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Seasonality, Volatility, and Market Fragmentation: Evidence from India's Little Millet Mandis

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Abstract:* This article examines the scale, seasonality, volatility, and spatial price integration of little millet (Panicum sumatrense) markets in India using Agricultural Marketing Information Network (AGMARKNET) arrivals and price records. National and subnational market structure is assessed over 2007-2024, while district-level price integration is evaluated for Kabirdham, Chitradurga, and Dharwad over January 2017-December 2024. The analysis combines arrival-weighted prices, seasonal-trend decomposition using LOESS, Parkinson range-based volatility, augmented Dickey-Fuller unit-root tests, and static and rolling Johansen trace tests. Cumulative arrivals are highly concentrated: Karnataka accounts for 48.7 percent, the three leading states account for 90.6 percent, and Hosadurga mandi alone accounts for 34.1 percent. Annual arrivals decline from the high-volume early years before a marked 2024 recovery, whereas nominal prices rise substantially. District series display recurring seasonal components but also large irregular shocks, consistent with discontinuous trading. All price levels are non-stationary and log returns are stationary. The static Johansen statistic for no cointegration is 23.74, below the 5 percent critical value of 34.91, and every rolling-window statistic also remains below its rejection threshold. The evidence therefore identifies a concentrated yet spatially fragmented market in which aggregation at a leading hub has not produced a stable interdistrict price system.
***Keywords:* AGMARKNET, little millet, market integration, market thinness, price volatility, spatial markets.**

I. INTRODUCTION

Little millet (*Panicum sumatrense*), also known regionally as saame in Kannada and kutki in Hindi, is a rainfed cereal adapted to marginal production environments. It contributes to crop and dietary diversity, yet it remains underrepresented in crop-specific research and market statistics [1]. Its nutritional and agronomic attributes have supported renewed policy and consumer interest [1], [2], but production potential alone does not ensure that farmers participate in transparent, liquid, and spatially connected output markets.

Earlier work on small-millet commercialization shows that collective action, processing, and coordinated value-chain development can help transform locally important crops into marketed products [3], [4]. Those studies also imply that commercialization is constrained when aggregation, transport, grading, processing, and market information remain weak. For little millet, however, systematic evidence on mandi arrivals, price volatility, and intermarket price transmission remains scarce. The empirical gap is important because a crop can have geographically dispersed production while trade is concentrated in a small number of reporting markets. In that setting, a high-volume hub need not guarantee effective arbitrage with distant districts.

This article provides a market-level assessment of little millet trade in India. It asks four questions. First, where are recorded arrivals concentrated across states, districts, and mandis? Second, do arrivals and prices show regular seasonal patterns or predominantly episodic movements? Third, how does price volatility differ across leading districts? Fourth, do the selected district prices share a stable long-run equilibrium, either over the full sample or within rolling windows? The contribution is to connect market scale and liquidity with volatility and spatial integration rather than treating price series independently of the physical volume on which they are based.

II. CONCEPTUAL AND INSTITUTIONAL CONTEXT

A. *Thin Markets and Spatial Price Transmission*

Spatial market integration describes the extent to which price signals are transmitted among geographically separated markets after accounting conceptually for transfer costs and trade frictions [5]. When arbitrage is effective, prices may diverge temporarily but retain a common long-run relationship. Cointegration tests are therefore widely used to evaluate whether non-stationary regional prices share such an equilibrium [6]. Failure to find cointegration does not by itself prove market inefficiency: quality differences, changing trade routes, non-overlapping transactions, and threshold transport costs can also prevent continuous co-movement. It nevertheless indicates that shocks in one market are not reliably offset through a stable long-run price relation with the others.

Thinness sharpens these concerns. Low or irregular trading volume reduces the number of transactions from which representative prices can be formed, weakens price discovery, and can magnify the effect of a small number of trades. Developing-country grain markets that are isolated, thin, and weakly integrated may therefore exhibit both price thresholds and elevated volatility [7]. In the present study, thinness is assessed through cumulative arrivals, the number of active mandis, active trading days, discontinuities in the arrival series, and range-based volatility. These indicators are interpreted jointly rather than as interchangeable measures.

B. Market Information and Procurement Setting

The Agricultural Marketing Information Network records market-wise arrivals and minimum, maximum, and modal prices reported by agricultural produce markets across India [8]. It provides an unusually broad source for mapping little millet trade, but it measures activity in reporting mandis rather than total production or all marketing channels. Zero-reporting days, direct transactions, own-consumption, and sales outside covered markets are therefore not observed. The official portal also cautions users that market data are supplied by the respective APMCs or markets [8].

For most of the study period, little millet lacked a uniform crop-specific national procurement floor. A relevant institutional change occurred in Chhattisgarh, where Mission Millet Chhattisgarh was launched in September 2021 and the state cooperative federation was assigned procurement and processing functions for kutki [9]. This setting motivates comparison of Kabirdham with the Karnataka districts, but the present analysis is not a policy-impact design. Any post-2021 change is therefore treated as temporal coincidence rather than a causal procurement effect.

III. DATA AND METHODS

A. Data Scope and Aggregation

The empirical data consist of little millet arrivals and mandi prices from AGMARKNET. The national market profile covers 2007-2024. Cumulative state, district, and mandi rankings use recorded arrivals in metric tons, numbers of active markets, and active trading days. Annual nominal volume-weighted average price (VWAP) is calculated as the sum of transaction price multiplied by arrivals divided by total arrivals for the corresponding aggregation period. Weighting gives greater influence to observations associated with larger reported quantities and limits the effect of isolated low-volume price quotations.

The time-series analysis focuses on Chitradurga and Dharwad in Karnataka and Kabirdham in Chhattisgarh, three leading districts with sufficient monthly price coverage. The comparable integration sample runs from January 2017 to December 2024. Prices are nominal rupees per quintal. This distinction matters: the upward trend should not be read as a real-price or producer-welfare measure without deflation and cost data.

B. Seasonality and Volatility

Monthly arrivals and VWAP are decomposed into trend, seasonal, and remainder components using seasonal-trend decomposition based on LOESS (STL) [10]. STL is useful for market series with changing trends and recurring monthly structure. A large remainder relative to the trend and seasonal components is interpreted as evidence of episodic market activity, although reporting gaps may also contribute.

Price variability is summarized with the Parkinson range estimator, which uses the logarithmic ratio of the observed maximum and minimum prices and extracts more information from the intraperiod range than a close-to-close measure [11]. In this application, the index is used descriptively to compare the timing and magnitude of volatility episodes across districts. Very large values can reflect genuine dispersion, quality heterogeneity, or sparse transactions; they are not interpreted automatically as speculative shocks.

C. Unit Roots and Spatial Integration

The augmented Dickey-Fuller (ADF) procedure tests the null hypothesis of a unit root in each log price level and in its first difference, reported as the log return [12]. Because cointegration inference requires series with a common order of integration, the Johansen trace procedure is applied only after confirming that prices are integrated of order one [13]. The static test evaluates the rank of the three-price system over the full comparable sample.

Parameter stability is assessed with a rolling-window Johansen procedure following the logic of rolling cointegration analysis [14]. For each window, the trace statistic is divided by its 5 percent critical value. A normalized value above one indicates rejection of the corresponding null; a value below one indicates that the null cannot be rejected. The rolling exercise is especially relevant for thin markets because a full-sample estimate can conceal temporary integration or structural change.

IV. RESULTS AND DISCUSSION

A. National Arrivals, Prices, and Market Concentration

Fig. 1 shows a pronounced divergence between annual arrivals and nominal VWAP. Recorded arrivals are highest in several early years, exceeding 15,000 metric tons in 2007, 2009, and 2011. Volumes then weaken and become more uneven, reaching particularly low levels in 2021 and 2023 before rebounding in 2024. Nominal VWAP, by contrast, rises from roughly Rs. 700 per quintal in 2007 to above Rs. 3,500 at its peak, followed by some moderation by 2024. The opposite medium-run movement of quantities and prices is consistent with scarcity, demand growth, inflation, changing quality composition, or a combination of these forces; the descriptive series cannot separately identify them.

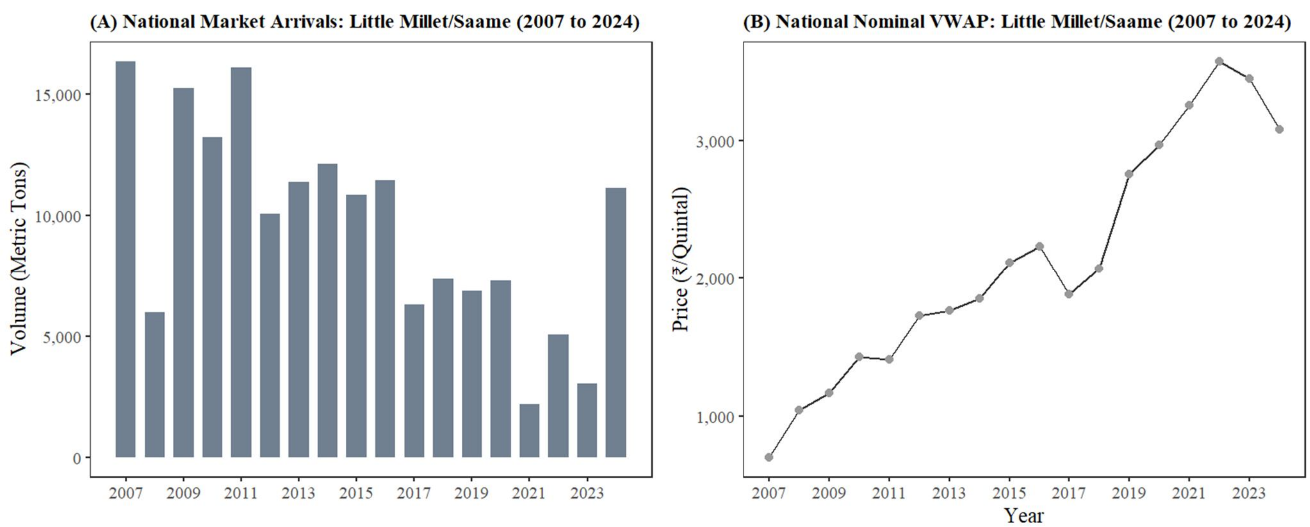


Fig. 1 Annual recorded arrivals and nominal volume-weighted average price for little millet, 2007-2024.

Source: Authors' calculations from AGMARKNET data.

Cumulative recorded arrivals total 173,581 metric tons across the seven states listed in Table I. Karnataka accounts for 48.7 percent, followed by Madhya Pradesh with 27.1 percent and Chhattisgarh with 14.8 percent. The leading three states therefore account for 90.6 percent of all recorded arrivals. Apparent geographic breadth is partly misleading: Gujarat, Punjab, and Haryana each report only one active trading day, so their shares represent isolated bulk transactions rather than continuously operating little millet markets.

TABLE I
STATE-LEVEL CONCENTRATION OF RECORDED LITTLE MILLET ARRIVALS

No.	State	Arrivals (metric tons)	Active mandis	Active trading days	Share (%)
1	Karnataka	84,509	21	3,403	48.7
2	Madhya Pradesh	47,115	23	3,097	27.1
3	Chhattisgarh	25,683	10	1,668	14.8
4	Gujarat	9,867	1	1	5.7
5	Punjab	4,760	1	1	2.7
6	Haryana	1,560	1	1	0.9
7	Uttar Pradesh	87	1	43	0.1

Source: Authors' calculations from AGMARKNET data.

Concentration is sharper at the mandi level (Table II). Hosadurga alone accounts for 59,275 metric tons, or 34.1 percent of total arrivals. The five largest mandis jointly account for 73.7 percent. This pattern identifies Hosadurga as the principal aggregation hub, but it also implies systemic dependence on a small number of nodes. Morbi and Mallanwala each appear with only one active day; they should be treated as episodic transactions rather than durable price-discovery centers.

TABLE II
LEADING APMC MANDIS BY RECORDED LITTLE MILLET ARRIVALS

No.	Market	District	State	Arrivals (metric tons)	Active days	Share (%)
1	Hosadurga	Chitradurga	Karnataka	59,275	1,749	34.1
2	Mandla	Mandla	Madhya Pradesh	22,736	1,222	13.1
3	Pandariya	Kabirdham	Chhattisgarh	19,839	1,110	11.4
4	Bichhiya	Mandla	Madhya Pradesh	14,812	1,098	8.5
5	Huliyar	Tumkur	Karnataka	11,463	607	6.6
6	Morbi	Morbi	Gujarat	9,867	1	5.7
7	Mallanwala	Ferozpur	Punjab	4,760	1	2.7
8	Ranebennur	Haveri	Karnataka	3,893	83	2.2
9	Dharwar	Dharwad	Karnataka	3,456	351	2.0
10	Surajpur	Surajpur	Chhattisgarh	3,185	186	1.8

Source: Authors' calculations from AGMARKNET data.

B. Seasonal Structure and Arrival-Price Divergence

The STL decompositions reveal recurring monthly structure, but market-specific trends and large remainders dominate the economic interpretation. Chitradurga (Fig.2) shows an arrival trend that rises from a low base, strengthens through the late 2010s, softens around 2021-2022, and rises again toward the end of the sample. Its price trend follows a broad cycle rather than a monotonic path: it falls initially, increases to a high level around 2019-2020, and then eases. The seasonal arrival amplitude is modest relative to the largest remainder spikes. Even the dominant hub is therefore not a continuously deep market.

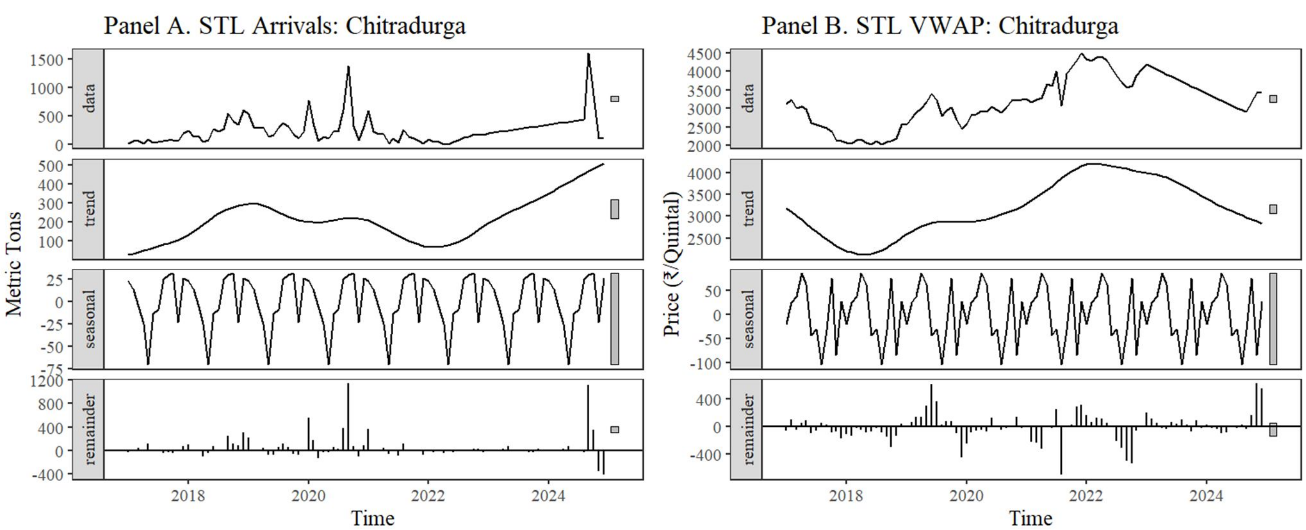


Fig. 2 STL decomposition of recorded arrivals and nominal VWAP in Chitradurga district.
Source: Authors' calculations from AGMARKNET data.

Dharwad is markedly thinner (Fig. 3). Arrivals peak early, including isolated observations above 100 metric tons, and then contract toward a low baseline. The seasonal component remains regular, but its amplitude is small relative to exceptional arrival shocks. Nominal VWAP trends upward over much of the sample and shows substantial remainder volatility from 2022 onward, including deviations approaching Rs. 1,000 per quintal. This combination - low quantities, recurring seasonal structure, and large price residuals - is consistent with fragile price discovery in a discontinuously traded market.

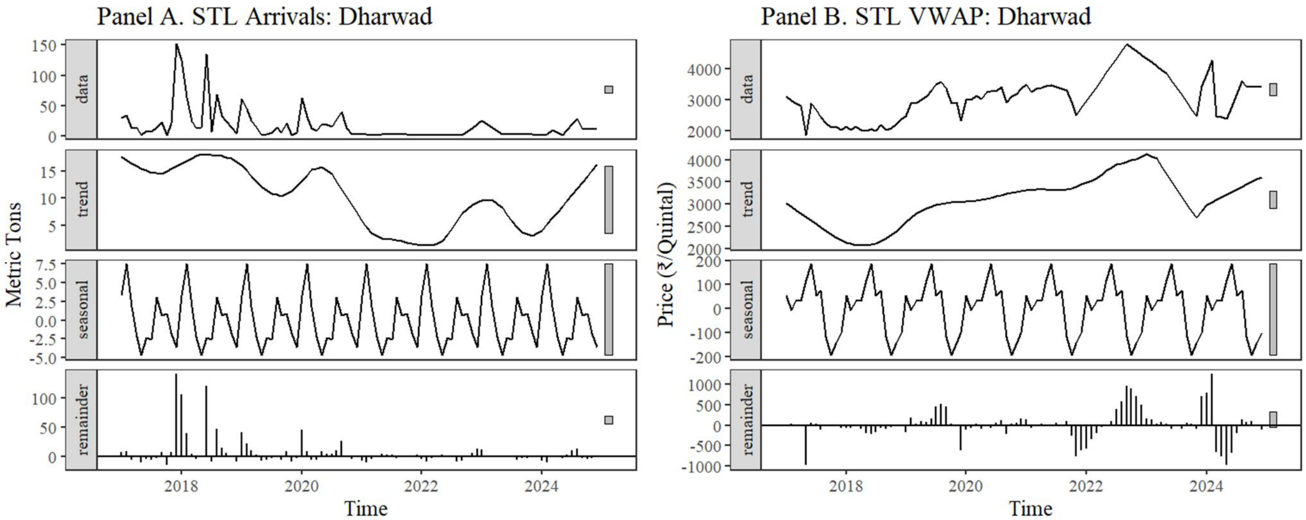


Fig. 3 STL decomposition of recorded arrivals and nominal VWAP in Dharwad district.
Source: Authors' calculations from AGMARKNET data.

Kabirdham differs from both Karnataka districts (Fig. 4). Its arrival trend declines from a high initial level, briefly firms around the middle of the sample, and then returns to a low level. Its price trend rises substantially by the end of the period. The visual evidence does not show a sustained post-2021 increase in the arrival trend. Consequently, the launch of the state mission should not be described as having increased mandi arrivals on the basis of this decomposition alone. A defensible conclusion is narrower: the district retains a visible seasonal pattern, but long-run volume remains weak while nominal prices rise.

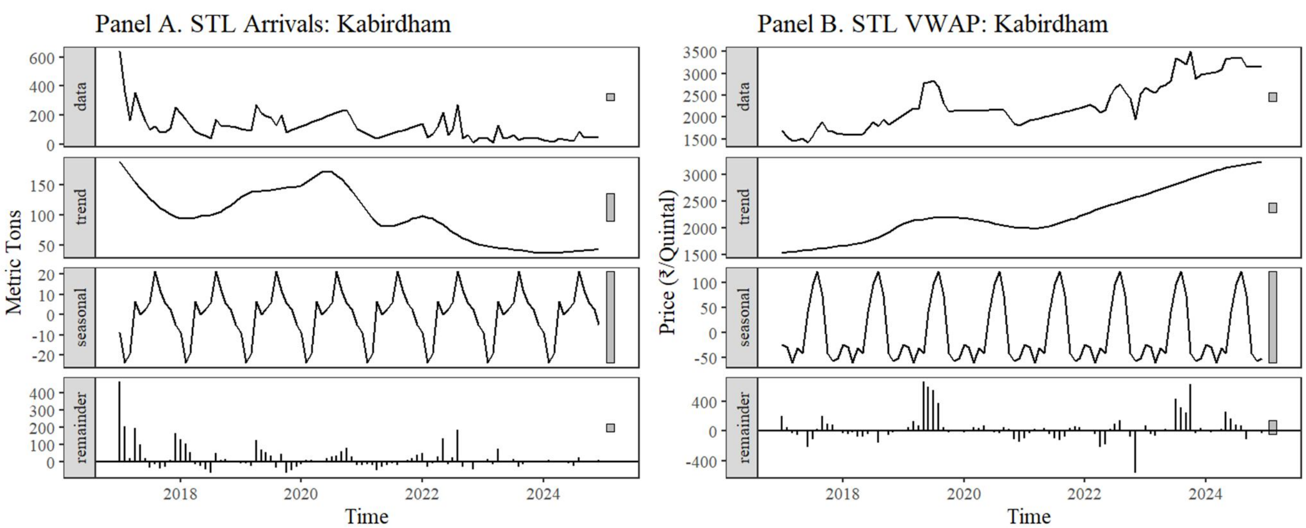


Fig. 4 STL decomposition of recorded arrivals and nominal VWAP in Kabirdham district.
Source: Authors' calculations from AGMARKNET data.

C. Price Volatility and Market Depth

Fig. 5 shows that volatility is episodic rather than uniformly high. Chitradurga records the largest single spike, near 1.4 in 2018, followed by another large episode around 2020. Between spikes, its index returns to a much lower baseline. Dharwad also shows pronounced early spikes and renewed instability near the end of the sample. Kabirdham lacks the extreme peaks of Chitradurga but displays persistent smaller fluctuations and a late rise. Market depth therefore appears to reduce neither all volatility nor all irregularity: the leading hub can absorb routine trade while remaining vulnerable to exceptional price ranges when transactions or grades change abruptly.

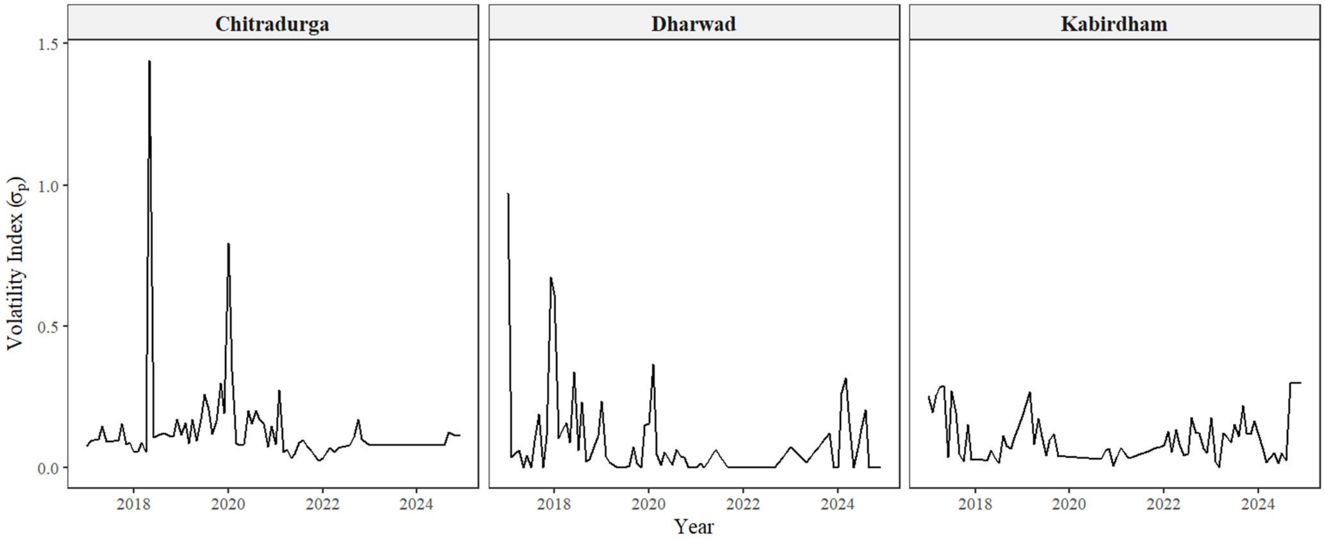


Fig. 5 Parkinson range-based volatility index for selected little millet districts.
Source: Authors' calculations from AGMARKNET data.

A visual moderation of Kabirdham volatility after 2021 is not sufficient to identify a procurement effect. The graph contains no counterfactual, formal break test, or controls for reporting intensity and composition of trade. The policy-relevant interpretation is instead that sustained procurement could potentially improve price discovery if it generates regular volumes, transparent quality standards, and reliable transaction reporting. Procurement that is intermittent or bypasses observable markets may not have the same effect.

D. Static and Time-Varying Spatial Integration

District price levels move upward over the sample, but their turning points and price levels differ substantially (Fig. 6). Chitradurga rises strongly after 2020, Dharwad exhibits large reversals, and Kabirdham generally remains at a lower price level before narrowing part of the gap late in the sample. Common inflation can generate parallel upward trends without establishing spatial arbitrage. Formal inference therefore requires unit-root and cointegration tests.

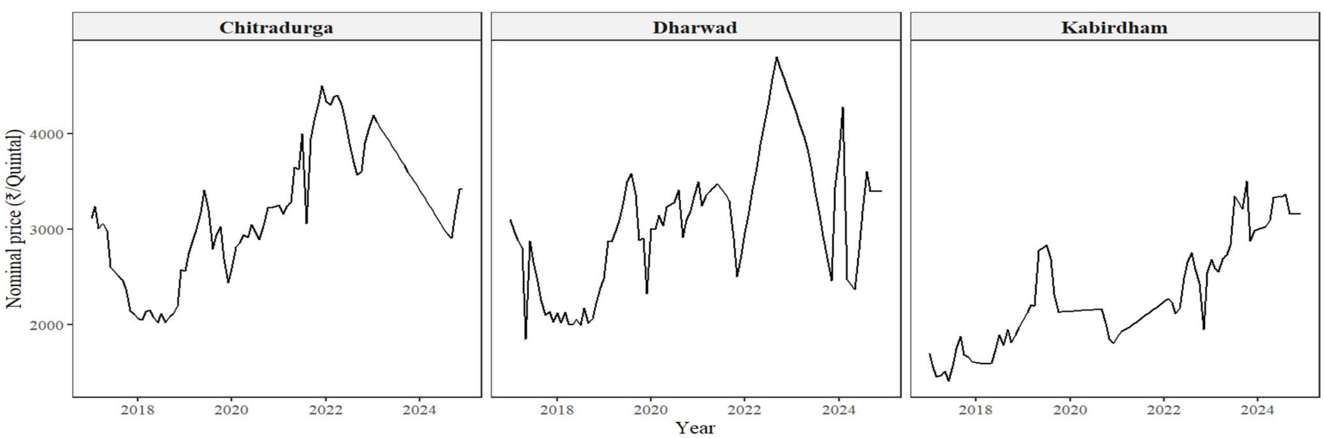


Fig. 6 Evolution of nominal little millet prices in selected districts, January 2017-December 2024.
Source: Authors' calculations from AGMARKNET data.

The ADF results in Table III are internally consistent. At levels, the test statistics range from -2.14 to -2.97 and all p-values exceed 0.20, so the unit-root null cannot be rejected. Log returns are strongly stationary, with test statistics from -7.22 to -10.45 and reported p-values of 0.00. The three series are therefore treated as integrated of order one, supporting application of the Johansen procedure.

TABLE III
AUGMENTED DICKEY-FULLER UNIT-ROOT TEST RESULTS

Series	Level test statistic	Level p-value	Log-return test statistic	Log-return p-value
Kabirdham	-2.97	0.21	-9.87	0.00
Chitradurga	-2.14	0.62	-10.45	0.00
Dharwad	-2.66	0.35	-7.22	0.00

Source: Authors' calculations from AGMARKNET data.

The static Johansen trace test provides no evidence of a common long-run price relation (Table IV). For the null of no cointegration (r = 0), the trace statistic is 23.74, compared with critical values of 32.00, 34.91, and 41.07 at the 10, 5, and 1 percent levels. Because the first rank null is not rejected, the subsequent rank statistics do not alter the central inference: the three prices do not form a statistically significant cointegrated system over the full sample.

TABLE IV
STATIC JOHANSEN TRACE TEST FOR DISTRICT PRICE INTEGRATION

Cointegration rank null	Trace statistic	10% critical value	5% critical value	1% critical value
r = 0	23.74	32.00	34.91	41.07
r <= 1	6.67	17.85	19.96	24.60
r <= 2	1.31	7.52	9.24	12.97

Source: Authors' calculations from AGMARKNET data.

Rolling inference confirms that this full-sample result is not hiding a temporary integrated regime (Fig. 7). The normalized statistic for r = 0 remains between roughly 0.42 and 0.81 and never crosses the 5 percent threshold of one. The statistics for the higher-rank nulls also remain below one. Thus, no rolling window supplies evidence of even one stable cointegrating vector. The most defensible conclusion is not that prices are unrelated in every month, but that observed co-movement never consolidates into a statistically stable long-run system.

The result connects directly to the concentration evidence. Hosadurga can dominate recorded physical trade without transmitting a common price signal to Dharwad and Kabirdham. Possible mechanisms include thin and non-overlapping trading calendars, quality and variety differences, high transfer and search costs, localized processor demand, and transactions outside reporting mandis. The data do not distinguish among these mechanisms, but they clearly reject the assumption that a large cumulative market share is equivalent to national spatial integration.

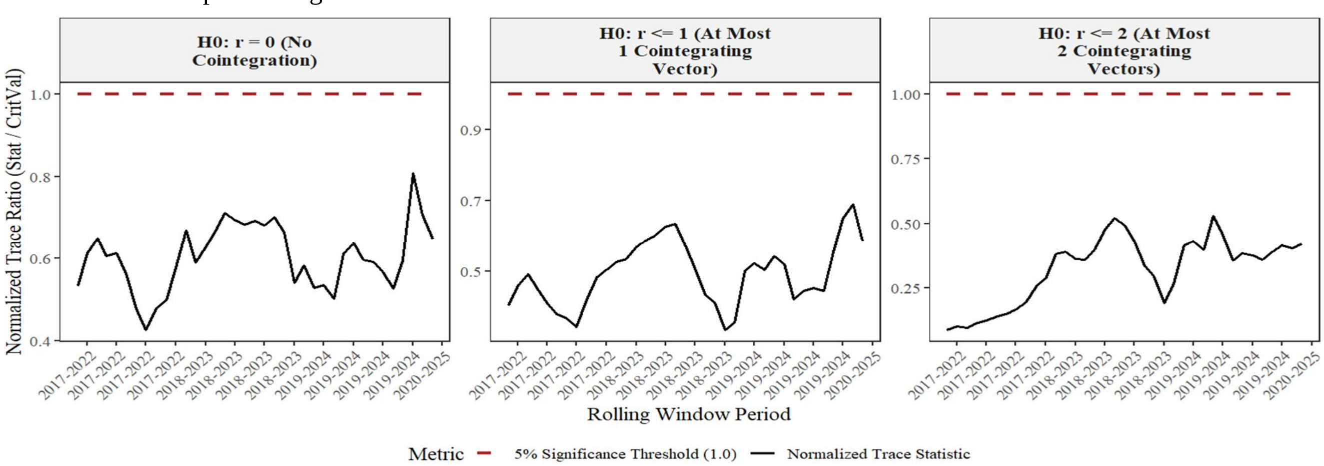


Fig. 7 Normalized rolling-window Johansen trace statistics for dynamic spatial integration. The dashed line at one is the 5 percent rejection threshold.

Source: Authors' calculations from AGMARKNET data.

V. POLICY IMPLICATIONS

The immediate policy priority is to deepen observable trade rather than focus only on headline procurement prices. A market can publish a support price yet remain thin if procurement is irregular, quality standards are unclear, payments are delayed, or transactions are routed outside transparent price-reporting systems. Regular buying schedules, publicly reported quantities and grades, and timely payment would make procurement more useful for both participation and price discovery.

Second, aggregation capacity should be strengthened beyond a single dominant hub. Hosadurga is important because it concentrates supply, but dependence on one mandi also increases vulnerability to local shocks. Producer organizations, collection points, assaying facilities, storage, and transport links in secondary districts could reduce search costs and make trade calendars overlap more consistently. These investments should complement rather than mechanically duplicate the leading hub.

Third, data quality is itself market infrastructure. Commodity naming, variety and grade definitions, units, and zero-arrival days should be standardized across mandis. Reporting systems should distinguish a true absence of trade from missing submission. Because the volatility and integration estimates are sensitive to irregular observations, improved reporting would increase both transparency for market participants and the reliability of policy evaluation.

Finally, policy evaluation should separate nominal price increases from improved farmer outcomes. Rising VWAP alongside falling arrivals may reflect stronger demand, but it may also reflect scarcity, quality composition, or selective reporting. Linking mandi data with procurement quantities, production, grades, farmgate prices, and marketing costs would allow future research to test whether institutional support raises participation, stabilizes prices, and improves producer realization.

VI. CONCLUSIONS

This study finds that India's recorded little millet trade is both concentrated and spatially fragmented. Karnataka supplies nearly half of cumulative AGMARKNET arrivals, the three leading states supply more than 90 percent, and Hosadurga alone contributes more than one third. Yet the district price system does not display a stable long-run relationship. ADF tests establish that prices are integrated of order one, while both static and rolling Johansen tests fail to reject no cointegration.

The descriptive evidence further shows why physical-market structure matters for interpreting prices. Annual arrivals weaken after the early high-volume years before recovering in 2024, while nominal VWAP rises sharply. STL decompositions show recurring seasonal patterns but also large market-specific remainders, and Parkinson indices reveal episodic volatility even in the dominant trading district. Together, these results describe a market in which cumulative volume is concentrated but continuous liquidity and spatial arbitrage remain limited.

The analysis is bounded by the coverage of reporting mandis, nominal prices, and the absence of direct information on trade flows, grades, production, and procurement quantities. These limitations do not weaken the central result; they define its scope. Within the observable mandi system, concentration has not generated a common interdistrict price equilibrium. Deepening transparent, regularly reported trade is therefore essential if growing interest in little millet is to translate into stronger price discovery and more reliable market participation.

REFERENCES

[1] M. Vetriventhan et al., "Genetic and genomic resources, and breeding for accelerating improvement of small millets: Current status and future interventions," The Nucleus, vol. 63, pp. 217-239, 2020, doi: 10.1007/s13237-020-00322-3.

[2] A. Kumar, V. Tomer, A. Kaur, V. Kumar, and K. Gupta, "Millets: A solution to agrarian and nutritional challenges," Agriculture & Food Security, vol. 7, art. no. 31, 2018, doi: 10.1186/s40066-018-0183-3.

[3] G. Gruere, L. Nagarajan, and E. D. I. O. King, "The role of collective action in the marketing of underutilized plant species: Lessons from a case study on minor millets in South India," Food Policy, vol. 34, no. 1, pp. 39-45, 2009, doi: 10.1016/j.foodpol.2008.10.006.

[4] A. Adekunle, D. Lyew, V. Orsat, and V. Raghavan, "Helping agribusinesses-small millets value chain-to grow in India," Agriculture, vol. 8, no. 3, art. no. 44, 2018, doi: 10.3390/agriculture8030044.

[5] P. L. Fackler and B. K. Goodwin, "Spatial price analysis," in Handbook of Agricultural Economics, vol. 1, B. L. Gardner and G. C. Rausser, Eds. Amsterdam, The Netherlands: Elsevier, 2001, pp. 971-1024.

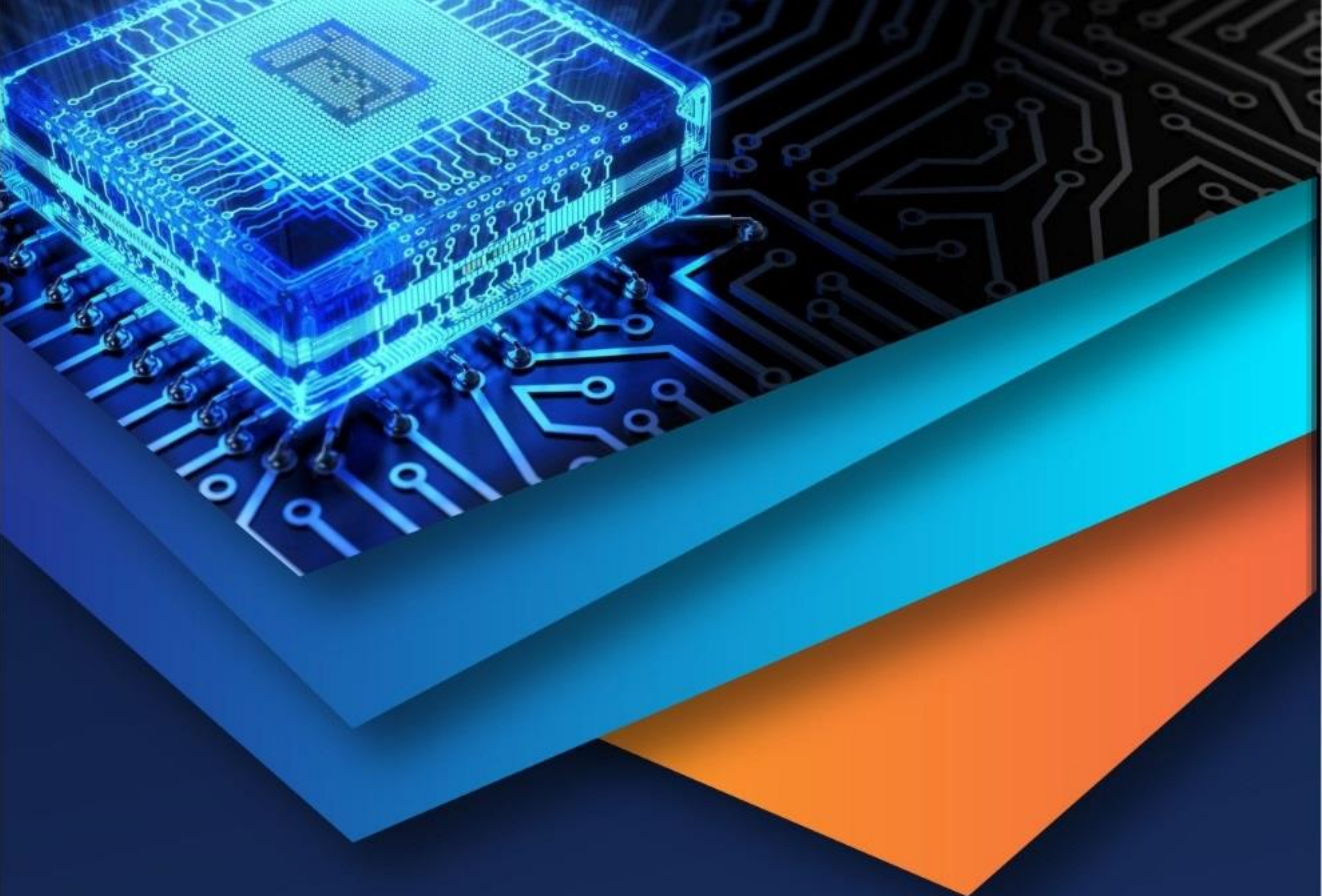
[6] B. K. Goodwin and T. C. Schroeder, "Cointegration tests and spatial price linkages in regional cattle markets," American Journal of Agricultural Economics, vol. 73, no. 2, pp. 452-464, 1991, doi: 10.2307/1242730.

[7] G. E. Shively, "Price thresholds, price volatility, and the private costs of investment in a developing country grain market," Economic Modelling, vol. 18, no. 3, pp. 399-414, 2001.

[8] Directorate of Marketing and Inspection, Government of India, "AGMARKNET 2.0: Agricultural market price and arrival information." [Online]. Available: https://agmarknet.gov.in/. Accessed: Aug. 16, 2026.

[9] Chhattisgarh State Minor Forest Produce (Trading and Development) Cooperative Federation Ltd., "Mission Millet Chhattisgarh: Procurement, processing, packaging, and distribution tender notice," Raipur, India, 2024. [Online]. Available: https://www.cgmfpfed.org/.

[10] R. B. Cleveland, W. S. Cleveland, J. E. McRae, and I. Terpenning, "STL: A seasonal-trend decomposition procedure based on LOESS," Journal of Official Statistics, vol. 6, no. 1, pp. 3-73, 1990.
[11] M. Parkinson, "The extreme value method for estimating the variance of the rate of return," Journal of Business, vol. 53, no. 1, pp. 61-65, 1980.
[12] D. A. Dickey and W. A. Fuller, "Distribution of the estimators for autoregressive time series with a unit root," Journal of the American Statistical Association, vol. 74, no. 366a, pp. 427-431, 1979, doi: 10.1080/01621459.1979.10482531.
[13] S. Johansen, "Statistical analysis of cointegration vectors," Journal of Economic Dynamics and Control, vol. 12, nos. 2-3, pp. 231-254, 1988, doi: 10.1016/0165-1889(88)90041-3.
[14] N. Mylonidis and C. Kollias, "Dynamic European stock market convergence: Evidence from rolling cointegration analysis in the first euro-decade," Journal of Banking & Finance, vol. 34, no. 9, pp. 2056-2064, 2010, doi: 10.1016/j.jbankfin.2010.01.012.



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