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Co-integration tests and spatial integration of Karnataka's Ragi (Finger Millet) markets

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Abstract
The goal of the study was to evaluate the co-integration of the five most important Ragi (finger millet) markets in Karnataka. The study employed secondary monthly time series of wholesale price data from Krishi Marata Vahini, spanning the period of January 2010 to July 2022. (Online Agricultural Marketing Information System). The Johnson's multiple co-integration results showed that, three of five markets were cointegrated at a 5 per cent level of significance indicating that the markets for finger millet were cointegrated and had long-run equilibrium relationships and there existed co-integration among these markets. The price of the Kadur market has demonstrated a two-way relationship with the prices of the Bengaluru, Tumakuru and Nagamangala markets indicating that, the former market in each pair Granger causes the formation of the wholesale price in the latter market, which in turn gives the former market feedback. The results of the Vector Error Correction Model (VECM) showed that 0.5% to 2.7% of divergence from the long-run equilibrium was being corrected monthly, with the coefficient of speed of adjustment ranging from -0.005 to -0.027. In conclusion, the main policy advice would be to reinforce the state's physical infrastructure, make agricultural policies more transparent, and employ information and communication technologies to assist, create a uniform and integrated economic market.

Keywords: Co-integration, non-stationary, unit root, long-run equilibrium, causality, error correction model

1. Introduction

Due to its diverse agricultural resources in terms of soil, rainfall, and climate, India has a wide variety of crops. In India, coarse cereals are grown as both human food and animal fodder in areas that are prone to drought (Kiran *et al.,* 2014) [8]. The majority of coarse cereals are cultivated in rainfed environments. Markets are crucial for facilitating the exchange of goods and services and can improve the welfare of participants in those transactions. Additionally, markets send out signals regarding the real cost of resources and direct resource allocation toward optimal usage. After taking into consideration transmission costs between markets, integrated markets could aid in equating the value of a resource across space in addition to providing indications about the worth of resources. In most situations, the lack of well-developed infrastructure and market institutions that promote the simple flow of commodities and information between markets causes agricultural markets in developing nations to be poorly integrated (Christopher and Emelly, 2008) [1].

When price signals and information are seamlessly conveyed, prices of a commodity in geographically distinct marketplaces move together. This is referred to as spatial market integration (Henry and Rebecca, 2012; Ghafoor *et al.*, 2009) [6, 2]. The link between the prices of geographically separated markets can be used to evaluate spatial market performance, and spatial price behavior in regional markets can be used as a gauge of overall market performance. The study of market performance has made extensive use of the spatial pricing correlations. When markets operate effectively, producers receive lucrative prices, and consumers receive fair prices.

In India, Karnataka is the state that grows the most finger millet (56.21%) and produces the most (59.52%). In Southern Karnataka, it is the primary staple cuisine that the vast majority of people eat. It is grown as rainfed as well as irrigated crop, mostly cultivated by marginal and small farmers and cultivated as pure as well as intercrop (www.eands.dacnet.nic.in).

The government uses different instruments for achieving the objectives of price policy. The Government announces every year support prices for selected crops. At this price the Government is prepared to buy any amount of the crops from producers when there is a good harvest in that period, in the absence of a support price, the market price may fall below the cost of production. In addition, incentives in the form of procurement prices for major crops are offered to farmers to promote investment and growth in agriculture. The government also operates a public distribution system (PDS) for the supply of food grains and other commodities to selected groups of people at subsidized prices (issue price) (Neetu and Fiona, 2019) [13]. For the successful operation of the PDS, the government agencies undertake a procurement programme of food grains at procurement prices from the surplus producers. In Karnataka, after the establishment of Targeted Public Distribution System (TPDS), the demand for finger millet has been increasing (Raju *et al.,* 2018) [14]. This in turn helps the farmers to grow more of ragi in rainfed as well as irrigated situation in order to get more profit through selling their produce at minimum support price to the Government.

When assessing the effectiveness of the marketing system, it is crucial to consider how closely wholesale prices of a commodity are related in various marketplaces. The type and degree of competition substantially influences how prices in various markets are related to one another. An examination of these interactions enables us to comprehend the effectiveness of the marketing system. Southern Karnataka is one of the major finger millet producing regions in the state (Raju *et al.,* 2018) [14]. This study aims to shed light on the effectiveness of the marketing system in the State, assisting planners and policymakers in locating the major integrated finger millet markets within the State and determining whether or not the government should get involved in the markets.

2. Methodology

The data on monthly average wholesale price of finger millet (Rs. /q) in Bengaluru, Tumakuru, Nagamangala, Arasikere and Kadur markets from January 2010 to July 2022 were taken from the Krishi Marata Vahini (Department of Agricultural Marketing and Karnataka State Agricultural Marketing Board) Government of Karnataka. To remove changes in price series movement brought on by level variances, all of the series were converted into natural log-form. The study's analytical methods are detailed below, and the statistical programme E-views (Econometric views) was employed for this particular investigation.

Analytical tools used

2.1 Co -integration technique

For examining integration between finger millet markets, the study adopts co-integration technique. The co-integration approach to market integration is intuitively appealing and straight forward in application. Integrated markets are those where prices are determined interdependently. This has generally been assumed to mean that the price changes in one market will be fully transmitted to other markets. Markets that are not integrated may convey inaccurate price information that might distort marketing decisions and contribute to inefficient product movements.

When a long-term equilibrium relationship exists between two series, the relationship is referred to as co-integration. In other words, two series cannot eventually diverge from one another. In other words, there is a mechanism for bringing the two series into equilibrium. Co-integration between price series implies long-term dependence between any two markets when this idea is applied to them. It follows that co-integration between prices in two specific markets implies integration of the markets as the fundamental component of market integration is the price dependency across markets.

To examine the price relation between two markets, the following basic relationship commonly used to test for the existence of market integration may be considered.

$$Pit=\alpha_0+\alpha_1 P_{jt}+\varepsilon t \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (1)$$

Where P_i and P_j are price series of a specific commodity in two markets i and j, εt are the residual term assumed to be distributed identically and independently. The test of market integration is straight forward if pi and p_j are stationary variables. Often, however, economic variables are non-stationary in which case the conventional tests are biased towards rejecting the null hypothesis. Thus, before proceeding to further analysis, it is important to check for the stationarity of the variables (Granger and Newbold, 1974) [3].

A stationary time series is one in which the mean, variance, autocorrelation, and other statistical features remain constant across time. The next stage is to check whether there is a co-integrating (Long run equilibrium) relationship between the variables after their non-stationarity status has been established.

2.2 Augmented Dickey-Fuller (ADF) test

The variables should not be stationary at the level of zero order, but should become stationary after the first or second differencing, according to an implicit assumption in Johansen's co-integration approach. The model is used to check the order of integration using the Augmented Dickey-Fuller test. (2):

$$\Delta Y_t = \alpha + \delta T + \beta_1 Y_{t-1} + \sum_{i=1}^{p} \beta_1 \; \Delta Y_{t-1} + \varepsilon_t \text{---} \qquad (2)$$

where, Δ is differencing operator ε_t is pure white noise term, α is the constant-term, T is the time trend effect, and p is the optimal lag value which is selected on the basis of Schwartz information criterion1 (SIC). The null hypothesis is that β_1, the coefficient of Y_{t-1} is zero. The alternative hypothesis is: $\beta_1 < 0$. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary (Gujarati, *et al,* 2012) [5].

2.3 Co-integration analysis using Johansen methodology

The Johansen procedure examines a vector auto regressive (VAR) model of Y_t, an (n × 1) vector of variables that are integrated of the order one- I (1) time series. This VAR can be expressed as equation (3):

$$\Delta Y_t = \mu + \sum_{i-1}^{p-1} \Gamma_i \, Y_{t-1} \prod Y_{t-1} + \varepsilon_t \text{ ---} \qquad (3)$$

Where, I and Π are matrices of parameters, *p* is the number of lags (selected on the basis of minimum SIC) (Schwarz information criterion), ε_t is an (n×1) vector of innovations. The presence of at least one co-integrating relationship is necessary for the analysis of long-run relationship of the prices to be possible. To detect the number of co-integrating vectors, Johansen proposed two likelihood ratio tests: Trace test and Maximum Eigen value test, shown in Equations (4) and (5), respectively.

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i) \text{---} \quad (4)$$

$$J_{max} = -T \ln(1-\lambda_r+1) \text{------} \quad (5)$$

Where, T is the sample size and λ_i is the i^{th} largest canonical correlation. The trace test examines the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. The maximum Eigen value test, on the other hand, tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of $r+1$ cointegrating vectors (Hjalmarsson and Osterholm, 2010) [7].

2.4 Granger causality test

To determine whether there is and in which direction there is a long-term causal price relationship between the markets, the Granger causality test is carried out within the context of a Vector Auto Regression (VAR) model (Granger, 1969) [4]. It is an F-test to determine whether modifications to one price series have an impact on another. The test was based on the following pairs of OLS regression equations through a bivariate VAR, using the causation link between (Bengaluru) and (Tumakuru) wholesale finger millet markets as an example:

$$P \ln B_t = \sum_{i=1}^{m} \alpha_i \ P\ln B_{t-i} + \sum_{i=1}^{m} \beta_j \ P \ln D_{t-j} + \varepsilon_{1t} \text{---} \quad (6)$$

$$P \ln D_t = \sum_{i=1}^{m} \gamma_i \ P\ln D_{t-i} + \sum_{i=1}^{m} \delta_j \ P \ln B_{t-j} + \varepsilon_{2t} \text{---} \quad (7)$$

where, B and D are Bengaluru and Tumakuru markets, P ln stands for price series in logarithm form and t is the time trend variable. The subscript stands for the number of lags of both variables in the system. The null hypothesis in equation H_0:$\beta_1 = \beta_2 = ... = \beta_j = 0$ against the alternative, i.e., H_1: Not H_0, is that P ln D_t does not Granger cause P ln B_t. Similarly, testing H_0: $\delta_1 = \delta_2 = ... = \delta_j = 0$ against H_1: Not H_0 is a test that P ln B_t does not Granger cause P ln D_t. In each case, a rejection of the null hypothesis will imply that there is Granger causality between the variables (Gujarati, *et al*, 2012) [5].

2.5 Error Correction Model (ECM)

After establishing the co-integrating relationships between the two-price series, we constructed the Vector Error Correction Model (VECM) to find the short-term disturbances and the adjustment mechanism to estimate the speed of adjustment in prices of corresponding markets. The ECM explains the difference in y_t and y_{t-1} (i.e. Δy_t) by equation.

$$\Delta Y_t = \alpha + \mu (Y_{t-1} - \beta x_{t-1}) \sum_{i=0}^{i=t} \delta_i \ \Delta x_{t-i} + \sum_{i=1}^{i=t} \Delta y_{t-i} \text{ -(8)}$$

It includes the lagged differences in both x and y, which have a more immediate impact on the value of Δy_t. For example, if Δx_t increases by one percentage point, then Δy_t would increase by δ percentage point. The value of β indicates the percentage point would change in the long-run in response to changes in x. Therefore, part of the change in Δy_t could be explained by y correcting itself in each period to ultimately reach the long-run path with x. The amount by which the value of y changes (or corrected) in each period is signified by μ. This coefficient (μ) indicates the percentage of the remaining amount that y has to move to return to its long- run path with x. In explaining changes in a variable, the ECM accounts for its long-run relationship with other variables. The advantage of ECM over an ordinary OLS model is that it accounts for dynamic relationships that may exist between a dependent variable and explanatory variable, which may span several periods.

3. Results and Discussions

3.1 General features of the selected markets

Table 1 displays an overview of the wholesale price data for finger millet for the months of January 2010 through July 2022. The findings showed that throughout the study period, the average price ranged from Rs. 740 /q in Kadur to Rs. 1100 /q in Bengaluru, while the average price's maximum values ranged from Rs. 2600 /q in Arasikere to Rs. 3200 /q in Bengaluru. The Bengaluru wholesale market has the highest average price (Rs. 2500/q) and the highest price standard deviation (Rs. 995).

Table 1: Summary statistics of monthly wholesale prices of finger millet in selected markets in Karnataka for the period January 2010 to July 2022 (Rs. /q)

Sl. No.	Markets	Observations	Minimum	Maximum	Mean	Std. Dev.
1	Bengaluru	150	1100	3200	2500	995
2	Tumakuru	150	980	2730	2280	923
3	Nagamangala	150	930	2700	2010	832
4	Arasikere	150	800	2600	1920	800
5	Kadur	150	740	2670	1950	756

3.2 Unit root test

The results of the Augmented Dickey-Fuller (ADF) unit root test applied at level and first difference to the logarithmically transformed prices of finger millet are given in Table 2. The empirical evidence suggests that price series had unit root problem at their level form. The null hypothesis of the unit root at level form cannot be rejected for all price series as the absolute values of the ADF statistics are well below the 5 per cent critical values of the test statistics.

Table 2: Augmented Dickey-Fuller (ADF) unit root results for wholesale prices of ragi in selected markets of Karnataka

Sl. No.	Markets	At level/first difference	T-cal.	(Prob.*)	Remarks
1	Bengaluru	ln BEN	-1.045	(0.7357)	Non-Stationary
		Δln BEN	-12.177**	(0.0000)	Stationary
2	Tumakuru	ln TUM	-0.865	(0.7963)	Non-Stationary
		Δln TUM	-14.097**	(0.0000)	Stationary
3	Nagamangala	ln NAG	-0.903	(0.7847)	Non-Stationary
		Δln NAG	-12.850**	(0.0000)	Stationary
4	Arasikere	ln ARA	-1.009	(0.7488)	Non-Stationary
		Δln ARA	-15.472**	(0.0000)	Stationary
5	Kadur	ln KAD	-0.802	(0.8148)	Non-Stationary
		Δln KAD	-14.370**	(0.0000)	Stationary

Note: a) ** indicate that unit root at level or in the first difference were rejected at 1 per cent as well as at 5 per cent significance. b) The (Prob.*) denotes MacKinnon-Haug-Michelis (1999) [9] p-values c) ln denotes wholesale price in logarithmic form and Δln denotes the price series in logarithm form after first difference

Thus, it is concluded that all the price series are non-stationary at their level forms. The data became stationary after the first difference as absolute values of the ADF statistics were now greater than the 5 per cent critical values of the test statistics, so a unit root test of first difference was performed to test the level or number of unit roots in the data. This test revealed that the number of unit roots was equal to one. With the evidence that the price series were non-stationary and integrated of the order 1, the maximum likelihood method of Johansen was used to test for co-integration among the chosen finger millet markets. These results are consistent with those from Mousavi and Leelavathi (2013) [12].

3.3 Johansen's multiple co-integration test

Johansen's multiple co-integration test was used to ascertain the long-term link between the price series from a range of five price series. According to the findings in Table 3, three of the five markets had cointegration at a 5 per cent level of significance. This suggests that there was co-integration between the chosen finger millet markets and that there was a long-run equilibrium relationship between them. Using Johansen's cointegration test, the integration of finger millet prices between a number of different pairs of marketplaces was evaluated. A thorough integration and efficient transmission of price signals from one market to the next were confirmed by the test, which found that each of the five finger millet markets that were chosen had three cointegrating vectors out of five cointegrating equations.

Table 3: Results of multiple co-integration analysis for finger millet

Null Hypothesis	Eigen-value	Trace	Critical value	Prob.**
None *	0.2184	86.913	69.818	0.0012
Atmost 1*	0.1594	54.632	47.856	0.0101
Atmost 2 *	0.1352	31.884	29.797	0.0283
Atmost 3	0.0895	12.847	15.494	0.1205
Atmost 4	0.0042	0.5617	3.841	0.4536

Note: *denotes rejection of the null hypothesis at the 0.05 level ** MacKinnon-Haug-Michelis (1999) [9] p-values

The selected wholesale finger millet markets in Karnataka were thus shown to be well-connected in terms of finger millet prices by the Johnson co-integration test, indicating that there was long-run price linkage between them despite their geographical isolation and spatial segmentation. These findings are in confirmatory with the results of Meera *et al.* (2015) [11].

3.4 Granger causality test

A pair-wise co-integration was also performed across the markets, the results of which are given in Table 4. Following the discovery of co-integration between several finger millet markets in Karnataka, Granger causality was also assessed between the chosen pairs of finger millet markets.

Table 4: Pair-wise Granger causality in selected finger millet markets in Karnataka

Sl. No.	Null Hypothesis	F-Statistics	Probability	Granger cause	Direction
1	Tumakuru RMP does not Granger cause Bengaluru RMP	12.5170	1.E-05**	Yes	Bidirectional
	Bengaluru RMP does not Granger cause Tumakuru RMP	2.5816	0.0796*	Yes	
2	Nagamangala RMP does not Granger cause Bengaluru RMP	21.8481	7.E-09**	Yes	Unidirectional
	Bengaluru RMP does not Granger cause Nagamangala RMP	0.76470	0.4676	No	
3	Arasikere RMP does not Granger cause Bengaluru RMP	14.1897	3.E-06**	Yes	Unidirectional
	Bengaluru RMP does not Granger cause Arasikere RMP	1.08821	0.3399	No	
4	Kadur RMP does not Granger cause Bengaluru RMP	2.50184	0.0859*	Yes	Bidirectional
	Bengaluru RMP does not Granger cause Kadur RMP	8.66860	0.0003**	Yes	
5	Nagamangala RMP does not Granger cause Tumakuru RMP	20.0861	3.E-08**	Yes	Unidirectional
	Tumakuru RMP does not Granger cause Nagamangala RMP	0.66728	0.5149	No	
6	Arasikere RMP does not Granger cause Tumakuru RMP	17.9401	1.E-07**	Yes	Unidirectional
	Tumakuru RMP does not Granger cause Arasikere RMP	0.41269	0.6627	No	
7	Kadur RMP does not Granger cause Tumakuru RMP	6.79937	0.0016**	Yes	Bidirectional
	Tumakuru RMP does not Granger cause Kadur RMP	5.68034	0.0043**	Yes	
8	Arasikere RMP does not Granger cause Nagamangala RMP	5.78202	0.0039**	Yes	Bidirectional
	Nagamangala RMP does not Granger cause Arasikere RMP	4.66315	0.0111**	Yes	
9	Kadur RMP does not Granger cause Nagamangala RMP	0.30343	0.7388	Yes	Bidirectional
	Nagamangala RMP does not Granger Kadur RMP	26.4673	2.E-10**	Yes	
10	Kadur RMP does not Granger Arasikere RMP	1.34148	0.2651	No	Unidirectional
	Arasikere RMP does not Granger Kadur RMP	24.5820	9.E-10**	Yes	

Note: The lags of the dependent variable used to obtain white-noise residuals were determined using the Schwarz Information criterion (SIC). **and *denotes rejection of the null hypothesis at 1 and 5 per cent level of significance. (RMP= Ragi market price).

The Granger causality demonstrates the direction of price development between two marketplaces and the associated spatial arbitrage, *i.e.*, physical movement of the good to reduce price discrepancy (Ghafoor *et al.*, 2009) [2]. According to the findings of the Granger causality tests, each of the four F-statistics used to analyze the impact of wholesale pricing in the Bengaluru market on other markets was statistically significant. For the Bengaluru market, the null hypothesis that there is no Granger causation was rejected in each instance. Five of the 10 co-integration results, according to the Granger causality test, were bidirectional while the remaining five were unidirectional. The bidirectional causalities of market pairs were Bengaluru-Tumakuru, Tumakuru-Bengaluru, Kadur-Bengaluru, Bengaluru-Kadur, Kadur-Tumakuru, Tumakuru- Kadur, Kadur- Nagamangala, Nagamangala-Kadur and Arasikere- Nagamangala, Nagamangala-Arasikere. In these cases, the former market in each pair Granger causes the wholesale price formation in the latter market which in turn provides the feedback to the former market as well.

The wholesale markets in Nagamangala-Bengaluru, Bengaluru-Nagamangala, Arasikere-Bengaluru, Bengaluru-Arasikere, Nagamangala- Tumakuru, Tumakuru-Nagamangala, Arasikere-Tumakuru, Tumakuru-Arasikere, Kadur-Arasikere, Arasikere-Kadur all showed unidirectional causality which means that a price change in the former market in each pair Granger causes the price formation in the latter market, whereas the price change in the latter market was not feedback by the price change in the former market in each pair.

The findings of the pair-wise Granger causality test revealed that prices in the markets of Bengaluru and Tumakuru had a bidirectional influence, i.e., prices in the Bengaluru market had a bidirectional influence on prices in the Tumakuru market. Bengaluru, Tumakuru, and Nagamangala market prices have all exhibited evidence of a bidirectional relationship with the price at the Kadur market. The pricing in the Arasikere market have shown a two-way influence on those in the Nagamangala market. The prices in Arasikere and Nagamangala have shown a one-way causal relationship with the market price in Bengaluru. Pricing in the Arasikere, Nagamangala, and Kadur markets have shown evidence of a one-way influence from Tumakuru market prices. Bengaluru, Tumakuru, and Kadur market prices have exhibited a one-way causal relationship with the price at the Arasikere market. Bengaluru and Tumakuru market prices were shown to have a one-way impact from Nagamangala market pricing. The prices at the Kadur market have a one-way causal relationship with those at the Arasikere market. This suggests that market prices for finger millet change in response to supply and demand conditions. Similar type of findings was reported by Mahella, *et al.* (2015) [10].

3.5 Vector Error Correction Model (VECM)

In order to know the co-integration between the selected markets of finger millet. Vector error correction analysis was performed and the results are presented in Table 5. By contrasting the 't' values with the table 't' values (1.7), the significance of the co-integration coefficients was determined.

Table 5: Results of vector error correction model with two lag period in selected finger millet markets of Karnataka

Markets	D (BMP)	D (TMP)	D (NMP)	D (AMP)	D (KMP)
D (BMP(-1))	-0.085	0.025	-0.067	0.186	0.280
	[-1.007]	[0.315]	[-0.727]	[1.804]	[2.257*]
D (BMP(-2))	-0.046	-0.197	0.077	0.119	0.106
	[-0.601]	[-2.679*]	[0.924]	[1.276]	[0.947]
D (TMP(-1))	0.081	-0.326	-0.083	-0.064	-0.170
	[0.982]	[-4.137*]	[-0.929]	[-0.640]	[-1.411]
D (TMP(-2))	0.413	-0.244	0.050	0.111	0.018
	[4.932*]	[-3.051]	[0.551]	[1.096]	[0.147]
D (NMP(-1))	0.265	-0.307	-0.188	-0.037	0.023
	[2.117*]	[-2.563*]	[-1.374]	[-0.246]	[0.126]
D (NMP(-2))	-0.135	-0.219	-0.031	0.002	-0.064
	[-1.191]	[-2.023*]	[-0.250]	[0.0186]	[-0.387]
D (AMP(-1))	-0.005	-0.149	0.216	-0.515	-0.352
	[-0.061]	[-1.696]	[2.146*]	[-4.614*]	[-2.615*]
D (AMP(-2))	-0.144	0.070	0.137	-0.325	-0.150
	[-1.590]	[0.813]	[1.384]	[-2.953*]	[-1.129]
D (KMP(-1))	-0.024	0.136	-0.027	0.116	-0.244
	[-0.375]	[2.149*]	[-0.378]	[1.458]	[-2.527*]
D (KMP(-2))	-0.057	0.070	-0.066	0.0341	-0.135
	[-0.921]	[1.190]	[-0.984]	[0.455]	[-1.495]

Note 1: D is difference, ln is natural logarithm and (-1) and (-2) indicate number of lags
2: BMP= Bengaluru Market Price
3: TMP= Tumakuru Market Price
4: NMP= Nagamangala Market Price
5: AMP= Arasikere Market Price
6: KMP= Kadur Market Price

The error correction term describes how quickly the variables in the dynamic model adjust before reaching equilibrium. In the long term, the coefficients demonstrate how rapidly variables return to equilibrium. According to the coefficient of speed of adjustment, which ranged from -0.005 to -0.027, 0.5 per cent to 2.7 per cent of divergence from the long-run equilibrium was being corrected monthly. Lagged pricing had both positive and negative effects in the chosen markets, indicating that in the short run, these marketplaces did not fully communicate price shocks contemporaneously. Tumakuru finger millet market prices were influenced by its own one month lagged price to the extent of 32.68 per cent. Bengaluru market prices were influenced by Kadur market price in one-month lag to the extent of 28.09 per cent and Tumakuru market prices were influenced by two month lags to the extent of 19.73 per cent, Tumakuru markets prices were influenced by Bengaluru market prices in two month lags to the extent of 41.36 per cent. Nagamangala market prices were influenced by Bengaluru market prices in one-month lag to the extent of 26.58 per cent and Tumakuru market prices by one month and two month lags to the extent of 30.79 per cent and 21.98 per cent, respectively. The process of adjustment, however, was relatively faster between these markets. This might be due to lesser transfer and transaction costs in these markets due to proximity and better infrastructure. Arasikere markets prices were influenced by its own one month and two month lagged prices to the extent of 51.56 per cent and 32.57 per cent, respectively. Again, Arasikere market prices were influenced by Nagamangala and Kadur market prices to extent of 21.60 per cent and 35.22 per cent, respectively. In Arasikere market, its own lagged prices and the prices of Nagamangala and Kadur markets tended to move closer.

Kadur markets prices were influenced by its own one month lagged prices to the extent of 24.44 per cent and also influenced by Tumakuru market prices in one month lags to extent of 13.61 per cent, therefore its own lagged prices and the prices in Tumakuru market tend to move closer.

To strengthen the linkage and interconnections among markets for faster transmission of price and management of a commodity from surplus area to deficit area, there is a need to enhance the development of market infrastructure, use of information technology in transaction of goods, processing, transportation and other back-end supply chain of finger millet. This would definitely help in the development of single integrated economic market in the state. The findings are in line with the results of Mahella, *et al.* (2015) [10].

4. Conclusion and policy Recommendations

Despite the fact that we are well aware of how volatile agricultural commodity prices may be, these prices are extremely important when it comes to state policy. Since agricultural prices have a negative impact on consistent economic growth and development, this analysis uses the Johansen test to determine the degree of co-integration of wholesale prices of finger millet among the key markets in Karnataka. Additionally, it uses the Granger causality tests to look at causality and the Vector Error Correction Model to measure how quickly finger millet markets react to changes in long-term equilibrium (VECM). Five main Karnataka markets' monthly wholesale prices from January 2010 to July 2022 were considered for the analysis. E-views, a statistical programme, was utilised for co-integration analysis. The findings showed that after restating and correcting prices ranging from 0.5% to 2.7% every month in the chosen marketplaces, market prices in general achieve a long-run equilibrium relationship and converge over time. Even the geographically separated finger millet markets were integrated. However, half of the market pairs have demonstrated bidirectional causation, indicating that Granger affects the creation of wholesale prices in each pair's latter market, which then feeds back to the former market, and the other half of the market pairs have shown unidirectional causality. The finger millet markets were found to be effectively integrated in the short term, and some, but not all, price changes were transmitted simultaneously. This demonstrated that after correcting short- and long-term variations, finger millet markets in the area have developed competitive strength in price formation. However, the rate of adjustment differs between various market pairs.

The study's findings have significant policy ramifications, which include: When a group of food markets are shown to be spatially linked, the government may consider scaling back or even ceasing its efforts to affect those markets' price processes. By maintaining a balance between regions that produce non-food cash crops, food surpluses, and regions that produce food deficits, thus, market integration ensures regional food security.

Based on the aforementioned findings, it is advised that the state's physical infrastructure, usage of ICT, and clearly stated transparent agricultural policy/market measures all need to be strengthened. These steps will support the growth of a single, uniform market in the area in particular and the state of Karnataka generally.

5. References

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