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A Tribal Crop and a Market Commodity: An Analysis of Kodo Millet Wholesale Markets in India

Prasanna Surathkal[1], B.H. Nagoor[2]
[1]*Research Scholar,* [2]*Seniour Professor, Department of Economics, Karnatak University, Dharwad, India*

Abstract: ***Kodo millet, Paspalum scrobiculatum (L), is one of the least commercially visible minor millets in India, yet its formal market presence has increased sharply in recent years. Using AGMARKNET arrivals and mandi price data for 2007-2024, this article examines the geography, liquidity, seasonality, volatility, and spatial integration of kodo millet markets. The data analysis shows that kodo millet is not a broad national market. Its recorded APMC trade is concentrated overwhelmingly in Madhya Pradesh and Chhattisgarh, which together account for more than 95 percent of arrivals. The main trading belt lies in tribal and highland districts such as Dindori, Kabirdham, Mandla, Singroli, Katni, Dantewada, and Surguja. Recorded arrivals expanded sharply after 2017, suggesting greater formalization and visibility in regulated markets rather than the emergence of a fully mature commercial market. Seasonality is irregular and district-specific; arrivals occur in episodic bursts rather than smooth marketing cycles. Prices show a more systematic upward trend, but volatility is market-specific and influenced by thin trading, quality variation, and reporting practices. ADF tests broadly support cointegration analysis, while Johansen results indicate one cointegrating relation among six district price series at the 5 percent level. Rolling-window tests show that higher-order integration is unstable. Overall, kodo millet markets are partially integrated, but substantial district-level independence remains. The discussion highlights that tribal geography, infrastructure deficits, affected-area conditions, and Aspirational District development priorities are central to interpreting this market system.***

Keywords: AGMARKNET, kodo millet, minor millets, market arrivals, spatial market integration, Johansen cointegration, price volatility, tribal markets, Aspirational Districts.

I. INTRODUCTION

Millets have returned to policy and research debates in India because they combine agronomic resilience, nutritional value, and relevance for dryland farming systems. Minor millets remain less well understood from a market perspective even though they are embedded in local food systems and livelihood strategies in several tribal and rainfed regions. Kodo millet, locally known as haaraka in parts of Karnataka and by other regional names across central India, is an especially important case because it occupies the boundary between subsistence cultivation, local trade, and emerging policy recognition.

This article analyzes kodo millet markets using AGMARKNET data on arrivals and prices in regulated agricultural markets. The empirical focus is not only on prices but also on the scale and geography of arrivals. This distinction matters because price data alone can give a misleading impression of market development. A price series may show upward movement or some degree of co-movement across districts, but the underlying market can still be thin, episodic, and institutionally fragile. For minor millets, the amount of produce actually arriving in formal markets is therefore a central indicator of liquidity and market depth [1].

Kodo millet differs sharply from better-established cereals. Until recently, it did not have an independently determined central minimum support price. However, the situation is changing. From 2023, the Government of India introduced a temporary reference-price procurement arrangement for kodo millet for a three-year period. Before this, Chhattisgarh was the only state identified in the results as having a state-level procurement price for kodo millet. This institutional history makes kodo millet a useful test case for studying how thin markets function before the emergence of strong price-support architecture.

The central argument of the article is that kodo millet markets have become more visible in formal market channels, but this visibility has not yet produced deep and stable spatial integration. Recorded arrivals increased sharply after 2017, and prices moved upward across the selected districts. However, the market remains geographically concentrated in Madhya Pradesh and Chhattisgarh, seasonality is irregular, volatility is highly local, and cointegration evidence points to partial rather than complete integration. Kodo millet therefore represents a market in transition: more visible than before, but still constrained by thin trade, tribal geography, and weak market infrastructure.

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II. CONCEPTUAL BACKGROUND

Spatial market integration refers to the extent to which prices in geographically separated markets are connected through trade, arbitrage, and information flows. In an integrated system, price shocks in one location are transmitted to other locations, and deviations from long-run equilibrium generate corrective responses. The Law of One Price provides the basic intuition, but agricultural markets rarely satisfy its strict form because transport costs, storage costs, quality differences, market power, and policy interventions can sustain price gaps even when markets are linked [2].

For minor millet markets, institutional and transaction-cost perspectives are particularly relevant. Markets located in remote tribal regions face higher costs of search, transport, aggregation, quality verification, and contract enforcement. Weak road networks, limited warehousing, low buyer density, and poor information systems can all reduce trader participation and slow arbitrage. New Institutional Economics therefore helps interpret market integration as a function of rules, incentives, and transaction costs rather than as a purely statistical relationship among prices [3].

Smallholder market participation is also central to the kodo millet case. Where crops are partly retained for household use, locally exchanged, or sold through informal channels, regulated-market arrivals may represent only a portion of total production. High or rising APMC arrivals can therefore indicate increasing commercialization or market formalization, but low arrivals do not necessarily imply low production. This distinction is important in tribal food systems, where crops may have livelihood and subsistence functions that are not fully captured in formal market data [4].

Three empirical expectations follow from this framework. First, arrivals should be highly concentrated because formal trade is likely to emerge first in a few market nodes. Second, arrivals should be irregular because thin markets respond strongly to localized harvests, procurement windows, and trader participation. Third, price integration may exist among selected major districts, but it is unlikely to be complete or stable across all markets because transaction costs and local institutional conditions remain heterogeneous.

A. Relationship to Existing Literature

The empirical literature on Indian agricultural market integration has historically focused on major cereals, pulses, oilseeds, and vegetables. These studies have demonstrated that market integration is rarely uniform: major producing and consuming centers often move together in the long run, while short-run deviations persist because of transaction costs, procurement operations, quality differences, and regional policy interventions. Kodo millet adds a different kind of evidence to this literature because it is not a large procurement-backed commodity, and its formal market presence is concentrated in relatively remote tribal districts.

The millet-specific literature is narrower. Existing work on millets has often focused on production, nutrition, marketing margins, consumer acceptance, or crop promotion rather than the spatial structure of arrivals and prices. Kodo millet remains marginal in the formal marketing system and therefore allows the analysis to ask whether market integration can emerge when traded volume is small, the commodity is closely tied to tribal livelihood systems, and the institutional base is still developing.

A further gap concerns the role of arrivals. Many price studies treat markets as comparable once price data are available, but this isproblematic for thin commodities. A price in a market with one or two sporadic transactions is not equivalent to a price in a market with continuous arrivals, multiple buyers, and active competition. Arrival quantities and active trading days therefore provide information on market liquidity, commercial relevance, and the reliability of the price signal. This is central to the kodo millet case, where formal prices are observed in markets that differ sharply in trade volume and reporting continuity.

The article therefore contributes by connecting three strands of analysis that are often treated separately: the geography of arrivals, the behavior of reported prices, and the econometric evidence on spatial integration. It asks not simply whether kodo millet prices are cointegrated, but what kind of market system could generate the observed result. The answer is a partial and geographically localized integration process, in which some common price movement exists but is constrained by thin arrivals, irregular seasonality, and uneven district-level market development.

III. DATA AND METHODS

The dataset covers daily reported arrivals and prices from regulated agricultural markets and is aggregated for descriptive and econometric analysis. Annual arrivals and volume-weighted average prices are used to describe national trends, while state, district, and mandi-level arrival summaries identify the geography of formal trade. The empirical period for annual arrivals and VWAP is 2007-2024, while the spatial integration analysis uses district price series from 2017 to 2024 because reliable price data for kodo millet become more consistent only in the later period.

The analysis proceeds in five stages. First, annual arrivals and volume-weighted average prices (VWAP) are examined to identify broad changes in formal-market activity. Second, arrivals at the state, district, and mandi levels are analyzed to assess market concentration and liquidity. Third, the seasonal and trend decomposition using the LOWESS (STL) decomposition method is applied to arrival and price series for selected districts in Chhattisgarh, separating trend, seasonal, and irregular components. This method is especially appropriate for noisy agricultural time series because it allows trend and seasonal movements to be interpreted independently [5]. Fourth, Parkinson volatility is calculated using the reported maximum-minimum price range to measure intra-period price dispersion [6].

Fifth, spatial market integration is investigated through unit-root and cointegration methods. The ADF test is used to examine whether price series are nonstationary in levels but stationary after first differencing [7]. Once this condition is broadly confirmed, Johansen trace tests are employed to identify the number of cointegrating relationships among district-level price series [8], [9]. Rolling-window Johansen tests are then used to determine whether the degree and strength of market integration change over time, since a static full-sample analysis may conceal evolving relationships among markets [10].

The results should be interpreted with caution. AGMARKNET captures regulated-market reporting, not all trade. In kodo millet, this limitation is especially relevant because informal sales, localized exchange, and household use may remain important. In addition, the high-low price range may reflect quality differences, lot composition, and reporting practices as well as genuine price uncertainty. The analysis therefore treats volatility as reported price dispersion rather than as a pure measure of risk.

The descriptive tables are interpreted as indicators of formal market liquidity rather than as complete measures of production. Total arrivals identify where recorded marketed surplus reaches regulated markets, active mandis indicate the geographical spread of reporting, and active trading days capture the regularity of trade. A market with a high cumulative arrival volume but very few active trading days may represent a large episodic transaction rather than a deep market. Conversely, a market with modest arrivals but many active trading days may play a more reliable price-discovery role.

The econometric analysis uses nominal prices because spatial arbitrage is based on observed transaction prices and nominal transfer costs. For a thin minor millet, deflating prices is useful for understanding purchasing power over time, but integration among markets depends on whether traders, farmers, and buyers respond to contemporaneous nominal price differences. The use of logs also allows the analysis to focus on proportional price movement rather than absolute rupee differences across markets.

IV. RESULTS AND DISCUSSION

A. *Overall Arrivals and Price Trends*

The annual summary of the data in Figure 1 indicates a small formal market base. Recorded APMC arrivals are very low in the early years, then rise sharply after 2017. The data analysis shows that this increase may reflect rising demand, improved reporting, market formalization, state-level millet promotion, and procurement-linked initiatives. It does not necessarily imply that production itself increased by the same magnitude.

The price series in Fig 1 also shows an upward movement. VWAP rises over the sample period, although the path is less smooth than would be expected in a more deeply institutionalized commodity market. This is consistent with a thin market in which price formation is episodic and vulnerable to local shocks. For most of the sample period, the VWAP series is the principal indicator of realized market prices rather than a price series operating around a well-established support price.

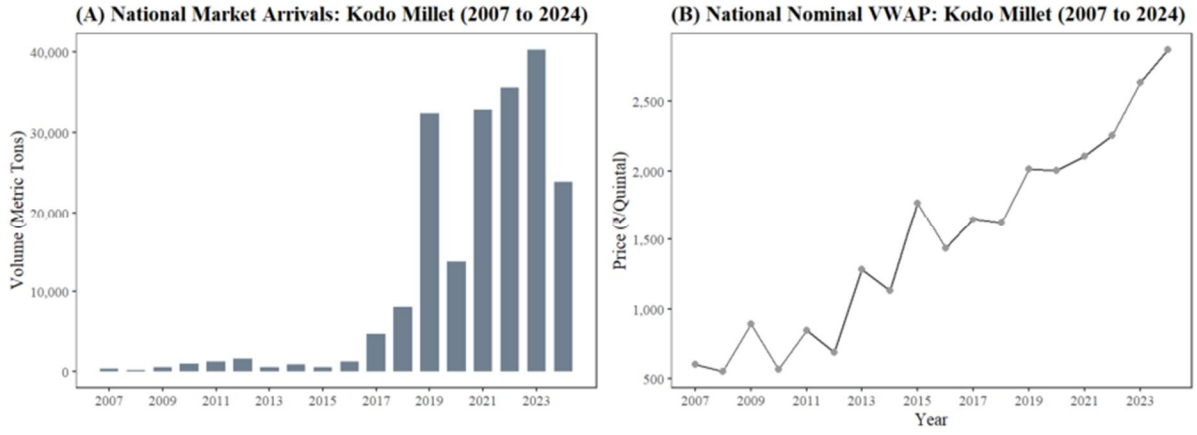

Fig. 1. Annual total arrivals and volume-weighted average price for kodo millet, 2007-2024.

The policy context changed near the end of the sample. From 2023 the central government permitted procurement of kodo millet for a three-year period under a reference-price arrangement, while Chhattisgarh had already introduced a state-level price for kodo millet. These are important institutional developments, but their effects cannot be isolated causally within the descriptive evidence. The observed rise in arrivals and prices is likely the result of multiple forces: demand, awareness, market reporting, procurement initiatives, and general agricultural price inflation.

A key interpretive issue is whether the post-2017 increase reflects commercialization or measurement. The data indicate that Madhya Pradesh reports almost no kodo millet arrivals before 2017 except one early observation, even though the state has historically been a major production region. This suggests that the rise in recorded arrivals may partly reflect market digitization, more formal reporting of minor millets, and the incorporation of previously informal trade into regulated systems. The sharp increase should therefore be read as formal-market visibility rather than as a simple production boom.

This distinction matters for policy evaluation. If recorded arrivals increase because reporting improves, it is a positive administrative achievement, but not necessarily proof that farmers are receiving better prices or that trade has become more competitive. If arrivals increase because actual marketed surplus is expanding, then it may indicate stronger demand and greater commercialization. In practice, both forces may be operating. Kodo millet therefore requires mixed evidence: market data, procurement records, production statistics, and field-level information on how producers choose between home consumption, local sale, and mandi transactions.

B. Geographical Concentration and Market Liquidity

The state-level distribution of arrivals (Table I) confirms that kodo millet is concentrated in the formal market of Central India. Madhya Pradesh accounts for 123,922 metric tons, or 60.2 percent of total arrivals, across 40 active mandis and 6,431 active trading days. Chhattisgarh accounts for 72,101 metric tons, or 35.0 percent, across 36 mandis and 5,251 active trading days. Together, these two states contribute 95.2 percent of recorded national APMC arrivals. Tamil Nadu is a distant third with 9,632 metric tons and a 4.7 percent share, while Pondicherry and Uttar Pradesh are negligible.

This geography is more than a statistical pattern. It shows that formal kodo millet trade is rooted in the central Indian highland and tribal belt. The districts and mandis that dominate the data are not the large metropolitan or commercially dense grain markets that appear in major cereal studies. They are often located in areas where road connectivity, aggregation infrastructure, warehousing, and market information systems are weaker. The result is a market that is not merely small but institutionally different from more mature cereal markets.

TABLE I. State-Level Concentration Of Kodo Millet Arrivals In Agmarknet Markets

State	Arr. (mt)	Mandis	Days	Share (%)
Madhya Pradesh	123,922	40	6,431	60.2
Chhattisgarh	72,101	36	5,251	35.0
Tamil Nadu	9,632	20	3,037	4.7
Pondicherry	63	1	30	0.03
Uttar Pradesh	22	1	23	0.01

The district-level evidence (Table II) sharpens this interpretation. Dindori in Madhya Pradesh leads with 25,395 metric tons and a 12.3 percent share, followed by Kabirdham in Chhattisgarh with 23,520 metric tons and an 11.4 percent share. Mandla, Singroli, Katni, Umariya, Shehdol, Sidhi, Dantewada, and Surguja complete the top ten. All ten leading districts are in Madhya Pradesh or Chhattisgarh, confirming that the kodo millet market is not nationally dispersed but regionally anchored.

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Table II. Leading Kodo Millet Districts By Arrival Share

District (State)	Arr. (mt)	Days	Share (%)
Dindori (MP)	25,395	1,137	12.3
Kabirdham (CG)	23,520	350	11.4
Mandla (MP)	16,971	1,324	8.3
Singroli (MP)	15,167	615	7.4
Katni (MP)	12,467	279	6.1
Umariya (MP)	9,950	577	4.8
Shehdol (MP)	9,423	718	4.6
Sidhi (MP)	7,572	412	3.7
Dantewada (CG)	7,449	160	3.6
Surguja (CG)	7,197	356	3.5

As shown in Table III, the market is more polycentric at the mandi level than the state-level. Shahpura in Dindori district leads with 19,912 metric tons and a 9.7 percent share, followed by Kawardha in Kabirdham district with 19,185 metric tons and a 9.3 percent share. No single mandi exceeds 10 percent of total arrivals. This differs from markets in which one dominant urban or wholesale hub controls a much larger share. Kodo millet trade is geographically narrow but internally dispersed across multiple tribal and highland mandis.

Table III. Leading Apmc Mandis In Kodo Millet Arrivals

Mandi (District)	Arr. (mt)	Share (%)
Shahpura (Dindori)	19,912	9.7
Kawardha (Kabirdham)	19,185	9.3
Singroli (Singroli)	15,167	7.4
Katni (Katni)	12,467	6.1
Umariya (Umariya)	9,950	4.8
Bichhiya (Mandla)	9,466	4.6
Sidhi (Sidhi)	7,572	3.7
Gidam (Dantewada)	7,449	3.6
Mandla (Mandla)	6,700	3.3
Amarwda (Chhindwara)	5,404	2.6

This polycentric structure has policy implications. Improving only one market yard may not be sufficient. Because arrivals are distributed across several district nodes, market development would require a network approach: aggregation centers, grading facilities, local storage, farmer producer organizations, and transport links connecting villages to nearby mandis. The importance of Dindori and Shahpura is also notable because they indicate the emergence of a central Indian minor-millet aggregation zone rather than a single dominant urban hub.

The concentration in Madhya Pradesh and Chhattisgarh also means that national averages are not very informative. A national VWAP or national arrival total may obscure the fact that the effective market is built around a small set of contiguous or near-contiguous districts. For this reason, state, district, and mandi tables are not simply descriptive appendices; they are the foundation for identifying which price series are meaningful for spatial integration analysis.

The presence of Aspirational Districts and Left Wing Extremism-affected districts in the kodo millet trading geography raises an important institutional point. Market integration in such areas is not only a question of price information or trader behavior. It is also affected by road connectivity, security conditions, public procurement capacity, storage, and the ability of farmers to aggregate small quantities. These conditions increase the transaction-cost band within which price differences can persist without triggering arbitrage. Partial integration is therefore not surprising; it is consistent with the underlying institutional geography.

C. Seasonality and Market Calendars

The seasonality analysis focuses on Bemetara (Fig 2), Balrampur (Fig 3), and Surguja (Fig 4) in Chhattisgarh. The choice is institutionally meaningful because Chhattisgarh is identified as the only state with an operational state-level MSP and procurement system for kodo millet. The STL decomposition therefore captures the interaction between market behavior and a limited procurement intervention. Unlike an established procurement system that shapes trade continuously, the Chhattisgarh system appears to operate through more specific procurement windows and localized market events.

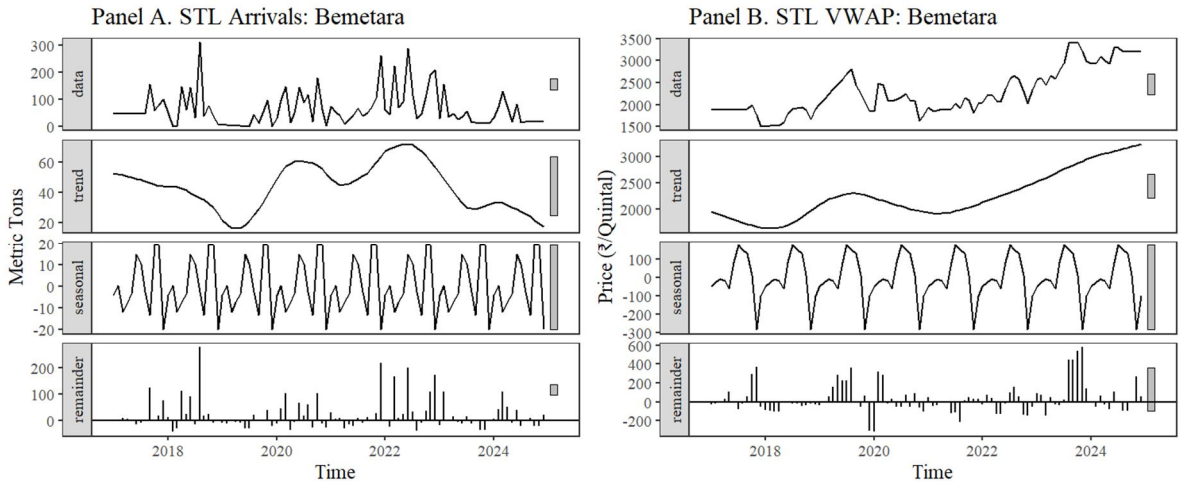

Fig 2. STL decomposition of the arrival quantities and prices of Kodo millet in BENETARA district of Chhattisgarh.

Across the three districts, arrivals are irregular and lack a consistent directional trend. Bemetara, Balrampur, and Surguja show episodic surges and declines rather than smooth seasonal cycles. The seasonal component is detectable, which is expected for a kharif crop harvested mainly in the later part of the year, but the remainder component is large. This indicates that idiosyncratic market participation, procurement episodes, localized weather events, and reporting irregularities matter more than predictable seasonal forces.

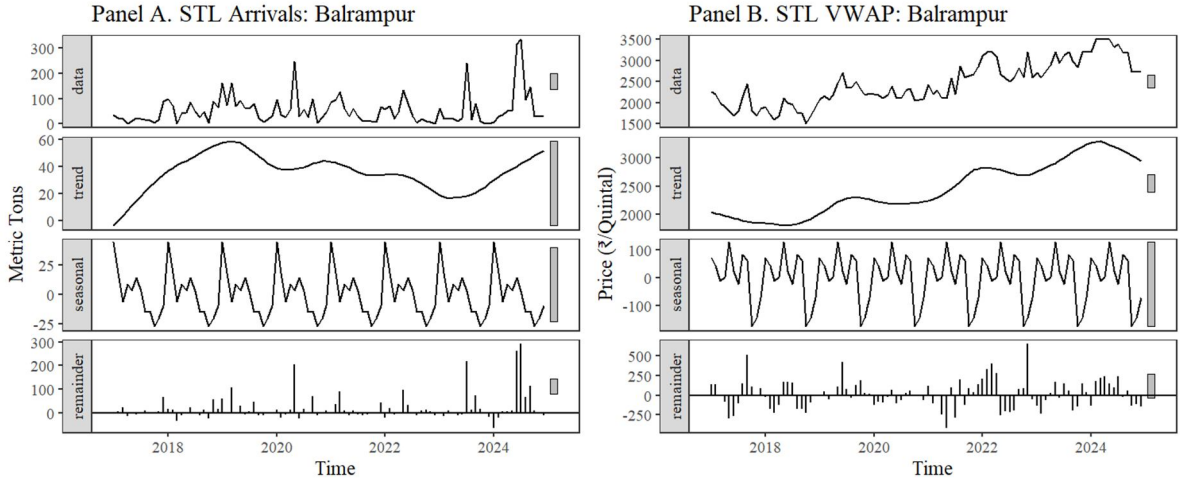

Fig 3. STL decomposition of the arrival quantities and prices of Kodo millet in BALRAMPUR district of Chhattisgarh.

Price seasonality is weaker than arrival seasonality. In most calendar-month panels, prices rise over time, indicating that long-run price growth dominates within-month movements. Monthly average prices vary, but there is no clear evidence of strong seasonal price cycles. For kodo millet, however, the irregularity is more extreme because the market is thinner and institutionally less mature. In a competitive agricultural market, one might expect harvest arrivals, storage behavior, and trader arbitrage to generate more predictable seasonal price patterns. Kodo millet does not show such a structure. The weak inverse relationship between arrivals and prices suggests that competitive storage and continuous arbitrage remain limited. Prices may respond more to localized procurement, demand, and buyer participation than to a stable annual market cycle.

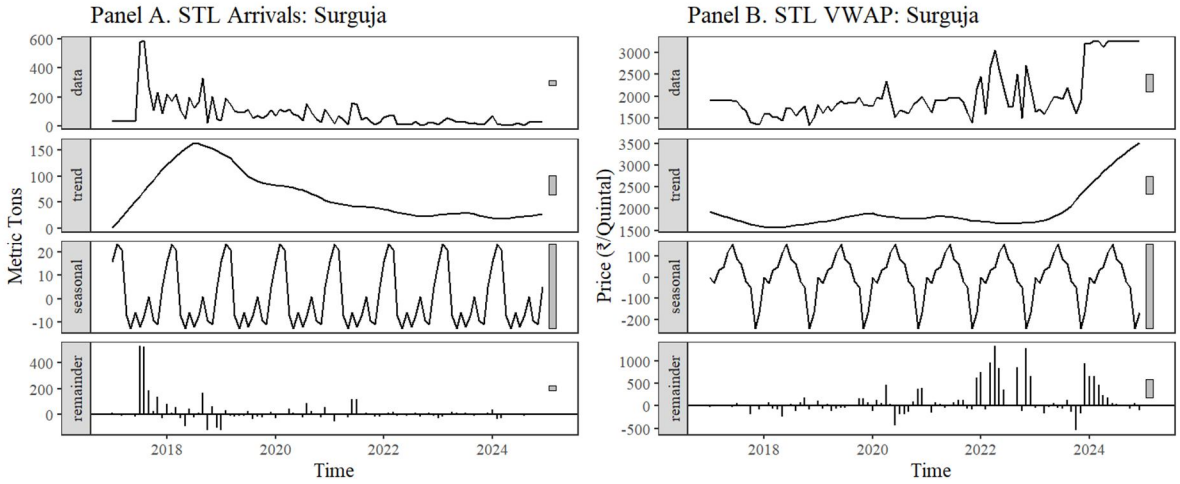

Fig 4. STL decomposition of the arrival quantities and prices of Kodo millet in SURGUJA district of Chhattisgarh.

D. Volatility and Thin-Market Price Dispersion

The volatility results in Fig IV. show that kodo millet price dispersion is market-specific rather than system-wide. Surguja has the highest and most persistent volatility among the three selected districts. Its Parkinson index reaches higher levels than Balrampur and Bemetara, particularly in the earlier part of the sample. This indicates substantial within-period price dispersion. However, in a thin market, such dispersion should not be interpreted mechanically as pure market risk. It may also reflect quality heterogeneity, small lot sizes, uneven buyer participation, and inconsistencies in the reporting of maximum and minimum prices.

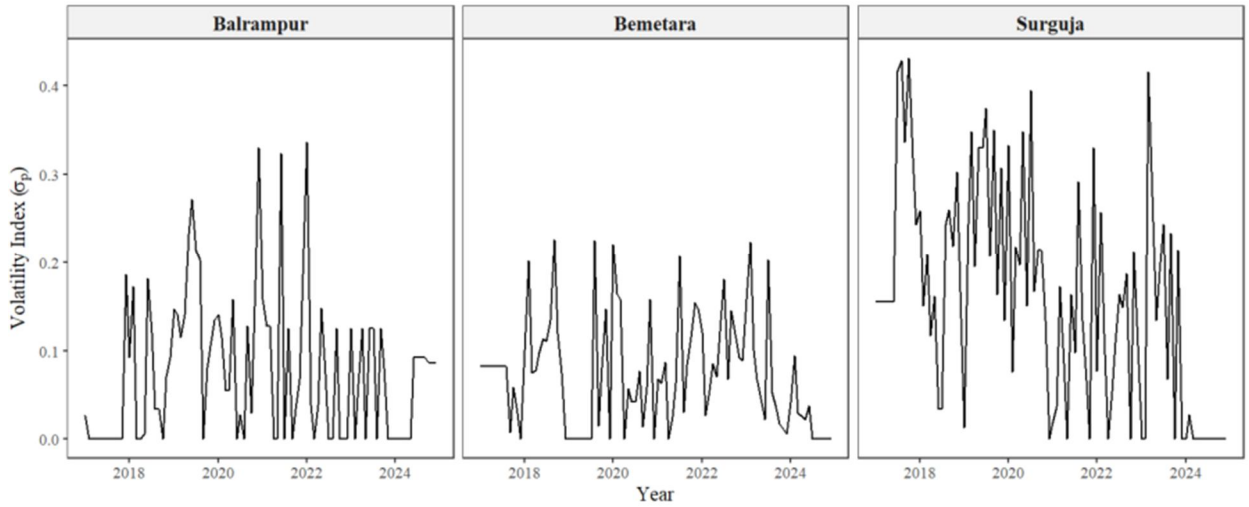

Fig iV.. Parkinson volatility indices for selected kodo millet district markets.

Balrampur and Bemetara show lower volatility than Surguja but still experience repeated spikes. Balrampur has several volatility episodes between 2018 and 2022 and becomes relatively calmer after 2023. Bemetara shows moderate volatility throughout the sample, with frequent but smaller fluctuations. These differences suggest that local market depth and reporting practices matter. Even within the same state, kodo millet mandis do not form a homogeneous volatility environment.

The volatility results are useful because they show that price dispersion is not system-wide but concentrated in particular districts, especially Surguja. For producers and traders, this means that price signals may be noisy and difficult to interpret, especially where quality, lot size, buyer participation, and transaction composition are not standardized.

E. Spatial Market Integration

The spatial integration analysis uses six district price series: Balrampur, Bemetara, Kanker, Mungeli, Rajnandgaon, and Surguja. The price plots (Fig V) show upward movement across all six districts from 2017 to 2024, but the timing and size of price changes differ. Balrampur rises steadily with some moderation after 2024. Bemetara and Mungeli show stronger upward movements after 2021. Kanker rises sharply around 2023, Surguja has irregular spikes, and Rajnandgaon becomes more volatile toward the end of the sample. These differences already suggest that the system is not perfectly synchronized.

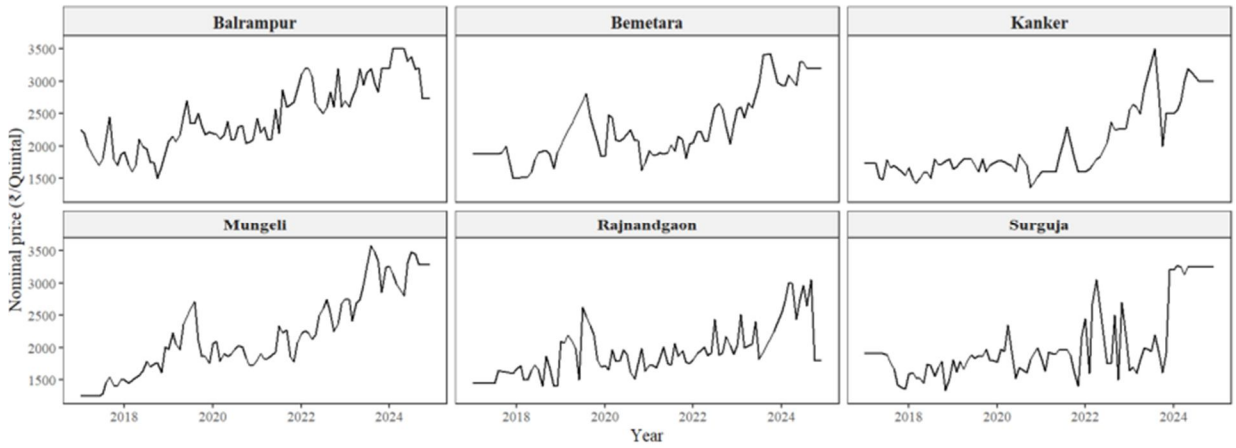

Fig. V. Evolution of kodo millet prices in selected district markets, 2017-2024.

The ADF tests broadly support cointegration analysis. All six level price series fail to reject the unit-root null at the 5 percent level, suggesting nonstationarity in levels. Most log-return series are stationary, with p-values reported as 0.00. Mungeli is weaker, with a log-return p-value of 0.07, implying stationarity only at the 10 percent level. This result does not invalidate the analysis, but it does call for caution in interpreting the strength of the cointegration system.

TABLE IV. ADF UNIT-ROOT RESULTS FOR SELECTED KODO MILLET DISTRICT PRICES

Series	Log-Level stat.	Log-Level p-value	Log-difference stat.	Log-difference p-value
Balrampur	-2.50	0.29	-11.93	0.00
Bemetara	-3.38	0.17	-8.06	0.00
Kanker	-3.12	0.14	-9.68	0.00
Mungeli	-2.67	0.29	-1.99	0.07
Rajnandgaon	-3.52	0.10	-10.14	0.00
Surguja	-3.10	0.19	-6.89	0.00

The full-sample Johansen trace test indicates partial integration. At the 5 percent level, the null of no cointegration is rejected because the test statistic for $r = 0$ is 115.41, which exceeds the 5 percent critical value of 102.14. However, the null of at most one cointegrating vector is not rejected at the 5 percent level because the test statistic of 76.01 is just below the 5 percent critical value of 76.07. The conservative conclusion is therefore that there is one cointegrating relation among the six price series. At the 10 percent level, the evidence is slightly stronger and suggests two cointegrating relations.

TABLE V. STATIC JOHANSEN TRACE TEST FOR KODO MILLET DISTRICT PRICES

Null	Trace stat.	10% CV	5% CV	1% CV
r = 0	115.41	97.18	102.14	111.01
r <= 1	76.01	71.86	76.07	84.45
r <= 2	44.48	49.65	53.12	60.16
r <= 3	26.27	32.00	34.91	41.07
r <= 4	13.38	17.85	19.96	24.60
r <= 5	2.48	7.52	9.24	12.97

Rolling-window Johansen results show that the degree of integration is not stable at higher ranks. The normalized statistic for $r = 0$ remains above one for most of the sample, confirming persistent evidence against no cointegration. However, it weakens toward the end. The statistic for $r \leq 1$ rises above the threshold during the middle of the sample but falls below it in later windows, while the statistic for $r \leq 2$ exceeds the threshold only during limited periods. Higher-rank nulls remain below the threshold throughout.

These results imply that kodo millet markets share some common long-run price movement but remain far from fully integrated. The evidence is consistent with a market that is linked but fragmented: prices do not move independently, but district-level autonomy remains substantial. The data analysis therefore points to partial integration rather than a deeply unified market system.

The interpretation of one cointegrating relation among six prices should be careful. It does not mean that all district prices obey the Law of One Price, nor does it imply that price shocks transmit quickly and fully across the system. It means that the six prices share one stable long-run relationship over the sample period. Since the maximum possible rank for six I(1) prices is five, a rank of one indicates that several independent stochastic trends remain. The system is connected, but only weakly and incompletely.

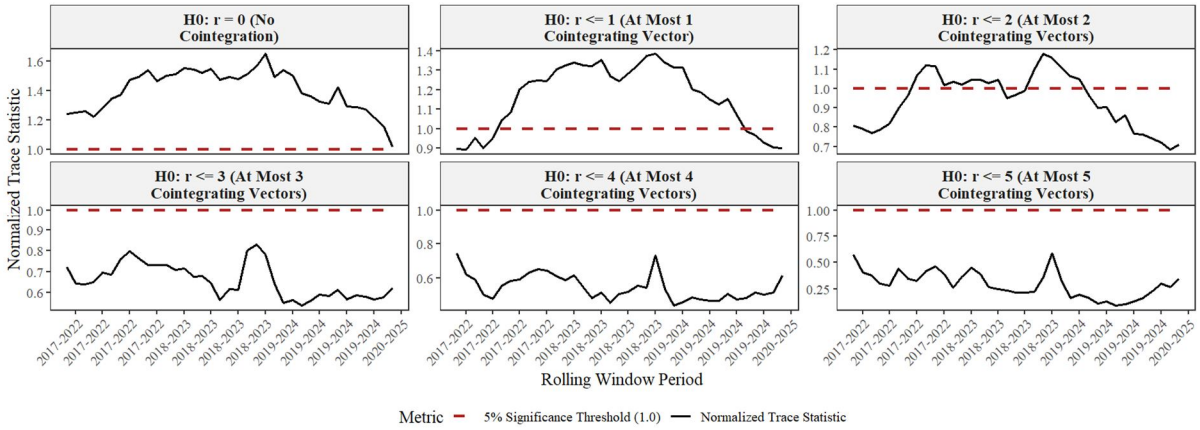

Fig. 4. Normalized rolling-window Johansen trace statistics for dynamic spatial integration.

This interpretation also helps reconcile the descriptive and econometric evidence. The descriptive plots show a common upward price tendency, which is consistent with shared inflationary, demand, and policy forces. The Johansen result confirms that this common movement is not purely accidental. However, the low rank and unstable rolling results show that the common component is not strong enough to dominate local market behavior. Kodo millet prices therefore contain both a common market signal and substantial district-specific variation.

V. TRIBAL BELTS, INFRASTRUCTURE, AND ASPIRATIONAL DISTRICTS

The data analysis places kodo millet trade within the central Indian tribal and highland belt rather than in commercially dense grain corridors. Leading arrivals are concentrated in Dindori, Kabirdham, Mandla, Singroli, Katni, Umariya, Shehdol, Sidhi, Dantewada, and Surguja. This geography matters because tribal livelihood systems combine subsistence use, local exchange, and intermittent formal sale; regulated-market arrivals are only the visible part of this wider system.

Infrastructure deficits shape liquidity and integration. Dispersed settlements, forested terrain, weak road connectivity, limited warehousing, small aggregation points, and thin buyer networks raise search, transport, and monitoring costs. These costs widen the band within which price differences can persist without immediate arbitrage.

Aspirational Districts are important to the interpretation. The kodo millet trading geography overlaps with development-priority districts and nearby regions where public policy already recognizes deficits in infrastructure, health, education, financial inclusion, and basic services [13]. The market results should therefore be read alongside district-level development constraints.

Affected-area conditions also matter. Parts of the central Indian tribal belt have historically faced Left Wing Extremism-related security and governance challenges, and the Ministry of Home Affairs links such regions to security, development, rights, governance, and public perception [14]. Infrastructure disruption, perceived risk, low trader density, and uneven state capacity can delay arbitrage and weaken price transmission.

Therefore, a rank of one reflects a market where common price forces coexist with high local transaction costs. District-level price independence is consistent with fragmented transport and information channels, periodic procurement windows, and localized reporting events.

The data analysis shows that formalization after 2017 should be treated as both an economic and administrative process. Greater reporting can bring previously invisible trade into AGMARKNET without immediately increasing market depth, especially where small volumes move through local channels before reaching regulated mandis.

A territorially targeted market-building strategy is therefore more appropriate than a generic national-market approach. For kodo millet, the relevant policy unit is the tribal-highland trading belt across Madhya Pradesh and Chhattisgarh. Roads, village collection points, primary processing, grading, and storage can reduce transaction-cost barriers to deeper integration.

The overall discussion places kodo millet in a category of partial integration. Prices contain a common market signal, but the trading system remains institutionally constrained. The policy challenge is to convert localized, episodic arrivals into reliable trading networks accessible to tribal producers.

VI. POLICY IMPLICATIONS

The data analysis points to several policy priorities. First, market information must improve. Kodo millet recorded arrivals expanded sharply after 2017, but part of this change may reflect reporting improvements rather than only trade expansion. Reliable, continuous, and commodity-specific reporting is essential for understanding kodo millet markets. Without it, policy may misread increases in recorded arrivals as increases in production or commercialization.

Second, aggregation infrastructure is central. Kodo millet trade is concentrated in tribal and highland districts where production is likely dispersed across small farms and villages. Producer organizations, local aggregation centers, and collective marketing arrangements can reduce search and transport costs. In affected and infrastructure-constrained areas, these institutions can also lower the risks of moving small quantities from villages to mandis [11].

Third, grading and quality standards are important. Reported high-low price ranges may partly reflect genuine uncertainty, but they also likely reflect heterogeneous grades, varieties, moisture levels, and transaction characteristics. Better grading would make prices more comparable across mandis and improve the reliability of market signals. This is particularly important for kodo millet, where quality differentiation is often local and informal [12].

Fourth, procurement should be designed carefully. The introduction of proxy MSP arrangements and state-level procurement can create price support, but thin markets may respond unevenly. Procurement that is too small may fail to shift market outcomes; procurement that bypasses mandis may reduce observed market arrivals; procurement without storage and processing infrastructure may not be sustained. For kodo millet, procurement needs to be linked with decentralized processing, local consumption programs, and predictable market calendars rather than treated only as a price-support intervention.

Fifth, the regional character of kodo millet should be recognized. The market is not a broad national commodity system. It is a central Indian minor millet market embedded in tribal livelihoods. Policies should therefore support both commercialization and local food-security roles.

Sixth, price information systems should be strengthened. AGMARKNET makes it possible to identify market patterns that would otherwise remain hidden, but data usefulness depends on continuous and accurate reporting. Kodo millet markets should be monitored not only through prices but also through active trading days, market-level arrivals, and quality categories. Without these details, thin markets can be misclassified as either inactive or integrated when the underlying evidence is more complex.

Seventh, market investment should be coordinated with Aspirational District and affected-area development programs rather than planned only through commodity departments. Roads, collection centers, storage, primary processing, and digital reporting systems would have stronger effects if they are integrated with existing district-development interventions.

Eighth, nutrition and welfare programs can be linked to market development. Since kodo millet is embedded in tribal food systems, procurement for public nutrition programs could support both market demand and local dietary diversity. A balanced strategy would combine local procurement, local processing, school meals or nutrition programs, and fair prices for producers.

VII. LIMITATIONS AND FUTURE RESEARCH

Three limitations qualify the findings. First, the analysis relies on AGMARKNET data from regulated markets. Kodo millet trade occurring through informal channels, local exchange, direct procurement, or household consumption is not fully captured. This is a serious limitation for a crop that remains partly embedded in tribal food systems.

Second, the period of reliable price data is relatively short. The spatial integration analysis begins in 2017, which limits the length of the time series and the number of rolling windows. The results are therefore best interpreted as evidence for the recent formal market period rather than as a long-run historical account of kodo millet trade.

Third, the analysis is descriptive and econometric, but not causal. The rise in arrivals and prices after 2017 may reflect policy shifts, demand changes, reporting improvements, procurement initiatives, or general price inflation. The article cannot isolate the separate causal effect of each factor. Future work could combine market data with production statistics, procurement records, household surveys, and field interviews in the major kodo millet districts.

VIII. CONCLUSION

Kodo millet markets in India present a distinctive combination of increasing formal visibility and persistent structural thinness. Recorded arrivals expanded sharply after 2017, and prices show a broad upward trend. Yet the market remains overwhelmingly concentrated in Madhya Pradesh and Chhattisgarh, especially in the central Indian tribal belt. The leading districts and mandis form a localized trading system rather than a broad national market.

The empirical results show that arrivals and prices behave differently. Arrivals are irregular, episodic, and district-specific, reflecting thin trade, localized production, and procurement or reporting events. Prices are more systematically upward-moving, suggesting common demand, inflationary, and policy-related forces. Volatility remains highly local, with Surguja showing the most persistent price dispersion among the selected Chhattisgarh districts.

The integration evidence is clear but limited. ADF tests broadly support the use of cointegration methods, and the Johansen test identifies one cointegrating relation among six district price series at the 5 percent level. Rolling-window results show that higher-order integration is unstable. Kodo millet markets therefore share a limited common long-run price relationship, but substantial district-level independence remains.

The broader implication is that market development for kodo millet cannot be judged only by rising prices or rising recorded arrivals. Kodo millet needs a policy approach that recognizes its tribal geography, improves market reporting, builds aggregation and grading infrastructure, supports decentralized processing, links market investments with Aspirational District and affected-area development programs, and treats procurement as part of a wider market-building strategy.

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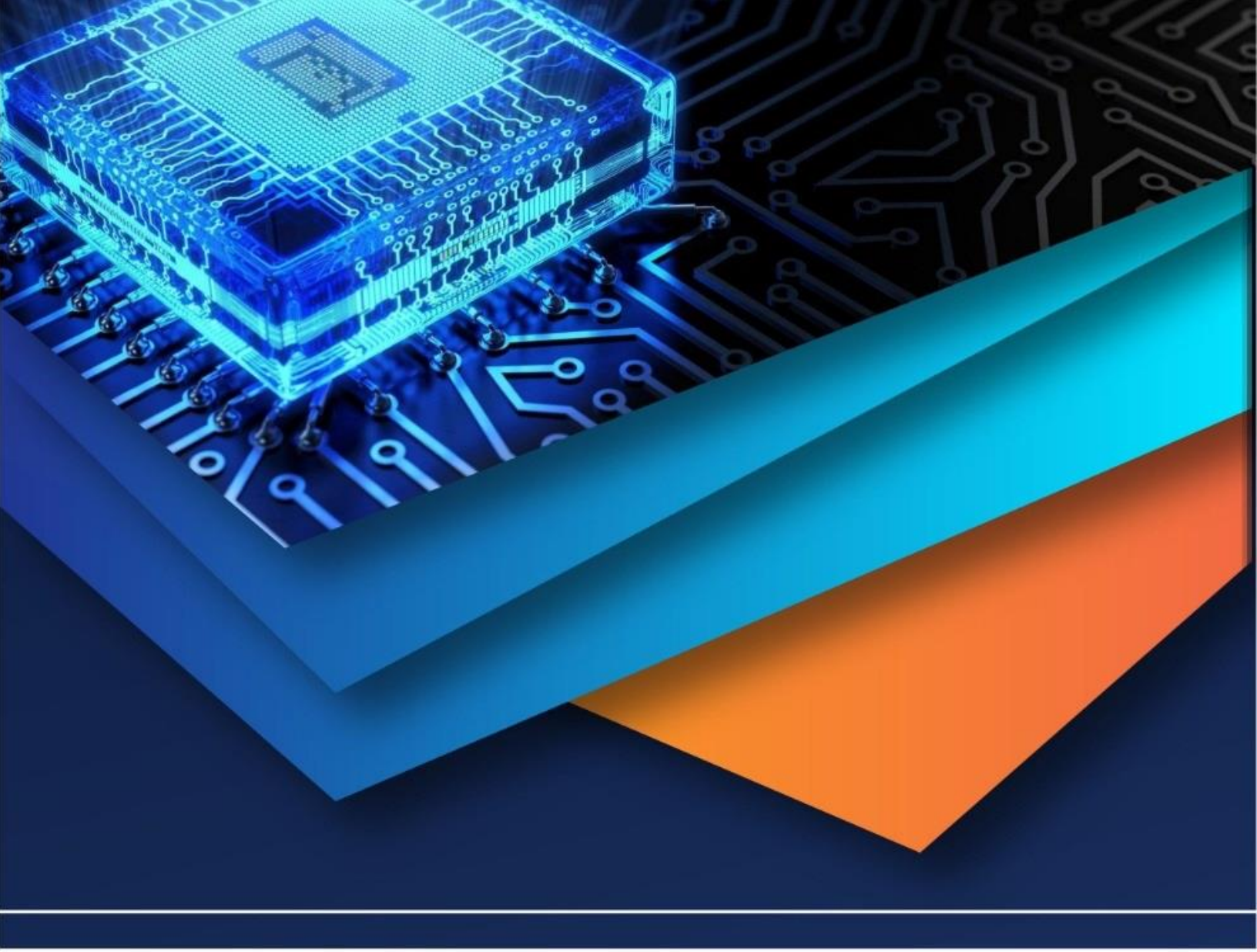

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