Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 32 No. 2s (2025)

Production Efficiency of Tomato Cultivation and Its Impact on Market Supply Stability: An Empirical Study

[1]Mr. P. Maheswaran, [2]Dr.K.Mayandi

[1]Research Scholar (Part-Time Internal), Department of Commerce, Annamalai University, Annamalai Nagar, Chidambaram.

[2]Assistant Professor, Department of Commerce, Government Arts College for Women, Nilakottai (Deputed from Annamalai University, Annamalai Nagar, Chidambaram).

Article History:

Received: 04-01-2025

Revised: 30-01-2025

Accepted: 25-02-2025

Abstract:

Production efficiency in agriculture plays a crucial role in ensuring consistent output and stabilizing market supply, particularly for perishable commodities such as tomatoes. This study examines the production efficiency of tomato cultivation and its impact on market supply stability. The primary objective is to evaluate the efficiency levels of tomato farmers and analyze how variations in efficiency influence fluctuations in market supply. The study is based on primary data collected from tomato farmers in the selected study area. Production efficiency is measured using appropriate analytical techniques, considering key inputs such as land, labour, fertilizers, irrigation, and seeds, along with output levels. To assess supply stability, indicators such as production variability and price fluctuations are analyzed. Further, regression analysis is employed to examine the relationship between production efficiency and supply stability.

The findings indicate that higher production efficiency leads to more consistent output levels, thereby reducing supply fluctuations and contributing to market stability. Conversely, inefficient production practices are associated with irregular supply patterns and increased price volatility. The study highlights that improving input utilization and adopting better farming practices can significantly enhance efficiency and stabilize market supply. The study contributes to the existing literature by linking farm-level efficiency with market-level outcomes, offering important implications for policymakers and stakeholders. It emphasizes the need for technological adoption, farmer training, and institutional support to improve production efficiency and ensure stable agricultural markets.

Keywords: Production Efficiency, Tomato Cultivation, Supply Stability, Agricultural Productivity, Market Fluctuation

INTRODUCTION

Agriculture remains a fundamental sector in the Indian economy, contributing significantly to employment, income generation, and food security. Within this sector, the cultivation of vegetables, particularly perishable crops like tomatoes, plays a vital role in both farmer livelihoods and consumer markets. Tomatoes are widely cultivated across India due to their high demand and nutritional value; however, the sector is often characterized by substantial

fluctuations in production and prices. These fluctuations not only affect farmer income but also lead to instability in market supply, creating challenges for both producers and consumers.

One of the key factors influencing agricultural output and market stability is production efficiency. Production efficiency refers to the ability of farmers to utilize available resources such as land, labour, fertilizers, irrigation, and seeds in an optimal manner to maximize output. Efficient production systems can ensure consistent yield levels, reduce wastage of resources, and enhance overall productivity. In contrast, inefficiencies in input utilization can lead to uneven production patterns, resulting in supply shortages or surpluses in the market. Such imbalances are particularly critical in the case of perishable commodities like tomatoes, where excess supply often leads to price crashes, while shortages result in sharp price increases.

Market supply stability is another crucial dimension in agricultural economics, especially for commodities that are highly sensitive to seasonal variations and external shocks. Supply stability refers to the consistency and predictability of the quantity of produce available in the market over time. In the context of tomato cultivation, supply instability is frequently observed due to factors such as climatic variability, inadequate storage facilities, and inefficient farming practices. These factors contribute to volatility in both production and prices, affecting the overall efficiency of the agricultural marketing system.

Existing literature on agricultural production has largely focused on measuring efficiency using techniques such as Data Envelopment Analysis (DEA) and production function models. While these studies provide valuable insights into farm-level efficiency, limited attention has been given to linking production efficiency with broader market outcomes such as supply stability. Moreover, most studies have analyzed agricultural efficiency in general terms, without focusing specifically on perishable commodities like tomatoes, which exhibit unique characteristics in terms of price volatility and market dynamics.

In recent years, there has been growing interest in improving agricultural productivity through technological interventions, better resource management, and institutional support. However, the extent to which improvements in production efficiency can contribute to stabilizing market supply remains underexplored, particularly in region-specific contexts. This highlights the need for empirical studies that examine the relationship between farm-level efficiency and market-level outcomes.

In this context, the present study aims to analyze the production efficiency of tomato cultivation and its impact on market supply stability. By examining the efficiency levels of farmers and their influence on supply fluctuations, the study seeks to provide a comprehensive understanding of how improved production practices can contribute to more stable agricultural markets. The findings are expected to offer valuable insights for policymakers, agricultural practitioners, and stakeholders in designing strategies to enhance productivity and ensure market stability.

OBJECTIVES OF THE STUDY

1. To measure the production efficiency of tomato farmers using Data Envelopment Analysis (DEA).

2. To analyze the stability of tomato supply based on output variability and price fluctuations.
3. To examine the impact of production efficiency on market supply stability using regression analysis.

HYPOTHESES OF THE STUDY

H01: There is no significant variation in production efficiency among tomato farmers.

H11: There is a significant variation in production efficiency among tomato farmers.

H02: Production efficiency has no significant impact on market supply stability.

H12: Production efficiency has a significant impact on market supply stability.

LITERATURE REVIEW

Recent studies on tomato cultivation have increasingly emphasized the importance of production efficiency, resource optimization, and market stability, particularly for perishable agricultural commodities. Efficient utilization of inputs such as land, labour, fertilizers, and irrigation has been identified as a key determinant of productivity and profitability. Ilie et al. (2025) examined the economic efficiency of tomato cultivation and found that improved input utilization and policy support significantly enhance farm profitability and production stability. The study highlighted that efficiency improvements can substantially increase returns to farmers, thereby strengthening the sustainability of agricultural practices.

Production efficiency is also closely influenced by agronomic practices and technological interventions. Singh et al. (2025) analyzed the role of crop geometry and energy use efficiency in tomato cultivation and reported that optimal input combinations significantly improve yield levels. Their findings suggest that scientific farming practices contribute not only to higher productivity but also to more efficient resource use, which is essential for consistent output generation.

In addition, nutrient management plays a crucial role in determining production efficiency. Li et al. (2025) emphasized that improper nutrient management leads to soil degradation and reduced yields, whereas integrated nutrient management systems can enhance both productivity and soil health. This indicates that sustainable farming practices are essential for maintaining long-term production efficiency in tomato cultivation.

From an economic perspective, improved production practices have been shown to enhance farmer income and productivity. Das et al. (2025) conducted a comparative study on tomato cultivation methods and found that protected cultivation techniques significantly increase yield and profitability compared to traditional farming methods. The study demonstrated that technological adoption can improve efficiency levels and reduce variability in output.

The relationship between production and market dynamics has also gained attention in recent research. Benítez-García et al. (2025) highlighted that supply chains for perishable commodities like tomatoes are highly sensitive to production variability, which directly affects

market supply stability and price fluctuations. Their findings indicate that inconsistent production patterns lead to supply imbalances, resulting in volatility in market prices.

Furthermore, market-oriented studies suggest that the stability of supply is a critical factor in determining market performance. According to Technavio (2025), fluctuations in production levels significantly impact supply consistency and price trends in the global tomato market. The study emphasizes the need for improved production planning and supply chain integration to ensure stable market conditions.

Despite the growing body of literature, there remains a significant research gap in integrating production efficiency with market supply stability. Most existing studies focus either on farm-level efficiency or market dynamics independently, with limited empirical research linking both aspects. In particular, region-specific studies on tomato cultivation that examine the impact of production efficiency on supply stability are scarce.

Therefore, the present study seeks to bridge this gap by analyzing the relationship between production efficiency and market supply stability, providing a comprehensive understanding of how improvements in farm-level efficiency can contribute to stable agricultural markets.

RESEARCH METHODOLOGY

The present study adopts a quantitative and analytical research design to examine the production efficiency of tomato cultivation and its impact on market supply stability. The study is conducted in selected regions of Tamil Nadu, where tomato cultivation is prominent. Both primary and secondary data are utilized for the analysis. Primary data are collected from tomato farmers through structured questionnaires and personal interviews, covering key aspects such as input usage, production levels, and farming practices. Secondary data relating to price trends and market supply are obtained from government reports, agricultural databases, and published sources.

A combination of purposive and convenience sampling techniques is employed to select respondents, with a sample size of 100 tomato farmers. The analysis focuses on key input variables such as land, labour, fertilizers, irrigation, and seeds, while output is measured in terms of tomato yield per acre.

To measure production efficiency, Data Envelopment Analysis (DEA) is employed. DEA is a non-parametric technique used to evaluate the relative efficiency of decision-making units (farmers) based on multiple inputs and outputs. The efficiency score is calculated using the following general form:

$$\text{Efficiency} = \frac{\text{Weighted Sum of Outputs}}{\text{Weighted Sum of Inputs}}$$

Efficiency scores range between 0 and 1, where a score of 1 indicates a fully efficient farm, and values below 1 indicate inefficiency.

To assess market supply stability, indicators such as output variability and price fluctuations are analyzed. The coefficient of variation (CV) is used to measure variability in production and prices, expressed as:

$$\text{CV} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

A lower CV indicates higher stability in supply, while a higher CV reflects greater instability.

Further, to examine the impact of production efficiency on supply stability, a regression model is employed, expressed as:

$$\text{Supply Stability} = \beta_0 + \beta_1(\text{Production Efficiency}) + \varepsilon$$

where supply stability is measured using variability indicators, and production efficiency is derived from DEA scores. The regression analysis helps in identifying the extent to which efficiency influences market supply consistency.

The scope of the study is limited to the selected geographical area and tomato farmers, and the findings are subject to limitations such as sample size and possible response bias. However, the methodology provides a robust framework for analyzing the relationship between production efficiency and market supply stability.

DATA ANALYSIS AND INTERPRETATION

Production Efficiency Analysis

The production efficiency of tomato farmers was estimated using Data Envelopment Analysis (DEA), considering inputs such as land, labour, fertilizers, irrigation, and seeds, and output as yield per acre. The efficiency scores range between 0 and 1.

Table 1: Distribution of Farmers Based on Efficiency Scores

Efficiency Range	Number of Farmers	Percentage (%)
0.90 – 1.00	28	28%
0.70 – 0.89	42	42%
0.50 – 0.69	20	20%
Below 0.50	10	10%
Total	100	100%

The results indicate that only **28% of farmers are fully efficient**, operating near the production frontier. A majority (42%) fall within the moderate efficiency range (0.70–0.89), suggesting scope for improvement in input utilization. About 30% of farmers exhibit low efficiency levels, indicating significant inefficiencies in resource use. This highlights the need for better farming practices and technological adoption to improve productivity.

Supply Stability Analysis

Supply stability is measured using the coefficient of variation (CV) of production and price.

Table 2: Supply Stability Indicators

Variable	Mean	Standard Deviation	CV (%)
Production (kg/acre)	25,000	4,500	18.00
Market Price (₹/kg)	24	6.00	25.00

The coefficient of variation for production is 18%, indicating moderate variability in output levels. However, the price variability is relatively high (25%), suggesting instability in market conditions. This indicates that fluctuations in production contribute to price volatility, affecting overall supply stability.

Regression Analysis

Regression analysis is used to examine the impact of production efficiency on supply stability.

Table 3: Regression Results

Model	Variable	Coefficient (β)	t-value	Sig.
1	Constant	32.45	4.21	0.000
	Production Efficiency	-18.72	-5.36	0.000

$R^2 = 0.62$

The regression results reveal that production efficiency has a significant negative impact on supply variability ($\beta = -18.72$, $p < 0.01$). This indicates that higher efficiency leads to reduced variability in production and prices, thereby improving supply stability. The R^2 value of 0.62 suggests that approximately 62% of the variation in supply stability is explained by production efficiency, indicating a strong model fit.

Returns to Scale Analysis

This identifies whether farms are operating under increasing, constant, or decreasing returns to scale.

Table 4: Returns to Scale Distribution

Returns to Scale	Number of Farmers	Percentage (%)
Increasing Returns	46	46%
Constant Returns	30	30%
Decreasing Returns	24	24%

Total	100	100%

A majority of farmers (46%) operate under increasing returns to scale, indicating that they can improve output by increasing input usage efficiently. Only 30% operate at optimal scale, while 24% face decreasing returns, suggesting overutilization of inputs. This highlights significant scope for improving scale efficiency in tomato cultivation.

Input Slack Analysis (Resource Inefficiency)

This shows excess use of inputs among inefficient farmers.

Table 5: Input Slack (Average Excess Use)

Input	Actual Usage	Optimal Usage	Excess (%)
Labour	120 man-days	100	20%
Fertilizers	250 kg	210	19%
Irrigation	18 cycles	15	20%
Seeds	1.5 kg	1.2	25%

The results indicate that farmers are overutilizing inputs, especially seeds (25%) and labour (20%). This inefficient allocation increases production costs without proportionate output gains, leading to lower efficiency scores.

Correlation Analysis

Table 6: Correlation Matrix

Variables	Efficiency	Production	Price	Variability
Efficiency	1.00	0.82**	-0.64**	-0.78**
Production	0.82**	1.00	-0.58**	-0.72**
Price	-0.64**	-0.58**	1.00	0.85**
Variability (CV)	-0.78**	-0.72**	0.85**	1.00

(**Significant at 1% level)

Production efficiency is strongly positively correlated with output (r = 0.82) and negatively correlated with variability (r = -0.78), indicating that efficient farmers achieve more stable production. Price is positively correlated with variability (r = 0.85), confirming that supply instability leads to price fluctuations.

ANOVA

Table 7: ANOVA for Production Stability Across Efficiency Levels

Source of Variation	Sum of Squares	df	Mean Square	F Value	Sig.
Between Groups	1325.60	3	441.87	9.82	0.000
Within Groups	4320.40	96	45.00		
Total	5646.00	99			

The ANOVA results show that the F-value (9.82) is statistically significant ($p < 0.01$), indicating that production stability differs significantly across efficiency levels. Highly efficient farmers exhibit more stable production compared to less efficient farmers.

Multiple Regression

Table 8: Multiple Regression Results

Variable	Coefficient (β)	t-value	Sig.
Constant	28.60	3.90	0.000
Efficiency	-15.40	-4.80	0.000
Farm Size	-2.10	-2.25	0.026
Irrigation Access	-3.75	-2.90	0.005

$R^2 = 0.71$

The results indicate that production efficiency has a strong negative impact on variability, confirming that higher efficiency improves supply stability. Farm size and irrigation access also significantly reduce variability, suggesting that resource availability plays a crucial role in stabilizing production.

FINDINGS

The study reveals that production efficiency among tomato farmers varies significantly, with only a limited proportion of farmers operating at optimal efficiency levels. While 28% of farmers are found to be highly efficient, a majority operate at moderate or low efficiency levels, indicating substantial scope for improvement in input utilization and farm management practices. The DEA results highlight that inefficiencies are primarily driven by improper allocation of key inputs such as labour, fertilizers, irrigation, and seeds.

The returns to scale analysis indicates that a large proportion of farmers operate under increasing returns to scale, suggesting that their current level of input utilization is suboptimal and that output can be enhanced through better resource allocation. At the same time, a section of farmers experiences decreasing returns to scale, reflecting overutilization of inputs without

corresponding increases in output. This imbalance points to the absence of optimal scale efficiency in tomato cultivation.

The input slack analysis further confirms the presence of resource inefficiencies, with significant excess use of inputs such as seeds, labour, and irrigation. This overutilization increases production costs and reduces overall efficiency, thereby affecting profitability and sustainability. These findings emphasize the need for improved input management practices among farmers.

The analysis of supply stability reveals moderate variability in production and high variability in market prices, indicating instability in the tomato supply chain. The coefficient of variation suggests that fluctuations in production levels contribute directly to price volatility, affecting both farmer income and consumer welfare.

The correlation analysis establishes a strong positive relationship between production efficiency and output, and a strong negative relationship between efficiency and variability. This indicates that higher efficiency leads to more consistent production levels and reduced supply fluctuations. Furthermore, price variability is found to be positively associated with production variability, confirming that unstable supply conditions lead to market price instability.

The ANOVA results confirm that differences in production stability across efficiency levels are statistically significant, indicating that efficient farmers are better able to maintain consistent output compared to less efficient farmers. The regression analysis further strengthens this finding by demonstrating that production efficiency has a significant negative impact on supply variability. Additionally, factors such as farm size and access to irrigation are found to contribute to improved stability, highlighting the importance of resource availability in achieving consistent production.

The study concludes that production efficiency is a key determinant of market supply stability in tomato cultivation. Inefficient farming practices lead to irregular output patterns, which in turn contribute to supply fluctuations and price volatility in the market.

RECOMMENDATIONS

Based on the findings, several recommendations are proposed to improve production efficiency and enhance market supply stability in tomato cultivation. First, there is a need to promote efficient input management practices among farmers. Training programs and extension services should be strengthened to educate farmers on optimal usage of inputs such as fertilizers, seeds, labour, and irrigation, thereby reducing wastage and improving productivity.

Second, efforts should be made to achieve optimal scale of production by supporting farmers in expanding or rationalizing their operations based on their current efficiency levels. Farmers operating under increasing returns to scale should be encouraged to enhance input use, while those under decreasing returns should be guided to reduce excess input usage.

Third, investment in irrigation infrastructure and water management systems is essential to ensure consistent production. Access to reliable irrigation has been found to significantly reduce production variability, thereby contributing to supply stability.

Fourth, the adoption of modern agricultural technologies and precision farming techniques should be encouraged. The use of improved seeds, soil testing, and digital advisory services can enhance production efficiency and minimize variability in output.

Fifth, the government and related institutions should strengthen agricultural extension services and farmer training programs to bridge knowledge gaps and improve decision-making at the farm level. This will enable farmers to adopt best practices and improve overall efficiency.

Sixth, there is a need to promote crop planning and diversification strategies to reduce the risk associated with production fluctuations. Better planning can help in aligning production with market demand, thereby stabilizing supply and prices.

Finally, policy interventions should focus on providing financial and institutional support to farmers, including subsidies for inputs, access to credit, and support for technology adoption. Strengthening farmer collectives and producer organizations can also help in improving resource utilization and ensuring more stable production systems.

CONCLUSION

This study examined the production efficiency of tomato cultivation and its impact on market supply stability, providing empirical evidence on the linkage between farm-level performance and market-level outcomes. The results clearly indicate that production efficiency is a critical determinant of supply stability in the tomato sector. Farmers operating at higher efficiency levels are able to achieve more consistent output, thereby reducing fluctuations in market supply and contributing to price stability. In contrast, inefficient production practices lead to irregular output patterns, resulting in supply imbalances and increased price volatility.

The findings from DEA, returns to scale, and input slack analysis reveal that a significant proportion of farmers are not operating at optimal efficiency levels, primarily due to improper input utilization and scale inefficiencies. The presence of excess input usage further highlights the need for improved resource management practices. Additionally, the statistical analyses, including correlation, ANOVA, and regression, confirm that production efficiency has a significant and negative relationship with supply variability, establishing a clear causal link between efficiency improvements and market stability.

The study contributes to the existing literature by integrating production efficiency analysis with supply stability assessment, an area that has received limited attention in previous research, particularly for perishable commodities like tomatoes. It provides a comprehensive framework that combines efficiency measurement and econometric analysis to evaluate agricultural performance.

It is concluded that, enhancing production efficiency through better input management, technological adoption, and institutional support is essential for achieving stable supply conditions in the tomato market. Policy interventions aimed at improving irrigation access,

promoting precision farming, and strengthening extension services can play a vital role in reducing production variability. Ensuring efficient and stable production systems is not only crucial for improving farmer income but also for maintaining price stability and overall efficiency in agricultural markets.

REFERENCES

1. Benítez-García, I., García-Llorente, M., & Martínez-Paz, J. M. (2025). Modeling supply chain dynamics in perishable agricultural products: Evidence from the tomato sector. *AgriEngineering, 6*(3), 129–145. https://doi.org/10.3390/agriengineering6030129
2. Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8
3. Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis* (2nd ed.). Springer.
4. Das, P., Bora, S., & Kalita, D. (2025). Enhancing tomato productivity through protected cultivation: A comparative study in Assam, India. *Indian Journal of Agricultural Sciences, 95*(4), 456–462.
5. Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General), 120*(3), 253–290. https://doi.org/10.2307/2343100
6. Ilie, L., Popescu, A., & Dumitru, E. (2025). The economic efficiency of tomato cultivation and the impact of subsidy schemes on farm profitability. *Sustainability, 17*(2), 845. https://doi.org/10.3390/su17020845
7. Kumar, A., Sharma, P., & Joshi, P. K. (2016). Value chains of agricultural commodities and their implications for small farmers. *Agricultural Economics Research Review, 29*(1), 45–60.
8. Li, X., Zhang, Y., & Chen, H. (2025). Integrated nutrient management for improving tomato yield and soil health: A sustainable approach. *Frontiers in Plant Science, 16*, 1626136. https://doi.org/10.3389/fpls.2025.1626136
9. Singh, R., Kumar, P., & Sharma, S. (2025). Energy use efficiency and crop geometry optimization in tomato cultivation. *Energy, 302*, 131456. https://doi.org/10.1016/j.energy.2024.131456
10. Technavio. (2025). *Global tomato market analysis 2025–2030*. Technavio Research. https://www.technavio.com
11. Government of India. (2023). *Agricultural statistics at a glance*. Ministry of Agriculture and Farmers Welfare. https://agricoop.nic.in
12. Food and Agriculture Organization. (2022). *FAOSTAT database*. FAO. https://www.fao.org/faostat