

Capacity Utilization and Production Efficiency of Sugar Industry of Bangladesh: An Application of DEA

Azharul Islam¹, Md. Kaysher Hamid²

Abstract

The current production of Sugar in Bangladesh is about 60 metric tons, which is only about 5% of the total demand for sugar in the country. One of the causes of lower sugar production in the industry is the insufficient supply of sugarcane in the factories and the sugar recovery rate is very low. Again, the industry is running only at 33% of its sugar production capacity and is a losing concern for the government of Bangladesh. The study aims to investigate the capacity utilization and production efficiency of sugar mills and identify the relationship between these two. It uses Data Envelopment Analysis (DEA) to measure the production efficiency of 15 sugar mills under BSFIC for a period covering from the fiscal year 2015-16 to 2019-20. DEA is a linear programming-based technique that 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, the study considers the consumption of sugarcane, crushing days, the number of employees as input variables, and the amount of sugar and jaggery production as output variables. The result shows that the overall efficiency under CRS is 0.868, which indicates that the industry is running with a 13.2% efficiency loss. The lowest efficiency score in the industry is for Rangpur Sugar Mill (0.664) represents that the mill can reduce its consumption of inputs by 33.6% without affecting the number of outputs. The findings can help policymakers formulate policies to enhance the operating efficiency of the sugar mills running in the economy. It can also provide guidelines to the development partners in identifying the priority of their development initiatives.

Key Words: Sugar industry, Sugarcane, Crushing Days, Capacity utilization, Production efficiency, and DEA.

¹ Assistant Professor, Dept. of Business Administration- General, Bangladesh University of Professionals (BUP); Mirpur Cantonment, Dhaka-1216, Bangladesh
Email: azharulru7025@gmail.com

² Assistant Professor, Dept. of Business Administration- General, Bangladesh University of Professionals (BUP); Mirpur Cantonment, Dhaka-1216, Bangladesh
Email: mkhamid21@gmail.com

1. Introduction

In the context of a dynamic world economic environment, the self-sufficiency and food security of the citizens get the highest priority (Luan et al., 2018; Ritchie et al., 2018) to gain people's satisfaction that they get their foods and products from the domestic market. The sugar market occupied a prominent place with significant stakes in the foods markets (Nieder-Heitmann et al., 2018). In Bangladesh, the sugar industry is one of the largest agro-based rural industries creating enormous opportunities for the people, especially in the rural area. The industry is creating employment by recruiting people and creating opportunities for the rural farmers to earn profit with the cultivation of sugar cane, which helps them be self-employed (Rahman, Khatun and Rahman, 2016). Being the second-largest processing industry, it has taken a continuous endeavor to improve the social welfare in underdeveloped rural areas. According to the recommendations of the Food and Agricultural Organization (FAO) and Bangladesh Nutritious Council about 9.00 Kg of Sugar is required for every people in Bangladesh annually. So, for more than 16 core people, Bangladesh has a demand of more than 15 lack matric tone annually (Development, UNICEF, Programme, & Organization, 2019). Though the country has a big market for sugar, we have a limited capacity of having only 15 inefficient mills to meet the local demand with the production of the local sugar industry. So, to meet the local demand, the country has to import about 13 lack matric tons of sugar, mostly from India and China.

Considering the current market scenario, the country has a huge opportunity to expand in this industry. Still, the major problem is that the mills in this industry suffer from loss. Although the industry plays a major role in solving the unemployment problem holding about 16,000 labor force directly in the industry (BSRI, 2004), its long-term existence is questionable because of its continuous loss. The total accumulated loss in this industry is about 4806.75 crore Taka (BSFIC 2016-17). Following a huge loss of the mills, the BSFIC has discontinued operating six out of the fifteen mills for an indefinite time from December 2020 onward. Such loss of the mills is because of the high production cost coupled with the low productivity of the decades-old production bases (Hasan, 2021). The major problems of the sugar industry are low recovery rate, more processing loss, low sugar price, and low-capacity utilization. The

efficiency of the sugar mills is decreasing year after year. The industry's average recovery rate of sugar is within 8% to 9%, which is much below the standard (BSFIC 2016-17). Although Thailand, as the major exporter of Sugar in Asian countries, suffers from inefficiency in its sugar production, it still showed a recoverability rate of about 11% (Chunhawong et al., 2018), which is above the efficiency of Bangladesh. So, the continuous loss of this industry can be mitigated by improving the overall efficiency of the industry.

Again, as the constant in sugar production, the capacity utilization remains underutilized. Alam et al. (2009) showed that the capacity utilization of the state-owned sugar mills has been decreasing since the Independence of Bangladesh. According to this study, the average capacity utilization during 2005-2006 was about 77.51 percent, much below the average capacity utilization in 1992-93 (92.7 percent) and 1994-95 (139.16 percent). The negative growth in the sector's capacity utilization results in a huge idle resource and a number of labor force underutilization, contributing to the accumulated loss of the industry. The mills utilizing the lower capacity are expected to show higher efficiency in the industry. Foster & Rosenzweig (2022) found that the smallest firms are highly efficient than the larger firms in most low-income countries. But as the country's sugar mills are state-owned operations that do not allow cut-off labor forces because of lower capacity utilization, they may not fall under the assumption that smaller capacity means higher efficiency. So, making a profitable industry is largely dependent on increasing the production efficiency in the form of recoverability from sugarcane and increasing capacity consumption in the form of maximization of resources utilization. The government of Bangladesh is looking for potential modernization of some of the state-owned mills (Hasan, 2021) with investment in advanced machinery to enhance productivity. But the policy formulation for such an initiative is not easy (Tulchynska et al., 2021) because of two reasons- firstly, modernization of the whole industry at a single time is very risky; secondly, the government may face difficulty in developing priority in choosing the mills for its modernization program as the production efficiency, and asset utilization of mills are not uniform across the industry. Islam (2015), in investigating the production efficiency of often state-owned mills, found that the production efficiency and capacity utilization of all the sugar mills are not the same across the country. Again, having the production efficiency score of only a limited number of mills and the absence of capacity utilization of such mills may lead the government to

adverse selection of the mills for the development program. So, there is a need for composite efficiency score of the sugar mills along with their level of capacity utilization. Therefore, identifying the problem of productivity variances among the mills will be crucial for the policymakers as their first step toward curbing the loss of the industry.

Hossain, Zaman, Rabbani, and Hossain (2006), in their study of problems and prospects of the sugar industry in Bangladesh, identified that the sugar mills are facing lots of problems and, therefore, they are failing to reach their target level of production. The main problem includes low-quality sugarcane with low Sugar content, low utilization of sugarcane by the old machines, the problem of timely and proper finance, and lack of commitment and corruption of the mill staff. On the other hand, the yield and recovery of varieties of sugarcane released from the Bangladesh Sugarcane Research Institute (BSRI) are much higher (93 to 102 tons/ha) than the average yield (43 tons/ha) and recovery (7.46%) as reported by BSFIC (Begum, Islam, Miah, Hossain and Islam, 2011; Sharma, Sengar, Singh and Sengar, 2018). This indicates the prospect of increased sugar production by reducing the yield and recovery gaps with high-quality sugarcane and efficient production mechanism. Therefore, the current research aims to identify the individual mills' capacity utilization and production efficiency and to identify whether they come together. To attain the main objective, some specific objectives are assigned as follows:

- i. To know the production position of the sugar mills under study.
- ii. To measure the operating efficiency as well as underutilization position of the selected sugar mills in Bangladesh. and
- iii. To identify the association between underutilization with the operational efficiency.

2. Literature Review

2.1 Background Literature

Capacity utilization is a concept in economics that refers to the extent to which an enterprise or facilities utilizes its fixed productive capacity (Simon-Oke and Awoyemi, 2010). Whereas productive capacity is the level of production at which no additional product can be produced without sacrificing an opportunity. So, the industry is said to be running optimally when its installed capacity is fully

utilized (Adeyemi and Olufemi, 2016). Again, production efficiency describes how efficiently the factors of production (inputs) have been utilized in producing outputs. So, efficiency focuses on utilizing the available resources and technology productively (Chavas et al., 2005). The efficiency score of a production facility can be decomposed into three important productivity scores, namely technical efficiency, allocative efficiency, and scale efficiency. Technical efficiency identifies the level of technology; allocative efficiency defines the soundness of resources allocation among productive facilities, and scale efficiency indicates the appropriateness of the size of the facility (Chavas et al., 2005). The DEA model, as discussed later, is a non-parametric technique to measure the total factor productivity having the technical and scale efficiency score (Serrano-Cinca et al., 2005). The capacity utilization and the application of DEA in measuring efficiency are unrestricted for specific firms but can be applied to firms ranging from manufacturing to service operations (Nishiyama et al., 2013; Ray, 2015).

2.2 Sugar Industry of Bangladesh

After the independence, the Bangladesh Sugar Mills Corporation and Bangladesh Food and Allied Industries Corporation were formed through the presidential order no 27 in 1972. In July 1976, both corporations merged into Bangladesh Sugar and Food Industries Corporation (BSFIC) through presidential order no 25. At that time total of 68 sugar mills and food, factories were in the industry. With a privatization policy, about 50 mills are returned to its owner by the government of Bangladesh. Now a total of 15 sugar mills are operating in the industry under the supervision of BSFIC. Rahman et al. (2016), in their exploratory analysis of the sugar industry of Bangladesh, find that only 5% of the country's demand is fulfilled with the production of sugar by the indigenous industry. The by-product of the same industry fulfills another 20% of the total demand, while 75% of the total demand for sugar is imported from India, Vietnam, Thailand, etc.

Hossain et al. (2006) identified that sugar mills face the problem of poor management, poor quality sugar cane, the low recovery rate of sugar from the sugar cane, and the backdated processing. They conclude that the above factors and the problem of timely and smooth finance and corruption force the industry to keep it away from the targeted production level. In their study, Khatun et al. (2011) mentioned that though the production of sugarcane is a long durable crop and cost-intensive, the price is relatively low, which influences the farmers to

allocate their lands to different short duration crops in place of sugarcane. In 2020-21 the production at state-run sugar mills (24,900 tonnes) hit its lowest point in over a decade as sugarcane processing has fallen sharply amid reduced supply (Chakma, 2022). The responsibility for the low supply of sugarcane in the mills remains with the mills' officials as they are the authorized people to train the cultivators of sugarcane in the mill zone area and to provide other necessary aids like high-quality seeds, timely advice, and financing facilities (*SDG Report*, 2019).

Rahman et al. (2016) also found that the yield of sugar production per unit area of Bangladesh is significantly lower than the yield of other sugar-producing countries. Khatun et al. (2011), in her Doctoral thesis, found that the average yield was about 58.53 t/ha, with the highest average at Rajshahi (62.30 t /ha) followed by Panchagar (57.80 t/ha) and Thakurgaon (55.80 t/ha). Among the farm categories, the large farmers produced the highest yield (59.83 t/ha), followed by medium (59.09 t/ha) and small (56.67 t/ha) farmers. She interviewed about 300 farmers and found that human labor, animal labor, seed, urea, furadan 5 G, and irrigation cost positively impacted sugarcane production.

2.3 Efficiency of Sugar Industry

The sugar mills in Bangladesh are relatively small, having an average capacity of about 4000 metric tons of sugar production per year. Being a small unit of manufacture, the mills are expected to run with greater efficiency. But, Islam (2015) found a lack of efficiency in the sugar industry of Bangladesh. Alam et al. (2009) also found that the average growth in sugar recovery rate is negative, with a capacity utilization rate of 92.79%. But both the studies are only on the average efficiency of the sugar industry of Bangladesh, and none of them have identified the individual mills based on their efficiency obtained during the study period. Raheman et al. (2009) used Non- parametric Data Envelopment Analysis to find out the reasons for inefficiency in the sugarcane production in Central Negroes Area, Philippines. By comparing the individual farms' relative technical, scale, and overall technical efficiency, they find that efficiency is mainly from the sugarcane used in the industry. Ahmad et al. (2002) calculated the technical efficiency of Pakistani farmers by farm-level input-output variables for 1997-98 regarding fertilizer used. He used the Cobb-Douglas frontier production function to find the relationship between inputs and outputs of farming. He discovered that educated farmers are more efficient than the owners or owner-cum tenants.

He also showed that a balanced diet of fertilizers and consultation with agricultural scientists positively impacts the technical efficiency of farming. Hossain et al. (2006) find sugarcane grown in the growers' fields is not of the same quality due to varietal differences and the variation in soil characteristics, agronomic practices, and climatic conditions.

Ramaswamy (1990) used the relative efficiency index to measure productivity and found that productivity is sensitive to an alternative measure of firm sizes, such as a firm's capacity and the number of employees. It also revealed a positive relationship between the capital-labor ratio and the unit's productivity. Labor productivity rises while capital productivity falls as the investment size of the unit increases. Therefore, firms level analysis can significantly contribute to raising the industry's productivity. Hasan and Islam (2010) studied the profitability and technical efficiency of wheat production in some selected areas of Bangladesh. The study employed farm-level cross-sectional data and found that there is the potential to increase wheat production by 16% in the country.

Murali and Puthira Prathap (2017) studied the technical efficiency of the sugarcane farms in Tamil Nadu of India based on the survey data of 198 firms collected in 2011-13. They found the differences in the output among the farms because of the dissimilarities in technical efficiency. The paper suggested that the technical efficiency of these farms can be improved by more laborer availability, reducing water shortage, an increase of wages, decreasing the price of fertilizers, and increasing the price of sugarcane.

To identify production efficiency and optimization, Data Envelopment Analysis (DEA) has been used in many studies related to different areas of the agriculture sector (Nandy et al., 2021). Ullah et al. (2019) studied the efficiency of the sugarcane production system in Thailand using Data Envelopment Analysis (DEA). They have identified significant differences in inefficiencies among the selected sugarcane production regions due to the differences in farm size and mechanization. In this respect, they have highlighted the need to reduce the present farm inputs for some regions and good management for others.

Çınar et al. (2021) studied the impact of privatization on the technical efficiency of Turkish sugar factories. By looking at 31 factories in Turkey through Data Envelopment Analysis, it is identified that, on average, both public and private factors have experienced a decrease in inefficiency. However, only one factory was public among the efficient factories, and the rest of those were private factories.

Padilla-Fernandez and Nuthall (2009) conducted a study on "Technical Efficiency in the Production of Sugarcane in Central Negros Area, Philippines: An Application of Data Envelopment Analysis". They used Non- parametric Data Envelopment Analysis to find out the reasons for inefficiency in the sugarcane production in Central Negros Area, Philippines. By comparing the individual farms' relative technical, scale, and overall technical efficiency, they find that efficiency is mainly from the sugarcane used in the industry. Previous researchers have utilized a similar method in analyzing the production efficiency of different firms across industries- forest (Lee, 2005), enterprises (Wu, Wang, Chiu, Li, and Lin, 2019), agriculture (SONG, XU, and ZHANG, 2008), fisheries (Shen & Shen, 2013) and chemical industry (De Clercq et al., 2017). Therefore, the current study chooses the DEA model to explore the technical and scale efficiency of the sugar industry of Bangladesh and to identify areas the policymakers should take emphasis on.

3. Methodology

3.1 Population and Sample

The research is conducted on the sugar industry of Bangladesh. There are 15 sugar mills under the control of BSFIC. The study considers all the 15 mills as its sample frame as the number of sugar mills is very limited as compared to the number of mills in other countries like India, and therefore taking all the mills as a decision-making unit (DMU) will reduce the probability of error in the study.. BSFIC starts reporting information on individual mills from the fiscal year 2015-16. Therefore, the study covers the period of five years from the fiscal year 2015-16 to 2019-20, as information about the individual mill is not available before the said period.

3.2 Data Sources

The secondary source of data is used in the study. Most of the data is collected from the annual MIS report of BSFIC. Data is also collected from previously published work, annual reports of the mill, newspapers, periodicals, and individual mills' websites.

3.3 Variables

Measuring efficiency indicators can be converted into output and input variables. Cane-based sugar and the by-product of Sugar (Jaggery) are treated as outputs. This study's input variables are the sugarcane used in sugar production, crushing days, and the number of employees in the mills. It is to be noted that molasses production is not considered output for efficiency analysis.

Table-1: Variable Definition

Classification	Name of Variables	Reference
Input variables	1. Amount of sugar care consumed (X ₁)	An increase in the production of sugar is due to the increase in the yield of sugar cane in the country (Islam, 2015; Raheman et al., 2009).
	2. No. of Employees (X ₂)	Growth in the production in the output is due to the increase in the labor force (Raheman et al., 2009)
	3. Number of crushing days (X ₃)	It reveals the underutilization of the sugar mills under variable crushing days (Islam, 2015).
Output variables	1. Amount of sugar production (Y ₁)	Productive efficiency of the sugar industry is measured by having sugar production as an output variable under output-oriented DEA.
	2. Amount of Jaggery production (Y ₂)	Jaggary a(Chita), a by-product of sugar mills, is a low-quality sugar (Afzal, Lawrey, Anaholy, & Gope, 2018).
Other variables	1. Target achievement of sugar production	In the measure of the percentage achievement of the annual production budget of sugar by the mills
	2. Target achievement of jaggery production	In the measure of the percentage achievement of the annual production budget of jaggery by the mills

3.4 Analytical Model

The study utilizes two types of analysis for measuring the efficiency of the sugar mills in Bangladesh. The first step calculates the percentage of capacity utilization of each of the fifteen mills, including the yield of sugar and jaggery production per employee and crushing day and the percentage of target achieved by the mills. The capacity utilization₂ is measured in the following way.

$$\text{Capacity utilization} = \frac{\sum \text{output of DMU}}{\text{Production capacity of DMU}} \dots\dots\dots(i)$$

The study estimates two types of capacity utilization in measuring capacity utilization: first, considering both sugar and jaggery production as outputs, and second considering only the sugar production as output. The yield of sugar and jaggery production has been measured utilizing the equation below (ii).

$$Production\ yield = \frac{\sum output\ of\ DMU}{\sum input\ of\ DMU} \dots\dots\dots(ii)$$

In the second step, we use Data Envelopment Analysis (DEA) to measure the efficiency of the sugar industry. It is non-parametric mathematical programming to estimate the frontier function. DEA provides the efficiency measure of different firms operating on the same input-output variables using a linear programming model of maximization of outputs or minimization of inputs. We use only the input-oriented method of DEA with the constant return to scale (CRS) as the measurement assumption in the first step. Eventually, the variable return to scale (VRS) is used to decompose the total efficiency into technical and scale efficiency. Let us consider the N number of DMUs producing M number of outputs using K number of inputs. Inputs are denoted as x_{ip} ($i = 1, 2, \dots, R$), and outputs are denoted as Y_{jp} ($j = 1, 2, \dots, Q$) for each farm p ($p = 1, 2, \dots, P$). The X represents the $K \times N$ input matrix, and Y represents $M \times N$ output matrix which presents the data of all DMUs.

Under input-oriented DEA having the assumption of CRS, one can get the linear programming problem as:

$$\begin{aligned} & \text{MIN}_{\theta, \lambda} \\ & \text{Subject to: } -y_i + Y\lambda \geq 0, \\ & \quad \theta x_i + X\lambda \geq 0 \text{ and} \\ & \quad \lambda \geq 0 \\ & \dots\dots\dots(iii) \end{aligned}$$

Where θ is a scalar that represents the production efficiency of a DMU, the λ is the $N \times 1$ vector of constants. The highest value obtained for θ is equal to 1, which means the DMU is efficient in utilizing the inputs. If the value of $\theta < 1$, that means the DMU is inefficient in using the inputs.

The results of CRS are only appropriate only when all the DMUs are operating at the optimum scale. It is often unlikely for the DMUs to be in optimum scale because they have a number of fixed factors that cannot be changed to make an optimum combination of all the productive factors. So, to get a further decomposition of the efficiency using another approach known as VRS. The results of VRS will measure the TE, which are confounded by the SE.

Under the VRS approach, the TE is determined by adding a convexity constant $N1\lambda=1$ with the LP model of CRS.

$$\begin{aligned} & \text{MIN}_{\theta, \lambda} \theta \\ \text{Subject to: } & -y_i + Y\lambda \geq 0, \\ & \theta x_i + X\lambda \geq 0, \\ & N1\lambda = 1 \quad \text{and} \\ & \lambda \geq 0 \\ & \dots\dots\dots\text{(iv)} \end{aligned}$$

Finally, we can determine the value of SE by developing another DEA problem with non-increasing returns to scale (NIRS). This can be done by altering the DEA problem in equation (iii) by substituting the $N1\lambda=1$ with restriction $N1\lambda \leq 1$. So the model is.....

$$\begin{aligned} \text{Subject to: } & -y_i + Y\lambda \geq 0, \\ & \theta x_i + X\lambda \geq 0, \\ & N1\lambda \leq 1 \quad \text{and} \\ & \lambda \geq 0 \\ & \dots\dots\dots\text{(v)} \end{aligned}$$

3.5 Model Discussion

Data Envelopment Analysis (DEA) is non-parametric mathematical programming used to identify the production possibility frontier by considering the factor's arbitrary combination, i.e., inputs. DEA can measure the efficiency of production of a number of firms operated under the same input and output variables. Charnes, Cooper, and Rhodes (1978) first introduced the term DEA and proposed an input-oriented model with CRS. DEA offers several unique and useful characteristics compared to traditional financial analysis methods like ratio analysis or regression analysis. Although all these techniques have their advantages and disadvantages. One of the most important features of DEA is comparing many parameters simultaneously and coming up with a scalar measure of overall performance (Hafezalkotob, Haji-Sami, & Omrani, 2015; Mahmud et al., 2014; Sharma et al., 2018). DEA is a non-parametric method that does not assume a specific production function.

Data Envelopment Analysis (DEA) measures the efficiency of a given decision-making unit (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 relatively less efficient units compared to the best-performing DMU. DEA compares each

producer with only the "best" producer. So, it measures how much output quantities can be proportionately expanded without altering the input quantities used (Coelli, 1998).

Finally, the study uses the Karl Pearson correlation coefficient to investigate the correlation between capacity utilization and total factor productivity. It also presents a correlation analysis of the target achievement of both sugar and Jaggery with other variables to identify their potential relationship.

4. Results

4.1 Descriptive Statistics

Table 2 shows the descriptive statistics of all the variables in 15 sugar mills running under BSFIC. The average sugarcane crushed by every mill per year is 75,736 metric tons, with average manpower of 881. The mills are grinding the cane only for 69 days on an average per year and produce about 4416 metric tons of sugar and 2,584 metric tons of Jaggery every year. The mills are running only at the 33% level of capacity utilization of its actual capacity of sugar production. The industry's highest average production of sugar is 10,508 metric tons, whereas the lowest average production is recorded as 1,870 metric tons. The number of employees, one of the inputs in the production of sugar and Jaggery, is highly fluctuating in the industry from 1897 to 655. As a low-capacity utilizer among the industries in Bangladesh, the industry experiences a high fluctuation of capacity utilization from 79% to 13%, with a standard deviation of 16.

Table-2: Descriptive Statistics

Measures	Sugar production	Jaggery Production	Sugar cane	No. of Employees	Crushing Days	Production Capacity	Capacity Utilization-total	Capacity Utilization-sugar
Mean	4416	2863	75736	881	69	14029	53	33
Max	10508	6009	175325	1897	117	20320	110	79
Min	1870	1567	40815	655	43	10160	23	13
SD	2145	1258	35067	302	20	3178	23	16

4.2 Capacity Utilization of the Sugar Industry

Table 3 shows the capacity utilization by the sugar mills. Total sugar production capacity is about 2.1 lac metric tons by all the 15 mills of BSFIC. But the actual production of sugar is about 0.66 lac metric tons, which means mills are utilizing only 32.94% of their total production capacity of sugar. If we add the Jaggery as a product along with the sugar, the capacity utilization is still very low, which is only 53.24% of their productive capacity. Let's look into the individual sugar mills. The NBSM is at the top in utilizing the production capacity having an average capacity utilization of 79.06%, with NSM ranking second with a capacity utilization of 50.82%. The lowest productivity score is for RnSM, with capacity utilization of only 12.56%, less than 1/6th capacity utilization of NBSM, leaving a significant part of the mill unutilized. The figure-1 represents the comparison of capacity utilization across all 15 mills both by the production of Sugar and production of Sugar and Jaggery together. Although the inclusion of jaggery as an output with the sugar increases the capacity utilization of the mills, the line graph demonstrates a similar pattern of capacity utilization across all mills in both cases.

The table-1 also represents the average yield of three inputs in the production of sugar and Jaggery across all the mills. The average sugar and Jaggery yield per employee and crushing day is 9.05 and 102.76 metric tons, respectively. In contrast, the industry gets total sugar and Jaggery at 9.57% of the sugar cane consumed by the industry. The figure-2 compares the yield of all the inputs on total production and the production capacity across the mills. The results represent the fluctuation in the production per crushing day is much higher than the fluctuation in all production yields of the other two inputs among the mills.

Figure-1: Capacity Utilization of Sugar Mills:

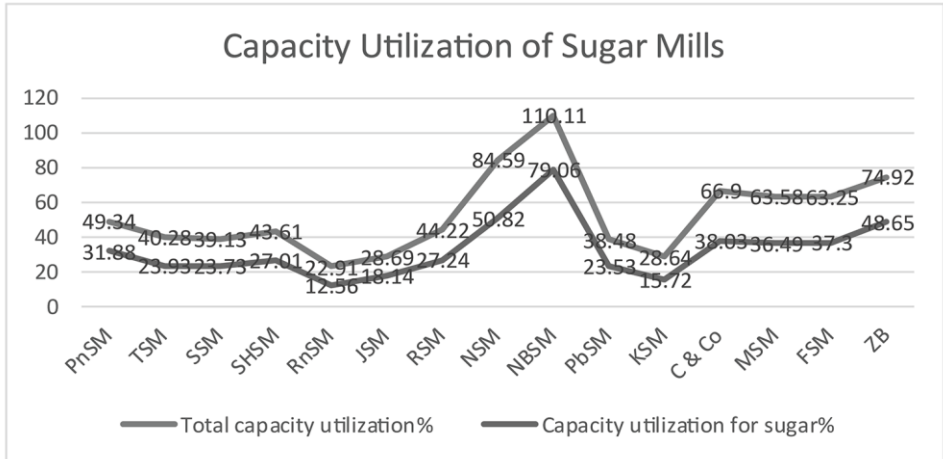


Figure-2: Yield of Inputs

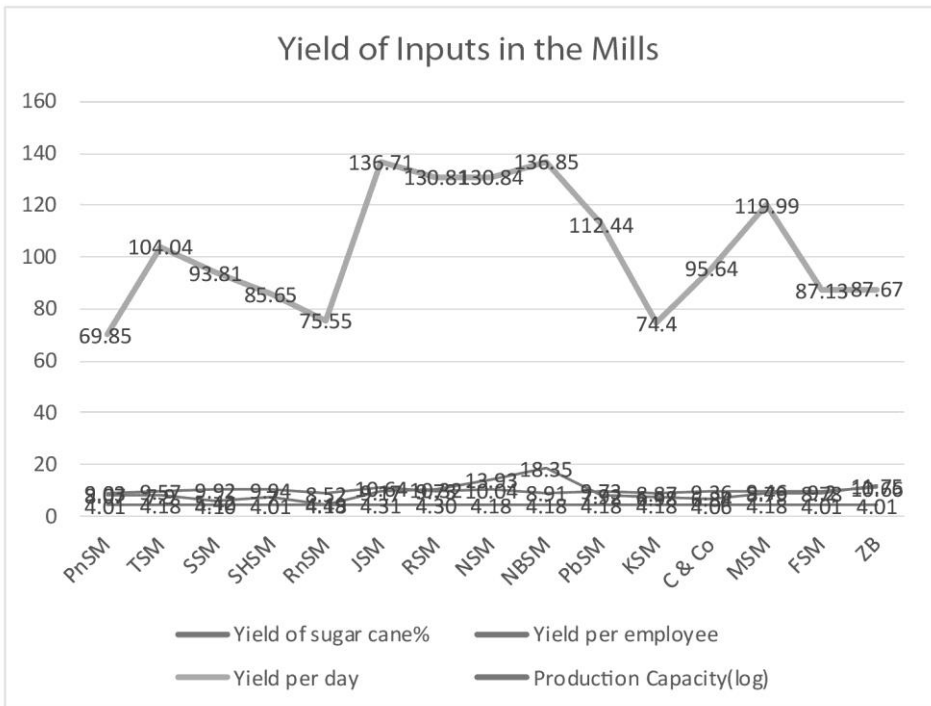


Table-3 : Capacity Utilization in Sugar Production: (Average of 2015-16 to 2019-20)

Name	PSM	TSM	SSM	SHSM	RSM	JSM	RSM	NSM
Production Capacity	10160	15240	12500	10160	15000	20320	20000	15000
Production of Sugar	3242	3638	2959	2746	1870	3686	5465	7621
Production of Chita	1771	2500	1932	1685	1567	2145	3378	5067
Consumption of cane	55534	64393	49285	44389	40815	54846	90811	127291
No of employees	671	799	912	664	798	667	891	915
Crushing days	72	60	52	52	46	43	67	98
The yield of sugar cane%	9.03	9.57	9.92	9.94	8.52	10.64	9.73	10.04
Total capacity utilization%	49.34	40.28	39.13	43.61	22.91	28.69	44.22	84.59
Capacity utilization for sugar%	31.88	23.93	23.73	27.01	12.56	18.14	27.24	50.82
Yield per employee	8.07	7.90	5.42	7.00	4.49	9.17	10.32	13.93
Yield per day	69.85	104.04	93.81	85.65	75.55	136.71	130.81	130.84
Target achievement for sugar%	61.48	52.80	70.56	57.31	42.47	57.08	65.91	63.30
Target achievement for Chita%	69.55	68.76	88.78	66.51	64.17	66.04	82.67	86.65
Name	NBC	PSM	KSM	C & Co	MSM	FSM	ZB	Total
Production Capacity	15000	15000	15240	11500	15000	10160	10160	210,440
Production of Sugar	10508	3521	2401	4395	5459	3787	4947	66,245
Production of Chita	6009	2252	1963	3298	4078	2639	2666	42,950
Consumption of cane	175325	58607	49294	82420	101733	69591	71711	1,136,045
No of employees	939	759	655	1149	1897	795	705	13,216
Crushing days	117	50	58	80	79	73	87	1,034
The yield of sugar cane%	8.91	9.73	8.87	9.36	9.46	9.20	10.66	9.57
Total capacity utilization%	110.11	38.48	28.64	66.90	63.58	63.25	74.92	53.24
Capacity utilization for sugar%	79.06	23.53	15.72	38.03	36.49	37.30	48.65	32.94
Yield per employee	18.35	7.92	6.98	6.84	8.79	8.78	11.75	9.05
Yield per day	136.85	112.44	74.40	95.64	119.99	87.13	87.67	102.76
Target achievement for sugar%	60.68	61.62	41.96	55.50	65.36	53.90	53.91	57.59
Target achievement for Chita%	72.61	78.81	63.34	80.33	96.32	74.81	63.95	74.89

Source: Annual Report of BSFIC(Amounts are in metric tons)

4.3 Production Efficiency

4.3.1 Efficiency of Total Production (Sugar and Jaggery)

Table 4 shows the summary of the DEA analysis considering the production of sugar and production of Jaggery as outputs and sugarcane, number of employees, and crushing days as inputs. The results show that the overall efficiency of all the mills is within the range of 85.00-100 percent compared to the efficient mills in the industry. As DEA analysis calculates only relative efficiency, not the absolute efficiency so among the production efficiency of the mills. The average production efficiency is 0.973, which indicates that the industry can reduce the consumption of its inputs by 9.4 without affecting the outputs of the industry. The PSM shows the industry's lowest efficiency score (85%), whereas the JSM, NSM, C & Co, and ZB are the most efficient mills in the industry, either by pure TE or SE.

Table-4: Production Efficiency of Sugar Including Jaggery

DMUs	Mills	TE	ARS TEARS	SE _{VRES}
1	PSM	0.850	1.000	0.850
2	TSM	0.973	0.979	0.994
3	SSM	0.987	1.000	0.987
4	SHSM	0.964	1.000	0.964
5	RnSM	0.958	1.000	0.958
6	JSM	1.000	1.000	1.000
7	RSM	0.954	0.978	0.975
8	NSM	1.000	1.000	1.000
9	NBC	1.000	1.000	1.000
10	PbSM	0.970	0.989	0.981
11	KSM	0.996	1.000	0.996
12	C & Co	1.000	1.000	1.000
13	MSM	1.000	1.000	1.000
14	FSM	0.950	1.000	0.950
15	ZB	1.000	1.000	1.000
MEAN		0.973	0.996	0.977

The results of VRS represent that the average pure TE is 99.6%, and the average SE of the industry is 97.7%.

4.3.2 Production Efficiency of Sugar as Only Output

Table 5 presents the results of the DEA analysis having only one output variable i.e, the production of sugar as it is the industry's main product. The average productivity of sugar production is 0.868, which is about 10% below the productivity of the production of sugar and Jaggery both together. The average scale efficiency in the industry is 0.879, which is less than 10.9% of the true TE of the industry (0.988). Like the results of table 4, one output variable's results also suggest that NBSM and ZB are at the top of the efficiency with an efficiency score of 1.00. The most inefficient mill is RnSM (0.664) with a SE of 0.664 but a pure TE of 1.000. The lowest pure TE is 0.933, attributable to TSM, which has a TR_{CRS} 0.819 lower than the average productivity. All the 15 mills experienced scale inefficiency except for NBSM and ZB sugar mills.

Table-5: Production Efficiency of Sugar Only

DMUs	Mills	TE	ARS TEARS	SE _{VRES}
1	PSM	0.846	1.000	0.846
2	TSM	0.819	0.933	0.878
3	SSM	0.870	0.979	0.889
4	SHSM	0.897	1.000	0.897
5	RnSM	0.664	1.000	0.664
6	JSM	0.974	1.000	0.974
7	RSM	0.924	0.969	0.953
8	NSM	0.960	0.970	0.990
9	NBC	1.000	1.000	1.000
10	PbSM	0.871	0.968	0.900
11	KSM	0.706	1.000	0.706
12	C & Co	0.820	1.000	0.820
13	MSM	0.849	1.000	0.814
14	FSM	0.814	1.000	0.814
15	ZB	1.000	1.000	1.000
Mean		0.868	0.988	0.879

Table-6 presents the correlation between the mills' total factor productivity (TFP) and capacity utilization (CapU). TFP is a measure of the efficiency of DMUs using the Malmquist productivity Index (a modified form of DEA applicable for panel data). The correlation value of 0.2922 shows a lower to medium level of

association between TFP and CapU, and the result is significant at level 0.05. Still, the correlation (0.0193) between TFP and production capacity (ProCap) is not significant. It reveals that the production efficiency of high-capacity utilizers is better than that of low-capacity utilizers. Still, it does not guarantee that the mills with higher production capacity (ProCap) are performing better in terms of efficiency. The target achievement for Sugar (TarAS) and Jaggary (TarAC) shows a positive relationship with CapU, and the result is statistically significant. The ProCap representing the size of the mills presents a low level of negative association with CapU, and the result is not significant. So, the production efficiency is not related to the size of the firm, but the capacity utilization might affect the mills' efficiency. Although the target achievement of jaggary (TarAC) has a significant high level of association with ProCap, the association between TarAS and ProCap is not significant.

Table-6: Pearson Correlation Between Capacity Utilization and Production Efficiency

	CapU	TFP	ProCap	TarAS	TarAC
CapU	1				
TFP	0.2922**	1			
ProCap	-0.1931	0.0193	1		
TarAS	0.3250**	0.2006	0.0555	1	
TarAC	0.2493*	0.0717	0.8441***		1

Note (* significance level 0.10, **significant level 0.05 and ***significant level 0.01)

5. Discussion

The capacity utilization analysis of the sugar mills shows that the overall capacity utilization of the industry is very low in terms of the total capacity to produce sugar. The industry is running at a 53.24% capacity level. Such low-capacity utilization maybe its low earning capacity as the industry is a losing concern. This low-capacity utilization also indicates low-value addition to the economy with a low level of development in this sector. Simon-Oke and Awoyemi (2010) identified a long-run positive relationship between capacity utilization in the manufacturing industry with their value addition to the economy. Similar results are also found in a Nigerian economy study, indicating that low utilization of capacity discourages policymakers from developing the sectors (Okunade, 2018). One of the reasons for the lower capacity utilization of the sugar mills in

Bangladesh is the country's lack of supply of sugarcane (Hossain et al., 2006). So without producing sufficient and high-quality sugarcane, it is not possible to increase sugar production. The production of sugar depends on the recoverability of sugar from sugarcane. The higher the recoverability higher the productivity of the mills. Therefore the quality of the sugarcane is a matter of the productivity of sugar in the industry (Hossain et al., 2006). The average recoverability of sugar from the sugar cane is 9.57%, which is much below the standard. A study in Thailand revealed that the average recovery rate of sugar from sugar cane is 13-15% across the sugar-producing countries (Chunhawong, Chaisan, Rungmekarat, & Khotavivattana, 2018). All the mills have their yearly targeted production of sugar, but the actual production of sugar is much below the targeted production. This indicates the inefficiency of the management and the operations.

The analysis based on three inputs shows that the overall efficiency of all the mills is within the range of 66.4- 100 percent compared to the efficiency of other mills. As DEA analysis calculates only relative efficiency, not the absolute efficiency of a firm, so we cannot recognize that mills having an index of 1.00 is fully efficient. Still, it has at least higher efficiency than other mills. The overall efficiency of sugar production is 86.8% indicates a low level of efficiency in the industry. The total 13.2% reduction in the industry's efficiency is contributed more by scale efficiency (0.879) than pure technical efficiency (0.988). The RSM and JSM have the highest efficiency in the industry. Still, they have a capacity utilization of only 19.17% and 27.67%, respectively, which is much below the average capacity utilization in the industry. This indicates that the mills having idle capacity have more efficiency in utilizing their inputs.

The DEA analysis and capacity utilization show that the NBSM and NSM have the highest production efficiency and utilize the majority of their fixed production capacity. Moreover, the RSM and KSM, which have the lowest efficiency, their capacity utilization is also lower than that of the average capacity utilization of the sugar mills in the industry. This represents mills aiming to maximize the capacity utilization achieving a production efficiency in utilizing its inputs. The Pearson correlation confirms the positive association of the mill's productivity and capacity utilization at a level of 0.05. The findings

align with the previous studies (Baldwin, Gu, & Yan, 2013; Deb, 2014) found that improved capacity utilization positively impacts productivity growth. An underutilization results in a decline in multifactor productivity.

6. Implication

At present, the local production of Sugar in Bangladesh is insufficient to meet the country's demand, and the production capacity of the state-owned sugar mill has remained idle. So, the findings of the study will have significant practical importance. It may induce the government to increase the outputs of indigenous sugar production by introducing advanced technology and improved comprehensive efficiency to achieve food security in this particular industry. It may also provide a guideline to the state informing priorities based on capacity utilization, and efficiency score observed to refurbish the mills as the modernization of this industry. The production yield of sugarcane, number of employees, and crushing day can be carefully utilized in developing their plan for sugarcane production/purchase and labor training to improve the machine's capacity utilization. The decomposition of production yield by sugarcane and the number of employees can provide significant insights into policy formulation for an appropriate combination of the factors to achieve optimality in sugar production. This study also contributes to the existing literature on sugar productivity in a developing country context. The analysis of production efficiency using more than one factor may open a new avenue for potential researchers to assess the efficiency of the other important sectors of the economy.

7. Limitations and Future Research

The study has several limitations. Firstly, the study uses the quantity of inputs and outputs, but the value of such inputs (cost) and outputs (revenue) has been ignored as the value of sugar and Jaggery is different, so only the quantitative efficiency might go wrong. Secondly, measuring production efficiency takes into account only the sugar and Jaggery but other by-products i.e, molasses, and bagasse, which may significantly influence the industry's production efficiency. Thirdly, the study measures the association between capacity utilization and production efficiency. Still, it does not confirm whether underutilization produces low efficiency or low-efficiency results in a low level of utilization.

Finally, the study is based on DEA analysis which focuses on the relative efficiency of the DMUs, so the picture of the efficiency measure does not represent the true efficiency of the mills.

Following the limitations of the current study, it can be recommended that future researchers carry out further analysis in measuring the efficiency of the sugar industry, considering both the value and quantity of sugar and jaggery production. The future researcher may also consider the mills from other sugar-producing countries like Thailand, India, and Pakistan to show the relative efficiency of Bangladesh's sugar industry with those countries.

8. Conclusion

Sugar is an essential food commodity with universal demand. If local production is inadequate, sugar must be imported at the expense of foreign currency. Local production of sugar can meet only 14.0% of the annual requirement for domestic consumption. This indicates the acute necessity of increasing sugar production in the country. A long-term policy is needed to increase sugar production in phases up to self-sufficiency. The sugar industry of Bangladesh has reached a critical stage where it has to make several crucial decisions. The input variable crushing time is highly underutilized in all the inefficient mills. The industry is running only at 53% of its capacity utilization, so there is a huge idle capacity which increases the cost of production. Although BSRI recommended using sugarcane production technology both in the mill and non-mill zone area in Bangladesh, there is no improvement. Simultaneously, the causes of low recovery of the factory also should be identified and eliminated. The analysis shows that there is low utilization of crushing days by the mills. Therefore, to turn the industry into a profit-earning concern, the government requires a long-run policy as the economy with low production of sugar will be highly affected by the market volatility of the sugarcane and the sugar in the south Asian economies region (Milovanovic & Smutka, 2016; Uddin). The government of Bangladesh should play its role in controlling the price of sugarcane and granting the mills to recover their production cost and profit from the sale of sugar.

References

- Adeyemi, P. A., & Olufemi, O. B. (2016). The determinants of capacity utilization in the Nigerian manufacturing sector. *Journal of Economics and Sustainable Development*, 7(5), 20-31.
- Afzal, M. N. I., Lawrey, R., Anaholy, M. S., & Gope, J. (2018). A comparative analysis of the efficiency and productivity of selected food processing industries in Malaysia. *Malaysian Journal of Sustainable Agriculture*, 2(1), 19-28.
- Ahmad, M., Chaudhry, G. M., Iqbal, M., & Khan, D. A. (2002). Wheat productivity, efficiency, and sustainability: A stochastic production frontier analysis [with comments]. *The Pakistan development review*, 643-663.
- Alam, M. M., Alam, M. M., Miah, M. S., & Rahman, M. K. (2009). Factors affecting sugar recovery of Bangladesh sugar industry. *Pakistan Sugar Journal*, 24(1).
- Baldwin, J. R., Gu, W., & Yan, B. (2013). Export growth, capacity utilization, and productivity growth: evidence from the Canadian manufacturing plants. *Review of Income and Wealth*, 59(4), 665-688.
- Begum, M., Islam, M., Miah, M., Hossain, M., & Islam, N. (2011). Production of somaclone in vitro for drought stress tolerant plantlet selection in sugarcane (*Saccharum officinarum* L.). *The Agriculturists*, 9(1-2), 18-28.
- Chakma, J. (2022, February 18). Sugar production at state mills lowest in a decade. *The Daily Star*. <https://www.thedailystar.net/business/economy/news/sugar-production-state-mills-lowest-decade-2964861>
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, 2(6), 429-444.
- Chavas, J. P., Petrie, R., & Roth, M. (2005). Farm household production efficiency: evidence from the Gambia. *American Journal of Agricultural Economics*, 87(1), 160-179.
- Chunhawong, K., Chaisan, T., Rungmekarat, S., & Khotavivattana, S. (2018). Sugar industry and utilization of its by-products in Thailand: an overview. *Sugar Tech*, 20(2), 111-115.

- Çinar, Y., ATICI, K., & Menten, C. (2021). Evaluating Technical Efficiency of Turkish Sugar Production in Pre and Post Privatization Periods. *Sosyoekonomi*, 29(47), 59-78.
- Coelli, T. (1998). A multi-stage methodology for the solution of orientated DEA models. *Operations Research Letters*, 23(3-5), 143-149.
- De Clercq, D., Wen, Z., Caicedo, L., Cao, X., Fan, F., & Xu, R. (2017). Application of DEA and statistical inference to model the determinants of biomethane production efficiency: A case study in South China. *Applied Energy*, 205, 1231-1243.
- Deb, A. K. (2014). Economic reforms, capacity utilization and productivity growth in Indian manufacturing. *Global Business Review*, 15(4), 719-746.
- Development, I. F. f. A., UNICEF, Programme, W. F., & Organization, W. H. (2019). *The state of food security and nutrition in the World: Safeguarding against economic slowdowns and downturns*: FAO.
- Foster, A. D., & Rosenzweig, M. R. (2022). Are There Too Many Farms in the World? Labor Market Transaction Costs, Machine Capacities, and Optimal Farm Size. *Journal of Political Economy*, 130(3), 636–680.
- Hafezalkotob, A., Haji-Sami, E., & Omrani, H. (2015). Robust DEA under discrete uncertain data: a case study of Iranian electricity distribution companies. *Journal of Industrial Engineering International*, 11(2), 199-208.
- Hasan, J. (2021, October 23). *Modernisation of Bangladesh sugar mills stalled*. <https://thefinancialexpress.com.bd/trade/modernisation-of-bangladesh-sugar-mills-stalled-1634957394>
- Hasan, M. K., & Islam, S. F. (2010). Technical inefficiency of wheat production in some selected areas of Bangladesh. *Bangladesh Journal of Agricultural Research*, 35(1), 101-112.
- Hossain, S., Zaman, M., Rabbani, M., & Hossain, M. (2006). Problems and Prospect of Sugar Industry in Bangladesh. *Progress. Agric*, 17(1), 283-293.
- Islam, M. N. (2015). Production Efficiency of Sugar Factory of Bangladesh: An Application of Data Envelopment Analysis. *Global Journal of Management And Business Research*.
- Khatun, N., Alam, M., Rahman, K., & Alam, M. (2011). An economic study on sugarcane pricing and its impact on sugar production in Bangladesh. *Pakistan Sugar Journal*, 26(4).

- Lee, J.-Y. (2005). Comparing SFA and DEA methods on measuring production efficiency for forest and paper companies. *Forest products journal*, 55.
- Luan, Y., Fischer, G., Wada, Y., Sun, L., & Shi, P. (2018). Quantifying the impact of diet quality on hunger and undernutrition. *Journal of Cleaner Production*, 205, 432–446.
- Mahmud, S., Azad, A. K., Rahman, M. M., Mahmud, S., Yasmin, M., Ali, R., & Hossain, A. (2014). Assessment of genetic variability of sugarcane varieties and somaclones based on RAPD Markers. *Journal of Nature Science and Sustainable Technology*, 8(1), 73.
- Milovanovic, V., & Smutka, L. (2016). South Asian countries in the global sugar market: a critical assessment. *Sugar Tech*, 18(6), 647–658.
- Murali, P., & Puthira Prathap, D. (2017). Technical Efficiency of Sugarcane Farms: An Econometric Analysis. *Sugar Tech*, 19(2), 109–116.
- Nandy, A., Singh, P. K., & Singh, A. K. (2021). Systematic Review and Meta-regression Analysis of Technical Efficiency of Agricultural Production Systems. *Global Business Review*, 22(2), 396–421.
- Nieder-Heitmann, M., Haigh, K. F., & Görgens, J. F. (2018). Process design and economic analysis of a biorefinery co-producing itaconic acid and electricity from sugarcane bagasse and trash lignocelluloses. *Bioresource Technology*, 262, 159–168.
- Nishiyama, H., Tada, Y., Kato, N., Yoshimura, N., Toyoshima, M., & Kadowaki, N. (2012). Toward optimized traffic distribution for efficient network capacity utilization in two-layered satellite networks. *IEEE transactions on vehicular technology*, 62(3), 1303–1313.
- Okunade, S. O. (2018). Effect of capacity utilisation on manufacturing firms' production in Nigeria. *Global Journal of Management and Business Research*.
- Padilla-Fernandez, M. D., & Nuthall, P. L. (2009). Technical efficiency in the production of sugarcane in Central Negros area, Philippines: An application of data envelopment analysis. *Journal of ISSAAS [International Society for Southeast Asian Agricultural Sciences](Philippines)*.
- Raheman, A., Qayyum, A., Afza, T., & Iqbal, M. M. (2009). Efficiency dynamics of sugar industry of Pakistan [with comments]. *The Pakistan Development Review*, 921–938.

- Rahman, M., Khatun, S., & Rahman, M. (2016). Sugarcane and sugar industry in Bangladesh: An overview. *Sugar Tech*, 18(6), 627-635.
- Ray, S. C. (2015). Non-parametric measures of scale economies and capacity utilization: An application to US manufacturing. *European Journal of Operational Research*, 245(2), 602-611.
- Ritchie, H., Reay, D. S., & Higgins, P. (2018). The impact of global dietary guidelines on climate change. *Global Environmental Change*, 49, 46-55.
- SDG Report. (2019). Bangladesh Sugar & Food Industries Corporation.
- Sharma, M. K., Sengar, K., Singh, A., & Sengar, R. (2018). Potential applications of molecular markers for genetic diversity and DNA fingerprinting in sugarcane. *Biotechnology to Enhance Sugarcane Productivity and Stress Tolerance*, 153-190.
- Shen, S., & Shen, Z. (2013). *Analysis of fishery production efficiency based on the three-stage DEA*. Paper presented at the Proceedings of the 2nd International Conference on Green Communications and Networks 2012 (GCN 2012): Volume 1.
- Serrano-Cinca, C., Fuertes-Callén, Y., & Mar-Molinero, C. (2005). Measuring DEA efficiency in Internet companies. *Decision Support Systems*, 38(4), 557-573.
- Simon-Oke, O., & Awoyemi, O. (2010). Manufacturing capacity utilization and industrial development in Nigeria: An assessment (1976-2005). *African Research Review*, 4(2).
- SONG, Z.-j., XU, Y.-q., & ZHANG, Z.-y. (2008). A DEA efficiency analysis of Chinese agriculture [J]. *Journal of Chongqing University (Social Science Edition)*, 3, 24-29.
- Tulchynska, S., Popelo, O. L. H. A., Vovk, O., Dergaliuk, B., Kreidych, I., & Tkachenko, T. (2021). The resource supply of innovation and investment strategies of the microeconomic systems modernization in the conditions of digitalization. *Transactions on environment and development*, 17, 819-828.
- Uddin, M. H. Competition in Sugar Market of Bangladesh.
- Ullah, A., Silalertruksa, T., Pongpat, P., & Gheewala, S. H. (2019). Efficiency analysis of sugarcane production systems in Thailand using data envelopment analysis. *Journal of Cleaner Production*, 238, 117877.
- Wu, P., Wang, Y., Chiu, Y.-h., Li, Y., & Lin, T.-Y. (2019). Production efficiency and geographical location of Chinese coal enterprises-undesirable EBM DEA. *Resources Policy*, 64, 101527.

Appendix-1: List of Sugar Mills and Institutions in Bangladesh

SI. No.	Name of the Enterprises	Location/Address	Abbreviation
1.	Panchagarh Sugar Mills Ltd.	Panchagarh	PSM
2.	Setabganj Sugar Mills Ltd.	Setabganj, Dinajpur	SSM
3.	Thakurgaon Sugar Mills Ltd.	Thakurgaon	TSM
4.	Shyampur Sugar Mills Ltd.	Shyampur, Rangpur	SHSM
5.	Jaipur has Sugar Mills Ltd.	Jaipur has	JSM
6.	Natore Sugar Mills Ltd.	Nature	NSM
7.	North Bengal Sugar Mills Ltd.	Gopalpur, Natore	NBC
8.	Rajshahi Sugar Mills Ltd.	Harian, Rajshahi	RSM
9.	Kushtia Sugar Mills Ltd.	Jagati, Kushtia	KSM
10.	Mobarakganj Sugar Mills Ltd.	Naldanga, Jhenaidah	MSM
11.	Carew & Co(BD) Ltd.	Darsana, Chuadanga	C&Co
12.	Faridpur Sugar Mills Ltd.	Madhukhali, Faridpur	FSM
13.	Pabna Sugar Mills Ltd.	Dashuria, Pabna	PSM
14.	Zeal Bangla Sugar Mills Ltd.	Dewanganj, Jamalpur	ZB
15.	Rangpur Sugar Mills Ltd.	Rangpur	RSM
16.	Bangladesh Sugar and Food Industries Corporation		BSC
17.	Bangladesh Sugarcane Research Institute		SRI