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Dynamics of technical efficiency of sugar mills in India: Stochastic Frontier Approach

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ABSTRACT

Using an annual survey industries unit level data pertaining to year 2014-15 from India, this paper examines the technical efficiency of sugar mills. A Stochastic Production Frontier (SFA) approach has been applied to measure technical efficiency of 490 sugar mills. The empirical results show that on an average sugar mills have 54% technical efficient, despite presence of considerable variations of technical efficiency among the selected states. This paper establishes a repertoire of management regimes varying in technical efficiency. It further reveals a significant difference in organization specific average technical efficiency of sugar mills across states. Overall, sugar mills are running under decreasing returns to scale. The emergent suggestion is to bring improvement in capital input use which is more effective than the labour input and augmentation in liability asset ratio. The management of less efficient mills needs to imbibe the best practices in terms of technology, policy and institutions of more efficient mills operating in other states.

Key words: India, Stochastic Frontier Approach, Sugar mills, Technical efficiency

Sugar industry is the second largest agro based industry after cotton and textile industries. At present Indian sugar industry's annual output is worth approximately ₹ 800 billion. There are 732 installed sugar mills in India in which, 327 co-operative sugar mills, 362 private sugar mills and 43 public sugar mills (Includes each refinery in West Bengal & Gujarat) (GoI 2018). Sugar assumes the importance of a political commodity due to its importance in national economies. Moreover, temporary and spatially, sugar industry suffers from bottlenecks viz. inadequate supply of sugarcane, excessive intervention of government in price fixation for both sugar and sugarcane. This led to variation in performance of sugar mills across the states. Despite several reforms in sugar sector (Mahajan 1998; Rangarajan 2012; Tuteja 2004) the mills still suffer a number of regulations like political control on sugar mills operations hampers the techno-economic viabilities and restricts them to expand their performance (Kumar and Arora 2009).

Several studies at India and rest of the world were conducted focusing on measuring efficiency and productivity at aggregated levels. Studies at state and region levels were conducted using parametric approach. The present is unique on two counts: First, it takes into account all sugar mills operating in India. Second, Unit level data of Annual Survey of Industries (ASI) was analysed using output oriented stochastic frontier approach to measure technical efficiency. The results will help the researchers in understanding how these changes have affected the output of the sugar production across states. In this backdrop, it becomes imperatives to study specific objectives: (1) To examine organization specific technical efficiency of sugar mills; (2) To discern the determinants of technical efficiency; and (3) To evaluate the variation in technical efficiency across states.

India is first largest sugar producing country after Brazil**,** and first largest consumer of sugar in the world. Sugar industry is the backbone of rural economy as it provides livelihood to 55 million unskilled peoples indirectly and 5 million skilled peoples directly. The industry's annual turnover in 2011-12 was ₹ 800 billion, with ₹ 550 billion as payment to the farmers (Singh 2016). Uttar Pradesh is the largest sugarcane producing state. Maharashtra is the second largest sugarcane producing state and most of the sugar mills located are co-operatively owned. The de-licensing policy of sugar mills in India started after the recommendation of Tuteja committee (Tuteja 2004). After implementation of the recommendations, number of sugar mills increased from 400 mills in 2004 and reached 538 mills in 2014. There is an overall improvement in area, yield, and production of sugarcane, production of sugar, average crashing duration and percentage recovery. The total supply of sugarcane could not be fully utilized by sugar mills. The rest was diverted for utilization in production of Khandsari

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and Gur (jaggery).This discerns reasons for percentage of sugarcane crushed by the mills vary significantly across years. Assured consistent supply of sugarcane ensures a definite crushing duration of processing units in the area. This lends the sugar industry in doldrums across the states. Erratic supply of sugarcane could be one of the reasons. The average recovery percentage of sugar ranges between 10.03 to 10.55%. The compound annual growth rate (CAGR) of sugar recovery was 1%. The industry suffers from up and downs due to severe drought and tight regulatory policy measures in some states.

MATERIALS AND METHODS

The present study is mainly based on secondary data of Annual Survey of Industries (ASI). The ASI framework comprises two sectors, census sector and sample sector. The census sector covers all factories employing 50 or more workers and using power, and 100 or more workers not using power. The sample sector covers remaining factories. The contributions of these two sectors is known as factory sector. The study is based on cross section data of the factory sector for year 2014-2015.

In empirical work of measurement of efficiency of sugar industries is based upon following Cobb-Douglas form of stochastic frontier model.

$$\text{Inyi} = \beta_0 + \beta_k \text{Ink}_i + \beta_1 \text{lnl}_i + \beta_i \text{lnf}_i + V_i - U \quad (1)$$

where, ln natural logarithm (i.e. logarithm to the base e). y_i represents all output principals due for all inputs of i^{th} sugar mills, k_i.represents capital of production measured in ₹ of i^{th} sugar mills. l_i represents wage of the total staff members and workers of i^{th} sugar mills, f_i represents total fuel used in the production of i^{th} Sugar mills, β_i**'s** are parameters to be estimated, v_i are assumed to be independent and identically distributed random errors which have normal distribution with mean zero and unknown variance σ_v^2 and u_i are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that u_i is obtained by truncation (at zero) of the normal distribution with mean μ_i and variance σ^2 in equation (1).

To know the factors affecting the technical efficiency are represented in technical efficiency effect model in equation (2). We have also followed Tobit regression as it used by various researchers (Abdulla and Ahmad 2017; Ahmad and Abdulla 2016; Singh *et al*. 2007; Singh 2006) in the case of sugar mills.

Technical efficiency effect model given as follows:

$$\mu_i + \delta_0 + \delta_i \text{ age}_i + \delta_2 \text{t\_mf\_days}_i + \delta_3 \text{land\_fc}_i + \delta_4 \text{build\_fc}_i + \delta_5 \text{pm\_fc}_i + \delta_6 \text{lib\_assets}_i + \delta_7 \text{tans\_fc}_i + \delta_8 \text{comp\_fc}_i + \delta_9 \text{super\_staff}_i + w_i \quad (2)$$

where, 'age' describe as the number of years in operations, 't_mf_days' describes as the ratio of no of manufacturing days to total manufacturing days in mills, 'land_fc' is the ratio of the fixed capital spend on land in mills,'build_fc' the ratio of the fixed capital spend over buildings in mills, 'pm_fc' the ratio of the fixed Capital spend over plant and machinery in mills, 'lib_assets' the ratio of the total liability and assets of the mills, 'trans_fc' the ratio of the fixed Capital to spend over the transportations in sugar mills, 'comp_fc' the ratio of the fixed Capital to spend over computer equipment's and 'super_staff" the ratio of supervisory staff over total workers, Δi parameters to be estimated, w_i is white noise error. Variables used in the models calculated by Annual Survey of Industries (ASI) tabulation program.

RESULTS AND DISCUSSION

The Table 1 depicts summary statistics of variables used in the frontier and efficiency effect models. For the frontier model, we used output variable as total sugar produced in a year. The main input variables used are fixed capital, total fuel used in production process and labour input as wages. There are several other variables (ratio of manufacturing and total manufacturing days, ratio of fixed capital to plant and machinery, transport, computerization, ratio of liability and assets and ratio of supervisory staff over total workers) which affect efficiency of any firms or industries. The efficiency effect model takes into account only important variables for measurement of efficiency of sugar mills.

Output is measured by the total ex-factory value of products and by-products produced by the firm during the production year. The inputs are labour (measured by the total wages and salary to workers), capital (measured by the net value of fixed assets of the firm at the beginning of a year) and energy (measured by the value electricity, coal, petrol etc.). Because only annual cross-section data are used to measure efficiencies, deflating the nominal values to take account of price changes was not necessary.

Table 2 shows the estimates of the efficiency of sugar mills in India using Stochastic Frontier model and Efficiency Effects model. The frontier model includes three input variables, viz. fixed capital, fuel and labour (wages). The signs of the coefficient are a prior expected. The partial slope coefficient of 0.34 measures the elasticity of total production of sugar with respect to capital input holding other variables constant. It explains that if the capital input increases by one percent, on an average, sugar production goes up by 0.34%. Similarly, holding the other inputs constant, if the labour (wage) increases by one percent, on an average, the total production of sugar goes up by about 0.21%. Hence one can say that capital input is more effective

Table 1 Summary statistics

Variable	Mean	Std. deviation.	Minimum	Maximum
Output (Lakh ₹)	19200	21800	0.001	259000
Capital (Lakh ₹)	10000	11100	0.773	75200
Labour (Lakh ₹)	917	618	0.025	4560
Fuel (Lakh ₹)	655	1400	0.001	9690

Source: Author's calculation based on Annual Survey of Industries (ASI) data: 2014-2015

Table 2 Estimates of the Stochastic Frontier Production function and Efficiency effects model

Variable	Frontier model parameter	Coefficient	Standard-error	t-ratio
Constant	β0	8.11***	0.460	17.72
Log capital	β1	0.34***	0.020	15.67
Log fuel	β2	0.18***	0.020	10.57
Log labour (wages)	β3	0.21***	0.030	8.46
Sigma-squared	σ2	6.44***	0.420	15.50
gamma	γ	0.98***	0.000	210.11
mu	μ	-5.01***	0.520	-9.59
log likelihood				-610.76
Inefficiency effect model				
constant	δ0	0.47***	0.070	6.96
Age	δ1	0.01**	0.000	3.19
Ratio of manufacturing days to total working days	δ2	0.10***	0.030	3.34
Ratio of liability and assets	δ3	-0.03***	0.010	-4.81
Ratio of land to fixed capital	δ4	-0.18*	0.070	-2.39
Ratio building to fixed capital	δ5	-0.01	0.080	-0.01
Ratio plant and machinery to fixed capital	δ6	0.04	0.070	0.61
Ratio transport to fixed capital	δ7	0.90***	0.250	3.63
Ratio computer to fixed capital	δ8	0.19	0.200	0.96
Ratio supervisory staff to total staff	δ9	0.03	0.060	0.54
Sigma	σ	0.04***	0.000	-15.56
Log likelihood				125.06

*** Significantly different from zero at the 5% level, ** significantly different from zero at the 10% level, * significantly different from zero at the 1% level. Source: Author's calculation based on Annual Survey of Industries (ASI) 2014-2015

(around 31%) than the labour input. The input variable fuel in frontier model is highly significant with 0.18 elasticity with respect to total production of sugar.

The sum of regression coefficient of production function is the production elasticity and their sum indicates return to scale. The sum of β1, β2 and β3 are equal to 0.73 which is less than one, and significantly different from unity. This indicates decreasing returns to the scale, suggested that if we increase the inputs the total production will increase but at slower rate.

Now the second model uses to estimate the factors, which are affecting the efficiency of the sugar mills in India. In Tobit regression efficiency is used as dependent variable and independent variable age of mills uses as experience that plays an important role in improving efficiency of any firm or industry (Abdulla; Ahmad 2017; Tariq and Mohd. Izhar 2010). Similarly, other variables such as liability assets ratio, expenditure on land, building, plant and machinery, transportations facility also affect the efficiency level. Therefore, these variables considered as the factor to determine the efficiency of sugar mills in India. The coefficient of age of mills (No. of year in operation) is significant at 5% level. Although the coefficient of positive reveals a direct relationship between technical efficiency and number of years in operation. This could be as most of the mills operating are mostly aged.

The coefficient of ratio of manufacturing days to total manufacturing days is significant at 5% level. The positive coefficient shows that there is a direct relationship between efficiency and the ratio between number of manufacturing days and total manufacturing days. This could be as the most of the mills were operating less than six months in a year.

The ratio of liability and total assets coefficient is negatively significant. This means the ratio of liability and total assets inversely affects the technical efficiency. Most of the sugar mills are at the brink of shut down since they are not in position to pay their dues (arrears) to clientele.

The significant coefficient of ratio of land and total fixed capital establishes an inverse relationship with technical efficiency, similar is the case for the ratio of building over fixed capital. In contrast to Ricardo and Neo-classical economist Karl Max, rent theory suggests that payment to

Table 3 Sate wise No. of mills and average technical efficiency of sugar mills in India

State	No. of sugar mills	Mean technical efficiency
Punjab	17	50%
Uttaranchal	9	60%
Haryana	8	51%
Uttar Pradesh	125	59%
Bihar	15	49%
West Bengal	1	65%
Odisha	3	31%
Chhattisgarh	2	50%
Madhya Pradesh	10	61%
Gujarat	15	66%
Maharashtra	175	57%
Andhra Pradesh	27	42%
Karnataka	55	55%
Goa	1	55%
Tamil Nadu	44	39%
Pondicherry	2	52%
Telangana	8	55%
Total	517	54%

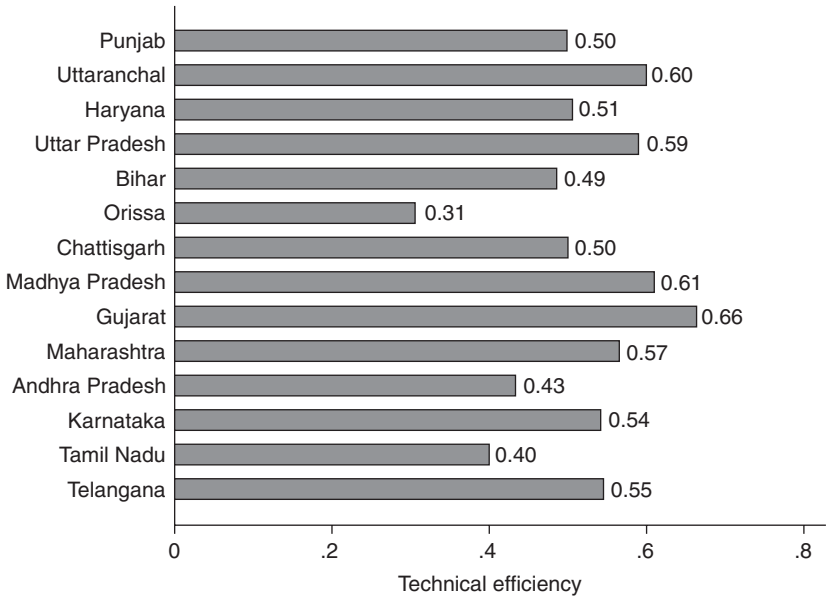

Fig 1 Average technical efficiency of sugar mills in Indian states.

landowner for the right to use the landlord's land is rent. The property in land and building which generates income from its rent considered in efficiency effect model is inversely affected the technical efficiency level. Because, most of the firms are using their own land and building. There is no need to expand the mill size once the mill started.

The another determinant for the measurement of efficiency effect is the ratio of plant and machinery and fixed capital shows the ratio of total amount to amount spent over the plant and machinery purchase. The sign of coefficient is positive but statistically insignificant.

The coefficient of ratio of transport and fixed capital is significant. In India the sugar mills did not provide any transportation to its all workers. The expenditure in transport equipment's can improve the efficiency of the sugar mills.

The variable computer is the ratio of computer and fixed capital is insignificant shows that computerization doesn't affect the technical efficiency of sugar mills.

The last variable is the ratio of supervisory staff over all workers. Instructor plays very important role in the development of any industry or firms. The coefficient of the variable ratio of supervisory staff over all workers is positive but insignificant. It merely establishes a direct relationship in the technical efficiency level to its managerial practices.

The Fig 1 shows the state wise mean technical efficiency level. The overall average technical efficiency of sugar mills in India was found to be 54%. The mean efficiency of Punjab, Uttaranchal, Haryana, Uttar Pradesh, Bihar, Odisha, Chhattisgarh, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Goa, Tamil Naidu, Pondicherry and Telangana were 50%, 60%, 51%, 59%, 49%, 31%, 50%, 61%, 66%, 57%, 43%, 54%, 40% and 55% respectively. The overall average highest efficiency level (66%) were found to be in the states of Gujarat and lowest (31%) in the state of Odisha.

Fig 2 is box-plot which excluded the extreme observations depicted as dots in the graph. The variability in average technical efficiency level in the state are divided into five levels. The third is the mean value of the technical efficiency of the state. In the states of Punjab and Puducherry technical efficiency of sugar mills are 50% below the states average and 50% above the states average. The states such as Uttaranchal, Haryana, Bihar, Madhya Pradesh, Gujarat, Maharashtra, Tamil Nadu and Telangana entails sugar mills containing highest variability and have efficiency below the average technical efficiency of these states. The higher variability in technical efficiency of the states, viz. Odisha and Andhra Pradesh, show that most of the sugar mills are operating above the mean technical efficiency of the states, viz. Odisha and Andhra Pradesh.

The Fig 3 shows about the organization specific efficiency level among the states in 2014-15. ASI

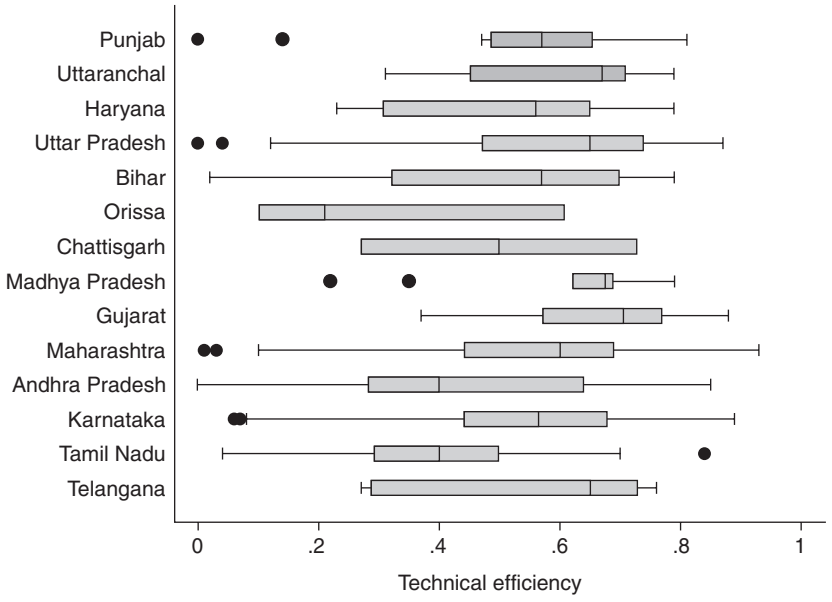

Fig 2 Box plot showing state-wise variability in average technical efficiency level.

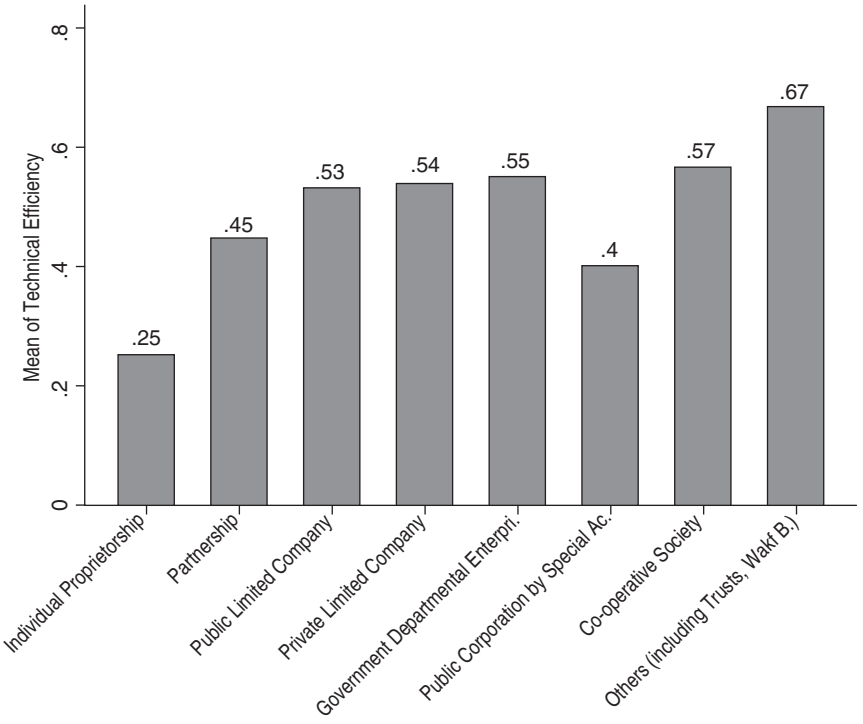

Fig 3 Organization specific average efficiency of Indian sugar mills (2014-2015.

defines organization form of the firm, viz. partnership, Public Limited Company, Private Limited Company and Co-operative Society respectively.

The average technical efficiency of co-operative mills has 56%. The government owned, individual proprietors, Partnership, Private Limited, Public Corporation, and Public Limited has 62%, has 30%, 44%, 55%, 45% and 54% respectively in India.

The co-operative organized sugar mills are more efficient in the states of Uttaranchal followed by Uttar Pradesh, Karnataka, Maharashtra and Goa. However, the least efficiency found in the states of Odisha. The government organized or local government organized sugar mills are only operating in the state of Uttar Pradesh and these mills are technically efficient. The Private Limited company sugar mills are more efficient in West Bengal. The state of Bengal has only one unit operated in the respective year. The public corporation organized sugar mills are efficiently operating in the states of Uttar Pradesh and Tamil Nadu. In most of the states the Public Limited Corporation organized sugar mills are operating. The average technical efficiency of the Public Limited Corporation sugar mills is in ascending order of the states as Gujarat, Haryana, Punjab, Andhra Pradesh, Telangana and Puducherry respectfully.

Conclusion

The overall technical efficiency of sugar mills at all India level found to be 54%. The state of Gujarat attained highest efficiency and Odisha lowest efficiency level. The result also depicts that the efficiency level in Uttar Pradesh is higher than that of Maharashtra. The organization specific efficiency was the highest in the government owned sugar mills and the lowest in the individual proprietor's sugar mills. The wholly private mills are more efficient and the central government owned mills are the least efficient mills in India.

The sum of the coefficients of the Cobb-Douglas production function is less than one suggest that there is a need to improve the scale of the production of the sugar mills in India. As the coefficients of the inefficiency effect variables, viz. liability assets ratio, ratio of fixed capital and land and ratio of fixed capital over building have negative sign suggest that there should be an increase the expenditure in the respective factors to improve the technical efficiency of sugar mills in India. The results also reveal that state-wise there is a significant difference in the, organization specific average technical efficiency of sugar mills.

The policy implications could be to bring reforms in sugar sector. The results emanating from the study provides clues to policy makers either to merge the most inefficient sugar mills with highly efficient sugar mills. This will not only increase the scale of operation but also bring best practices in management of the sugar mills. The sugar production depends on how farmer do sugarcane production practices at his own farm. The spill over of technical improvement of sugar mills would be on farmers' sugarcane field. This would bring closeness between farmers' production environment and sugar processing requirement at mills level. The improvement in sugar recovery and other by-products from sugarcane will help farmers fetch better price of produce. All this ultimately leads to reduction of wastage in sugar processing which indirectly enhances the technical efficiency. Presently, few states have not adopted Fair Remunerative Price of cane. Nevertheless, the government needs to rationalize cane pricing policy to make Indian sugar industry sustainable. Moreover, the recommendation of the (Indian and Committee 2012) of revenue sharing formula needs to be implemented for fair distribution of benefits between the sugar mills and the sugarcane growers.

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