The Pharma Innovation Journal 2021; SP-10(10): 269-271

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(10): 269-271

www.thepharmajournal.com
Received: 16-08-2021
Accepted: 18-09-2021

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A DEA approach to estimate of total factor productivity growth of sugarcane in Maharashtra

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Abstract
Productivity growth in agriculture is of paramount importance as higher yields are associated with declining rural poverty, suggesting that impact of growth in agricultural production on poverty remains high. Sugarcane is one of leading cash crop in India and stands at second to Brazil in sugarcane production in the world. Maharashtra is one of the leading producers of sugarcane in India but is its productivity has declined in the past recent years due to natural adversities such as draught and non-technological reforms. The paper attempts to estimate the Total Factor Productivity growth (TFP) using non-parametric DEA method in Maharashtra for the period 1980-2019. The results indicate the robustness of the methodology used and suggest suitable policy implications to revive the negative TFP growth of the crop in the state.

Keywords: DEA, malmquist, TFP, sugarcane

Introduction
The agricultural productivity continues to be an important driver of rural poverty reduction; especially it helps rise agricultural wages. The slow agricultural growth could be due to reduced demand for food, slow technological change in agriculture, lack of employment opportunities for part time smallholders, limited technology adoption by full-time farmers. The higher yields are associated with declining rural poverty, suggesting that impact of growth in agricultural production on poverty remains high.

Origin of Sugarcane (*Saccharum officinarum* L.) dates back to around 6000BC around New Guinea. Its cultivation slowly spread along nearly around 1000 BC, with human migration routes to Southern Asia and India. Sugarcane in India is cultivated broadly under two distinct agro-climatic conditions, commonly referred to as tropical and sub-tropical regions. Tropical region comprising the states *viz*., Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Telangana, Madhya Pradesh, Gujarat, Odisha and Chhattisgarh accounts for 42.9 per cent of the total sugarcane area in India. Whereas Sub-tropical region consists of Uttar Pradesh, Bihar, Punjab, Haryana, Uttarakhand, West Bengal and north-eastern states contributes 57.1 per cent of the total crop area (www.farmer.gov.in).

TFP plays a crucial role in economic fluctuations, economic growth and cross country per capita income differences Total factor Productivity is that part of output which is not explained by the amount of inputs used in production. As such, its level is determined by how intensely and efficiently the inputs are utilized in production.

The concept of productivity has two components: partial productivity and total factor productivity. Partial productivity measures the contribution of only one factor (say capital or labour) to output growth keeping the other factors constant. Generally, there are concepts of labour productivity and capital productivity which estimate the efficiency of resource use. However, partial productivity does not truly reflect whether the productivity growth is because of greater use of inputs or improvement in the technology or improvement in efficiency. Also, it ignores time, secondary products, inputs other than land, labour and capital and externalities, all of which must be included in a sustainability measurement of PFP estimates the ratio of total output to a single input, usually which is termed as labour.

With these points the paper attempts to determine the Total factor Productivity using non-parametric DEA Malmquist approach.

Data and Methodology
Data Sources
Time-series data for the estimation of TFP growth of sugarcane for the period 1980-81 to

2018-19 was collected from the Comprehensive Scheme for Studying Cost of Cultivation of Principal Crops published by CACP, Ministry of Agriculture, Government of India. Interpolation based on polynomial trends was used to predict the missing year data on input-use and yield per hectares.

The quantity data were given priority over price data, however where both were available to avoid anomalies in price information: Output (Kg), Human labours (in hours), animal labour (in paired hours), chemical inputs including manure and fertilizer (in Kg) and machine labour (computed by dividing the labour cost by the price indices of the same) (Gupta and Badal, 2021) [6].

Table 1: Summary of The Mean of Inputs of The Pre -Macro (1980s) and post-macro (1990s onwards) & (2000s onward) reform period

Maharashtra							
1980s	3232.30	2557.45	111.17	440.62	171.71	96.09	77483.5
1990s	2771.3	1970.64	113.36	349.29	256.16	98.96	80093.90
2000s	3658.40	2063.20	73.56	564.62	339.36	99.95	84313.60
2010s	2421.00	1808.21	53.66	638.86	456.33	90.54	98127.13

The summary of the mean of inputs used and output are presented in the Table I 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.

Methodological Skeleton

The difference between the actual production level of any firm and its actual production measures the technical efficiency.

Data envelopment analysis

Data Envelopment analysis (DEA) is a mathematical programming approach which assembles the frontier and estimates the efficiency relative to the constructed frontiers. The beauty of DEA lies in the fact that it does envelops the data without accommodation for noise. In consideration to the certain assumptions about the structure of production technology, it envelops the data as tightly as possible.

Non-Parametric DEA Model

In this paper, we have measured TFP growth using the Malmquist index method described in Fare *et al.* (1994) [5] and Coelli *et al.* (2005, Ch11) [4]. We have used the following model specified by Fare *et al.* (1994) [5]:

MOC (xt,yt,xt+1,yt+1)=E (xt+1,yt+1,xt,yt)∗T (xt+1,yt+1,xt,yt) (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 xt and xt+1.We have used DEAP (version 2.1) developed by Tim Coelli (1996b) [3] to estimate efficiency and productivity indices.

$$uit = \delta 0+\delta i ln Xit+\omega it \quad (2)$$

Where, ωit is the random error-term Xit are input variables (seed, human labour, animal labour, chemical fertilizers, irrigation) δs are the parameters of input variables to be estimated.

The technical efficiency measures,

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

Where, (eit=vit−uit), 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) [4].

$$Efficiency\ change = \frac{TE_{it}}{TE_{i(t+1)}} \quad (3)$$

$$Technical\ change = \exp\left(\frac{1}{2}\right)\left(\frac{\partial lnY_{i(t+1)}}{\partial(t+1)}\right) + \frac{\partial lnY_{it}}{\partial t} \quad (4)$$

And, Malmquist TFP = (Efficiency Change) × (Technical Change) (5)

Results and Discussion

The results of the decomposition analysis for the Maharashtra state have been given below in Table 2 which presents the summary of TFP change (TFPCH), technical change (TECHCH) and efficiency change (EFFCH) indices during the period 1980-81 to 2018-19, 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 2: 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

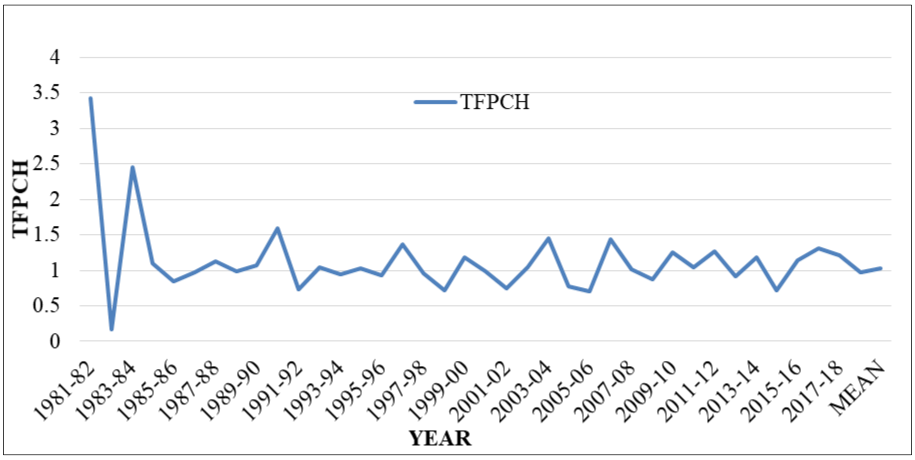

Fig 1: Summary of Malmquist productivity indices and its decomposition year wise in Maharashtra

Table 3: Summary of indices of Mamquist productivity, output growth and input contribution (1983-82 TO 2018-19)

States (1)	EFFCH (2)	TECHCH (3)	PECH (4)	SECH (5)	TFPCH (6)	TFP (%) (7)	Output Growth (8)	Input Growth (9)
Maharashtra	1.000	1.03	1.000	1.000	1.03	3	4.159506	4.038355

Summary and Conclusion

The main conclusion of the study is that technological progress has been a major contributor to the total factor productivity growth of sugarcane in Maharashtra (1.8 percent) but is witnessing an uneven growth among the major sugarcane producing states of India. In case of Maharashtra, which has been from drought quite a time recorded a 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. Poor performance in technical efficiency in technological less advance sugarcane producing states a greater potential to enhance productivity through improved technical efficiency. The empirical evidence obtained from the study suggests that technical efficiency has not been maintained. The increase or decrease in the total factor productivity growth is mainly due to increase or decrease in the technical change rather than any change due to technical efficiency. A low TFP growth implies that there is greater scope for increasing agricultural production by means of new technological advancements, enhancing investment in research and technology, and rural infrastructure. The analysis presented in this paper is the depiction of the major cash crop of the state. The decomposition of TFP growth using DEA has suggested that our results are quite robust to the choice of methodology. In comparison to previous decades Maharashtra has witnessed a fluctuating TFP growth. The drop in the TFP growth reveals an alarming picture on the sustainability of the sugarcane production in the state which holds the first place in the production. Lack of investment in technology is one the prominent reason for the poor technical change and low technical efficiency is due to management and incentive problems associated with poor information dissemination. An extension to this study would be the application of this approach to bring together a larger number of crops at state or district level.

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