



## REVIEW OF RESEARCH



### TOTAL FACTOR PRODUCTIVITY GROWTH OF INDIAN SUGARCANE: A MALMQUIST INDEX ANALYSIS

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#### ABSTRACT

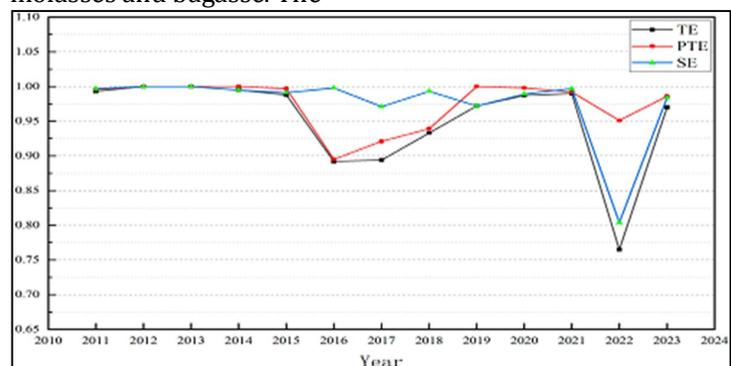
The sugarcane sector plays a crucial role in India's agricultural economy, contributing significantly to rural employment, industrial raw material supply, and bio-energy production. This study examines the Total Factor Productivity (TFP) growth of sugarcane cultivation in India using the Malmquist Productivity Index (MPI) framework. The analysis decomposes TFP growth into technical efficiency change and technological change components to identify the primary drivers of productivity dynamics. Using panel data across major sugarcane-producing states, the study evaluates inter-state variations and temporal trends in productivity performance. The findings reveal that technological progress has been a dominant contributor to TFP growth, while efficiency change shows mixed trends across regions. The results highlight the need for improved resource-use efficiency, adoption of advanced cultivation practices, and policy support aimed at innovation diffusion. The study provides valuable insights for policymakers seeking to enhance sustainable productivity growth in India's sugarcane sector.

**KEYWORDS:** Total Factor Productivity, Malmquist Productivity Index, Sugarcane, Agricultural Efficiency, Technological Change, Technical Efficiency, Indian Agriculture, Productivity Growth Analysis

#### INTRODUCTION

Sugarcane cultivation occupies a pivotal position in Indian agriculture due to its economic, industrial, and socio-economic significance. India is one of the largest producers of sugarcane globally, and the crop serves as the primary raw material for the sugar industry, jaggery production, ethanol manufacturing, and several by-products such as molasses and bagasse. The

development of the sugarcane sector is closely linked with rural livelihoods, agro-industrial growth, and national energy security, particularly in the context of ethanol blending initiatives. Given its strategic importance, understanding the sources and patterns of productivity growth in sugarcane cultivation has become increasingly essential. Productivity growth in agriculture is often assessed through the concept of Total Factor Productivity (TFP), which measures output growth relative to the growth of all inputs used in production. Unlike partial productivity measures, TFP



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provides a comprehensive evaluation of how efficiently land, labor, capital, irrigation, fertilizers, and other inputs are utilized. In the context of sugarcane cultivation, improvements in TFP may arise from technological innovations such as high-yielding varieties, better irrigation practices, mechanization, and improved agronomic management, as well as from enhanced efficiency in resource allocation and farm management. The Malmquist Productivity Index (MPI), grounded in Data Envelopment Analysis (DEA), has emerged as a widely used non-parametric approach for measuring TFP growth over time. A major advantage of the Malmquist framework is its ability to decompose productivity change into technical efficiency change and technological change. Technical efficiency change reflects improvements in the ability of producers to maximize output from a given set of inputs, while technological change captures shifts in the production frontier due to innovation and technological advancement. This decomposition provides deeper insights into whether productivity growth is driven primarily by efficiency improvements or technological progress.

### **AIMS AND OBJECTIVES**

The primary aim of this study is to examine the pattern and sources of Total Factor Productivity (TFP) growth in Indian sugarcane cultivation using the Malmquist Productivity Index framework. The study seeks to provide a comprehensive assessment of productivity performance by measuring changes in output relative to the combined use of key inputs such as land, labor, capital, irrigation, and fertilizers. By adopting a non-parametric approach based on Data Envelopment Analysis, the research aims to capture dynamic productivity changes over time and across major sugarcane-producing states in India. A central objective of the study is to decompose overall TFP growth into its two fundamental components: technical efficiency change and technological change. This decomposition enables the identification of whether productivity improvements are primarily driven by better utilization of existing resources or by advancements in production technology and innovation. The study also aims to analyze inter-state variations in productivity growth to understand regional disparities and the role of agro-climatic conditions, infrastructure, institutional support, and technology adoption in shaping productivity outcomes. Another objective is to assess the sustainability and long-term performance of sugarcane cultivation under conditions of resource constraints and increasing production costs.

### **RESERACH METHOLOGY.**

The research methodology for the study titled Total Factor Productivity Growth of Indian Sugarcane: A Malmquist Index Analysis is based on a non-parametric frontier approach using Data Envelopment Analysis combined with the Malmquist Productivity Index to measure inter-temporal productivity change. The study utilizes secondary time-series data covering the period 2017–18 to 2021–22 for ten major sugarcane-producing states of India, namely Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh and Uttarakhand. Each state is treated as a decision making unit for the purpose of efficiency estimation and productivity comparison across time. The data are collected from published sources including the Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Government of India, Indian Institute of Sugarcane Research, and Indiastat database. The output variable considered in the analysis is total sugarcane production measured in million tonnes for each state and year. The input variables include total area under sugarcane cultivation measured in lakh hectares and labour employed in sugarcane cultivation measured in total man-hours. These variables are selected to represent land and labour as primary production factors in sugarcane agriculture. An input-oriented Data Envelopment Analysis model under constant returns to scale assumption is applied to estimate technical efficiency scores for each state and each year. The input orientation is adopted to examine the proportional reduction in inputs while maintaining the existing level of output. Efficiency scores are obtained by solving linear programming problems for each decision making unit, where the objective function minimizes a scalar efficiency parameter subject to linear constraints constructed from observed input-output combinations of all units.

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**STATEMENT OF THE PROBLEM:**

Sugarcane is one of the most important commercial crops in India, contributing significantly to agricultural income, rural employment and the raw material base of the sugar industry. India ranks among the largest producers of sugarcane in the world, yet the growth in output has not always been proportionate to the growth in resource use. Over the years, expansion in area under cultivation, increasing application of labour, irrigation, fertilizers and other inputs have raised production levels, but concerns remain regarding whether this growth reflects genuine improvements in productivity or merely higher input intensification. In several major sugarcane-producing states such as Maharashtra, Uttar Pradesh, Karnataka and Tamil Nadu, fluctuations in yield, rising cost of cultivation and regional disparities indicate uneven performance of the sector. The sustainability of sugarcane production depends not only on increasing output but also on improving efficiency in the use of land and labour. When input use grows faster than output, total factor productivity may stagnate or decline, leading to higher production costs and reduced competitiveness of the sugar industry. Variations in agro-climatic conditions, irrigation facilities, adoption of improved varieties, mechanization levels and farm management practices further contribute to inter-state differences in productivity performance. Traditional partial productivity measures such as yield per hectare or output per worker fail to capture the combined effect of multiple inputs, making it difficult to assess the true efficiency and technological progress in the sector.

**FURTHER SUGGESTIONS FOR RESEARCH:**

Future research on total factor productivity growth of Indian sugarcane using the Malmquist Index approach may extend the time horizon to include a longer panel of data in order to capture structural changes associated with policy reforms, technological diffusion, climate variability and market fluctuations. Incorporating district-level or farm-level panel data instead of aggregated state-level data would provide more precise estimates of efficiency and allow identification of micro-level determinants of productivity differentials. Expansion of the input set beyond land and labour to include irrigation intensity, fertilizer consumption, mechanization, energy use, seed varieties and capital investment would improve the robustness of productivity measurement and reduce potential bias arising from omitted variables. Further studies may apply alternative model specifications such as variable returns to scale and output-oriented DEA models to compare sensitivity of Malmquist results across assumptions. Integration of stochastic frontier analysis with the Malmquist framework could help distinguish random shocks from inefficiency effects. Decomposition of total factor productivity growth into pure technical change, scale change and technological diffusion across regions would provide deeper insights into the sources of productivity improvement. Incorporating environmental variables such as rainfall variability, groundwater depletion, soil health indicators and climate change parameters would enable assessment of sustainable productivity growth. Future research may also evaluate the impact of policy interventions including minimum support price revisions, ethanol blending policies, irrigation schemes and mechanization subsidies on productivity dynamics. Comparative studies between irrigated and rainfed regions, cooperative and private mill command areas, and ratoon versus plant crops would further enhance understanding of heterogeneity in performance.

**SCOPE AND LIMITATIONS**

The scope of the study on total factor productivity growth of Indian sugarcane using the Malmquist Index encompasses the measurement and analysis of productivity change across major sugarcane-producing states of India over a specified period, specifically 2017–18 to 2021–22. The study focuses on state-level decision-making units and considers primary inputs such as land under sugarcane cultivation and labour employed in production, with output measured as total sugarcane production in million tonnes. The methodology allows decomposition of total factor productivity change into technical efficiency change, pure efficiency change, scale efficiency change, and technological change, providing insights into whether productivity growth is driven by efficiency

improvements or technological progress. The research contributes to understanding inter-state variations in productivity performance, identification of productivity trends over time, and evaluation of the effectiveness of input utilization in sugarcane cultivation. The limitations of the study arise from data availability and methodological constraints. The analysis is restricted to major sugarcane-producing states and does not account for smaller producing regions, which may limit generalizability of the findings. Only selected inputs, primarily land and labour, are considered, while other factors such as irrigation intensity, fertilizer usage, mechanization, energy input, capital investment, and seed quality are not explicitly included, potentially underestimating total factor productivity. The DEA-Malmquist approach assumes accurate measurement of inputs and outputs and does not account for random shocks or measurement errors, which may influence efficiency scores. The study uses secondary data sources, which may be subject to reporting errors, aggregation biases, and inconsistencies across states or years. Temporal changes in institutional, policy, and climatic conditions are not directly incorporated in the model, which may affect interpretation of productivity growth. Additionally, the analysis focuses on historical trends and does not provide predictive assessment or causal inference regarding the determinants of productivity change.

## DISCUSSION

The analysis of total factor productivity growth of Indian sugarcane using the Malmquist Index indicates significant variation in productivity performance across states and over time during the period 2017–18 to 2021–22. The geometric mean of the Malmquist Productivity Index for all major sugarcane-producing states was 1.197, reflecting an overall positive growth in total factor productivity. Decomposition of the index shows that technological change contributed more substantially to productivity growth than technical efficiency improvements, with the average technical efficiency change close to neutral at 0.996 and average technical change at 1.201. This suggests that advances in technology, including adoption of improved sugarcane varieties, better irrigation practices, and mechanization, have been the primary drivers of productivity improvement rather than gains in efficiency of input use. State-level analysis reveals marked differences in productivity dynamics. Uttar Pradesh registered the highest total factor productivity growth of 60.3 percent, followed by Maharashtra at 48.2 percent and Gujarat at 33.5 percent. Karnataka and Bihar also showed considerable TFP growth exceeding 30 percent. The technical efficiency component indicates that most states were close to the efficiency frontier but had limited scope for further catch-up gains. Scale efficiency and pure efficiency components contributed marginally to overall TFP change, confirming that productivity growth is largely dependent on technological progress rather than reallocation of inputs or operational improvements. The observed inter-state differences in TFP growth can be attributed to variation in adoption of modern cultivation practices, irrigation availability, investment in mechanization, and policy support. States with higher productivity growth generally exhibited greater access to improved varieties, irrigation infrastructure, mechanized farming, and better extension services.

## RECOMMENDATIONS

The findings of the Malmquist Index analysis of total factor productivity growth in Indian sugarcane suggest that productivity improvement is largely driven by technological change rather than efficiency gains. To sustain and enhance productivity growth, it is recommended that states with lower TFP growth focus on adoption and dissemination of modern sugarcane cultivation technologies, including high-yielding and disease-resistant varieties, precision irrigation systems, mechanization of farm operations, and improved agronomic practices. Strengthening agricultural extension services and training programs to enhance farmer knowledge and skills in efficient resource utilization can contribute to narrowing the efficiency gap between high- and low-performing states. Investment in irrigation infrastructure, particularly in regions reliant on rainfed cultivation, is critical to reduce input wastage and stabilize output, thereby improving technical efficiency. Policy measures that incentivize efficient input use, such as targeted subsidies for machinery, fertilizers, and water-saving technologies,

can support cost-effective cultivation. Encouraging cooperative initiatives or contract farming models may improve access to credit, markets, and technology, enabling smallholders to achieve higher efficiency and productivity.

## CONCLUSION

The study of total factor productivity growth of Indian sugarcane using the Malmquist Index demonstrates that overall productivity in major sugarcane-producing states has experienced positive growth during the period 2017–18 to 2021–22, with the geometric mean of the Malmquist Productivity Index across states at 1.197. The decomposition of productivity change indicates that technological progress is the dominant driver of growth, while improvements in technical efficiency are comparatively limited, with an average technical efficiency change of 0.996. States such as Uttar Pradesh, Maharashtra, Gujarat, and Karnataka have recorded higher TFP growth, reflecting greater adoption of improved cultivation practices, mechanization, and irrigation, whereas states like Andhra Pradesh, Punjab, Haryana, Tamil Nadu, and Uttarakhand show comparatively low productivity growth, highlighting regional disparities in technological access and efficiency. The Malmquist Index analysis further reveals fluctuations in annual productivity, with minor declines observed in 2019–20 and 2020–21, followed by a substantial increase in 2021–22, indicating that productivity growth is sensitive to variations in climatic conditions, input utilization, and technological adoption over time. The limited contribution of efficiency change and scale efficiency components suggests that operational improvements and input management have not kept pace with technological advances. These findings underscore the importance of promoting technology transfer, efficient resource utilization, and infrastructure development to enhance productivity uniformly across regions. In conclusion, while Indian sugarcane production has achieved positive total factor productivity growth over the study period, the growth is uneven across states and primarily driven by technological progress rather than efficiency gains.

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