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Price signals across onion markets in Tamil Nadu

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Abstract

This research investigates price volatility and market integration within select small onion markets across Tamil Nadu, India. Using monthly wholesale price data from the Dindigul, Chennai, Coimbatore, and Idukki markets for the period 2014 to 2023, the study employs an array of econometric methods to analyze price dynamics and market interconnections. The ARCH-GARCH model analysis revealed high price volatility persistence in selected small onion markets with the Coimbatore market displaying the highest levels of volatility. The Augmented Dickey-Fuller test established stationarity within the price series, while cointegration tests indicated a long-term equilibrium relationship across the markets analyzed in Tamil Nadu. Further examination through the Granger causality test revealed that price movements in the Coimbatore market had a causal impact on the Dindigul market. Additionally, the markets in Coimbatore, Dindigul, and Chennai were shown to exert influence over the Idukki market in Kerala. The Vector Error Correction Model (VECM) analysis demonstrated that in response to disequilibrium across the Coimbatore, Chennai, Dindigul, and Idukki markets, short-run price adjustments occurred at rates of 41%, 45%, 46%, and 48%, respectively, working towards restoring long-run equilibrium. In the Dindigul market, price adjustments with a one-month lag had a notable influence on current prices within Coimbatore, Chennai, and Dindigul. These findings underscore the interconnected nature of small onion markets within the region and shed light on price behavior patterns. Insights derived from this study could inform policy measures aimed at stabilizing prices and enhancing market efficiency in the small onion markets.

Keywords

ARCH-GARCH; granger causality test; market integration; onion; price volatility; vector error correction model

Introduction

Onion is also referred to as "the King of the Kitchen" (1), the onion stands among the world's 15 most-produced vegetables (2). In 2023, India led global production, yielding 31.687 million tonnes, with Maharashtra contributing 42.5% of this output (3, 4). In Tamil Nadu, small onions comprise 90% of onion cultivation, achieving an average yield of 12 tonnes per hectare (5). The districts of Perambalur and Trichy emerged as the primary small onion producers, followed by Namakkal, Tirupur, and Dindigul (6). These small onions are transported across states such as Kerala, Karnataka, and Andhra Pradesh, and Tamil Nadu's export markets span Sri Lanka, Singapore, Indonesia, and Malaysia. The onion is notably referred to as a "sensitive commodity" due to its profound effect on trade and economic stability. Price surges can benefit farmers, yet their share of consumer spending remains constrained due to intermediary layers (7). Despite rising demand driving prices upward, farmers often struggle to realize substantial gains, with unpredictable weather conditions reducing yields and impacting their income (8). Factors such as population growth, income levels, and industrial demand for onion as an input further shape its market dynamics. Between 2011 and 2016, onion prices showed considerable volatility, registering an instability index of 49.30% (9).

Understanding market integration is vital, as it reveals how price fluctuations in one market resonate in others. This study, therefore, aims to dissect the price behavior in Tamil Nadu's small onion markets and to examine the spatial market integration between selected markets in Tamil Nadu and those in Kerala, providing insight into the intricate interconnections and price influences within and beyond regional boundaries.

Materials and Methods

Data and Methodology

This study utilized monthly time series data on wholesale prices in selected small onion markets from Dindigul, Chennai, Coimbatore, and Idukki, covering the period from 2014 to 2023. The Idukki market, located in Kerala, sources small onions from Tamil Nadu markets and was chosen for comparative analysis. Data on wholesale prices and arrivals were collected from multiple sources, including the NHRDF office in Coimbatore, NBH, and the AGMARKNET website.

Price volatility

Volatility reflects the degree and speed of fluctuations in an economic variable, revealing how much and how quickly its value changes over time. To model and forecast this variability, Autoregressive Conditional Heteroscedasticity (ARCH) models were developed, capturing the dynamic nature of variance by linking it to the variable's historical values as well as those of related factors. Introduced by Engle (1982) and later expanded into the Generalized ARCH (GARCH) model by Bollerslev (1986), these models provide a refined approach to volatility analysis. Unlike traditional measures such as the unconditional standard deviation—which often leads to significant overestimations—GARCH models adjust for volatility clustering by modeling both the conditional mean and conditional variance. This method enables a more precise representation of price volatility, accounting for its persistence and responsiveness to past fluctuations. Two distinct specifications of the GARCH model were conditional variance and conditional mean, while the standard GARCH (p, q) specification, shown as

$$Y_t = a + b_1 X_{1t} + \cdots + b_k X_{kt} + e_t$$

$$\sigma_t^2 = \omega + \alpha e_{t-1}^2 + \beta \sigma_{t-1}^2$$

Where, Y_t = onion price in time t, ω = mean, σ_t^2 = Conditional variance, e_{t-1}^2 = ARCH term, σ_{t-1}^2 = measure of uncertainty in the price of the market

In the GARCH model, the GARCH term (β) reflects the variance forecasted from the prior period, capturing how past volatility influences current variance. Meanwhile, the ARCH component (α) represents the impact of recent price shocks, measured by the squared residuals from the mean equation. Together, the sum of α and β indicates the persistence of volatility within the price series. When this sum approaches 1, it signals prolonged volatility persistence, suggesting that price fluctuations are likely to continue over time. If the sum exceeds 1, it points to an explosive pattern where variance may escalate, deviating significantly from the mean. By examining these GARCH estimates, researchers can pinpoint periods of heightened volatility, gaining insights into when and how volatility intensifies, which is essential for managing price risks and understanding market dynamics.

Stationarity test

Before analyzing market integration, it is essential to confirm the stationarity of the time series data. Stationarity implies that the series has a stable mean and variance over time, ensuring that any patterns or relationships observed are meaningful and not merely artifacts of fluctuating trends. Non-stationary data, on the other hand, can lead to spurious correlations, resulting in unreliable and potentially misleading results. The Augmented Dickey-Fuller (ADF) test is commonly employed to assess stationarity. This test works by regressing the first difference of the variable on a constant term, its lagged level, and several

$$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \sum_{i=1}^{m} \propto_i \Delta y_{t-i} + \varepsilon_t$$

lagged first differences.

Where, Y_t monthly price of the onion at time t, ΔY_t = first difference (Y_t - Y_{t-1}), ε_t = white noise error term, m = optimal lag length

The alternate hypothesis, δ < 0 indicated that the time series was stationary, and the null hypothesis, δ = 0 exhibited that the presence of unit root, indicated that the time series is non-stationary. ADF statistics are used to reject the null hypothesis. Based on the Schwartz Information Criteria (SIC), the ideal lag length was determined until δ equals zero.

Cointegration analysis

Cointegration analysis is a robust statistical method in econometrics used to explore long-term relationships among multiple time series variables. To assess the long-term connections between price series of various small onion markets, a cointegration test was employed. This method, (10), helps to determine the number of cointegrating equations among the markets. For 'n' markets, there can be up to 'n-1' cointegrating equations. Once the time series data is stabilized and integrated in the same order, cointegration analysis is conducted. o identify the number of cointegrating equations, it is advisable to employ maximum likelihood ratio test statistics. The trace statistic serves as a key tool in this analysis, testing the null hypothesis that there are at most rrr cointegrating vectors against the alternative hypothesis that there are more than rrr cointegrating vectors. By assessing the trace statistic, researchers can ascertain the presence of significant long-term relationships among the time series variables. This method provides a robust framework for understanding the dynamics between the markets, enabling insights into their interconnectedness and stability over time. Alternatively, the maximum Eigenvalue test statistic can be used to test the null hypothesis of 'r' cointegrating vectors against the alternative hypothesis of 'r+1' cointegrating vectors. The number of cointegrating relationships indicates the degree of price co-movement among the onion markets.

Vector Error Correction Model (VECM)

The Vector Error Correction Model (VECM) integrates both the levels and first differences of the variables, allowing for a comprehensive analysis of time series data. Once the long-term relationships and the rank of the cointegrating vectors have been established, VECM is employed to investigate short-term interactions among the price series. This model is particularly adept at identifying how prices adjust in response to short-term imbalances while aiming to revert to their long-term equilibrium.

To analyse both short-term and long-term price behaviour in the small onion markets, a Generalized Error Correction Model (ECM) formulation can be developed, beginning with the autoregressive distributed lag (ADL) equation as outlined below:

$$m_0 = (1 - \Sigma_{i=1}^{k} a_{i2}) \qquad m_1 = \frac{\Sigma_{i=1}^{k} a_{i2}}{m_0}$$

ΔY_T

a_{i1}, a_{i2} m_0

$$\Delta Y_t = a_{00} + \sum_{i=0}^{k-1} a_{i1} \Delta X_{t-i} + \sum_{i=0}^{k-1} a_{i2} \Delta Y_{t-i} + m_0 [m_1 X_{t-k} - Y_{t-k}] + \varepsilon_t$$

Where , ,

= Differenced onion price series in selected markets,

= Short run coefficients and = Speed of adjustment

This parameter's theoretical range is 0 to 1. A value of 1 suggested an immediate adjustment, value of 0 indicated no modification. Any deviations will be gradually adjusted to the long-run equilibrium values if the value is between 0 and 1.

Granger causality test

Granger (11) developed a framework for examining the relationship between changes in one series and changes in another series. It determined that Y causes X and vice versa if the present value of X can be anticipated using the historical values of Y and other pertinent information, including the historical values of X. Any configuration was feasible, including bivariate causality, absence of causality, and univariate Granger causality from X_t to Y_t or fromY_t to X_t.

The causal relationship among the small onion markets was evaluated using the Granger causality test, which is essential for identifying potential long-term price relationships between the selected markets. This analysis was conducted within the framework of a Vector Auto-Regressive (VAR) model, allowing for a comprehensive examination of the dynamic interactions between the market prices.

In this context, a causal relationship is typically established when the probability value is less than the critical value, indicating that past values of one market significantly contribute to predicting current prices in another market. Conversely, if the probability value exceeds the critical value, it suggests that no significant causal relationship exists between the markets. This method not only reveals the presence of interdependencies among the

$$Y_t = \propto_0 + \propto_1 Y_{t-1} + \cdots + \alpha_i Y_{t-1} + \beta_1 X_{t-1} + \beta_i X_{t-1} + \varepsilon_t$$

$$X_t = \propto_0 + \propto_1 X_{t-1} + \cdots + \alpha_i X_{t-1} + \beta_1 Y_{t-1} + \beta_i Y_{t-1} + u_t$$

small onion markets but also clarifies the direction of influence, thereby providing crucial insights for stakeholders involved in market analysis and policy formulation. Understanding these causal dynamics can inform strategies aimed at improving market responsiveness and stability.

The autoregressive distributed lag model for the Granger Causality test is

where *X* and *Y* are the prices of onion in different markets at time 't'.

In the null hypothesis, in the first regression, *X* does not Granger cause *Y*, and in the second regression, *Y* does not Granger cause *X*.

Results and Discussion

Price volatility

Price volatility refers to the fluctuations in commodity prices over a specific period, significantly influencing both consumers and producers. For consumers, price instability can lead to sudden price hikes, reducing affordability and complicating access to essential goods. For farmers, periods of low prices result in diminished earnings, making financial planning and budgeting challenging. To address these concerns, stabilizing prices becomes paramount, necessitating the measurement of volatility and the identification of strategies to mitigate it. In this study, the volatility of prices in selected small onion markets was assessed using ARCH and GARCH analyses. These econometric techniques enable a nuanced examination of price volatility within individual series. The analysis indicated that when the sum of the ARCH and GARCH coefficients is closer to or greater than 1, it indicates a high degree of persistence in volatility. The null hypothesis was rejected at the 5 percent level of significance, affirming the presence of volatility in the prices of the selected small onion markets. Notably, past volatility was found to significantly influence future price fluctuations. The findings of the ARCH-GARCH analysis for the selected small onion markets are detailed in Table 1.

Table 1. ARCH-GARCH analysis for Selected Small Onion Markets

Markets	Alpha (α)	Beta(β)	Sum (α +β)
Dindigul	1.4715	-0.0162	1.4553
Coimbatore	1.4853	-0.0113	1.474
Chennai	1.4628	-0.0147	1.4481
Idukki	1.3831	0.0066	1.3897

The results indicated that the sum of the coefficients (α + β) exceeds 1, signifying a high persistence of volatility in the selected small onion markets. This finding aligns with the observations made by prior research (12). Among the analyzed markets, the Coimbatore market exhibited the highest volatility, recorded at 1.474, followed closely by Dindigul at 1.4553, Chennai at 1.4481, and Idukki, which demonstrated the lowest volatility at 1.3897. The volatility in these markets can be attributed primarily to fluctuations in the volume of arrivals, which, in turn, drove price variations in the small onion sector. Several factors influenced onion prices, including the area allocated for cultivation in the preceding year, production fluctuations, adverse weather conditions, transportation distances, and the involvement of intermediaries. In Tamil Nadu markets, the dynamics of price formation were particularly responsive to the volume of arrivals; prices tended to be lower during peak arrival periods and higher when arrivals were low (13). Thus, variations in arrivals were a significant contributor to price volatility in the small onion markets of Tamil Nadu. Notably, Indian onion exports have exhibited an upward trend from 2020 to 2022 (14). Tamil Nadu serves as a critical supplier, transporting onions to neighboring states such as Kerala, Karnataka, and Andhra Pradesh, as well as exporting to international markets, including Sri Lanka, Singapore, and Malaysia. This increase in export activities can lead to shortages in domestic markets, resulting in price surges and further contributing to price volatility. Such findings are corroborated by earlier research (15), emphasizing the intricate relationship between transport, export dynamics, and price fluctuations in the onion market.

Stationarity test

To assess the stationarity of the selected small onion market prices, a unit root test was conducted using the ADF test. The ADF test evaluates the null hypothesis that a unit root is present in the time series, which would indicate non-stationarity (16). If the calculated test statistic is less than the critical value, the null hypothesis can be rejected, confirming that the time series is stationary. The results from the ADF test indicated that at the 1 percent level of significance, we reject the null hypothesis for the Dindigul, Coimbatore, and Idukki markets, suggesting that the time-series data for prices in these markets are stationary. In the Chennai market, the null hypothesis was rejected at the 5 percent level of significance, further supporting the conclusion that the price data in the selected small onion markets exhibit stationarity. These findings are summarized in Table 2, which details the ADF test statistics and critical values for each market analyzed. The stationarity of the time series is crucial for ensuring valid econometric analysis in subsequent steps, such as cointegration analysis and the application of VECM.

Table 2. ADF test of selected small onion markets

Markets	Level	
	T statistic	Probability
Dindigul	-3.5330	0.0087***
Coimbatore	-3.5394	0.0086***
Chennai	-3.3757	0.0138**
Idukki	-5.0907	0.0000***

Cointegration test

Co-integration among the selected small onion markets is vital for establishing market efficiency, as it reflects a long-term equilibrium relationship between the price series. After confirming the stationarity of the price information time series, a co-integration test was performed to identify the existence of these long-term relationships among the markets. The results of the co-integration analysis are presented in Tables 3 and 4, which display the trace statistic and maximum eigenvalue statistic, respectively. At the 5 percent significance level, both tests provided evidence to reject the null hypothesis, indicating that co-integration exists among all four markets: Dindigul, Coimbatore, Chennai, and Idukki. This suggests that the price movements in these markets are interconnected, and they tend

Table 3. Results of Unrestricted Cointegration Rank Test using Trace Statistics

Hypothesized No. of CE(s)	Eigen Value	Trace statistic	Critical Value (5%)	Probability**
None*	0.2408	65.4388	47.8561	0.0005
At most 1*	0.1400	33.7553	29.7970	0.0166
At most 2*	0.0966	16.4065	15.4947	0.0364
At most 3*	0.0402	4.7181	3.8415	0.0298

*Denotes rejection of the hypothesis at the 0.05 level, ** Mackinnon - Haug - Michelis (1999) p-values.

Table 4. Results of Unrestricted Cointegration Rank Test using Max-Eigen Statistics

Hypothesized No. of CE(s)	Eigen Value	Max-Eigen Statistic	Critical Value (5%)	Probability**
None*	0.2408	31.6834	27.5843	0.0140
At most 1	0.1400	17.3488	21.1316	0.1562
At most 2	0.0966	11.6884	14.2646	0.1229
At most 3*	0.0402	4.7181	3.8415	0.0298

*Denotes rejection of the hypothesis at the 0.05 level, ** Mackinnon - Haug - Michelis (1999) p-values.

to move together in the long run, reinforcing the idea of market efficiency and the significance of regional market dynamics in the small onion trade. The identification of co-integrating relationships is essential for further analysis, as it allows for the application of VECM to examine short-term interactions and the adjustment process towards long-term equilibrium.

Granger Causality test

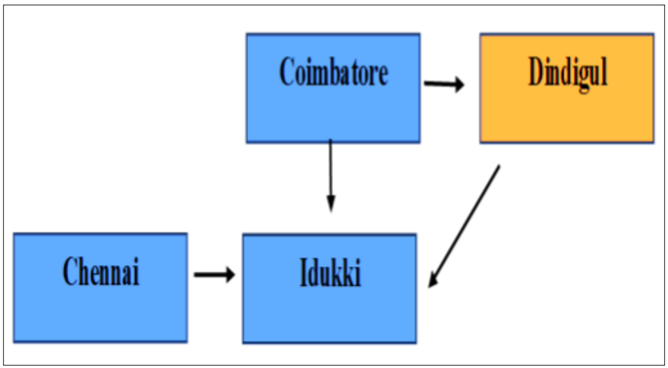

Fig. 1. Transmission of price signals among the selected onion markets based on Granger causality test

The Granger causality test focuses on assessing short-run relationships between variables, complementing the findings from the cointegration test that indicated long-term relationships among the small onion markets. To determine the directionality of these relationships in long-run equilibrium, the Granger causality test was applied. The results, illustrated in Fig. 1, reveal significant insights into the interactions among the markets. Specifically, the Coimbatore market exhibits a unidirectional relationship with the Dindigul market, indicating that changes in prices in the Coimbatore market Granger-cause changes in the Dindigul market, leading to the rejection of the null hypothesis. Furthermore, the Coimbatore, Dindigul, and Chennai markets all show a unidirectional influence on the Idukki market. This suggests that price changes in these Tamil Nadu markets have a significant effect on the prices in the Idukki market in Kerala, resulting in the rejection of the null hypothesis for these relationships as well. Overall, the Granger causality test results indicate that the Coimbatore market plays a pivotal role in influencing the price dynamics of the Dindigul market. Additionally, the price movements in the Coimbatore, Dindigul, and Chennai markets in Tamil Nadu significantly impact the prices in the Idukki market of Kerala. These findings are summarized in Table 5, providing a clear view of the causal relationships among the selected markets and underscoring the interconnectedness of onion prices across the regions.

Vector Error Correction Model

The results of the VECM for the selected small onion markets are summarized in Table 6. The error correction term reflects the speed of adjustment toward equilibrium in these dynamic markets. Specifically, the coefficients indicate how quickly each market returns to equilibrium following a period of disequilibrium. The adjustment speeds for the markets are as follows: Coimbatore shows a 41% adjustment rate, Chennai 45%, Dindigul 46%, and Idukki 48%. This suggests that Idukki prices have the fastest adjustment towards equilibrium, while Coimbatore has the slowest among the four. The t-statistics provide insights into the significance of the relationships among the markets. A t-statistic value greater than 1.96 indicates significance at the 5% level. In this context, the Idukki market has a t-statistic value of -2.4573, which is significant. This suggests that the past two-month lagged price of the Chennai market has a negative influence on the current price in the Idukki market, indicating potential market integration dynamics at play. Additionally, the lagged prices from the Dindigul market negatively affect the current prices in the Coimbatore, Chennai, and Dindigul markets. This indicates a directional influence where price movements in Dindigul can signal changes in the other markets, reinforcing the concept of price transmission among the selected markets. Overall, the presence of a cointegrating equation (CointEq1) signifies the long-term relationships between the Coimbatore, Chennai, Dindigul, and Idukki markets, suggesting that these small onion markets are integrated in the long run. The influence of one-month lagged prices from the Dindigul market on the other markets at a significant level further emphasizes its role as a signaling market, where fluctuations in Dindigul prices have implications for price movements in the Coimbatore, Chennai, and Idukki markets.

Table 5. Result of Granger causality test between selected onion markets

Null Hypothesis	Obs	F-statistic	Prob	Direction
CHN does not Granger cause CBE	118	0.02889	0.9715	Uni-directional
CBE does not Granger cause CHN		0.47402	0.6237	
DNL does not Granger cause CBE	118	2.87477	0.0606	Uni-directional
CBE does not Granger cause DNL		4.65301	0.0114	
IDK does not Granger cause CBE	118	0.72035	0.4888	Uni-directional
CBE does not Granger cause IDK		11.4542	3.E-05	
DNL does not Granger cause CHN	118	0.76238	0.4689	Uni-directional
CHN does not Granger cause DNL		2.36849	0.0983	
IDK does not Granger cause CHN	118	0.38358	0.6823	Uni-directional
CHN does not Granger cause IDK		11.4638	3.E-05	
IDK does not Granger cause DNL	118	0.15282	0.8585	Uni-directional
DNL does not Granger cause IDK		8.82058	0.0003	

Table 6. Vector Error Correction estimates of selected small onion markets

Error Correction	D(Coimbatore)	D(Chennai)	D(Dindigul)	D(Idukki)
CointEq	-0.4090 [-0.5040]	-0.4547 [-0.5676]	-0.4656 [-0.6108]	-0.4832*** [-2.4573]
D (Coimbatore (-1))	1.5456 [1.2717]	2.1435 [1.7870]	1.8006 [1.5770]	0.4536 [0.3307]
D (Coimbatore (-2))	-0.0362 [-0.0301]	0.1330 [0.1122]	0.3077 [0.2728]	-0.1904 [-0.1404]
D (Chennai (-1))	0.8851 [0.9925]	0.4000 [0.4545]	0.8012 [0.9567]	1.1403 [1.1330]
D (Chennai (-2))	-1.4899 [-1.6972]	-1.6389 [-1.8916]	-1.4299 [-1.7342]	-2.0188*** [-2.0374]
D (Dindigul (-1))	-2.3295*** [-2.0122]	-2.4401*** [-2.1356]	-2.5609*** [-2.3552]	-1.3611 [-1.0416]
D (Dindigul (-2))	0.9671 [0.8328]	0.8880 [0.7749]	0.5812 [0.5329]	1.7681 [1.3490]
D (Idukki (-1))	0.1628 [0.6432]	0.1826 [0.7310]	0.1906 [0.8016]	0.1365 [0.4778]
D (Idukki (-2))	0.1521 [0.7620]	0.1831 [0.9295]	0.1480 [0.7892]	0.0543 [0.2409]
R-squared	0.3344	0.3684	0.3477	0.4116
F-statistic	5.9730	6.9357	6.3371	8.3185
SIC	17.1654	17.1391	17.0400	17.4076

*** represents 10 percent level of significance, Values in the square bracket indicate t statistics.

Conclusion

This study focused on the price volatility and market integration of small onion markets in Tamil Nadu, yielding several important findings. The analysis revealed significant price fluctuations across the selected markets, with the ARCH and GARCH models indicating that volatility is a persistent characteristic in these markets. Among them, Coimbatore exhibited the highest degree of volatility, which can be attributed to various factors such as supply fluctuations, climatic conditions, transportation issues, and the influence of intermediaries. The ADF test confirmed the stationarity of the price series data, ensuring that the relationships observed were valid and meaningful. Furthermore, the Johansen cointegration test demonstrated long-term price relationships among the selected markets, indicating a stable equilibrium over time. The Granger causality test provided insights into the directional influence of prices among the markets. It confirmed a unidirectional relationship where changes in prices from the Coimbatore, Dindigul, and Chennai markets significantly affected the Idukki market. This suggests that these Tamil Nadu markets play a crucial role in influencing prices in the Idukki market in Kerala. Additionally, the VECM highlighted both short-term adjustments and the tendency of the markets to return to long-term equilibrium. The analysis revealed significant price transmission between the markets, suggesting that fluctuations in one market can have immediate and lasting effects on the others. Overall, the findings indicate that the small onion markets in Tamil Nadu are key drivers of price dynamics, particularly influencing the Idukki market. This highlights the importance of understanding market interconnections and the factors contributing to price volatility, which can aid policymakers and stakeholders in making informed decisions to stabilize prices and enhance market efficiency.

Policy suggestions

Price stabilization mechanisms should be implemented to reduce volatility in small onion markets. Enhancing market information systems will improve price transparency across regions, helping stakeholders make informed decisions. Increased investment in infrastructure can lower transportation costs and enhance market connectivity, facilitating smoother trade. Encouraging crop diversification and improving storage facilities are essential strategies for managing supply fluctuations and ensuring a consistent supply of onions. Additionally, raising awareness about weather-based crop insurance schemes can assist farmers in mitigating climate-related risks. Developing a regulatory framework to monitor and curb excessive speculation in onion marketing is also crucial for maintaining market stability. By implementing these strategies, the small onion markets in Tamil Nadu can become more efficient and equitable, ultimately benefiting both producers and consumers.

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Authors' contributions

Author DD was responsible for designing the study, conducting the statistical analysis, developing the protocol, and drafting the initial manuscript and remaining authors contributed and revised the manuscript. Other authors contributions are missing.

Compliance with ethical standards

Conflict of interest: There is no conflict of interest between the authors.

Ethical issues: None

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