} + \sum^K_{k-1} h_k P^2_{t-k} + \varepsilon_t$$

$$H_o: h_1 = h_2 = \ldots\ldots\ldots = h_t = 0$$

$$P^2_t = \delta + \Phi_o T + \sum^J_{j-1} \Omega_j P^1_{t-j} + \sum^K_{k-1} \Phi_k P^2_{t-k} + \upsilon_t$$

$$H_o: \Phi_1 = \Phi_2 = \ldots\ldots\ldots\ldots = \Phi_K = 0$$

Co-integration

Co-integration means that despite being individually non-stationary, a linear combination of two or more time series can be stationary. The series that satisfy this requirement are said to be co-integrated. Following Granger, a time series x_t which has a stationary, invertible, non-deterministic ARMA representation after differencing *d* times is integrated of order *d* and is denoted by $x_t \sim I(d)$. The components of the vector x_t are said to be co-integrated of order *d, b*, denoted CI (d, b), if all the components of x_t are I (d); there exists a vector 'x_t is 1(d-b), b>0.

The vector is then called a co-integrating vector. A necessary condition for co-integration is that the data series for each variable involved exhibit similar statistical properties, that is to be integrated to the same order with evidence of some linear combination of the integrated series.

Johansen developed a multivariate system of equations approach, which allows for simultaneous adjustment of both or even more than two variables. Johansen's approach is also widely used in many bivariate studies as it has some advantages to the single equation approach. First, the multivariate system of equations approach is more efficient than the single equation approach, *i.e.,* it allows estimating the co-integration vector with smaller variance. The second advantage of the multivariate approach is that in the simultaneous estimation it is not necessary to presuppose exogeneity of either of the variables.

Error Correction Model : Although price transmission analysis is a useful tool for understanding and predicting price trends, it only tells us about the relationship between two prices over time. It does not tell us why the price transmission is strong or weak, fast or slow. This interpretation can only be done with local knowledge of transportation routes, seasonal flows in staple foods, trade and agricultural marketing policies, the availability of foreign exchange and credit, the ease of obtaining permits and the competition for overland freight, among other factors.

Results and Discussion

Market Integration

The verification of stationary for the level and first-differenced price series utilized the ADF unit root test. Table 1. presents the ADF test results covering the period from January 2019 to December 2023. The equations were estimated with an intercept and time trend. The ADF unit root tests were conducted to assess the null hypothesis of non-

Table 1

ADF Unit root test for bajra in selected markets of Rajasthan

Variable	Level	P-value	First difference	P-value
Alwar	-0.8488	0.7974	-7.1083 ***	0.0000
Barmer	-1.4465	0.5534	-8.8424 ***	0.0000
Jaipur	-1.4830	0.5352	-7.1657 ***	0.0000
Jalore	-1.2904	0.6285	-7.2208 ***	0.0000
Jodhpur	-1.2052	0.6667	-8.2492 ***	0.0000

Note : *** Significant at 1 per cent level

stationary, utilizing critical values reported by MacKinnon. The results indicated that all price series were non-stationary in their levels, but became stationary upon taking first differences. Following the confirmation of stationary first-differenced price exchange rates, co-integration among bajra markets in futures was examined using Johansen's maximum likelihood procedure.

Additionally, the Engle-Granger bivariate co-integration technique was employed to investigate the presence of a long-run relationship among bajra prices in various markets of Rajasthan. Similar results were observed in study conducted by (Akshata *et al*., 2013) on sunflower crop in Chitradurga, Akola and Vellakoil of Karnataka, Maharashtra and Andhra Pradesh respectively, It is inferred that ADF test values were more than the critical value (1%) implying that the series are not stationary at their level confirming the existences of unit root as observed in above result. Furthermore (Vasanthi *et al*., 2017) conduct similar study on tomato by selecting Mysore, Bengaluru, Kolar and Chintamani markets of Karnataka. The results of ADF test conducted with null hypothesis of non-stationary or presence of unit root in price series against stationary of price series as an alternative hypothesis.

Granger Casualty Test

The causal relationships among the prices of major bajra markets in Rajasthan were investigated using the aforementioned techniques and the findings are presented in Table 2. The analysis revealed

TABLE 2

Pair-wise granger causality test for bajra markets in Rajasthan

Null hypothesis	F – statistic		P – value
BARMER does not Granger Cause ALWAR	2.2669		0.1136
ALWAR does not Granger Cause BARMER	29.1581	***	3.E-09
JAIPUR does not Granger Cause ALWAR	0.8087		0.4508
ALWAR does not Granger Cause JAIPUR	4.0883	**	0.0223
JALORE does not Granger Cause ALWAR	0.6313		0.5358
ALWAR does not Granger Cause JALORE	8.9816	***	0.0004
JODHPUR does not Granger Cause ALWAR	1.4403		0.2460
ALWAR does not Granger Cause JODHPUR	17.4343	***	2.E-06
JAIPUR does not Granger Cause BARMER	4.1717	**	0.0208
BARMER does not Granger Cause JAIPUR	2.9056		0.0635
JALORE does not Granger Cause BARMER	0.0130		0.9870
BARMER does not Granger Cause JALORE	2.8928		0.0642
JODHPUR does not Granger Cause BARMER	0.6334		0.5347
BARMER does not Granger Cause JODHPUR	7.8898	***	0.0010
JALORE does not Granger Cause JAIPUR	1.1499		0.5347
JAIPUR does not Granger Cause JALORE	2.4547		0.0956
JODHPUR does not Granger Cause JAIPUR	2.0351		0.1407
JAIPUR does not Granger Cause JODHPUR	6.3152	***	0.0035
JODHPUR does not Granger Cause JALORE	0.3211		0.7267
JALORE does not Granger Cause JODHPUR	1.3935		0.2571

Note : ***Significant at 1 per cent level; ** Significant at 5 per cent level

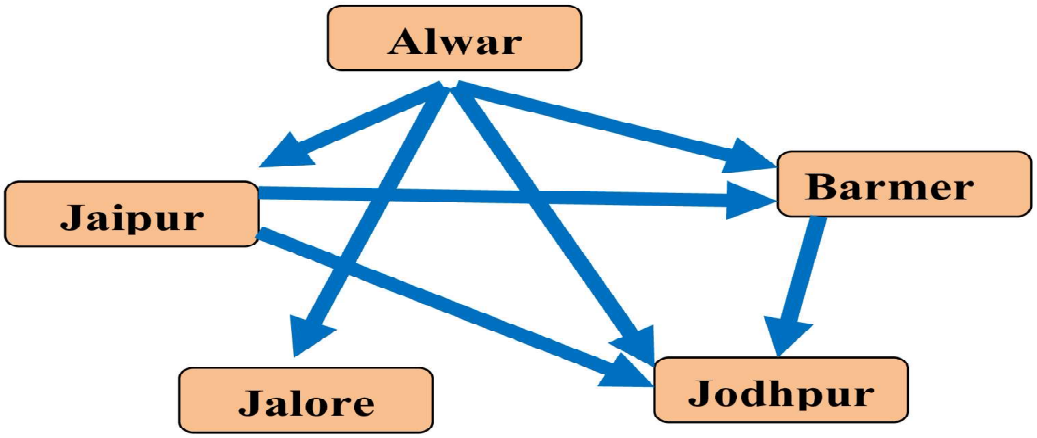

Fig. 1 : Pair-wise Granger causality of bajra markets in Rajasthan

predominantly unidirectional causality among the selected bajra markets. Specifically, a unidirectional relationship was identified from Alwar market to Barmer, Jaipur, Jalore and Jodhpur markets, indicating that the price of the Alwar market influences the prices of these markets. Similarly, the Jaipur market exhibited unidirectional causality towards the Barmer and Jodhpur markets (Fig. 1).

These results suggest a high degree of integration among the major bajra markets in Rajasthan, confirming that the price of one market influences the prices of others. The test for causality was based on F statistics. Notably, similar findings were reported in a study conducted by (Murulidhar *et al*., 2021a) on castor crop by choosing Chitradurga & Haveri markets in Karnataka, Mehsana & Patan Markets in Gujarat and Jodhpur & Pali markets of Rajasthan, results reveled that existence of mostly unidirectional causality as well as bidirectional causality among castor seed markets. The unidirectional relationship was found for the pair of Gujarat markets, indicates that price of Patan market influence the price of Karnataka and Rajasthan market. Similarly, bidirectional causality was exerted on Patan and Pali, Mehsana and Pali, Jodhpur and Mehsana markets of Gujarat and Rajasthan, evidencing the proximity of interstate price transmission.

Results of Johansen's Multiple Co-integration Analysis

Since all price series were non-stationary at the level confirming the existence of unit root during the study period, but stationary at the first difference, the Johansen co-integration test was applied to analyze the long-run equilibrium among the bajra markets. The results of the analysis revealed the presence of at least two co-integrations with one equation significant at the one per cent level and the remaining at 10 per cent level of significance (Table 3).

These findings suggest that a long-run equilibrium exists among the five major bajra markets in Rajasthan. Any shocks occurring in these markets would likely affect the prices of the other markets.

TABLE 3

Johansen's multiple co-integration analysis for bajra in selected markets of Rajasthan unrestricted co integration rank test (Trace)

Trace statistics of Series - Alwar, Barmer, Jaipur, Jalore and Jodhpur

No. of CE (s)	Eigen value	Statistic		Critical value	Probability
None	0.4714	82.72	***	69.81	0.0033
At most 1	0.3019	45.74	*	47.85	0.0779
At most 2	0.2559	24.89		29.79	0.1651
At most 3	0.0918	7.74		15.49	0.4926
At most 4	0.0365	2.16		3.84	0.1416

Note : Critical values based on MacKinnon (1999); LR test indicated 4 co-integrating equation

***Significant at 1 per cent level; *Significant at 10 per cent level

TABLE 4

Reduced form vector error correction estimates for bajra markets

Error Correction	D (ALWAR)	D (BARMER)	D (JAIPUR)	D (JALORE)	D (JODHPUR)
ECM	0.0191	*0.9664*	-0.0392	-0.0403	-0.2071
	[0.0721]	[4.1259]	[-0.1169]	[-0.1590]	[-0.8160]
ALWAR (-1)	0.1874	0.0008	0.4523	0.5278	*0.7165*
	[0.6215]	[0.0030]	[1.1827]	[1.8284]	[2.4776]
ALWAR (-2)	0.3254	0.1363	0.4716	0.1440	0.2275
	[1.2109]	[0.5732]	[1.3836]	[0.5598]	[0.8828]
BARMER (-1)	-0.2737	-0.1111	-0.3117	0.0413	-0.0973
	[-1.1952]	[-0.5485]	[-1.0730]	[0.1887]	[-0.4433]
BARMER (-2)	-0.1871	-0.0871	-0.2592	0.1267	-0.0128
	[-1.1598]	[-0.6102]	[-1.2665]	[0.8202]	[-0.0828]
JAIPUR (-1)	0.0069	0.2299	-0.1016	-0.0593	-0.0135
	[0.0478]	[1.7940]	[-0.5534]	[-0.4278]	[-0.0974]
JAIPUR (-2)	-0.0264	0.1057	-0.1956	*-0.2764*	-0.1296
	[-0.1832]	[0.8265]	[-1.0671]	[-1.9984]	[-0.9357]
JALORE (-1)	-0.1624	-0.0758	-0.0625	0.0061	-0.0749
	[-1.0764]	[-0.5680]	[-0.3265]	[0.0423]	[-0.5179]
JALORE (-2)	0.1812	*0.3696*	0.1348	0.1908	0.2022
	[1.2822]	[2.9553]	[0.7523]	[1.4103]	[1.4920]
JODHPUR (-1)	-0.0280	0.0447	0.0295	-0.0139	-0.1461
	[-0.1658]	[0.2993]	[0.1377]	[-0.0864]	[-0.9022]
JODHPUR (-2)	0.0399	0.0844	0.2678	-0.2678	0.0467
	[0.2514]	[0.6007]	[1.3284]	[-1.3694]	[0.3066]
C	5.55	3.53	3.04	-0.67	6.46
R-squared	0.16	0.65	0.16	0.29	0.32
AIC	12.33	12.09	12.81	12.24	12.25

Note: Bold and italics are the significant variable & t-statistic in [ ]

Notably, similar results were reported in a study conducted by (Sangeetha *et al*., 2017) on groundnut in Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat local markets. Since all the price series are non-stationary at level form and stationary at first difference level, the results of the analysis show that there is at least two co integration at 5 per cent level of significant. Hence, it is concluded that long run equilibrium exists among the four major markets. Any shocks in these markets would affect the prices of the other markets.

Vector Error Correction Model

The Vector Error Correction Mechanism (VECM) was employed to analyze the long-run association between the markets within the co-integration framework. The computed VECM results are presented in Table 4.

Specifically, it was found that one-month lagged prices of Alwar have a 71.65 per cent positive impact on present prices of Jodhpur market. Additionally, two-month lagged prices of Jaipur influence prices in the Jalore market by 27.64 per cent in the opposite

direction. Furthermore, two-month previous prices of the Jalore market impact present prices of Barmer by 36.96 per cent in a positive direction. These observations indicate significant price relationships among the bajra markets in Rajasthan over time. Similar findings were noted in prior studies, (Murulidhar *et al.,* 2021b) who conducted co-integration analysis of soybean markets by taking Bidar & Dharwad markets of Karnataka, Dewas & Ujjain markets of Madhya Pradesh and Amravati & Lathur markets of Maharashtra, shows results of one month lag prices of Dharwad market any variations in the prices will get it corrected by itself within 15.61 per cent of time. Two month previous prices of Dharwad market any variations in the prices will get it corrected by itself within 38.78 per cent of time (within 11 days). Two month lagged prices of Latur market will have impact on present prices in Bidar market to an extent of 53.59 per cent in positive direction.

The findings from the time series econometric analyses demonstrate a high level of integration among domestic bajra markets. Price transmission among these markets has been confirmed, indicating a long-run association within these domestic markets. The results of Johansen's multiple co-integration tests reveal that the domestic bajra markets of Rajasthans pecifically Alwar, Barmer, Jaipur, Jalore and Jodhpur are integrated with at least two co-integration vectors. Notably, the Alwar market in Rajasthan emerges as an independent market influencing bajra prices in the state, demonstrating unidirectional price influence on all other markets. These findings underscore the interconnectedness and influence of both domestic and international factors on bajra market dynamics in Rajasthan. The presence of co-integration and price transmission mechanisms suggests a significant level of market integration and responsiveness to global price movements within the domestic bajra markets.

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