Production Efficiency of Sugar Factory of Bangladesh: An Application of Data Envelopment Analysis

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Abstract

Measuring the efficiency of production departments is an important part of promoting and maintaining efficient operations. Dataenvelopment analysis (DEA) is a linear programmingbased technique which mirrors the capability of a decision making unit to attain the highest level of output from a given set of inputs.. To measure the efficiency, we have considered the use of sugarcane and crushing days as in put-variable and the amount of sugar production as an output-variable. About 99.6 percent of variations in the output variable was explained by these explanatory input variables (R2 = 99.6 percent).Applying DEA under CRS technology assumption, average production efficiency score is.97 in the sugar units .This indicates that on an average, the firms could increase their output by 3 percent with the existing level of inputs. Out of 10 sugar units,4 units showed significant decrease in efficiency.TSM had used excess 8.90 percent sugarcane and 31.20 percent crushing days due to production inefficiency and this unit would be able to increase sugar production by 9.77 percent as compared to peer units.

Index terms— data envelopment analysis, bsfic, input/output oriented.

1 Introduction

here is an increasing anxiety among the firms regarding the level of efficiency with which they assess the position of the compared work to their competitors. Sugar industry is one of the major agrobased industries that are playing a vital role in the rural development of our country. At present 15 sugar mills are running in producing cane-sugar in Bangladesh under direct control and supervision by BSFIC (Bangladesh sugar and food Industries Corporation). The sugar industry provides direct employment to large number of people and indirect employment to millions. The cane-sugar industry is one of the oldest industries in Bangladesh. Near about 5.0 Million people depend on sugarcane cultivation and 16,000 labor force engaged in sugar industry **??**BSRI, 2004). Sugar industry is a losing concern in Bangladesh. The main problems of the sugar industry are low recovery rate, more processing loss and low sugar price and low capacity utilization. Efficiency of the sugar mills are decreasing year after year. The purpose of this paper is to evaluate the efficiency of cane-sugar industry of Bangladesh. This paper describes the use of a linear programming technique called data envelopment analysis (DEA) to measure the overall efficiency of decision-making units (DMUs). White sugar is produced from sugarcane through sugar mills. In Bangladesh, Sugarcane based sugar factories are directly controlled by the Government of Bangladesh since the independent of Bangladesh. Sugar production is not sufficient and only about 2 lack metric tons of sugar is produced from the sugarcane and about 12 lack metric tons of sugar is supplied by private sugar producing mills where sugar are produced from imported raw sugar. The purpose of this paper is to present a methodology to evaluate efficiency and effectiveness of sugar factories in Bangladesh. The methodology is based on Data Envelopment Analysis (DEA) proposed by Charens et. at, 1978. DEA may be applied to allow each of the sugar mills in Bangladesh to evaluate them in terms of how efficient and effective they are compared to one another. Ferrantio et al.(1995)

examined the effect of organizational form on the efficiency of Indian sugar industry. Using the panel data set for 126 firms, covering the period from 1980-81 to 1984-85,the study observed average TE score of 0.85.The study concluded that the majority of sugar factories were operating close to the efficient frontier. The evidence to the organizational differences among the sugar firms confirms that there exists a slight difference between the efficiency of cooperative, public, and private sugar factories.

Sing (2006) utilized the technique of DEA to analyze the efficiency of 36 sugar mills of Uttar Pradesh of India operating during the year 2003-04.The study observed the prevalence of 9 percent inefficiency among the selected sugar firms. It has been also observed that 14 percent of sugar mills attained efficiency score equal to 1 and thus, identified as globally efficient under the constant returns-to-scale technology. A pressing need for capacity expansion of sugar mills has also been notified because most of the sugar mills are found to be operating in the zone of increasing return -to-scale. The post-DEA regression analysis reveals that net sugar recovery and plant size encompass a significant and positive effect on overall technical efficiency and scale efficiency of the sugar mills of Up of India.

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Dwivedi at al (2014) presented a working paper entitled, "Efficiency Measurement of Indian Sugar Manufacturing Firms: A DEA Approach". They have used to calculate the technical and scale efficiency measures of the public and private sugar manufacturing firms of Indian Sugar Industry (2006 to 2010).Empirical analysis using the panel data of five years from 43 Indian sugar manufacturing firms demonstrates that Indian firms have achieved, on an average technical efficiency, about 86-90 percent. From both input and output orientation industry efficiency average in a CRS is the same while it is different for VRS and showing better efficiency in case of output orientation.

Joshi at al (2009) wrote an article entitled, "Measuring Production Efficiency of Readymade Firms."The study was based on the primary data collected from eight ready-made garment firms located in Bangalore, India. To measure the efficiency, they considered the number of stitching machines and number of operators as input-variables and the number of pieces of garment produced as an output-variable. The DEA results showed that under the CRS technology assumption, average production efficiency score in the garment firms works out to be 0.75. This indicated that on an average, the firms could increase their output by 25 percent with the existing level of inputs. They also pointed out that DEA is an appropriate technique, as it considers multiple input-output variables to measure the relative performance of individual firms.

The literature review on the subject undoubtedly indicates that there has not been any study conducted on the sugar industry of Bangladesh that has used DEA to measure the production efficiency of individual sugar mill. This study measures the production efficiency of ten sugar mills of our country.

3 II.

4 Methodology

This study covers ten sugar manufacturing firms of Bangladesh.

5 (MBSM).

There are 15 sugar mills running at present in Bangladesh. The data is collected from the individual sugar mills and the consolidated data from the BSFIC during the period during 2004 to 2013.Data for the study is obtained from secondary sources in the form of annual reports of the sugar factories for the period 2004 to 2013. The selection of sugar mills will be sufficient to make conclusion about the sugar mills of Bangladesh. The process of measuring efficiency indicators can be converted into output and input variable. Cane-based sugar is treated as output and sugarcane used in sugar production and crushing days are taken as input variables for this study. It is to be noted that for efficiency analysis molasses production is not considered as output.

Data Envelopment Analysis (DEA) is a nonparametric mathematical programming to estimate the frontier function.DEA provides the efficiency of different firms operating on same input output variable. We illustrated the DEA method from both input and output orientation. The input-oriented model aims to minimize inputs while satisfying the given output levels. The output-oriented model attempts to maximize outputs without requiring more of any of the input variables. The constant returns to scale technology (CRS) imply that the production technology under consideration is such that, an increase in all the inputs by some proportion results in an increase in the outputs by the same proportion. Suppose a firm operates on two inputs (X 1 and X 2) to produce a single output Y. So the production function can be given as belowY =f(X 1 , X2)

This equation can be rewritten as follows 1=f(X 1 /Y, X 2 /Y) (assuming constant returns to scale).

In an input oriented measure the basic principle is to reduce inputs without reducing the amount of output. In calculating relevant results we have used software of DEAP Version 2.1.

This paper applies DEA methodology to measure production efficiency of the sugar factory of Bangladesh. DEA technique was first formulated by Charnes, Cooper and Rhodes in 1978.We have used Input oriented DEA specifically VRS and CRS model. For calculation, we have followed DEAP version 2.1 by Tim Coelli (1996). Data Envelopment Analysis (DEA) measures the efficiency of a given decision making units (DMU) in a group

relative to the best practicing DMU in that group. It helps to show how relative efficiencies can be estimated and identify units that are relatively less efficient compared to the best performing DMU. Here, we have considered input variables like sugarcane used in metric tons and total crushing days and production sugar as output variable in the selected sugar mills under the study period.

6 III.

7 Objectives of the Study

The specific objective of the study is to find out the main influencing factors for sugar production and efficiency of the sugar mills of Bangladesh. Other objectives of the study given below: 1. To find out the influencing factors of sugar production. 2. To assess the production efficiency of the canesugar mills.

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Production Efficiency of Sugar Factory of Bangladesh: An Application of Data Envelopment Analysis 3. To estimate the trend of cane-sugar production and cane used in sugar production during the study period. 4. To provide suggestions for increasing efficiency position in the sugar industry.

IV.

9 Hypotheses of the Study

1. There is no significant difference in recovery rate of sugar between 1st five years and 2nd five years among the sugar mills during the study period.

2. There is no significant difference in actual daily crushing capacity between 1st five years and 2nd five years among the sugar mills during the study period. 3. There is no significant difference between observed recovery rate and actual recovery rate of the sample units during the study period.

V. Selection of appropriate input and output variables is an important stage in DEA analysis. A model with a large number of variables is one that may fail to have any discriminatory power between firms because most firms will tend to be rated efficient (Majumdar, 1994). Therefore, input-output variables in DEA should be minimal. Here, the output variable is considered as the average production of sugar where as the input variables are sugarcane crushed and crushing days.

10 Result & Discussion

Multiple regression analysis has been conducted to know the extent of variation in sugar firms produced per year. Table **??** indicates that the output is significantly correlated with inputs such as sugarcane crushed and crushing days. The coefficient of correlation, R-square and adjusted R-square of input variables included in the model are 0.999, 0.997 and 0.996 respectively which indicates almost cent percent total variance explained by the variables included in the model. Notes: i) * represents growth rate average efficiency during 1st half period in comparison to 2nd half period; ii) ** represent that the value is significant at 5 percent level.(Note: In paired t-test, 1st 5 years efficiency scores and 2nd 5 years efficiency scores were taken together at a time. However, the positive and negative growth rate of JHSM and C& Co. were 5.68 and 5.91 respectively seem to be efficient but they were in significant.) Source: Author's calculation.

The analysis of table 2 reveals that for the entire period of the study, average efficiency was 0.969 percent, during 1st half of the period, sugar industry had found to be operating at the efficiency level of 96 percent in each year. But during 2 nd half of the period, sugar industry was running at 91 percent efficiency level. Growth rate was positive for JHSM and NTSM by 5.68 and 0.44 percent respectively. The positive growth rate of JHSM was insignificant for the study period. Other selected sugar mills showed negative growth rate of which the highest negative growth rate was found in PBSM i.e., 9.01 percent followed by TSM, KSM, C & Co., SHSM for 6.35 6.23,5.91 5.63 percent respectively which were significant except C& Co., for the study period. Production Efficiency of Sugar Factory of Bangladesh: An Application of Data Envelopment Analysis Table 3 indicates the utilization position of input variables sugarcane crushed, crushing days and output of the selected sugar mills in relation to efficient sugar mills under the study period. Using the method of VRS input oriented DEA it was estimated that TSM, PBSM, SHSM, FSM, KSM, JHSM, NTSM, C & Co, MBSM were inefficient units relative to the efficient unit NBSM. If it could be possible to recover underutilization of the variable crushing days by 24.48 percent, 18.28 percent, 45.66 percent, 35.56 percent, 32.22 percent, 10.51 percent, 10.69 percent, 29.76 and 18.67percent for the units TSM, PBSM, SHSM, FSM, KSM, JHSM, NTSM, C &Co and MBSM respectively then these units would be efficient like NBSM. Furthermore, it would be possible to expand the output level 9.77 percent by TSM, 4.87 percent by PBSM, 5.22 percent by SHSM, 0.75 percent by FSM, 2.87 percent by KSM, 4.30 percent by JHSM, 4.17percent by NTSM, 0.64percent by C &Co and 1.16 percent by MBSM during the study period.

11 VI. Hypothesis Testing

1. There is no significant difference in recovery rate of sugar between 1st five years and 2nd five years among the sugar mills during the study period.

2. There is no significant difference in actual daily crushing capacity between 1st five years and 2nd five years among the sugar mills during the study period.

Volume The hypothesis regarding actual daily crushing capacity between 1st five years and 2nd five years among the sugar mills reveals that there is no significant difference between the two periods at 5% level of significance. ANOVA indicates that calculated value of F is only 2.02 and the critical value is more i.e., 4.41 for the study period. Daily crushing capacities of the selected sugar mills were same for the study period.

3. There is no significant difference between observed recovery rate (rate given by the sugar industry) and actual recovery rate (actual sugar production/actual cane used) of the sample units during the study period.

One This table shows the one sample t-test for the recovery rate of the sample units during the study period. Here, calculated t = -7212.30 which is significant at 95 percent confidence interval of the difference with 9 degree of freedom and significant at 0.0 percent with 2-tailed test.

So we reject our null hypothesis and it implies that there is a significant difference between observed recovery rate and actual recovery rate of the sample units during the study period.

VII.

12 Suggestions

1. All concerned of the production department of sugar unit should have adequate knowledge in productivity and efficiency.

2. Proper arrangement of cultivation of quality sugarcane in sufficient quantities is required. 3. Management skills should be increased. 4. Foremost attention should be given to maximize output with minimum inputs.

5. Proper manpower planning is highly essential. 6. Proper utilization of sugarcane and daily crushing capacity must be enhanced.

13 VIII.

14 Conclusion

This paper estimates the production efficiency of the ten sugar factory of Bangladesh using DEA technique. The empirical results suggest that the entire sugar factories are technically efficient during the study period. Only TSM had lowest technical efficiency by 91 percent for the entire period TSM, PBSM, SHSM and KSM had decreased production efficiency for 2nd half significantly. On the other hand JHSM and NBSM showed increased efficiency but they were insignificant for the study period. VRS input oriented DEA indicates that SHSM would be able to produce more 2.87 percent sugar with same sugarcane and by reducing 32.22 percent crushing days for the study period as compared to peer unit.CRS input oriented DEA depicted that KSM would be able to produce same quantity of sugar by reducing 2.79 percent sugarcane as well as 34.11 percent crushing days if it were an efficient sugar mills. There is a significant difference of actual recovery rate of sugar between1st five years and 2 nd five years for the study period. It is found that there was no significant difference in daily crushing capacity between 1st five years and 2nd five years for the study period. Sufficient high quality sugarcane and overhauling machinery can be able to make inefficient sugar mills to efficient one. [1]

2

Mills	Entire Period	1 st half	2 nd half	Growth Rate(%) a	t-test Paired
TSM	0.911	0.888	0.831	-6.35	2.41**
NBSM	1.000	0.990	0.991	0.12	0.08
PBSM	0.954	0.939	0.854	-9.01	3.93**
SHSM	0.950	0.914	0.862	-5.63	2.75**
FSM	0.993	0.942	0.933	-0.93	0.09
KSM	0.972	0.932	0.874	-6.23	2.64**
JHSM	0.959	0.909	0.960	5.68	1.24
NTSM	0.960	0.913	0.917	0.44	1.55
C&Co.	0.994	0.978	0.920	-5.91	2.08
MBSM	0.989	0.942	0.932	-1.04	0.08
All mills	0.969	0.930	0.910		

Figure 1: Table 2

3

DMU	Te	Peers	Variable	Original	Expected	Diff.	%(D
			Sugar	6631.74	7279.56	647.82	9.77
TSM		NBSM	Cane	100366.00	100366.00	0.00	0.00
	0.911		Days	81.70	61.70	-20.00	-24.4
		NBSM	Sugar	14935.87	14935.87	0.00	0.00
NBSM			Cane	205926.50	205926.50	0.00	0.00
	1.000		Days	126.00	126.00	0.00	0.00
		NBSM	Sugar	6517.85	6835.58	317.73	4.87
PBSM			Cane	94244.70	94244.70	0.00	0.00
	0.954		Days	70.90	57.94	-12.96	-18.2
		NBSM	Sugar	3832.68	4032.61	199.93	5.22
SHSM			Cane	55599.10	55599.10	0.00	0.00
	0.950		Days	62.90	34.18	-28.72	-45.6
		NBSM	Sugar	8224.60	8286.637	62.04	0.75
FSM			Cane	114251.00	114251.00	0.00	0.00
	0.993		Days	109.00	70.240	-38.76	-35.5
		NBSM	Sugar	6257.20	6436.87	179.67	2.87
KSM			Cane	88747.60	88747.60	0.00	0.00
	0.972		Days	80.50	54.56	-25.94	-32.2
		NBSM	Sugar	7318.70	7633.12	314.42	4.30
JHSM			Cane	105240.70	105240.70	0.00	0.00
	0.959		Days	72.30	64.70	-7.60	-10.5
		NBSM	Sugar	10235.80	10662.64	426.84	4.17
			Cane	147009.90	147009.90	0.00	0.00
NTSM	0.960		Days	101.20	90.38	-10.82	-10.6
		NBSM	Sugar	8982.58	9040.25	57.67	0.64
			Cane	124641.40	12641.40	0.00	0.00
C &Co	0.994		Days	109.10	76.63	-32.47	-29.7
		NBSM	Sugar	9248.10	9355.29	107.19	1.16
			Cane	128984.90	128984.90	0.00	0.00
MBSM	0.989		Days	97.50	79.30	-18.20	-18.6

Source: Author' calculations.

Figure 2: Table 3

4

Utilization of Individual Input Variables of the Selected Sugar Mills
(CRS Input Oriented DEA)

DMU	Te	Peers	Variable	Original	Expected	Excess	%(Excess)
			Sugar	6631.74	6631.74	0.00	0.00
TSM		NBSM	Cane	100366.00	91434.31	8931.69	8.90
	0.911		Days	81.70	56.21	25.49	31.20
		NBSM	Sugar	14935.87	14935.87	0.00	0.00
NBSM	1.000		Cane	205926.50	205926.50	0.00	0.00
			Days	126.00	126.00	0.00	0.00
		NBSM	Sugar	6517.85	6517.85	0.00	0.00

Figure 3: Table 4

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