

Total Factor Productivity and Cost Dynamics of Paddy Cultivation in Tamil Nadu

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Abstract

Productivity growth is essential for maintaining agricultural production and improving farmers' income. However, paddy cultivation in Tamil Nadu faces problems such as declining cultivated area, increasing input costs, and climate-related risks. Although paddy is a major staple crop, very few studies have analyzed its long-term growth, instability, cost pattern, and productivity together. Therefore, this study analyzes growth trends, instability, cost and price dynamics, and Total Factor Productivity (TFP) growth in paddy cultivation using 25 years of time-series data (1997–98 to 2021–22). Area under cultivation declined slightly (-0.69 %), driven by water scarcity, urbanization, and crop diversification. Production stagnated (0.004%) with high variability (25.4%), influenced by rainfall and input fluctuations, while yield improved moderately (0.29%) due to technology adoption and better resource management. The Divisia-Tornqvist-Theil TFP index showed compound growth rate of 0.35% per annum with an average TFPI of 122.4 (22.4% above base year). Declines occurred in drought-affected years like 2002–03 (66.82) and 2015–16 (109.64), while gains appeared in 2001–02 and 2003–04 from stable inputs and higher output. Total Output Index (TOI: 121.6) outpaced Total Input Index (TII: 100.4), confirming positive TFP trends. Minimum Support Price (MSP) typically exceeded Cost of Production (CoP), except 2016–18 due to rising inputs; post-2018, MSP grew faster, bolstering incomes. The findings underscore the need for drought-resilient irrigation, stable input supply chains, and sustained MSP hikes to enhance TFP and farmer resilience. Policymakers should prioritize technology dissemination and adaptive production strategies to counter area decline and variability.

Key words: Growth and instability Total Factor productivity, Divisia-Tornqvist theil index, Minimum Support Price.

1. Introduction

Agriculture is a cornerstone of the Indian economy, ensuring food security, employment generation, and rural development. According to the Ministry of Statistics and Programme Implementation (MoSPI, 2024-25), the agricultural sector contributed 14.41 % to India's Gross Domestic Product (GDP) and provided employment to 46.1 % of the total workforce in 2024–2025. Over the past few decades, India has witnessed a substantial increase in

food grain production, rising from 198.34 million tonnes in 1996–97 to 353.95 million tonnes in 2024–25 (Government of India, 2025). However, the growth in agricultural production and productivity has not been uniform across crops, regions, and time periods, reflecting disparities in resource use, technology adoption, and climatic conditions (Birthal *et al.*, 2019; Kumar *et al.*, 2020)



Tamil Nadu, the eleventh largest state in India, has a total geographical area of 130.33 lakh hectares. Agriculture contributes around 13 % to the Gross State Domestic Product (GSDP) (at constant 2011–12 prices), with approximately 6.1–6.3 million hectares under cultivation (Government of Tamil Nadu, 2023). Cultivators and agricultural labourers together constituted 45.5 % of the total workforce during 2021–2022 (MoSPI, 2022). Being a coastal state, Tamil Nadu is highly vulnerable to climatic variability, seasonal fluctuations, and extreme weather events, which create significant uncertainty in agricultural production and productivity. Studies have shown that climatic variability and water stress significantly affect productivity growth, particularly in rice cultivation systems in water-stressed regions (Kumar et al., 2022).

Productivity refers to the relationship between output produced and inputs used in the production process. Among various productivity measures, the Total Factor Productivity (TFP) approach provides a comprehensive assessment of productivity growth by isolating the contribution of inputs such as land, labour, capital, and materials from other influencing factors including technological progress, infrastructure development, institutional support, and farmers' management practices (Coelli et al., 2005). Several empirical studies have demonstrated the significance of TFP in agricultural growth across regions and crops. For instance, Karunakaran (2014) reported stagnation in crop productivity in Kerala due to low TFP growth, while Sanap et al. (2015) observed positive TFP growth in sugarcane cultivation in Maharashtra due to improved irrigation and mechanization. Similarly, Sharma and Dupare (2016) reported moderate TFP growth in soybean cultivation in India, highlighting the importance of irrigation and research investment. These findings indicate that productivity growth depends not only on input use but also on technological and institutional factors. TFP growth in Indian agriculture has been modest (1.4–2.1% annually), often hindered by irrigation deficits and policy inconsistencies (Chand and Kumar, 2021). Therefore, estimating TFP for paddy crops in Tamil Nadu is crucial for assessing the efficiency of resource utilization and the role of technological advancement in enhancing productivity.

In this context, the objectives of the study aim, 1. To examine the growth and instability in area, production,

and productivity of paddy crops in Tamil Nadu, 2. To estimate and evaluate the Total Factor Productivity (TFP) index for paddy crops, and 3. To analyse the trend in Minimum Support Price (MSP) of paddy crops over time.

2. Limitations of the study

The study has certain limitations. For some inputs, only value data were available; in such cases, the corresponding quantities were derived through indirect methods. For instance, the quantity of by-product was estimated using grain–straw ratios. The wholesale Price Index of pesticides in agriculture has been used to derive the quantity of pesticides. Machine labour primarily consisted of tractors operating on diesel, and irrigation was generally carried out using diesel or electric pump sets. Therefore, indices were constructed (with 1997-98 as the base year) for both machine labour and irrigation expenditure by deflating the variables by the fuel and light index available from the Consumer Price Index (fuel and light) for agricultural labourers. However, such proxy methods are widely used in long-term productivity studies where direct quantity data are unavailable (Karunakaran 2014, Fuglie, 2020). Further, the study did not explicitly test for stationarity or structural breaks; therefore, future studies may incorporate advanced time-series diagnostics to further strengthen productivity estimation.

3. Data and methodology

The present study is based on state-level secondary data covering a period of 25 years from 1997–98 to 2021–22. The study period 1997–98 to 2021–22 was selected based on the availability of consistent and continuous time-series data on output and input variables from the Cost of Cultivation of Principal Crops published by the Ministry of Agriculture and Farmers Welfare. The period also captures major technological, irrigation, and policy changes affecting paddy productivity.

Total Factor Productivity (TFP) was estimated by considering two output components and eight input components. The output index comprised the main product (grain) and by-product (straw), while the input index included seed, fertilizer, manure, human labour, animal labour, machine labour, pesticides, and irrigation charges. Data on quantities and prices of output and input for paddy crop were compiled from Cost of Cultivation of Principal crops by Ministry of Agriculture, published



by the Ministry of Agriculture and Farmers Welfare, Government of India. All variables were initially available on a per hectare basis and all per-hectare observations were converted into aggregate annual values by multiplying them by the total area under paddy in the corresponding year.

4. Tools of analysis

4.1. Compound growth rate analysis

Estimation of growth rates is an important analytical tool used to measure the performance of economic variables over time. Growth rates summarize long-term trends in time-series data. In the present study, the compound growth rate (CGR) in area, production, and productivity of paddy crops was estimated using an exponential growth function, which assumes a constant proportional rate of change over time and has been widely applied in agricultural growth studies (Gujarati, 2004; Kannan, 2011).

The exponential growth function is specified as:

$$Y_t = ab^t e^{u_t}$$

Where,

Y_t = Dependent variable (area, production, productivity) in year t

a = intercept (initial value)

b = regression coefficient (growth factor)

t = time variable (year)

e = Base of natural logarithm

u_t = disturbance term

To estimate the growth rate, the above equation was transformed into logarithmic form:

$$\ln Y_t = \ln(a) + t \ln(b) + u_t$$

The compound growth rate (g) in percentage was computed from the relationship:

$$G = \{(\text{anti ln of } \ln b) - 1\} * 100$$

4.2. Instability analysis

Measurement of instability in area, production, and productivity is essential for policy formulation, as high variability can affect food security, farmer income, and market stability. The coefficient of variation (CV) is commonly used as a measure of instability. However, time-series data often exhibit long-term trends, and the simple

CV may overestimate instability due to the presence of such trends.

To account for the trend component and obtain a more reliable measure of instability, the Cuddy–Della Valle Index (CDVI) was employed (Cuddy and Della Valle, 1978). This index adjusts the coefficient of variation by incorporating the goodness of fit of the trend equation. The instability index is computed as:

$$CDVI = CV \sqrt{1 - R^2}$$

CV = Coefficient of variation, R^2 = Coefficient of determination of trend, $CV = (\text{Standard Deviation} / \text{Mean}) * 100$

4.3. Estimation of total factor productivity (TFP) Index

The Divisia-Tornqvist index was preferred because it is a flexible functional form consistent with translog production technology and requires only price and quantity data. It is widely used in agricultural productivity studies due to its ability to approximate Divisia indices and handle multiple inputs and outputs efficiently (Coelli *et al.*, 2005).

4.4. Construction of output and input indices

Let $Y_{jt} Y_{jt}$ denote the quantity of output jj in year tt , where $j = 1, 2, j = 1, 2$ refers to grain and straw, and let $X_{it} X_{it}$ denote the quantity of input ii in year tt , where $i = 1, \dots, 8, i = 1, \dots, 8$ refers to the eight input categories. Let $P_{jt} P_{jt}$ be the price of output jj and $W_{it} W_{it}$ the price of input ii in year tt . The annual Tornqvist Total Output Index (TOI) between year $t - 1t - 1$ and year tt was computed as:

$$\ln \left(\frac{TOI_t}{TOI_{t-1}} \right) = \sum_{j=1}^m \frac{1}{2} (R_{jt} + R_{j,t-1}) \ln \left(\frac{Y_{jt}}{Y_{j,t-1}} \right)$$

where $R_{jt} R_{jt}$ is the revenue share of output jj in total output value in year tt , defined as:

$$R_{jt} = \frac{P_{jt} Y_{jt}}{\sum_{j=1}^m P_{jt} Y_{jt}}$$

Similarly, the annual Tornqvist Total Input Index (TII) between year $t - 1t - 1$ and year tt was estimated as:

$$\ln \left(\frac{TII_t}{TII_{t-1}} \right) = \sum_{i=1}^n \frac{1}{2} (S_{it} + S_{i,t-1}) \ln \left(\frac{X_{it}}{X_{i,t-1}} \right)$$



where S_{it} is the cost share of input i in total input cost in year t , defined as:

$$S_{it} = \frac{W_{it}X_{it}}{\sum_{i=1}^n W_{it} X_{it}}$$

The Total Factor Productivity Index (TFPI) for year t was then obtained as the ratio of the output index to the input index:

$$TFPI_t = \frac{TOI_t}{TII_t}$$

Using 1997–98 as the base year (1997-98=100) the chained indices were constructed recursively so that:

$$TOI_t = TOI_{t-1} \times \exp \left[\ln \left(\frac{TOI_t}{TOI_{t-1}} \right) \right]$$

$$TII_t = TII_{t-1} \times \exp \left[\ln \left(\frac{TII_t}{TII_{t-1}} \right) \right]$$

$$TFPI_t = \frac{TOI_t}{TII_t} \times 100$$

Under this framework, a TFPI value greater than 100 indicates productivity improvement relative to the base year, while a value below 100 indicates deterioration in productivity (Coelli *et al.*, 2005).

5. Result and discussion

5.1. Trend in Growth and instability of area, production and productivity of Paddy crops in Tamil Nadu from 1997-98 to 2021-2022.

Table 1 shows that paddy area in Tamil Nadu declined significantly at -0.69 % per annum, indicating a structural contraction in the cropped area under paddy. This decline may be attributed to water scarcity, urban expansion, and the shift of farmers toward alternative crops with lower risk or higher returns, which have been identified as major factors influencing land-use changes in agriculture (BIRTHAL *et al.*, 2019; Chand and Kumar, 2021). Production remained nearly stagnant with a negligible growth rate of 0.004 %, but the high instability of 25.43 % suggests that paddy output was highly vulnerable to rainfall variability, irrigation constraints, and fluctuations in input availability, consistent with findings reported in earlier studies on agricultural instability and climate sensitivity (Kumar *et al.*, 2022). Yield increased modestly at 0.29 % per annum, implying some improvement in technology adoption and farm management, although the gain was not strong enough to generate substantial output growth. The comparatively high instability in productivity also indicates that productivity improvements were uneven across years and sensitive to climatic and institutional shocks.

Table 1. CGR and Instability in Area, Production and Productivity

Sl. No.	Details	Paddy	
		CGR (% per annum)	Instability
1	Area ('000 ha)	-0.69**	13.87
2	Production ('000 t)	0.004	25.43
3	Productivity (kg/ha)	0.29	16.60

*, **, *** Significant at 1%, 5 % and 10 % levels

The findings suggest three direct policy priorities. First, water-saving interventions such as micro-irrigation, canal modernization, tank rehabilitation, and climate-resilient irrigation scheduling are essential to stabilize paddy area and output. Second, input management should be strengthened through timely seed and fertilizer supply, better pest management, and promotion of precision agriculture to reduce cost pressure and input-related volatility which have been recognized as critical drivers of productivity improvement (Fuglie, 2020). Third,

because productivity is highly exposed to rainfall and climate variation, policies should focus on drought-tolerant varieties, crop insurance, early warning systems, and region-specific climate adaptation support.

5.2. Estimation of total factor productivity (TFP) indices of paddy crops

To estimate the total factor productivity (TFP) of the paddy crops in Tamil Nadu state for a period of twenty-five years from 1997-98 to 2021-22. For this purpose, the parametric approach was applied in this section in which



the Tornqvist indices were estimated. This approach is a chained index method in which the TFP of each year is measured relative to the preceding year and subsequently linked to the base year (1997–98). The base year index was set equal to 100, and any index value greater than 100 indicates an improvement in productivity over the base year, while a value below 100 represents a decline in productivity.

Table 2. Total factor productivity indices of Paddy Crops in Tamil Nadu (Indices Relative to First Observation) from 1997-98 to 2021-22)

YEAR	Paddy		
	TII	TOI	TFPI
1997-98	100	100	100
1998-99	81.47	97.65	119.85
1999-00	83.73	103.80	123.97
2000-01	89.42	104.86	117.27
2001-02	95.63	155.16	162.25
2002-03	130.33	87.09	66.82
2003-04	75.96	127.26	167.54
2004-05	105.17	118.86	113.02
2005-06	92.45	120.85	130.72
2006-07	88.38	108.42	122.67
2007-08	95.77	120.43	125.74
2008-09	98.63	131.09	132.91
2009-10	101.66	117.76	115.84
2010-11	97.70	110.91	113.52
2011-12	93.95	111.38	118.55
2012-13	119.49	145.52	121.79
2013-14	104.76	116.31	111.03
2014-15	105.83	119.73	113.12
2015-16	98.71	108.23	109.64
2016-17	139.91	155.88	111.42
2017-18	105.83	143.25	135.37
2018-19	114.51	153.02	133.63
2019-20	103.16	127.72	123.81
2020-21	97.73	131.23	134.27
2021-22	91.05	123.08	135.17
Average	100.4	121.6	122.4
CAGR (% per annum)			0.35

It is observed from the Table 2, the Total Factor Productivity Index (TFPI) for paddy crop during the period 1997-98

to 2021-22 exhibited considerable fluctuations across the years. With 1997-98 taken as the base year (100), the average Input Index (TII) stood at 100.4, while the average Output Index (TOI) was 121.6, indicating that output growth was relatively higher compared to input use. Consequently, the TFPI averaged 122.4 over the study period. The compound growth rate (CGR) of TFPI was estimated at 0.35 percent per annum, suggesting a marginal but positive growth in productivity over time.

The index declines sharply in some years, such as 2002–03 (66.82) and 2015–16 (109.64), while years like 2001–02 and 2003–04 recorded relatively higher TFPI values. These year-to-year fluctuations may be associated with variations in climatic conditions, input use patterns, or other external factors.

5.3. Analyse the trend in minimum support price of paddy crops

Minimum Support Price (MSP) is a form of market intervention by the Government of India to insure agricultural producers against any sharp fall in farm prices. The minimum support prices are announced by the Government of India at the beginning of the sowing season for certain crops on the basis of the recommendations of the Commission for Agricultural Costs and Prices (CACAP), taking into account factors such as cost of cultivation, demand–supply conditions, and price parity among crops.

The analysis of Cost of Production (COP) and Minimum Support Price (MSP) for paddy over the period 1997-98 and 2021-22 (Figure 1) revealed significant trends in pricing and profitability. In 1997-98, the COP was Rs.488.25 per quintal, while the MSP was lower at Rs.415 per quintal, reflecting a negative margin for farmers. This situation persisted in several years up to 2006-07, where COP (Rs.836.07) consistently remained higher than MSP (Rs.580), indicating cost–price imbalance. However, from 2007-08 onwards, a reversal occurred as MSP (Rs.850) exceeded COP (Rs.766.47), offering farmers positive price support. Post-2018, MSP continuing to remain higher than COP in subsequent years, such as 2018-19 (COP Rs.1166 vs. MSP Rs.1750) and 2021-22 (COP Rs.1394 vs. MSP Rs.1940) reflecting stronger government price support.

The trend in MSP indicates a transition from an unfavourable cost-price relationship in the early years to a sustained positive margin after 2007–08, and particularly after 2018, suggesting stronger government price support



for paddy cultivation in Tamil Nadu. This support may have helped sustain farmer incentives and cultivation decisions, although its effect on productivity appears indirect and mediated through profitability, input use, and production risk. The results obtained in the present study are consistent with earlier findings. For instance, BIRTHAL

et al. (2019) reported a steady increase in MSP for major cereals in India, emphasizing its role in stabilizing farm income. Similarly, Kannan and Sundaram (2011) observed that rising MSP levels contributed to improved farmer profitability and encouraged the adoption of modern inputs in paddy cultivation.

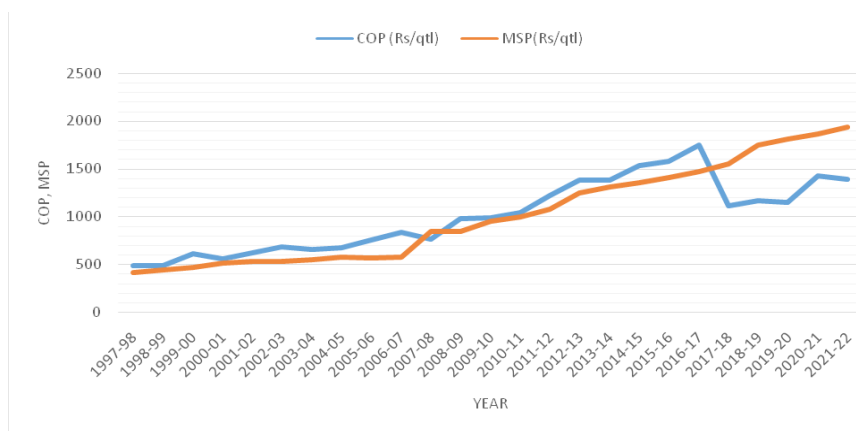


Figure 1. COP and MSP of Paddy (Rs/qtt)

6. Conclusion

The present study examined the growth, instability, Total Factor Productivity (TFP), and price support dynamics of paddy cultivation in Tamil Nadu over 1997–98 to 2021–22. The results indicate that paddy cultivation underwent structural stress over the study period, with cultivated area declining at -0.69 % per annum, production remaining almost stagnant at 0.004 %, and productivity showing only a modest increase of 0.29 % per annum. At the same time, production instability remained high, suggesting that paddy output was highly exposed to rainfall variation, irrigation uncertainty, and input-related fluctuations. The average TFPI of 122.4 and its growth rate of 0.35 % per annum show that productivity improved only gradually and was not strong enough to offset the broader production constraints.

The study period can be broadly divided into three phases based on observed trends in MSP and cost relationships. This phase-wise classification is descriptive in nature and not based on formal statistical tests for structural breaks. During the first phase (1997–98 to around 2006–07), paddy cultivation operated under relatively weak price incentives, as MSP remained below the cost of production in several years. This situation likely reduced profitability and limited farmers’ ability to invest in productivity-enhancing inputs. In the second phase

(2007–08 to 2017–18), MSP began to exceed the cost of production, which appears to have strengthened farmer confidence and provided improved price protection. However, the continued instability in production during this period indicates that price support alone was not sufficient to offset the influence of climatic variability and fluctuations in input use. In the third phase, after 2018, MSP widened further above cost of production, indicating stronger nominal support to farmers, but the long-term productivity gains still remained modest, implying that price policy improved income security more than physical productivity. The Total Factor Productivity (TFP) results reinforce this pattern. Although output increased faster than input use on average, fluctuations in the Total Factor Productivity Index (TFPI) indicate that productivity gains were uneven and vulnerable to external shocks. Overall, the findings indicate that paddy performance in Tamil Nadu is influenced not only by farm-level efficiency, but also by broader factors such as water availability, climatic variability, and government policy support.

7. Policy Implication

The findings suggest three important policy priorities. First, water-saving measures such as micro-irrigation, tank rehabilitation, and better irrigation management should be strengthened, as water scarcity remains a major challenge for paddy cultivation. Second, improving productivity



requires stronger extension support through farmer training, field demonstrations, and promotion of suitable technologies. Third, MSP should be regularly revised to match rising cultivation costs and protect farmers' income. In addition, policies should focus on timely access to quality inputs, crop insurance, and better market linkages. These steps can help reduce instability and make paddy cultivation more sustainable in the long run.

Declarations

Funding

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

G. Harshavardhini: Conceptualization, data collection, analysis, manuscript writing and editing. L. Umamaheshwari and S. Parthasarathi: Methodology development, supervision, and manuscript review.

Ethical Approval

This study used secondary data from publicly available sources and did not involve human participants or animals. Therefore, ethical approval was not required.

Use of Generative AI

No generative AI or AI-assisted technologies were used in the preparation of this manuscript.

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