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Total factor productivity growth of sugarcane in Uttar Pradesh: Parametric and non-parametric analysis

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Abstract
Productivity growth measurement remains a very essential for taking appropriate policy decision for the development of the agricultural sector. The present study measures total factor productivity growth of sugarcane in Uttar Pradesh leading producer of India. Parametric Stochastic Frontier Analysis (SFA) and Non-Parametric Data Envelopment Analysis (DEA) are used for this study. The results indicated the robustness of the methodology used, the TFP has witnessed a negative growth for the overall period the MLE estimates also suggested a non significant behavior. Sugarcane being a labour and capital intensive crop, however the low PECH in comparison to SECH of Uttar Pradesh suggested that inefficiency is mainly due to inefficient sugarcane production practices. For sugarcane production to sustain in the future, the government must look carefully into the factors which have led to a decline in the TFP growth over the years.

Keywords: DEA, SFA, sugarcane, total factor productivity

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 Uttar Pradesh. Using the panel data for the time period (1980-81to 2019-2020), we have estimated parametric stochastic frontier analysis (SFA) (Aigner *et al*., 1977) [1] and non-parametric data envelopment analysis (DEA) (Charnes *et al*., 1978) [2] 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 [5] 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) [6] 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.

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) [7]. The objectives of the paper is to analyze the growth in Total factor Productivity of Sugarcane in Uttar Pradesh using parametric and non-parametric analysis.

Data and Methodology

Data Sources

For the estimation of TFP growth of sugarcane, time-series data were collected of the period of 1980-81 to 2018-19 from the Comprehensive Scheme for Studying Cost of Cultivation of Principal Crops published by CACP, Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. The missing year data on input-use and yields per hectare were predicted using the interpolation based on the polynomial trends available in the data.

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).

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 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. 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) [6] and Coelli *et al.* (2005, Ch11) [5]. We have used the following model specified by Fare *et al.* (1994) [6]:

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

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 (1996 b) [4] 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) [8].

We have used the software FRONTIER (4.1) developed by Tim Coelli (1996 a) [3]. In this paper, we have used the following stochastic frontier production model with time-varying inefficiency in panel data as:

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

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, *uit* can be written as:

$$uit = \delta_0 + \delta_i \ln X_{it} + \omega_{it} \quad (3)$$

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) [5].

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

$$\text{Technical change} = \exp\left(\frac{1}{2}\right)\left(\frac{\partial \ln Y_{i(t+1)}}{\partial (t+1)}\right) + \frac{\partial \ln Y_{it}}{\partial t} \quad (5)$$

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

Results and Discussion

With the methodology explained above we have compared the results of the DEA and SFA of TFP growth of Sugarcane in

Uttar Pradesh. Table 2 represents the summary of the Malmquist productivity indices and its decomposition year-wise. The Malmquist Productivity Index was decomposed into the technical change index (TECHCH) and efficiency change (EFFCH) index and in order to identify the changes in scale efficiency, EFFCH was further decomposed into scale efficiency change (SECH) and pure efficiency change (PECH).

Table 2: Summary of Malmquist productivity indices and its decomposition year wise

Uttar Pradesh							
Year	**TFPCH**	**Year**	**TFPCH**	**Year**	**TFPCH**	**Year**	**TFPCH**
1980-81	0.785	1990-91	0.771	2000-01	0.969	2009-10	1.332
1981-82	1.022	1991-92	1.034	2001-02	0.917	2010-11	0.830
1982-83	0.829	1992-93	1.041	2002-03	1.182	2011-12	1.113
1983-84	1.069	1993-94	1.105	2003-04	1.421	2012-13	0.985
1984-85	0.996	1994-95	0.941	2004-05	0.908	2013-14	1.258
1985-86	1.064	1995-96	1.062	2005-06	0.897	2014-15	1.659
1986-87	1.119	1996-97	1.386	2006-07	0.971	2015-16	0.920
1987-88	1.088	1997-98	1.225	2007-08	0.873	2016-17	1.340
1988-89	1.122	1998-99	0.772	2008-09	0.867	2017-18	0.596
1989-90	0.909	1999-00	0.929	2009-10	1.332	2018-19	0.796
MEAN	0.909	MEAN	1.026	MEAN	1.033	MEAN	0.949

The results indicated that the total factor productivity change (TFPCH) in sugarcane production averaged at 2.0 percent for the period 1980-81 to 2018-19 (Table 2). This shows that the being the leading producing state, Uttar Pradesh is performing fairly well in terms of the production. The growth in technical efficiency and decline in technical change suggested that the increased TFP in the sugarcane production arose from the improvements in technical efficiency rather than the innovation in technology.

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

State	Effch	Techch	Pech	Sech	Tfpch	TFP (%)	Output Growth	Input Growth
Uttar Pradesh	1.000	1.018	1.000	1.000	1.018	-1.8	9.903324	9.728216

It is to be noted that TFP growth percentage for the period 1983-82 to 2018-19 is -1.8 (Table 3), the input growth and output growth are approximately same~ 9.7-9.9. Now if we divide the entire study period into two groups of pre-reforms (1980-81 to 2000-01) and post-reforms (2001-02 to 2018-19) it can be noted that decomposition of TFPCH into its components suggests that the major source of the productivity growth remains technological progress (TECCH) rather than an efficiency increase (EFFCH).

Table 4: Maximum Likelihood Estimate of Stochastic Production Frontier (SFA) output for Sugarcane Uttar Pradesh (1980-1981 to 2018-19)

Variable & Parameters		MLE Estimates		
		Coefficient	**Standard Error**	**t-Ratio**
Constant	$ß_0$	2.37	2.856	0.831
Seed	$ß_1$	0.407	0.0348	1.169
Human Labour	$ß_2$	1.12**	0.591	1.898
Animal Labour	$ß_3$	-0.088	0.056	1.561
Chemical Labour	$ß_4$	-0.024	0.0281	0.885
Machine Labour	$ß_5$	0.020	0.159	0.131
Irrigation	$ß_6$	0.239	0.290	0.823
Sigma Squared	σ^2	0.006*	0.003	1.715
Gamma	γ	0.999***	0.000	17.596
LR Test		8.063		
Log Likelihood Function		67.571		

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) [7].

The MLE estimates (Table 4) suggested that inputs such as seed, irrigation and machine labour are less significant and the human labour is more significant, also the likelihood test revealed that the LR value is less than the table value of chi-square taken from Kode and Palm (1986) [7]. The gamma value is also significant. DEA approach has found the mean TFP growth of 1.8 percent (Table 3), which depicts the robustness of the technology used. The results of input contribution also suggested "input intensification" in Uttar Pradesh.

Summary and Conclusion

The analysis presented in this paper is the depiction of the major cash crop of the state. The decomposition of TFP growth using both DEA and SFA has suggested that our results are quite robust to the choice of methodology. In comparison to previous decades Uttar Pradesh has witnessed a fluctuating TFP growth. This raises questions on the long run sustainability of the cash crop of the state. Further, the overall DEA TFP series is more volatile as DEA method is more sensitive to year-to-year changes while SFA smoothen these effects up to some degree. The possible reason for the fluctuating TFP of the state may be due to the capital and labour intensive nature of the crop, which is permitting the growers for the acreage expansion of the crop. The technical efficiency has been stagnated throughout, with fluctuating highs and lows, indicating that as the production frontier continued to shift outwards and no change in efficiency occurred otherwise. 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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