Indian Journal of Agricultural Economics 80: 3 (2025): 742-763
DOI:10.63040/25827510.2025.03.013

Co-Integration and Causal Relationships in Paddy Prices: A Multi-State Analysis in India

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ABSTRACT

This study examines the spatial price transmission and price discovery mechanisms in wholesale paddy markets across Karnataka, Kerala, and Punjab, the three states representing distinct institutional and structural contexts within India's agricultural marketing landscape. Using monthly price data from 2011 to 2023 across 12 major markets, the study employs a suite of time series econometric tools, including Augmented Dickey-Fuller tests, Vector Autoregression model, Johansen's Cointegration Test, Vector Error Correction Models (VECM), Granger causality tests, and Impulse Response Functions (IRFs) to assess market integration and the directionality of price influence. The results reveal strong intra-state price dynamics in Karnataka, with Davanagere emerging as a central market influencing price formation across the region. In Punjab, Ferozepur and Ludhiana serve as primary price transmitters, while Amritsar primarily acts as a passive recipient. Kerala markets exhibited limited internal and inter-state integration, with only Wayanad and Kasaragod displaying a significant bidirectional linkage. Johansen's cointegration test confirmed the existence of long-run relationships among Karnataka markets, but not among those in Kerala. VECM results highlight short-run adjustments and long-run equilibrium, particularly in Mysore and Davanagere. IRF analysis confirmed statistically significant, sustained price shocks only in Punjab markets, particularly emanating from Firozpur. Overall, the findings highlight regional heterogeneity in market efficiency and integration, which is shaped by procurement intensity, digital market reforms, and production-consumption balances. These insights have important implications for refining Minimum Support Price policies, enhancing inter-market connectivity, and improving price stabilisation efforts.

Key words: Paddy markets, price transmission, market integration, Vector Error Correction Model, Granger causality

JEL Codes: C32, C51, Q11, Q13, Q18

I

INTRODUCTION

Paddy (rice) is a cornerstone of Indian agriculture, playing a crucial role in ensuring both national food security and rural livelihoods. As the primary staple food for over 65 per cent of India's population, rice occupies about 43 million hectares, making it the single largest crop by area (Mohapatra et al., 2024). For millions of small and marginal farmers who comprise more than 85 per cent of the farming population, paddy cultivation is not just a source of income but a way of life (Kamble and Tikadar, 2021). India is also the world's largest exporter of rice, contributing significantly to the global rice market and generating substantial foreign exchange earnings for the economy (FAO, 2023; USDA, 2023). The crop's dual importance as a food and cash crop has placed it at the centre of various government schemes, including the Minimum Support Price (MSP) system, public procurement programs, and irrigation initiatives such as the Pradhan Mantri Krishi Sinchai Yojana. Despite increased production and government support through MSP, market volatility

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continues to impact farmer income (Sendhil et al., 2023), primarily due to inefficient price transmission and asymmetries in price discovery across regional markets (Timmer, 2012; Pavithra and Gaddi, 2022).

Price discovery, the process through which markets incorporate information into commodity prices, plays a vital role in ensuring that farmers receive fair remuneration (Arunendra and Prasanth, 2022). In an economy with spatially fragmented and information-heterogeneous agricultural markets, such as India's, understanding how paddy prices adjust and transmit across different market centres becomes essential for both market efficiency and policy intervention. The main determinants of paddy price behaviour include infrastructure, trader participation, state-specific market laws, and procurement procedures. Price signals and transmission are significantly shaped by institutional marketing structures, including regulated markets, MSP operations, and digital trading platforms (Acharya et al., 2012).

Hence, the study of the price discovery mechanism of paddy across diverse state contexts in India holds significant analytical and policy relevance. In India, Punjab, Karnataka, and Kerala are among the states representing three distinct models of agricultural marketing systems. Punjab, as a surplus-producing state, operates under a strong MSP procurement regime administered through well-established, regulated mandis, which facilitates relatively stable price signals (Acharya et al., 2012). Although Punjab accounts for approximately 10-12 per cent of India's total rice production, its share in central procurement consistently exceeds this, underscoring its dominant role in the national procurement system (The Hindu, 2022). On the other hand, Karnataka pioneered digital reforms in agricultural marketing through the Unified Market Platform (UMP), which fully integrated 162 regulated wholesale mandis in the state by November 2019. Empirical evaluation reveals that UMP implementation resulted in an average modal price increase of approximately 5.1 per cent for paddy, thereby enhancing transparency, competition, and market efficiency (Levi et al., 2020). Kerala, being a consumption-oriented and largely deficit state in paddy production, meets only 15 per cent of its total consumption requirement (Athira, 2017). Kerala's paddy market operates outside the APMC framework, with state agencies playing a dominant role in procurement. The government procures a majority of paddy through decentralised channels, offering an additional bonus above the MSP to support farmers and stabilise incomes (Athira, 2017; Sukanya, 2015). Together, these three states represent institutional, structural, and spatial contrasts in market operation. As previously mentioned, a sound marketing system must have effective markets to pay farmer-sellers a fair price for their produce and to offer items to the customers at affordable costs (Kaur and Sekhon, 2016). By examining these three states together, the study enables a comparative understanding of how institutional frameworks, regional surplus-deficit balances, and marketing infrastructures influence the temporal and spatial transmission of prices. Moreover, such a cross-regional investigation addresses the research gap on how heterogeneous market conditions, including variations in infrastructure quality, geographic distance, and policy environments, significantly influence both the efficiency and the timing of price discovery and transmission, especially for staple crops such as rice (Andrle and Blagrave, 2020).

II

DATA AND METHODOLOGY

2.1 Data

Data for the present study were obtained from a secondary source (www.agmarknet.gov.in). Time series data on the weekly wholesale prices of paddy for the period 2011-2023 in five markets of Karnataka and Punjab, and two markets of Kerala, were collected and then averaged to obtain monthly data. The total number of observations was 1872. Since higher arrival volumes generally reflect key producing regions and more active representative price formation processes, the selection of markets for investigation was based on the volume of paddy arrivals. Accordingly, the Raichur, Bellary, Koppal, Davanagere, and Mysore markets in Karnataka, as well as the Kasaragod and Wayanad markets in Kerala, and the Patiala, Amritsar, Sangrur, Ludhiana, and Firozpur markets in Punjab, were identified as major markets.

2.2 Methodology

The sequence of Econometric Framework followed is: Unit root test → Cointegration or VAR → VECM → Granger Causality → IRF

2.2.1 Stationarity

The first step in the time-series analysis, before testing for cointegration and Granger causality, is to examine the stationarity for each time series. A series is said to be stationary (weak) if up to second-order statistics of the series are time invariant. If the series is not tested for stationarity, the situation might lead to the problem of spurious regression between variables generated by a non-stationary process (Ghafoor et al., 2009).

2.2.2 Augmented Dickey-Fuller (ADF) Unit Root Test

Using model (1), the ADF test is used to verify the order of integration or stationarity.

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

Where, $\Delta Y_t = Y_t - Y_{t-1}$, $\Delta Y_{t-1} = Y_{t-1} - Y_{t-2}$, and $\Delta Y_{t-2} = Y_{t-2} - Y_{t-3}$, etc, Y_t= Price of paddy in a given market at time t, 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 based on Schwartz information criterion1 (SIC). The null hypothesis is that

$\beta 1$, the coefficient of $Yt{-}1$, 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, 2010).

2.2.3 Cointegration test

The term "market integration" describes the long-term correlation between prices in different geographical areas. It implies that if there is a stationary linear combination of two or more non-stationary series, then those series are considered to be co-integrating.

2.2.4 Cointegration Analysis Using Johansen Methodology

The Johansen procedure examines a VAR model of Y_t, an $(n \times 1)$ vector of variables that are integrated of order one, I(1) time series. This VAR can be expressed as Equation (2):

$$\Delta Y_t = \mu + \sum_{i=1}^{p-1} \Gamma\, Y_{t-1} + \Pi Y_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots(2)$$

Where, Γ and Π are matrices of parameters, p is the number of lags (selected based on Schwarz information criterion), and ε_t is an $(n \times 1)$ vector of innovations. For the study of the price's long-term relationship to be plausible, there must be at least one cointegrating relationship. Johansen suggested two likelihood ratio tests, the trace test and the maximal eigenvalue test, which are displayed in Equations (3) and (4), respectively, to determine the number of co-integrating vectors.

$$J_{trace} = -T * \Sigma_{i=r+1}^{n} [\ln(1 - \lambda_i)] \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$J_{max} = -T \ln (1 - \lambda_r + 1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

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 no cointegrating vectors. The maximum eigenvalue 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). In our analysis, only this trace test has been used.

2.2.5 Vector Auto Regression (VAR)

To examine the dynamic interrelationships and price transmission among the selected agricultural markets, we employed the Vector Autoregression (VAR) framework as proposed by Sims (1980). VAR models are well-suited for analysing multivariate time series data without requiring strong a priori theoretical assumptions about endogeneity among variables.

Let Yt be a vector of k endogenous variables (here, market prices across different locations), the VAR(p) model is specified as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t$$

Where Yt is a (k × 1) vector of endogenous variables, Ai are (k × k) coefficient matrices, and εt is a vector of white noise disturbances with zero mean and constant variance. The optimal lag length for the VAR model was selected based on information criteria such as the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC).

2.2.6 Vector Error Correction Model

Following the discovery of cointegration, the error correction model, as updated by Engle and Granger (1987), is used to determine the short-term relationship and the pace of adjustment towards equilibrium. Equations (3) and (4) can be used to represent the error correction model:

$$\Delta \ln X_t = \alpha_0 + \Sigma\beta_{1i}\, \Delta \ln Y_{t-1} + \Sigma\beta_{2i}\, \Delta \ln X_{t-1} + \gamma ECT_{t-1} \quad \ldots(3)$$

$$\Delta \ln Y_t = \beta_0 + \Sigma\alpha_{1i}\, \Delta \ln X_{t-1} + \Sigma\alpha_{2i}\, \Delta \ln Yt{-}1 + \gamma ECT_{t-1} \quad \ldots(4)$$

Where ECT_{t-1} is the error correction term lagged one period generated by the error correction model, and γ is the error correction coefficient that measures the response of the regressors in each period to departures from equilibrium.

The rate of adjustment in reestablishing equilibrium following disequilibrium is represented by negative and statistically significant values of γ. The assumption that the dependent variable does not instantly adapt to its long-term determinants is reflected in the inclusion of ECT_{t-1}. As a result, a short-term adjustment is made to address any long-term imbalance. As a result, the error correction model illustrates how the system approaches the long-term equilibrium. The error correction term provides the long-term influence, whereas the lagged explanatory factors show the short-term impact.

2.2.7 Granger Causality

Granger's (1988) conventional Granger causality test looks at how one variable explains the most recent value of another. The F-test determines if changes to one price series have an impact on another (Granger, 1969). It states that a variable X can be used to predict the values of a variable Y if Y is Granger-caused by X, and vice versa. (Paul et al., 2015). The null hypothesis (H_0) that was tested in this instance was that neither variable X nor variable Y Granger causes the other. Granger causality between the variables will be implied in each scenario if the null hypothesis is rejected (Gujarati, 2010). The lagged value of one variable aids in forecasting the value of another, and vice versa, if a variable Granger causes another variable.

2.2.8 Impulse Response Function

The relative strength of causality effects outside of the chosen time frame cannot be ascertained using Granger causality tests. Because causality tests cannot reveal the extent of feedback between variables outside of the chosen sample period, they are inappropriate in these situations (Rahman and Shahbaz, 2013). The time trajectories of prices following exogenous shocks, or impulse responses, are the most effective approach to assess the models' implications for patterns of price transmission, causation, and adjustment (Vavra and Goodwin, 2005). Over a range of time horizons, the impulse response function illustrates how a one-standard-deviation or one-unit shock to one of the variables affects the present and future values of all the endogenous variables in a system (Rahman and Shahbaz, 2013). In this study, the Orthogonal Impulse Response Function (OIRF) has been employed. In standard VAR models, residuals are typically contemporaneously correlated, which complicates the interpretation of standard impulse responses (Lutkepohl,2005). To address this, orthogonalisation via Cholesky decomposition of the variance-covariance matrix of the error terms is performed. This procedure transforms correlated shocks into uncorrelated (orthogonal) shocks, enabling clearer identification of causal relationships.

Mathematically, given a VAR(p) process:

$$Y_t=A_1Y_{t-1}+A_2Y_{t-2}+\cdots+A_pY_{t-p}+\varepsilon_t$$

where $\varepsilon t \sim N(0,\Sigma)$, the Cholesky decomposition of $\Sigma=PP'$ is used to orthogonalize the shocks. The OIRF is then computed based on this transformation, allowing the shock to one variable to be traced across the system without being confounded by contemporaneous correlation (Pfaff, 2008).

III

RESULTS

Table 1 presents the summary statistics of wholesale paddy prices (Rs/quintal) across major markets in Karnataka, Kerala and Punjab. It reveals that Karnataka markets showed moderate mean prices ranging from ₹1556.89 in Koppal to ₹1774.31 in Davanagere. The Coefficient of Variation (CV) remained relatively low (17.28% to 22.27%), indicating low price volatility. Raichur exhibits the strongest growth (CAGR: 8.93) among Karnataka markets, but at the cost of increased price variability (CV: 22.27%, CDVI: 13.91), suggesting an emerging yet less stable market environment. Davanagere is found as the most balanced market (high growth and low volatility). Mysore is the most stable over time (lowest CDVI), ideal for price predictability. Bellary and Koppal had relatively low dispersion and moderate price levels, further supporting their efficiency and consistency. Wayanad reported the highest mean price among Kerala markets, but also a higher volatility and instability. This reflects a less predictable price behaviour. In contrast, the Kasaragod market showed moderate price consistency. Punjab markets are characterised by higher mean prices and significantly greater volatility, notably higher volatility found in Patiala and Ludhiana markets.

TABLE 1. DESCRIPTIVE STATISTICS OF PADDY PRICES FOR MAJOR MARKETS IN STUDY STATES

State	Markets	Mean	Median	Maximum	Minimum	SD	CV (%)	CAGR	CDVI
Karnataka	Davanagere	1774.31	1797.34	2996.96	1017.48	322.03	18.15	8.33	10.52
	Raichur	1707.73	1744.71	2752.78	835.13	380.30	22.27	8.93	13.91
	Koppal	1556.89	1549.40	2260.78	879.86	278.28	17.87	6.03	14.33
	Bellary	1627.31	1679.77	2841.44	943.14	281.27	17.28	7.98	13.02
	Mysore	1586.60	1578.36	2511.33	999.43	299.10	18.85	6.56	9.32
Kerala	Kasaragod	1671.12	1722.67	2178.00	902.50	298.60	17.87	5.77	9.11
	Wayanad	1801.76	1939.77	2611.76	878.40	401.97	22.31	6.10	15.70
Punjab	Patiala	2198.95	2075.81	4400.00	1063.18	691.08	31.43	5.34	31.30
	Amritsar	2362.93	2285.21	3857.14	1345.00	485.54	20.55	0.55	20.62
	Sangrur	1867.23	1849.74	3850.00	1120.00	473.68	25.37	5.34	23.68
	Ludhiana	1997.87	1888.00	3631.25	1110.34	630.25	31.55	3.43	29.82
	Firozpur	1832.24	1835.00	3275.00	930.00	454.37	24.80	6.27	21.53

Note: Prices are in Rupees per quintal, SD- Standard Deviation, CV- Coefficient of variation, CAGR- Compound Annual Growth Rate, CDVI - Cuddy-Della Valle Index
Source: Author's estimate.

Before analysing co-integration, it is necessary to check the univariate time-series data-generating process to examine whether the series under study exhibits a common stochastic dynamic process. This was analysed using the ADF test, and the results are presented in Table 2.

TABLE 2. UNIT ROOT TESTS FOR SELECTED PADDY MARKETS

Sl.no	Markets	Level	Pr	First Difference	Pr
1	Davangere	-0.016	0.470	-1.011	0.000
2	Raichur	-0.075	0.023	-1.218	0.000
3	Koppal	-0.205	0.002	-1.793	0.000
4	Bellary	-0.112	0.038	-1.370	0.000
5	Mysore	-0.035	0.276	-1.524	0.000
8	Kasaragod	-0.027	0.122	-1.022	0.000
9	Wayanad	-0.041	0.054	-1.078	0.000
6	Patiala	-0.393	0.000	-1.261	0.000
7	Amritsar	-0.725	0.000	-1.688	0.000
10	Sangrur	-0.641	0.000	-1.753	0.000
11	Ludhiana	-0.621	0.000	-1.468	0.000
12	Firozpur	-0.686	0.000	-1.786	0.000

Source: Author's estimate.

The results of the ADF test reject the null hypothesis of a unit root at the level only for Punjab markets. Still, the series for all markets in Karnataka and Kerala were found to be non-stationary at the level, as the null hypothesis was not rejected at 1 per cent and 5 per cent levels of significance. After the first difference, these series also became stationary. Thus, the series for Punjab markets is integrated of order 0, while the series for Kerala and Karnataka markets is integrated of order 1. Hence, cointegration models do not apply to Punjab markets. The VAR model has been used to evaluate integration within the state, and Johansen's cointegration test has been employed for the market series of Kerala and Karnataka. To assess cointegration across states, only the markets of Kerala and Karnataka were analysed jointly, as they share the same order of integration. Punjab markets were not combined with Kerala and Karnataka markets in the further cointegration and VECM analysis due to the mismatch in integration orders. Combining series with different levels of integration can lead to spurious results and incorrect inference in the cointegration framework.

3.1 Vector Auto Regression

As the VAR model relies on a constant mean and variance over time for reliable inference, it is appropriate for time series data that are stationary at the level (Lütkepohl, 2005). When variables are stationary, the VAR framework captures the dynamic interdependencies among multiple time series without requiring differencing or error correction terms (Sims, 1980). VECM is made explicitly for cointegrated non-stationary series. Hence, VAR is chosen over VECM (Pfaff, 2008) for analysing the dynamic interdependency of markets in Punjab, while VECM has been used for the Karnataka markets.

To estimate the VAR model, an appropriate lag was selected based on the AIC and SBC. VAR (5) was chosen as the appropriate model for Punjab markets, since AIC and SBC were the least for VAR of order 5 (Annexure Table- 1). The results of the VAR model in Table 3 show that there were 130 coefficients at five lags, of which 6 and 5 coefficients were significant at 10 per cent and 5 per cent level of significance, respectively. The VAR model reveals that the price in Patiala was significantly influenced by Firozpur prices at lags 1 and 3, with positive coefficients indicating strong short-term and medium-term transmission. Sangrur market prices exhibited a negative response to Patiala prices at lag 3, and a strong positive relationship with Ludhiana prices at lag 3, highlighting the influence of both markets on price formation in Sangrur. Firozpur prices responded positively to Patiala prices at lag 2, while their own lagged prices at lags 2 and 3 showed a negative and positive impact, respectively, suggesting both corrective mechanisms and price persistence. Additionally, Sangrur prices at lags 3 and 4 had a significant effect on Firozpur, indicating robust inter-market adjustments over longer horizons. Importantly, Amritsar prices were significantly influenced by Ludhiana prices at lag 5, revealing a delayed but strong spatial price transmission.

TABLE 3: COEFFICIENTS OF UNRESTRICTED VAR MODEL FOR PUNJAB

Markets	Amritsar		Firozpur		Ludhiana		Patiala		Sangrur	
Amritsar (-1)	C (1)	-0.035	C (27)	-0.267	C(53)	-0.299	C(79)	-0.286	C(105)	0.607
Amritsar (-2)	C (2)	0.138	C (28)	-0.510	C(54)	-0.538	C(80)	-0.328	C(106)	-0.545
Amritsar(-3)	C (3)	0.698	C (29)	1.052	C(55)	1.028	C(81)	1.253	C(107)	-0.031
Amritsar (-4)	C (4)	0.298	C (30)	-0.226	C(56)	0.069	C(82)	0.068	C(108)	0.131
Amritsar (-5)	C (5)	-0.057	C(31)	0.755	C(57)	0.385	C(83)	0.963	C(109)	-0.513
Firozpur (-1)	C (6)	1.195	C(32)	2.424	C(58)	2.373	C(84)	3.349*	C(110)	0.575
Firozpur(-2)	C (7)	-0.281	C(33)	-1.665*	C(59)	-0.226	C(85)	-0.429	C(111)	0.172
Firozpur(-3)	C (8)	2.655	C(34)	3.163*	C(60)	2.391	C(86)	4.017*	C(112)	1.020
Firozpur(-4)	C (9)	0.613	C(35)	-0.017	C(61)	0.272	C(87)	0.678	C(113)	-0.590
Firozpur (-5)	C (10)	1.362	C(36)	1.636	C(62)	1.569	C(88)	2.065	C(114)	-0.128
Ludhiana(-1)	C (11)	-0.079	C(37)	1.366	C(63)	0.527	C(89)	0.939	C(115)	-1.126
Ludhiana(-2)	C (12)	-1.319	C(38)	-2.175	C(64)	-0.918	C(90)	-2.170	C(116)	1.519
Ludhiana(-3)	C (13)	0.321	C(39)	0.995	C(65)	0.908	C(91)	1.256	C(117)	2.902**
Ludhiana(-4)	C (14)	-1.093	C(40)	-1.210	C(66)	-0.700	C(92)	-0.782	C(118)	-0.075
Ludhiana (-5)	C (15)	2.008*	C(41)	1.732	C(67)	1.051	C(93)	1.453	C(119)	0.226
Patiala(-1)	C (16)	-0.554	C(42)	-2.120	C(68)	-1.607	C(94)	-2.728	C(120)	0.764
Patiala(-2)	C (17)	0.737	C(43)	2.349**	C(69)	0.389	C(95)	1.412	C(121)	-0.739
Patiala(-3)	C (18)	-2.203	C(44)	-2.088	C(70)	-1.895	C(96)	-3.063	C(122)	-2.778**
Patiala(-4)	C (19)	-0.617	C(45)	-0.787	C(71)	-0.569	C(97)	-1.659	C(123)	0.943
Patiala (-5)	C (20)	-1.716	C(46)	-2.089	C(72)	-1.760	C(98)	-2.292	C(124)	1.156
Sangrur(-1)	C (21)	-0.138	C(47)	0.023	C(73)	-0.073	C(99)	-0.105	C(125)	-0.474
Sangrur(-2)	C (22)	-0.217	C(48)	0.213	C(74)	0.319	C(100)	-0.031	C(126)	0.036
Sangrur(-3)	C (23)	-1.091	C(49)	-2.436**	C(75)	-1.744	C(101)	-2.325*	C(127)	-0.804
Sangrur(-4)	C (24)	1.730	C (50)	2.923**	C(76)	1.690	C(102)	2.597	C(128)	-0.333
Sangrur (-5)	C (25)	-1.248	C(51)	-1.619	C(77)	-0.888	C(103)	-1.638	C(129)	-1.103
Constant	C (26)	-50.638	C(52)	-736.329	C(78)	-1343.030	C(104)	-2260.141	C(130)	474.848

An implicit assumption in Johansen's cointegration approach is that the variables should be non-stationary at the level, but stationary after first differencing. Thus, to check for cointegration among paddy prices in the major markets of Karnataka and Kerala, the Johansen method of cointegration was applied. The cointegration analysis suggests that one series helps predict the other. In a way, it indicates price transmission from one market to another. The results of Johansen's cointegration test for the markets of Karnataka and Kerala, as well as an analysis combining the markets of both states to assess cross-border relations, are presented in Table 4 using the trace statistic. It is indicated that across five markets in Karnataka, there are three cointegrating relationships. In Kerala, no cointegrating relationship was found; however, a combined analysis for both Karnataka and Kerala markets also revealed three cointegrating relationships. Inter-state price dynamics help assess whether surplus-producing regions influence price formation in deficit areas, indicating the extent of spatial integration across markets. Such analysis also reveals how effectively national market reforms, like e-NAM and MSP, are fostering unified price signals across state boundaries (Acharya et al., 2012; Nuthalapati et al., 2020).

TABLE 4. COINTEGRATION AMONG MAJOR PADDY MARKETS IN STUDY STATES

Null Hypothesis ($r \leq$)	Trace statistic	10%	5%	1%	Conclusion @ 5%
Karnataka markets, No. of Co-integrating Vectors = 3					
None	125.28	71.86	76.07	84.45	Reject H_0
At most 1	74.32	49.65	53.12	60.16	Reject H_0
At most 2	42.87	32	34.91	41.07	Reject H_0
At most 3	15.07	17.85	19.96	24.6	Do not reject H_0
At most 4	4.08	7.52	9.24	12.97	Do not reject H_0
Kerala markets, No. of Co-integrating Vectors = 0					
None	10.43	17.85	19.96	24.6	Do not reject H_0
At most 1	4.79	7.52	9.24	12.97	Do not reject H_0
Combined Markets (Karnataka + Kerala), No. of Co-integrating Vectors = 3					
None	171.53	126.58	131.7	143.09	Reject H_0
At most 1	117.86	97.18	102.14	111.01	Reject H_0
At most 2	76.150	71.86	76.07	84.45	Reject H_0
At most 3	41.59	49.65	53.12	60.16	Do not reject H_0
At most 4	22.49	32.00	34.91	41.07	Do not reject H_0
At most 5	9.65	17.85	19.96	24.6	Do not reject H_0
At most 6	3.72	7.52	9.24	12.97	Do not reject H_0

Since VECM is not appropriate when the variables are not cointegrated, it specifically models both short-run dynamics and long-run equilibrium relationships that exist only among cointegrated series (Johansen, 1991). In the absence of cointegration, using VECM may lead to misleading inferences. Thus, VECM becomes inapplicable for Kerala markets as there exists no cointegrating relationship. Instead, a VAR model in first differences is preferred, as it effectively captures short-run interdependencies among non-stationary, non-cointegrated variables (Enders, 2014). The differenced VAR model excludes long-run equilibrium relationships and focuses solely on interdependencies in the short-run fluctuations.

Investigation of differenced VAR model (Table 5) suggests that a price increase in Kasaragod market tends to exhibit a positive response to price raise in Wayanad and while Wayanad market tends shows a strong positive effect (coefficient = 0.401) in the first period followed by a significant negative effect (coefficient = -0.458) in next period which implies that a short-term increase in Kasaragod prices leads to a contemporaneous rise in Wayanad prices in the immediate next period, followed by a correction effect in the second period. Overall, the differenced VAR model confirms the presence of bidirectional significant short-run linkages between the two markets and highlights that these linkages are only present in the short run.

TABLE 5. COEFFICIENTS OF DIFFERENCED VAR MODEL FOR KERALA

Markets	Kasaragod	Wayanad
Kasaragod (-1)	-0.081	0.401***
Kasaragod (-2)	-0.126	-0.458 ***
Wayanad (-1)	0.205***	0.022
Wayanad (-2)	0.071	-0.120
Constant	7.102	11.298

Notes: Superscript *** denotes significance at the 1 per cent.
Figures in parentheses are the number of lags selected by the AIC.

3.2 Vector Error Correction Model

To understand the dynamic interactions and price adjustments across regional paddy markets in Karnataka, VECM was estimated. The model captures both short-run dynamics through differenced lag variables and long-run equilibrium adjustments via the Error Correction Term (ECT). The following results outline the key inter-market linkages and price adjustment patterns:

In the Bellary market, the lagged own price difference is found to be negative and statistically significant, suggesting that deviations in Bellary prices from equilibrium are corrected over time through internal market forces. Additionally, Raichur price changes significantly influence Bellary in the short run, indicating a positive transmission of price movements from Raichur to Bellary. The Davanagere market exhibits a significant and negative ECT coefficient, confirming the existence of long-run equilibrium forces that drive adjustment when deviations occur. In the short run, Raichur prices again demonstrate a significant and positive influence on Davanagere, underlining Raichur's leadership in regional price dissemination. For the Koppal market, the model shows strong internal adjustment through its own lag, suggesting rapid convergence toward its own equilibrium price level following any shocks. However, the error correction term is not statistically significant, implying weaker long-run alignment. The Mysore market reflects a strong long-run equilibrium adjustment, as indicated by a highly significant ECT coefficient (0.542, $p < 0.01$). In terms of short-run dynamics, the market is positively influenced by both

Davanagere and Raichur, revealing multidirectional integration with central Karnataka markets. Moreover, Mysore's own lagged price term is significantly negative (–0.671, $p < 0.01$), confirming strong autoregressive mean-reversion in the short run. In contrast, the Raichur market does not show any significant ECT or short-run coefficients, suggesting that Raichur may function more as a source market exerting influence on others, rather than reacting to price movements in neighbouring markets.

$\Delta P\ Bellary_t = 0.070 \cdot ECT_{t-1} + 0.130 \cdot \Delta Davanagere_{t-1} + 0.305 \cdot \Delta Raichur_{t-1}{}^{**} - 0.039 \cdot \Delta Koppal_{t-1} - 0.367 \cdot \Delta Bellary_{t-1}{}^{***} - 0.099 \cdot \Delta Mysore_{t-1} + \varepsilon_t$

$\Delta P\ Davanagere_t = -0.263 \cdot ECT_{t-1}{}^{**} - 0.137 \cdot \Delta PDavanagere_{t-1} + 0.143 \cdot \Delta PRaichur_{t-1}{}^{*} + 0.068 \cdot \Delta PKoppal_{t-1} + 0.081 \cdot \Delta PBellary_{t-1} + 0.078 \cdot \Delta PMysore_{t-1} + \varepsilon t$

$\Delta P\ Koppal_t = 0.326 \cdot ECT_{t-1} - 0.221 \cdot \Delta PDavanagere_{t-1} + 0.078 \cdot \Delta PRaichur_{t-1} - 0.486 \cdot \Delta PKoppal_{t-1}{}^{**} - 0.072 \cdot \Delta PBellary_{t-1} + 0.090 \cdot \Delta PMysore_{t-1} + \varepsilon t$

$\Delta P\ Mysore_t = 0.542 \cdot ECT_{t-1}{}^{**} + 0.307 \cdot \Delta PDavanagere_{t-1}{}^{*} + 0.211 \cdot \Delta PRaichur_{t-1}{}^{**} - 0.027 \cdot \Delta PKoppal_{t-1} - 0.123 \cdot \Delta PBellary_{t-1} - 0.671 \cdot \Delta PMysore_{t-1}{}^{**} + \varepsilon t$

$\Delta P\ Raichur_t = -0.100 \cdot ECT_{t-1} - 0.152 \cdot \Delta PDavanagere_{t-1} + 0.021 \cdot \Delta PRaichur_{t-1} - 0.001 \cdot \Delta PKoppal_{t-1} + 0.029 \cdot \Delta PBellary_{t-1} - 0.036 \cdot \Delta PMysore_{t-1} + \varepsilon_t$

3.3 Interstate VECM

The existence of three co-integrating relationships, as found through the trace statistics for the combined markets of Kerala and Karnataka, qualifies the suitability of VECM in analysing price behaviour. The inclusion of Kerala markets (Kasaragod and Wayanad) alongside those in Karnataka in the VECM enables cross-state price transmission analysis. Results indicate that short-run transmission from Kerala to Karnataka is limited, but within-state connections like Wayanad → Kasaragod and Davanagere ↔ Mysore are stronger. The Kasaragod–Wayanad linkage is the only significant Kerala–Kerala connection. At the same time, Bellary and Mysore serve as key responsive markets in Karnataka, with Mysore uniquely showing long-run equilibrium correction, reinforcing its systemic importance in regional paddy price discovery.

Notably, Kasaragod responds to Wayanad, but does not significantly influence any Karnataka markets, suggesting limited cross-border spillovers. In contrast, markets in Karnataka, such as Raichur and Mysore, exhibit broader interconnectedness.

$\Delta P\ Bellary_t = -0.015 \cdot ECT_{t-1} - 0.102 \cdot \Delta PKasaragod_{t-1} + 0.196 \cdot \Delta PWayanad_{t-1} + 0.235 \cdot \Delta PDavanagere_{t-1} + 0.225 \cdot \Delta PRaichur_{t-1}{}^{*} - 0.063 \cdot \Delta PKoppal_{t-1} - 0.391 \cdot \Delta PBellary_{t-1}{}^{***} - 0.155 \cdot \Delta PMysore_{t-1} + \varepsilon t$

$\Delta P\ Davanagere_t = 0.014 \cdot ECT_{t-1}{*} + 0.059 \cdot \Delta PKasaragod_{t-1} + 0.052 \cdot \Delta PWayanad_{t-1} - 0.128 \cdot \Delta PDavanagere_{t-1} + 0.111 \cdot \Delta PRaichur_{t-1} + 0.088 \cdot \Delta PKoppal_{t-1}{*} + 0.077 \cdot \Delta PBellary_{t-1} + 0.059 \cdot \Delta PMysore_{t-1} + \varepsilon_t$

$\Delta P\ Koppal_t = -0.017 \cdot ECT_{t-1} - 0.228 \cdot \Delta PKasaragod_{t-1} - 0.069 \cdot \Delta PWayanad_{t-1} - 0.204 \cdot \Delta PDavanagere_{t-1} + 0.256 \cdot \Delta PRaichur_{t-1} - 0.536 \cdot \Delta PKoppal_{t-1}{***} - 0.107 \cdot \Delta PBellary_{t-1} + 0.052 \cdot \Delta PMysore_{t-1} + \varepsilon_t$

$\Delta P\ Mysore_t = -0.037 \cdot ECT_{t-1}{***} + 0.086 \cdot \Delta PKasaragod_{t-1} + 0.152 \cdot \Delta PWayanad_{t-1} + 0.354 \cdot \Delta PDavanagere_{t-1}{*} + 0.177 \cdot \Delta PRaichur_{t-1}{*} + 0.010 \cdot \Delta PKoppal_{t-1} - 0.172 \cdot \Delta PBellary_{t-1}{*} - 0.655 \cdot \Delta PMysore_{t-1}{***} + \varepsilon t$

$\Delta P\ Raichur_t = +0.004 \cdot ECT_{t-1} - 0.092 \cdot \Delta PKasaragod_{t-1} - 0.029 \cdot \Delta PWayanad_{t-1} + 0.010 \cdot \Delta PDavanagere_{t-1} - 0.051 \cdot \Delta PRaichur_{t-1} + 0.026 \cdot \Delta PKoppal_{t-1} - 0.080 \cdot \Delta PBellary_{t-1} - 0.035 \cdot \Delta PMysore_{t-1} + \varepsilon t$

$\Delta P\ Kasaragod_t = 0.002 \cdot ECT_{t-1} - 0.0821 \cdot \Delta PKasaragod_{t-1} + 0.218 \cdot \Delta PWayanad_{t-1}{***} + 0.044 \cdot \Delta PDavanagere_{t-1} + 0.039 \cdot \Delta PRaichur_{t-1} + 0.036 \cdot \Delta PKoppal_{t-1} + 0.034 \cdot \Delta PBellary_{t-1} + 0.004 \cdot \Delta PMysore_{t-1} + \varepsilon_t$

$\Delta P\ Wayanad_t = +0.0026 \cdot ECT_{t-1} + 0.2929 \cdot \Delta PKasaragod_{t-1} + 0.0399 \cdot \Delta PWayanad_{t-1}{*} - 0.1966 \cdot \Delta PDavanagere_{t-1} + 0.0782 \cdot \Delta PRaichur_{t-1} - 0.0084 \cdot \Delta PKoppal_{t-1} + 0.0893 \cdot \Delta PBellary_{t-1} + 0.0123 \cdot \Delta PMysore_{t-1} + \varepsilon t$

3.4 Granger Causality Test

The results of the pair-wise Granger causality test across major paddy markets of Karnataka are presented in (Annexure Table 5). If the null hypothesis is rejected, then the results are significant. Thus, in the Punjab state, only unidirectional causality was found, running from Patiala, Ludhiana, and Firozpur markets to Sangrur market (Figure 1a), whereas Sangrur market did not Granger-cause any other markets. In the case of Karnataka, it has been found that unidirectional causality exists between Davanagere and the other four markets, but not vice versa. And in Kerala (Figure 1c), bidirectional causality between Wayanad and Kasaragod markets is once again confirmed.

A look at the causality relationship between the markets of southern states, specifically Kerala and Karnataka (Figure 1d), reveals the existence of bidirectional causality between Davangere and Wayanad. Additionally, these two markets exhibit unidirectional causality with Raichur, Koppal, Mysore, Bellary, and Kasaragod markets, where the causality flows from Davangere and Wayanad to all these markets.

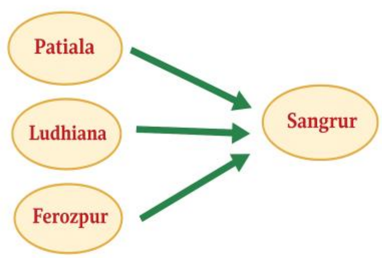

Figure 1(a)

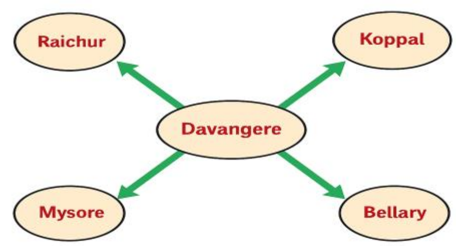

Figure 1(b)

Figure 1(c)

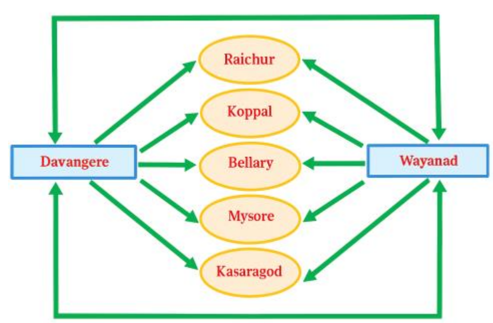

Figure 1(d)

FIGURE 1. GRANGER CAUSALITY PLOTS A. PUNJAB MARKETS. B. KARNATAKA MARKETS C. KERALA MARKETS D. INTERSTATE MARKETS (KARNATAKA- KERALA)

3.5 Impulse Response Function

The results of impulse response functions, given in Figure 2, show how and to what extent a standard deviation shock in one of the paddy markets affects the current as well as future prices in all the integrated important markets of Punjab over a period of ten years. The results reveal that Firozpur emerges as a dominant market, transmitting significant shocks at multiple horizons to all four markets. Self-responses (Firozpur → Firozpur) are mostly significant at early and mid-periods, indicating strong internal price correction dynamics. Thus, Firozpur functions as a regional transmitter with mid- to long-run price influence, especially over Amritsar and Sangrur. The sustained transmission effects from Firozpur to peripheral markets, notably Amritsar and Sangrur, indicate the presence of strong spatial arbitrage relationships and confirm Firozpur's role as a reference market for regional price formation. The Ludhiana market is found to have multiple significant effects on Patiala, Sangrur, and Amritsar. However, the influence is not sustained, and responses often turn insignificant later.

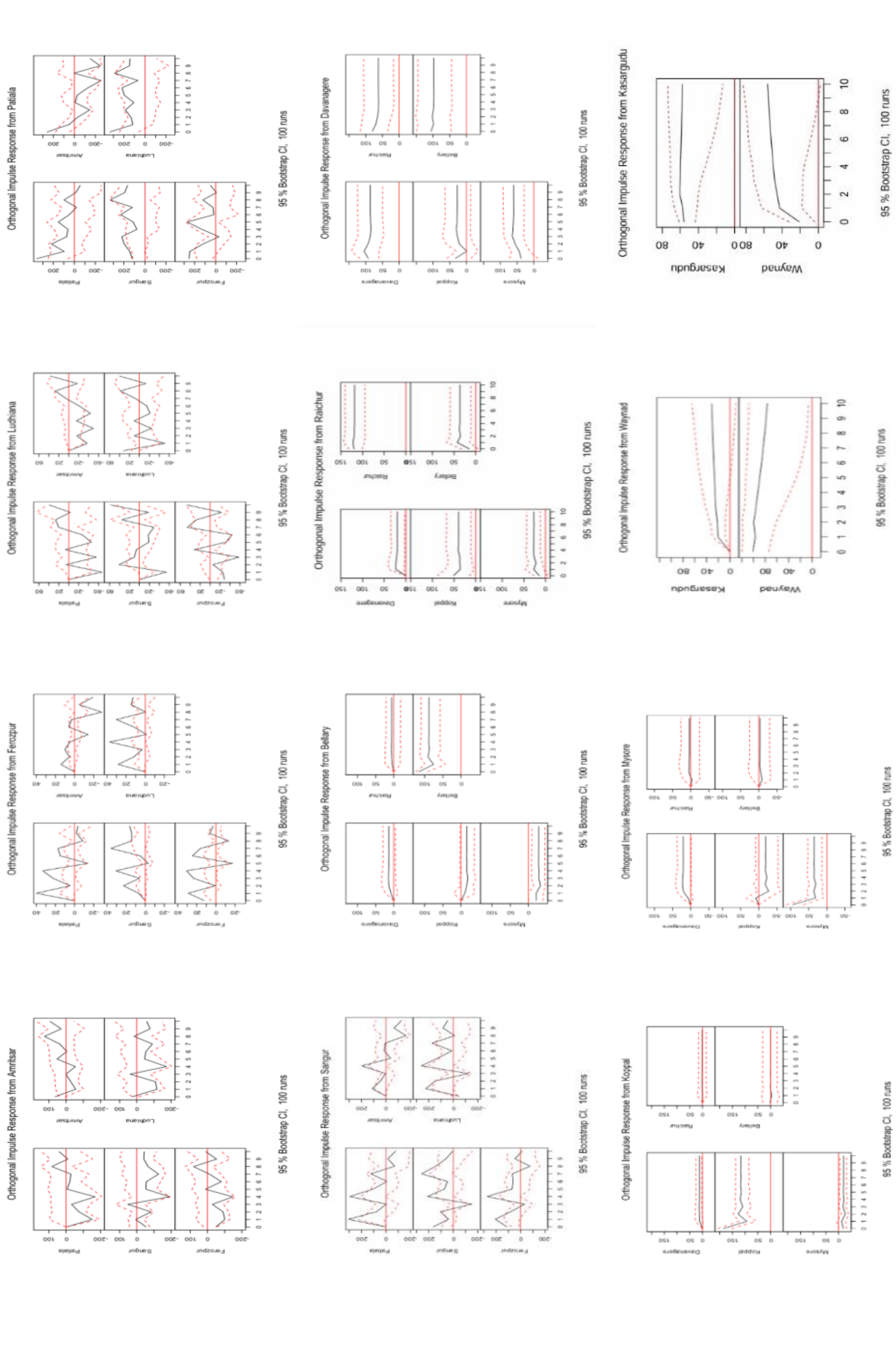

FIGURE 2. ORTHOGONAL IMPULSE RESPONSE FUNCTION FOR MARKETS OF PUNJAB, KARNATAKA AND KERALA

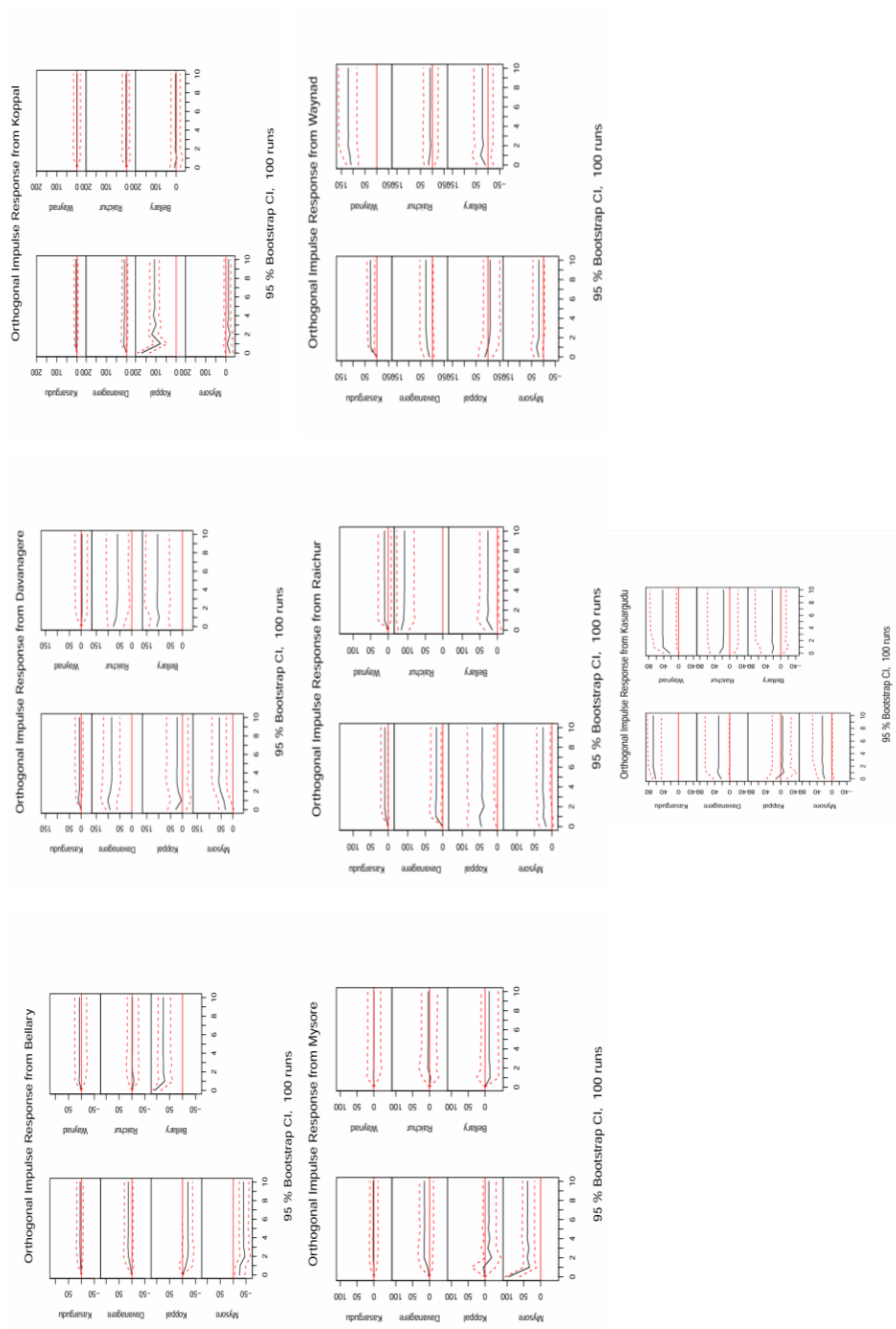

FIGURE 3. ORTHOGONAL IMPULSE RESPONSE FUNCTION FOR MARKETS ACROSS STATES (KARNATAKA AND KERALA)

This pattern suggests that while Ludhiana possesses considerable market power, its influence operates primarily through short-term arbitrage mechanisms rather than sustained structural relationships. Patiala has a widespread, short-term influence on key regional markets. Sangrur demonstrates a unique bidirectional transmission pattern, functioning simultaneously as both a shock recipient and transmitter. It receives early and middle shocks from Patiala, Ludhiana, and Firozpur, and also creates a significant early impact on these markets, confirming it as a moderate short-run influencer. Despite being a large market, Amritsar behaves more like a passive or follower market, absorbing shocks rather than transmitting them, with only initial and isolated effects from the leading markets. These finding challenges conventional assumptions regarding the relationship between market size and price leadership, suggesting that geographic positioning, infrastructure, and institutional factors may be more determinative of market hierarchy than mere volume considerations. Similar analysis for the Karnataka and Kerala markets revealed that, despite some visually positive or negative IRF trajectories, none of the estimated responses were statistically significant at a 95 per cent confidence interval. Observed response in any market may be due to random chance rather than an effect of the shock. A similar outcome was found when the analysis was done for combining the markets of Kerala and Karnataka (Figure 3).

IV

CONCLUSION

The investigation of price behaviour across major markets of Karnataka, Kerala, and Punjab reveals significant inter- and intra-regional heterogeneity in price behaviour, integration, and leadership dynamics. Descriptive statistics indicate that Karnataka markets, especially Davanagere, exhibit a favourable combination of high average prices, moderate volatility, and consistent growth, signifying a mature and relatively efficient market. In contrast, Raichur exhibits strong growth, albeit with high volatility, indicating emerging yet unstable price conditions. Kerala's Wayanad market reports the highest average prices, but with limited predictability due to volatility, while Punjab markets generally display higher price levels with substantial dispersion, particularly in Patiala and Ludhiana. Unit root tests confirmed the presence of I(1) processes in Karnataka and Kerala markets, justifying the application of Johansen's cointegration approach, while the Punjab market series were stationary at the level, allowing VAR estimation. Johansen's test established long-run cointegrating relationships within Karnataka (three vectors) and between Karnataka-Kerala markets (three vectors), whereas Kerala markets alone lacked long-run equilibrium linkages. Punjab's VAR model showed significant short-run interactions, particularly with Firozpur acting as a major influencer, as reflected in both the lag structure and IRFs. Granger causality results underscore the asymmetric nature of price leadership. In Punjab, Sangrur emerged as a price follower, influenced by Patiala, Ludhiana, and Firozpur. In Karnataka, Davanagere exerted unidirectional influence on all other markets, reinforcing its centrality in price dissemination. Kerala's market pair (Wayanad and Kasaragod) demonstrated bidirectional causality, suggesting localised integration. Cross-state analysis revealed a bidirectional causality between Davanagere and Wayanad, suggesting potential for cross-border integration, although limited by geographical and market institutional factors. VECM results further substantiated these relationships by identifying long-run equilibrium adjustments and short-run inter-market influences. Mysore and Davanagere emerged as strong long-run equilibrating markets, while Raichur appeared more as a short-run leader without internal adjustment. Notably, Mysore stood out with strong autoregressive correction and multidirectional short-run integration. Impulse response functions corroborated Firozpur's leadership in Punjab, with persistent effects on Amritsar and Sangrur, highlighting its structural role in regional price formation. Sangrur, despite being influenced by multiple markets, also exerted modest short-run shocks, indicating bidirectional influence. Conversely, Amritsar behaved as a passive market, challenging the notion that size dictates price leadership. The IRFs for Karnataka lacked statistical significance, indicating either the absence of strong shock propagation or limitations due to sample or model specification.

REFERENCES

Acharya, S. S., Chand, R., Birthal, P. S., Kumar, S., & Negi, D. S. (2012). *Market integration and price transmission in India: A case of rice and wheat with special reference to the world food crisis of 2007/08* (pp. 447–456). Food and Agriculture Organization.

Andrle, M., & Blagrave, P. (2020). *Agricultural market integration in India.* International Monetary Fund.

Arunendra, M., & Prasanth, K. R. (2022). Price discovery of agri commodities: An integrated approach. *Finance: Theory and Practice, 26*(3), 226–240.

Athira, H. (2017). *Scenario analysis of rice cultivation in Palakkad district* (Doctoral dissertation, Department of Agricultural Extension, College of Agriculture, Vellayani).

Directorate of Marketing and Inspection. (2025). *Agmarknet: Agricultural Marketing Information Network.* Ministry of Agriculture and Farmers Welfare, Government of India. https://agmarknet.gov.in

Enders, W. (2008). *Applied econometric time series.* John Wiley & Sons.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 55*(2), 251–276.

Food and Agriculture Organization. (2023). *FAOSTAT statistical database.* Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/TCL

Ghafoor, A., Mustafa, K., Mushtaq, K., & Abedulla. (2009). Cointegration and causality: An application to major mango markets in Pakistan. *Lahore Journal of Economics, 14*(1), 85–113.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37*(3), 424–438.

Granger, C. W. (1988). Causality, cointegration, and control. *Journal of Economic Dynamics and Control, 12*(3), 551–559.

Gujarati, D. N. (2010). *Econometrics by example.* Macmillan Publishers.

Hjalmarsson, E., & Österholm, P. (2010). Testing for cointegration using the Johansen methodology when variables are near-integrated. *Empirical Economics, 39*(1), 51–76.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*(6), 1551–1580.

Kamble, R. K., & Tikadar, K. S. (2021). Paddy cultivating marginalised farmers' climate change perceptions, impacts and adaptation strategies in Chandrapur district, Central India. *Research Inspiration, 6*(3), 1–13.

Kaur, P. J., & Sekhon, M. K. (2016). Market integration of food grain in India: The case of the rice market. *Indian Journal of Economics and Development, 12*(1a), 457–462.

Levi, R., Rajan, M., Singhvi, S., & Zheng, Y. (2020). The impact of unifying agricultural wholesale markets on prices and farmers' profitability. *Proceedings of the National Academy of Sciences, 117*(5), 2366–2371.

Lütkepohl, H. (2005). *New introduction to multiple time series analysis.* Springer.

Mohapatra, S., Wen, L., Sharp, B., & Sahoo, D. (2024). Unveiling the spatial dynamics of climate impact on rice yield in India. *Economic Analysis and Policy, 83*, 922–945.

Nuthalapati, C. S. R., Bhatt, Y., & Beero, S. K. (2020). *Electronic National Agricultural Market (e-NAM): A review of performance and prospects* (Working Paper No. 376). Indian Council for Research on International Economic Relations (ICRIER).

Paul, R. K., Saxena, R., Chaurasia, S., & Rana, S. (2015). Examining export volatility, structural breaks in price volatility and linkages between domestic and export prices of onion in India. *Agricultural Economics Research Review, 28*(1), 101–116.

Pavithra, K. N., & Gaddi, G. M. (2022). Price volatility and transmission: A case study of paddy and redgram markets in Karnataka. In *Proceedings of National Seminar on Price Volatility in Agriculture* (pp. 143–152).

Pfaff, B. (2008). VAR, SVAR and SVEC models: Implementation within R package vars. *Journal of Statistical Software, 27*(4), 1–32.

Rahman, M. M., & Shahbaz, M. (2013). Do imports and foreign capital inflows lead economic growth? Cointegration and causality analysis in Pakistan. *South Asia Economic Journal, 14*(1), 59–81.

Sendhil, R., Arora, K., Kumar, S., Lal, P., Roy, A., Varadan, R. J., & Pouchepparadjou, A. (2023). Price dynamics and integration in India's staple food commodities—Evidence from wholesale and retail rice and wheat markets. *Commodities, 2*(1), 52–72.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica, 48*(1), 1–48.

Sukanya, S. D. (2015). *Adequacy of procurement price for paddy farmers in Kerala* (Doctoral dissertation, College of Agriculture, Vellayani).

The Hindu Business Line. (2022, March 31). Punjab farmers got 25 per cent of the total benefits of paddy purchases under MSP scheme in Kharif 2021. https://www.thehindubusinessline.com/economy/agri-business/punjab-farmers-got-25-per-cent-of-the-total-benefits-of-paddy-purchases-under-msp-scheme-in-kharif-2021/article65274129.ece

Timmer, C. P. (2012). Rice price formation in the short run and the long run: The role of market structure in explaining volatility. In *Global uncertainty and the volatility of agricultural commodities prices* (pp. 151–184). IOS Press.

United States Department of Agriculture. (2023). *Grain: World markets and trade – Rice.* Foreign Agricultural Service. https://apps.fas.usda.gov/psdonline/circulars/grain.pdf

Vavra, P., & Goodwin, B. K. (2005). Analysis of price transmission along the food chain. *OECD Food, Agriculture and Fisheries Working Paper No. 3.* OECD Publishing.

APPENDICES

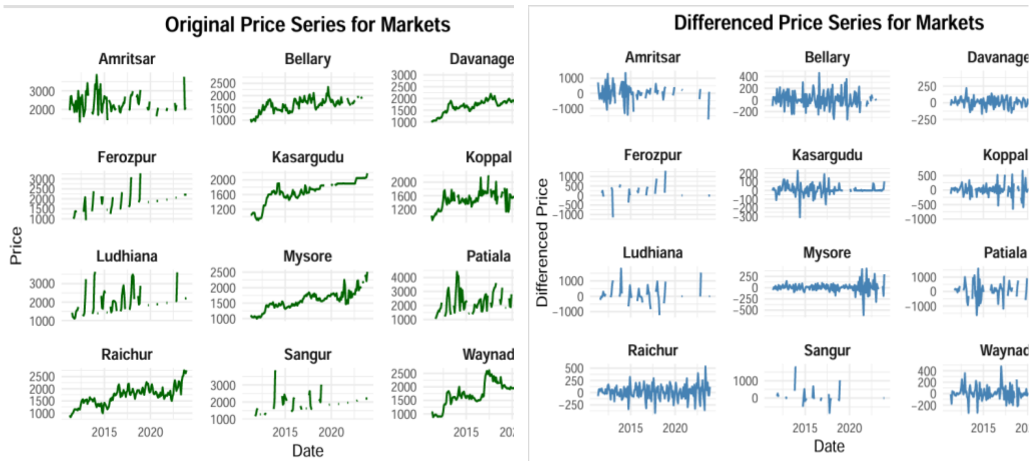

FIGURE 1. STATIONARITY TEST

TABLE 1. SELECTION OF APPROPRIATE LAG FOR VAR MODEL FOR PUNJAB MARKETS

Lag	1	2	3	4	5
AIC	55.14	54.28	53.64	52.03	41.57
SBC	56.52	56.82	57.34	56.89	47.58

TABLE 2. SELECTION OF APPROPRIATE LAG FOR KARNATAKA MARKETS

Lag	0	1	2	3	4	5	6	7	8	9
AIC (n)	48.15	48.32*	48.43	48.64	48.77	48.89	48.89	48.97	49.00	48.64
HQ (n)	48.45	48.86*	49.21	49.66	50.04	50.41	50.65	50.98	51.25	51.14
SC (n)	48.88	49.65*	50.36	51.17	51.91	52.63	53.24	53.92	54.55	54.80
FPE (n)	8.17E+20	9.74E+20*	1.08E+21	1.35E+21	1.58E+21	1.84E+21	1.92E+21	2.19E+21	2.45E+21	1.90E+21

TABLE 3. SELECTION OF APPROPRIATE LAG FOR KERALA MARKETS

Lag	0	1	2	3	4	5	6	7	8	9
AIC (n)	17.48	17.39*	17.33	17.31	17.35	17.39	17.42	17.43	17.45	17.48
HQ (n)	17.53	17.48*	17.46	17.47	17.54	17.62	17.69	17.73	17.78	17.85
SC (n)	17.61	17.61*	17.64	17.70	17.83	17.95	18.07	18.17	18.27	18.39
FPE (n)	39002686	35991751.441*	33718424	32829085	34273096	35633828	36910646	37378757	37851575	39047495

TABLE 4. SELECTION OF APPROPRIATE LAG FOR COMBINED MARKETS OF KERALA AND KARNATAKA

Lag	0	1	2	3	4	5	6	7	8	9
AIC(n)	65.88	66.20*	66.50	66.56	66.64	66.71	66.52	66.56	65.98	64.58
HQ (n)	66.45	67.27*	68.07	68.64	69.22	69.80	70.11	70.65	70.57	69.67
SC (n)	67.29	68.85*	70.39	71.69	73.01	74.32	75.37	76.64	77.30	77.14
FPE(n)	4.08E+28	5.712e+28*	7.91E+28	8.94E+28	1.07E+29	1.34E+29	1.39E+29	2.01E+29	1.79E+29	8.55E+28

TABLE 5. GRANGER CAUSALITY TESTING BETWEEN MAJOR PADDY MARKETS OF KARNATAKA

Null Hypothesis	F-Statistic	Prob.	Decision
Davanagere does not Granger-cause Raichur	2.305	0.020	Reject H_0
Davanagere does not Granger-cause Koppal	2.305	0.020	Reject H_0
Davanagere does not Granger-cause Bellary	2.305	0.020	Reject H_0
Davanagere does not Granger-cause Mysore	2.305	0.020	Reject H_0
Raichur does not Granger-cause Davanagere	1.391	0.197	Accept H_0
Raichur does not Granger-cause Koppal	1.391	0.197	Accept H_0
Raichur does not Granger-cause Bellary	1.391	0.197	Accept H_0
Raichur does not Granger-cause Mysore	1.391	0.197	Accept H_0
Koppal does not Granger-cause Davanagere	1.0405	0.404	Accept H_0
Koppal does not Granger-cause Raichur	1.0405	0.404	Accept H_0
Koppal does not Granger-cause Bellary	1.0405	0.404	Accept H_0
Koppal does not Granger-cause Mysore	1.0405	0.404	Accept H_0
Bellary does not Granger-cause Davanagere	0.6227	0.759	Accept H_0
Bellary does not Granger-cause Raichur	0.6227	0.759	Accept H_0
Bellary does not Granger-cause Koppal	0.6227	0.759	Accept H_0
Bellary does not Granger-cause Mysore	0.6227	0.759	Accept H_0
Mysore does not Granger-cause Davanagere	1.0656	0.386	Accept H_0
Mysore does not Granger-cause Raichur	1.0656	0.386	Accept H_0
Mysore does not Granger-cause Koppal	1.0656	0.386	Accept H_0
Mysore does not Granger-cause Bellary	1.0656	0.386	Accept H_0

TABLE 6. GRANGER CAUSALITY TESTING BETWEEN MAJOR PADDY MARKETS OF KERALA

Null Hypothesis	F-Statistic	Prob.	Decision
Kasaragod does not Granger-cause Wayanad	6.227	0.000	Reject H_0
Wayanad does not Granger-cause Kasaragod	8.321	0.000	Reject H_0

TABLE7. GRANGER CAUSALITY TESTING BETWEEN MAJOR PADDY MARKETS OF PUNJAB

Null Hypothesis	F-Statistic	Prob.	Decision
Patiala does not Granger-cause Amritsar	0.375	0.860	Accept H_0
Amritsar does not Granger-cause Patiala	0.951	0.471	Accept H_0
Patiala does not Granger-cause Sangrur	3.545	0.019	Reject H_0
Sangrur does not Granger-cause Patiala	1.817	0.155	Accept H_0
Patiala does not Granger-cause Ludhiana	2.338	0.080	Accept H_0
Ludhiana does not Granger-cause Patiala	1.926	0.135	Accept H_0
Patiala does not Granger-cause Firozpur	0.623	0.684	Accept H_0
Firozpur does not Granger-cause Patiala	0.244	0.938	Accept H_0
Amritsar does not Granger-cause Sangrur	1.102	0.390	Accept H_0
Sangrur does not Granger-cause Amritsar	1.316	0.297	Accept H_0
Amritsar does not Granger-cause Ludhiana	0.786	0.572	Accept H_0
Ludhiana does not Granger-cause Amritsar	2.162	0.100	Accept H_0

Amritsar does not Granger-cause Firozpur	1.087	0.398	Accept H_0
Firozpur does not Granger-cause Amritsar	1.056	0.413	Accept H_0
Sangrur does not Granger-cause Ludhiana	2.220	0.092	Accept H_0
Ludhiana does not Granger-cause Sangrur	5.818	0.002	Reject H_0
Sangrur does not Granger-cause Firozpur	1.882	0.143	Accept H_0
Firozpur does not Granger-cause Sangrur	3.194	0.028	Reject H_0
Ludhiana does not Granger-cause Firozpur	0.547	0.739	Accept H_0
Firozpur does not Granger-cause Ludhiana	1.649	0.193	Accept H_0

TABLE 8. GRANGER CAUSALITY TESTING BETWEEN MARKETS OF KERALA AND KARNATAKA

Null Hypothesis	F-Statistic	Prob.	Decision
Kasaragod does not Granger-cause Wayanad	1.097	0.360	Accept H_0
Kasaragod does not Granger-cause Davanagere	1.097	0.360	Accept H_0
Kasaragod does not Granger-cause Raichur	1.097	0.360	Accept H_0
Kasaragod does not Granger-cause Koppal	1.097	0.360	Accept H_0
Kasaragod does not Granger-cause Bellary	1.097	0.360	Accept H_0
Kasaragod does not Granger-cause Mysore	1.097	0.360	Accept H_0
Wayanad does not Granger-cause Kasaragod	2.464	0.004	Reject H_0
Wayanad does not Granger-cause Davanagere	2.464	0.004	Reject H_0
Wayanad does not Granger-cause Raichur	2.464	0.004	Reject H_0
Wayanad does not Granger-cause Koppal	2.464	0.004	Reject H_0
Wayanad does not Granger-cause Bellary	2.464	0.004	Reject H_0
Wayanad does not Granger-cause Mysore	2.464	0.004	Reject H_0
Davanagere does not Granger-cause Kasaragod	1.861	0.036	Reject H_0
Davanagere does not Granger-cause Wayanad	1.861	0.036	Reject H_0
Davanagere does not Granger-cause Raichur	1.861	0.036	Reject H_0
Davanagere does not Granger-cause Koppal	1.861	0.036	Reject H_0
Davanagere does not Granger-cause Bellary	1.861	0.036	Reject H_0
Davanagere does not Granger-cause Mysore	1.861	0.036	Reject H_0
Raichur does not Granger-cause Kasaragod	1.215	0.268	Accept H_0
Raichur does not Granger-cause Wayanad	1.215	0.268	Accept H_0
Raichur does not Granger-cause Davanagere	1.215	0.268	Accept H_0
Raichur does not Granger-cause Koppal	1.215	0.268	Accept H_0
Raichur does not Granger-cause Bellary	1.215	0.268	Accept H_0
Raichur does not Granger-cause Mysore	1.215	0.268	Accept H_0
Koppal does not Granger-cause Kasaragod	1.697	0.063	Accept H_0
Koppal does not Granger-cause Wayanad	1.697	0.063	Accept H_0
Koppal does not Granger-cause Davanagere	1.697	0.063	Accept H_0
Koppal does not Granger-cause Raichur	1.697	0.063	Accept H_0
Koppal does not Granger-cause Bellary	1.697	0.063	Accept H_0
Koppal does not Granger-cause Mysore	1.697	0.063	Accept H_0
Bellary does not Granger-cause Kasaragod	0.652	0.797	Accept H_0
Bellary does not Granger-cause Wayanad	0.652	0.797	Accept H_0
Bellary does not Granger-cause Davanagere	0.652	0.797	Accept H_0
Bellary does not Granger-cause Raichur	0.652	0.797	Accept H_0
Bellary does not Granger-cause Koppal	0.652	0.797	Accept H_0
Bellary does not Granger-cause Mysore	0.652	0.797	Accept H_0
Mysore does not Granger-cause Kasaragod	0.713	0.739	Accept H_0
Mysore does not Granger-cause Wayanad	0.713	0.739	Accept H_0
Mysore does not Granger-cause Davanagere	0.713	0.739	Accept H_0
Mysore does not Granger-cause Raichur	0.713	0.739	Accept H_0
Mysore does not Granger-cause Koppal	0.713	0.739	Accept H_0
Mysore does not Granger-cause Bellary	0.713	0.739	Accept H_0