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Trends in total factor productivity of sugarcane in Maharashtra: A state level evidence using DEA and SFA approach

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Abstract
This paper applied the both parametric and non-parametric approaches of productivity estimation for sugarcane in Maharashtra for the period of 1980-81 to 2020-21. The result from both the approaches signifies the importance in shift due to technological adoption as a vital source of productivity growth. The estimation of DEA and SFA produced similar results at spatial and temporal directions thus validating the TFP estimation. The analysis for growth rate, instability and decomposition analysis has been carried out for five sub-periods as per the reforms in the sugarcane industry and overall period (1950-51 to 2020-21). The state is witnessing a positive growth rate in area, production and productivity after the Mature Economic Reforms after 1990's. However the state is suffering from serious instability issues in the sub-periods IV and V due to the scarcity of water and decline in groundwater table of the state. The positive TFP growth has been associated with associated with 0.3 per cent and a declining mean technical efficiency by -0.1 per cent per year. The TFP revived by 1.09 percent after the reforms in the sugar industry. The estimated regression results for TFP determinants revealed pressure on irrigation facilities due to prolonged drought condition of state. Since sugarcane is the leading cash crop of the state and large revenue is being generated by the crop sugar mills, balanced nutrients, and rural literacy all of these have a positive and significant contribution in increasing the agricultural productivity of the state. The results have revealed the yield stagnation is not only due to technology fatigue, but could be due to slacked input intensification. An obvious extension of the study could be incorporating more crops and states for an exhaustive and comparative analysis.

Keywords: TFP growth, Malmquist index, DEA, SFA, sugarcane

Introduction

The agricultural productivity always remains an important driver for the especial concerns such as food availability and rural poverty since the 1990s. The growth in the TFP promotes the rural sector to spend more on the non-farm sectors. This more specifically leads to the support the rural farm communities towards the non-farm commodities and service such as consumer goods and service, inputs and services to boost agricultural production, processing and marketing services. The slow agricultural growth could be due to reduce demand for food, slow technological change in agriculture, lack of employment opportunities for part time smallholders, limited technology adoption by full-time farmers.

India is the largest consumer and the second-largest producer of sugar in the world after Brazil. Average annual production of sugarcane is around 35.5 crore tonnes which is used to produce around 3 crore tonnes of sugar. The domestic consumption is estimated to be around 2.6 crore tonnes in the current financial year. Sugarcane is one of the most important cash crop of Uttar Pradesh. It is the highest sugarcane producing State in sub-tropical zone having area about 22.77 lakh ha with the production of 135.64 Million tonne cane. About 50 million farmers and 3-5 lakhs skilled and unskilled workers are engaged in cultivation of sugarcane and sugar industries and its allied industries.

There are few studies which have documented the total factor productivity of sugarcane using both the parametric and non-parametric approaches. This paper has looked upon the major trends and factors affecting TFP of the major cash crop of Maharashtra. Using the panel data for the time period (1980-81to 2020-2021), we have estimated parametric stochastic frontier analysis (SFA) (Aigner *et al*., 1977) [1] and non-parametric data envelopment analysis (DEA) (Charnes *et al*., 1978) [3] and discussed he results obtained from both the approaches. The purpose of using both the approaches was to counter verify the results obtained by one another.

Using the Malmquist index (see Coelli and Rao, 2005 [6] for more details) non-parametric DEA can be used to decompose TFP growth into movements of the frontier and movement towards the frontier. On the other hand, the merit of SFA is that it considers stochastic noise in data (e.g. capital or labor variation) and also allows for the statistical testing of the hypothesis keeping under consideration the production structure and degree of inefficiency. However, its main limitations are that it explicit obtruding of a particular functional form and distributional assumption for the inefficiency terms. DEA is supposed to be a better choice when random disturbances are less and price information is not available (Fare *et al.* 1994) the non-parametric technique allows to isolate the contribution of improving efficiency frim the contribution of technological progress. The SFA is more prominent where data suffers from errors in the measurement, difficulty in identifying them as well as random events. The contrasting results have been witnessed in case of the leading producing states in Uttar Pradesh using both DEA and SFA (Gupta and Badal, 2021) [8].

With these points here the question arises what is the direction of productivity? What is the growth of inputs and output? Are inputs efficiently utilized? The TFP for the Indian crops at a bigger scale was determined by Rosegrant and Evenson (1992) [11]. The objectives of the paper is to analyze the

1. To estimate Growth, relative contribution and instability in area, production and productivity of Sugarcane in Maharashtra
2. To estimate growth in Total factor Productivity using parametric and non-parametric analysis.

Data Sources

The present analysis is based on secondary data which was collected from the Directorate of Economics and Statistics (DES), Government of India and Indian Institute of Sugarcane Research, Lucknow (IISR) website for 70 years from (1950-51 to 2019-20). The analysis periods have been classified into five sub-periods to determine the trends in growth pattern level of sugarcane production in India as whole and leading producing states.

Period I (1950-51 to 2020-21)

Overall Period.

Sub-Period I (1950-51 to 1979-80)

Spread of Sugarcane Factories, Introduction of Sugarcane Price Policies (SAP).

Sub-Period II (1980-81 to 1990-91)

Sugarcane Development Plan (1982), Prominent Role of the State, Technology Dissemination.

Sub-Period III (1991-92 to 2000-01)

Early Economic Reform/ De-licensing and Decontrol of Sugar Sector (1998).

Sub-Period IV (2001-02 to 2020-21)

Mature Economic Reform/ Sustainable Development Based Cropping System (SUBACS) (2000), New Sugarcane Policy

The Total factor Productivity was measured using the data from Commission for Agricultural Costs and Prices, Ministry of Agriculture & Farmers Welfare, Government of India (Various issues 1980-81 to 2020-21).

To analyze the determinants of the total factor productivity growth the data on Government expenditure on education and research programmes, Government expenditure on extension and transfer of technology for farmers, percent irrigated area, percent of rural literacy and is number of Sugar mills in each state have been compiled from the published sources. The Combined Finance Accounts published by Comptroller and Auditor General of India provides data on the government expenditure on research, training and extension. Information on the percent irrigated are, rural literacy and fertilizer consumption has been compiled from the Statistical Abstract of the respective states published by Directorate of Economics and Statistics. The data on the number of the sugar mills have been used from the Indian Sugar Mills Association.

Table 1: Summary of the mean of inputs of the Pre-Macro (1980s) and Post-Macro (1990s Onwards) & (2000s Onward) REFORM PERIOD

Years (1)	Seed (2)	HL (3)	AL (4)	Chem (5)	Mach (6)	IRR (7)	Yield (8)
1980s	2537.5	1168.854	97.053	66.69	173.775	87.44	39593
1990s	2427.6	1283.361	43.491	154.831	259.389	90.007	47513.6
2000s	2449.10	1263.23	19.82	185.34	385.31	91.35	50003.30
2010s	2421.00	1206.03	11.85	196.92	484.18	95.00	53226.75

Source: Compiled from the Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops in India, Government of India (various issues)

The summary of the mean of inputs used and output are presented in the Table 1 for the pre-macro (1980's) and post-macro (1990's). One of the obvious and important attribute of Sugarcane to be noted is of being a much labour and capital intensive crop.

Methodology

Compound growth rates were estimated with the following exponential model using least square techniques which are given below:

Where,

Y= Trend value of dependent variable (area/ total production/yield)

a = constant

b =Trend coefficient (slope of line)

t = time variable (Years)

The function takes the form of a linear equation in logarithmic and become log- linear as under

Log Y= log a + log b

Compound growth rate (CGR) = (Antilog β-1)×100

CGR was estimated by applying OLS method. The t-test was performed to test the significance of β

The change in sugarcane production during any time period was decomposed into different components in the following manner which was used by Allauddin and Tisdell (1986) [2] and Devraj (2006):

Production = Area*Yield
$P_o = A_o*Y_o$; $Pn= A_n*Y_n$
$P_n= (Ao+\Delta A)*(Y_o+\Delta Y)$
$P_n= (A_o*Y_o)+(A_o*\Delta Y)+(\Delta A*Y_o)+(\Delta A*\Delta Y)$

For the calculation of change in Production, Pn Subtracting by Po,

$P_n-P_o= (A_o*Y_o)+(A_o*\Delta Y)+(\Delta A*Y_o)+(\Delta A*\Delta Y) -(A_o*Y_o)$

$\Delta P = [A_o*\Delta Y] + [Y_o*\Delta A] + [\Delta A* \Delta Y]$

Change in production = Yield effect +Area effect + Interaction effect

P_o, A_o and Y_o are area, production and yield in the base year and P_n, A_n, and Y_n are area, production and yield in a current year.
For a better measure of variability, the instability index was adopted which was developed by Cuddy and Dell (1978) as follows:

$$\text{Instability Index}(\%) = CV \times \sqrt{1-\bar{R}^2}$$

Where, II – Instability Index, CV – Coefficient, variation, $\bar{R}^2$ – coefficient determination from a time trend regression adjusted by the number of degrees of freedom.
The difference between the actual production level of any firm and its actual production measures the technical efficiency. The estimation method can be parametric or non-parametric as both of these differ in the assumptions they make regarding the shape of the frontier and existence of error.

Non-Parametric DEA Model
In this paper, we have measured TFP growth using the Malmquist index method described in Fare *et al.* (1994) [7] and Coelli *et al.* (2005, Ch11) [6]. We have used the following model specified by Fare *et al.* (1994) [7]:

$$M_{OC}\,(x^t, y^t, x^{t+1}, y^{t+1}) = E\,(x^{t+1}, y^{t+1}, x^t, y^t) * T\,((x^{t+1}, y^{t+1}, x^t, y^t)(1)$$

Where, E (.) represents the relative efficiency change under Constant return to scale (CRS), this one of the way of reaching the best possible frontier for each time periods *t* and *t+1* are the two time periods for the observation of the frontiers, and T (.) represents the technical change measures the shift in the frontier of technology (or innovation) between the two time periods appraised at x^t and x^{t+1}.We have used DEAP (version 2.1) developed by Tim Coelli (1996b) [5] to estimate efficiency and productivity indices.

Parametric SFA Model
The SFA measures the technical efficiency and recognizes the fact that random shocks are beyond the control of the producers which may affect the production input. Aigner *et al.*, (1977) [1] and Meeusen and van den Broeck (1977) [10]. We have used the software FRONTIER (4.1) developed by Tim Coelli (1996a) [4]. In this paper, we have used the following stochastic frontier production model with time-varying inefficiency in panel data as:

$$\ln Y_{it} = \beta_0 + \beta_0 \ln X_1 + \beta_0 \ln X_2 + \beta_0 \ln X_3 + \beta_0 \ln X_4 + \beta_0 \ln X_5 + \beta_0 \ln X_6 \; + vit - uit \qquad (2)$$

Where,
Ln denotes the natural logarthim,
Y_{it} denotes the sugarcane productivity per hectare for the i^{th} state at time
X_{1-6} denotes various input variables

The introduction of time trend, t, interacted with input variables that allows for non-neutral technical change in the model. The technical inefficiency function, it can be written as:

$$uit = \delta_0 + \delta_i lnX_{it} + \omega_{it} \qquad (3)$$

Where,
ω_{it} is the random error-term
X_{it} are input variables (seed, human labour, animal labour, chemical fertilizers, irrigation)
δ_s are the parameters of input variables to be estimated

The technical efficiency measures,

$$TE_{it} = E\lfloor \exp(-u_{it})e_{it} \rfloor$$

Where,
$(e_{it} = v_{it} - u_{it})$, can be used to calculate the efficiency change component.

With the help of above technical efficiency measures, the efficiency change can be estimated using following equations (Coelli *et al*., 2005: 301) [6]

$$Efficiency\ change = \frac{TE_{it}}{TE_{i(t+1)}} \qquad (4)$$

$$Technical\ change = \exp(\tfrac{1}{2})\left(\frac{\partial lnY_{i(t+1)}}{\partial(t+1)}\right) + \frac{\partial lnY_{it}}{\partial t} \qquad (5)$$

And Malmquist TFP = (Efficiency Change) × (Technical Change) (6)

Results and Discussion
The growth trend in area, production and productivity of sugarcane in Maharashtra is presented in table 5 below. The second leading producing state after Uttar Pradesh has been undergoing a declining trend in all the three measure of classification due to the draught in the state which occurs at frequent intervals. The growth trend of area was significantly positive and increasing for the sub-periods II, III, IV, and V at a rate of 4.3 percent, 2.0 percent, 3.5 percent and 4.2 respectively and for the overall period I the growth rate was 3.9 percent.
The growth trend in production was positively significant for overall period I at 4.0 percent and was highest in sub-period II at 5.2 percent however which became insignificant though positive in sub-period III at 0.6 percent. However it again shoot to around 4.4 percent in sub-period IV which again declined in the sub-period V at 3.8 percent the reason of which can be attributed to the draught in the state which has resulted in severe reduction in the production of sugarcane in Maharashtra.

Growth trend in productivity was positive and significant for the sub-period II at 0.9 percent and was positive and less significant for the period I at 0.1 percent and remained positive but insignificant for the sub-period IV and V and negative and insignificant for the period III.

Table 2: Growth Rate of Area, Production and Yield of Sugarcane in Maharashtra during 1950-51 to 2019-20 (in per cent)

Period	Maharashtra		
	Area	Production	Productivity
Period I (1950-51 to 2020-21)	3.9 (36.491) ***	4 (27.360) ***	0.1 (1.120) **
Sub-Period I (1950-51 to 1979-80)	4.3 (12.740) ***	5.2 (13.993) ***	0.9 (3.789) ***
Sub-Period II (1980-81 to 1990-91)	2 (1.730) ***	0.6 (0.387)	-1.4 (-3.705)
Sub-Period III (1991-92 to 2000-01)	3.5 (2.231) ***	4.4 (2.464) ***	0.9 (1.705) *
Sub-Period IV (2001-01 to 2020-21)	4.2 (4.311) ***	3.8 (2.949) ***	0.4 (-1.019)

Note: Figures in parenthesis shows't' values. ***. 001 level,* *.01 level.

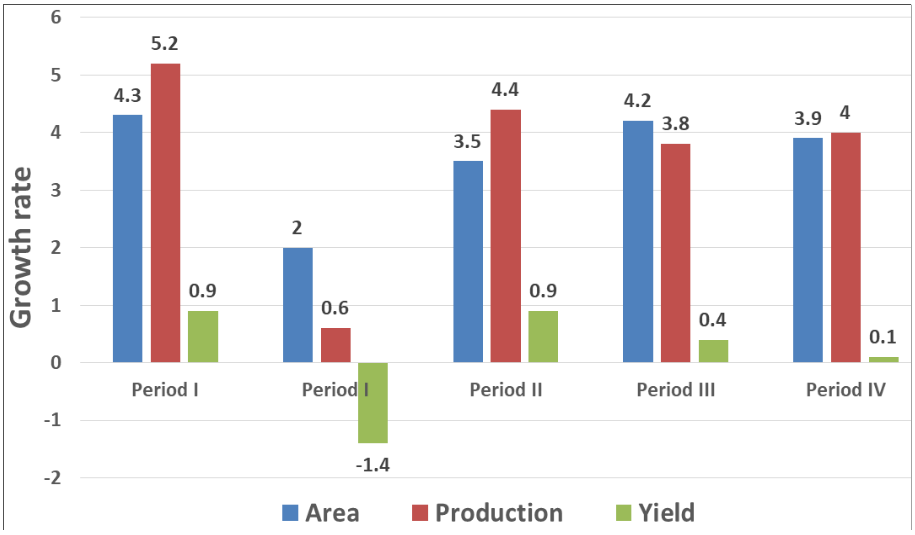

Fig 1: Growth rate of area, production and yield of sugarcane during 1950-51 to 2020-21 in Maharashtra (in percent)

Table 3: Decomposition of change in production of sugarcane in Maharashtra (1950-51 to 2020-21)

Maharashtra			
Period	Area Effect	Yield Effect	Interaction Effect
Period I (1950-51 to 2020-21)	0.33	95.490	4.180
Sub-Period I (1950-51 to 1979-80)	11.380	66.29	22.310
Sub-Period II (1980-81 to 1990-91)	6.680	90.090	3.280
Sub-Period III (1991-92 to 2000-01)	2.966	96.058	0.975
Sub-Period IV (2001-02 to 2020-21)	8.180	85.940	5.875

Note: Sum of all three effects=100

The decomposition analysis of change in production of sugarcane in Maharashtra is presented in Table 3. The second leading producing state has yield as its major contributor in the sugarcane output production. The sub-period IV has the maximum contribution of 96 percent, next to it is period I which has a yield contribution of 95.49 percent. The sub-period II saw a serious drop in the contribution of yield effect and was rather distributed in the area and there interaction which was 11.38 and 22.31 respectively. The sub-period III again got momentum in the yield effect and has a contribution of 90 percent. The decomposition analysis results of Maharashtra clearly indicated a dominant presence of yield as a major contributor in the output of sugarcane production.

The instability analysis of the second leading producing state is presented below in Table 4. The overall period I in the area and production has a high degree of instability with 30.78 percent and 30.50 percent (at 1 percent level of significance) respectively and a moderate degree of instability with 13.06 percent (at 10 percent level of significance).The sub-period I has a moderate degree of instability for all the parameters of area, production and yield with 13.49 percent, 18.35 percent and 11.42 percent (at 1 percent level of significance) respectively. The sub-period II has a moderate degree of instability in area and production with 10.75 percent and 11.58 percent (at 10 percent level of significance) respectively, whereas the yield reported a low degree of instability with 3.40 percent (at 1 percent level of significance) the same trend was followed in the sub-period IV with 12.99 percent and 14.70 percent (at 10 percent level of significance) respectively, whereas the yield reported a low degree of instability with 4.74 percent (at 1 percent level of significance). The economic reform sub-period V has moderate degree of instability for area and yield with 19.83 percent and 10.65 percent (at 1 and 10 percent level of significance) respectively and production has high degree of instability with 26 percent (at 1 percent level of significance). The results of the instability analysis of Maharashtra revealed that the state is suffering with serious instability issues. The main reason of increased instability in yield of sugarcane was several droughts during the sub-period IV and V the scarcity of water and decline in groundwater table has also contributed to the increase in instability.

Table 4: Instability in Area, Production and Yield of Sugarcane in Maharashtra (1950-51 to 2019-20)

Field of Measurement	Measurement Statistics	Period I I (1950-51 to 2020-21)	Sub-Period I (1950-51 to 1979-80)	Sub-Period II (1980-81 to 1990-91)	Sub-Period III (1990-2000)	Sub-Period IV (2000-01-2020-21)
		Maharashtra				
Area	CV	75.7874	36.18650	11.91666	15.99030	28.5337
	t- Value	18.738***	13.433***	1.746*	2.374**	4.619***
	R̄ square	0.835	0.861	0.185	0.340	0.517
	Instability Index (%)	30.7849	13.49130	10.7580	12.99058	19.8304
Production	CV	73.34035	46.0197	12.94226	19.1154	30.72313
	t- Value	18.175***	12.405***	0.436*	2.686**	2.876**
	R̄ square	0.827	0.841	0.199	0.408	0.277
	Instability Index (%)	30.50464	18.35026	11.58314	14.7076	26.1236
Yield	CV	13.08193	14.06865	5.13223	5.2332	10.72551
	t- Value	1.041*	3.994***	3.729***	1.721*	1.118*
	R̄ square	0.001	0.340	0.589	0.179	0.013
	Instability Index (%)	13.0688	11.429	3.4056	4.7415	10.6556

Note: CV- Coefficient of Variation, ***.001 level, **.01 level and *.05 level

The results of the decomposition analysis for the Maharashtra state have been given below in Table 75which presents the summary of TFP change (TFPCH), technical change (TECHCH) and efficiency change (EFFCH) indices during the period 1980-81 to 2019-20, the indices are calculated taking preceding year as the base.

The mean average values of the Maharashtra represent for decades 1980', 1990's and 2000's are positive and greater than one (1.218, 1.049 and 1.028) respectively. Whereas for the decade 2010's the TFPCH is less than one (0.977) the declining TFPCH can be attributed to the draught and irrigation problems in the state. The maximum TFPCH (1.866) was recorded during the early 2000's when the new economic reforms were arrived. A TFPCH greater than one indicates progress in the TFP, while a TFPCH less than one indicates implies that TFP is regressing and EFFCH index has achieved no change and regress during the period.

Table 5: Summary of Malmquist Productivity Indices and its Decomposition year wise

Maharashtra							
Year	TFPCH	Year	TFPCH	Year	TFPCH	Year	TFPCH
1980-81	3.432	1990-91	1.593	2000-01	0.987	2009-10	1.250
1981-82	0.169	1991-92	0.728	2001-02	0.744	2010-11	1.038
1982-83	2.459	1992-93	1.048	2002-03	1.037	2011-12	1.270
1983-84	1.104	1993-94	0.941	2003-04	1.450	2012-13	0.919
1984-85	0.850	1994-95	1.031	2004-05	0.776	2013-14	1.185
1985-86	0.978	1995-96	0.932	2005-06	0.710	2014-15	0.722
1986-87	1.133	1996-97	1.362	2006-07	1.442	2015-16	1.139
1987-88	0.984	1997-98	0.953	2007-08	1.008	2016-17	1.312
1988-89	1.074	1998-99	0.716	2008-09	0.877	2017-18	1.212
1989-90	1.218	1999-00	1.186	2009-10	1.250	2018-19	0.975
Mean	1.218	Mean	1.049	Mean	1.028	Mean	0.977

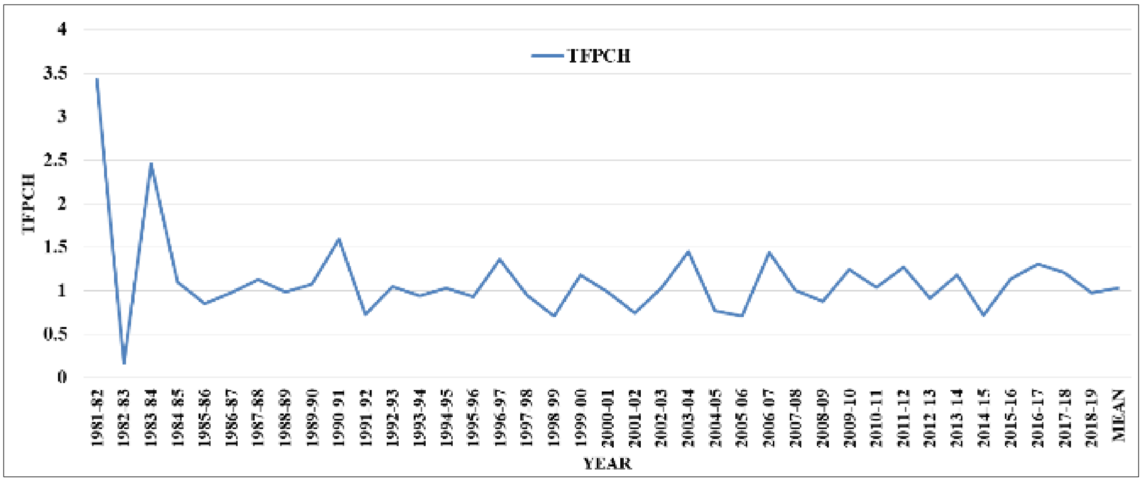

Fig 2: Summary of Malmquist productivity indices and its decomposition year wise in Maharashtra

Table 6: Maximum Likelihood Estimate of Stochastic Production Frontier (SFA) output for Sugarcane of Maharashtra (1980-1981 to 2019-20)

Variable & Parameters		MLE Estimates		
		Coefficient	Standard Error	t-Ratio
Constant	ß0	5.244***	0.997	5.256
Seed	ß1	-0.090	0.776	0.116

Human Labour	ß2	0.505	0.738	0.683
Animal Labour	ß3	0.019	0.922	0.206
Chemical Labour	ß4	0.302	0.897	0.360
Machine Labour	ß5	0.347	0.559	0.620
Irrigation	ß6	0.182	0.953	0.191
Sigma Squared	σ2	0.026	0.079	0.341
Gamma	γ	0.971***	0.985	0.985
LR Test		17.809		
Log Likelihood Function		34.338		

Figure in the Parenthesis shows ***1%, **5%, *10% Level of Significance

LR value < Chi-Square value (1% Level of Significance) i.e., 12.483 taken from Kode and Palm (1986) [9]

The gamma (γ) value indicates that stochastic frontier production model is an appropriate specification as the value is 0.971 which is closer to one given above in Table 5.4.1.1.8. The results of the MLE also show that among the different inputs used in production all of them are positive but statistically insignificant (at 1 percent level of significance) these results are alarming and also throws light at the way the resources are being utilized being the second largest producer of sugarcane in the country. Also, the likelihood ratio test values (17.809) are greater than the chi-square table value taken from Kode and Palm (12.483) at (1 percent level of significance) that implies technical inefficiency present in the model.

Conclusion and Policy Implications

Sugarcane is one of the most important commercial led industrial crops in India. The low risk associated with the crop assures farmers up to some extent about return even in adverse condition. In Maharashtra, the highest growth trend in area and production was recorded during sub-period II (1950-51 to 1979-80) of 4.3 percent and 5.2 percent (1 percent level of significance) respectively productivity was highest during both sub-period II (1950-51 to 1979-80) and sub-period IV at 0.9 percent (1 percent level of significance) respectively. It is noteworthy here that even being the second highest producer of sugarcane in India its production is lagging behind Tamil Nadu. The frequent droughts and excess burden on the irrigation is one of major shortcomings in the state. The decomposition analysis results of Maharashtra clearly indicated a dominant presence of yield as a major contributor in the output of sugarcane production. The sub-period II saw a serious drop in the contribution of yield effect and was rather distributed in the area and there interaction which was 11.38 and 22.31 respectively. The relationship between area and production of sugarcane in all the periods was very strong (Range in between 0.907-984) at 1 percent level of significance level. The results of the instability analysis of Maharashtra revealed that the state is suffering with serious instability issues. The main reason of increased instability in yield of sugarcane was several drought, the scarcity of water and decline in groundwater table has also contributed to the increase in instability and also contributed to the declining TFP growth of 18.6 percent in pre-reform period to 25 percent in post-reform which dropped to 14 percent which could point out to a cycle of total factor productivity of in Maharashtra's sugarcane production. The empirical evidence obtained from the study suggests that technical efficiency has not been maintained. In order to balance out the differences in the contributions of the technological change and efficiency change to the TFP of sugarcane, the researchers must develop input responsive sugarcane varieties to improve efficiency of the crop.

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