

Research Article

# Efficiency Measurement: An Application of Data Envelopment Analysis (DEA) on Natural Gas Marketing Companies in Bangladesh

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## Abstract

Performance evaluation is crucial for companies to monitor their efficiency and economic status. In the context of the natural gas marketing companies in Bangladesh, their profitability has declined, leading to challenges in meeting demand. The main objective of the study is to measure the efficiency and total factor productivity changes. For five natural gas marketing companies, 10 years of data were analyzed to measure efficiency. Both non-financial indicators (input purchase units, workforce, No. of customers, length of distribution network, output- sales units) and financial indicators (input capital, cost of goods sold, operating expenses, total assets, output- profit) are used to measure efficient by applying Data envelopment analysis (DEA) and Malmquist DEA. Based on the result, newly established companies are more efficient, and the total factor productivity growth is better. To become more productive and move up to the position of an efficient company, the inefficient one should cut down on its excessive input components. The management should optimize employee use and renovate the distribution network with new technology. Innovation in technology and infrastructure development, such as AI systems for operation, leakage findings and maintenance, pressure control, online metering, and metering for all types of customers, can improve technological efficiency and reduce system loss.

## Keywords

Efficiency, Performance Evaluation, Economic Status, Malmquist DEA

## 1. Introduction

The market, both national and international, is competitive for any company. To sustain itself in the competition, the company has to be efficient in its financial and effective operations. Performance measurement is significant since inaccurate measurement results in bad choices and challenges [1]. Performance evaluation is helpful in monitoring a company's efficiency and sound economy and provides infor-

mation to lead the way for corporate decisions [2]. Generally, financial indicators are used, but these are not sufficient factors for measuring performance. Performance evaluation is the primary way to monitor the company's efficiency and financial status. Both financial and non-financial analyses are used to measure and compare performance, using DEA to measure operational and technical efficiency [2]. Efficiency is

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a firm's ability to achieve the target goals with limited resources and minimize the excessive usage of resources, including labour hours and energy. Efficiency should be measured to assess the comparative performance of the organization. Actual performance is vital for decision-making for both internal and external users [3]. There are different types of efficiency measurement, such as financial and economic efficiency, technical efficiency, market efficiency, and innovation efficiency. Strategic efficiency is also a kind of efficiency that is a combination of three efficiency types: operational efficiency, investment efficiency, and financial efficiency. Operational efficiency is focused on the indicators of sales volume, sales amount, productivity, etc., and investment efficiency is focused on the return on investment in case of merger, acquisition, research & development; financial efficiency is focused on the indicators of liquidity, interest rate on loan, financial leverage [3]. However, in modern situations, to assess financial (economic) efficiency, the company must pay attention to turnover (sales) and profitability [4, 5]. Financial efficiency is achieved with the increase of labour productivity, increasing working capital turnover, practical training, automation of operational processes, cost reduction, reducing no. of employees, etc. [3, 5, 6].

The profitability of gas distribution companies declined, and TGDTCI incurred a loss in the years 2022-2023 [7]. Therefore, a challenge will be faced by natural gas distribution companies to run the business of supplying gas to customers to meet demand. It is time to measure the financial and operational performance of the natural gas distribution company to find out the causes of inefficiency. The efficiency of natural gas distribution companies in Bangladesh has yet to be measured by benchmarking techniques like DEA, which can be a helpful technique for finding out the excessive use of input resources. It will be able to make the comparison to give the proper guidelines for measuring the company's effective uses of inputs that will help increase productivity, profitability, and efficiency.

## 2. Reviews of Related Literature

Various kinds of publications are reviewed for the conceptual framework's development; a few are listed below:

Hemmasi, Talaeipour [8] studied Iran's wood industry's limitations in production technologies and raw material supplies using a Slack-based measure model (SBM). The study found that ten organizations were stable, but many were still inefficient and unstable. Halkos and Tzeremes [9] developed a single performance indicator using financial data and ratios but noted that including financial factors introduces bias in efficiency assessments. Tehrani, Mehragan [10] found that every commercial organization had a performance measurement system that created a competitive environment. Yardımcı and Karan [11] investigated the efficiency and service quality of Turkey's gas distribution companies using DEA as a non-parametric tool and SFA (Stochastic Frontier

Analysis) as a parametric tool. They recommended a reward and penalty model for setting up tariffs. Fenyves, Tarnóczy [2] stated that performance evaluation aims to monitor company efficiency and economy, providing information for decision-making. Data Envelopment Analysis (DEA) is a method that uses both financial and non-financial information to complete traditional indicator analysis for operational and technical efficiency. They found that general efficiency is static, not like scale efficiency, and companies should improve their general efficiency. Majumdar and Asgari [12] applied the DEA theory to measure performance in non-financial companies in the UAE, finding that the food and beverage, telecommunication, and pharmaceutical industries were the best performers during the post-crisis period. Meanwhile, real estate, construction, and cement industries suffered. Maradin, Drazenovic [13] analyzed performance evaluation in baking sectors in the European Union, particularly in Croatia, revealing that new banks and small banks were more efficient than local banks. Lin, Yan [14] developed an IDEA model to analyze China's seaport performance, focusing on undesirable outputs and resource consumption. Lee and Choi [15] analyzed the environmental performance of Korean manufacturing industries using the Malmquist-Luenberger index, revealing that technical change is more than efficiency; it is about improving productivity performance. Sueyoshi and Ryu [16] studied operational and environmental performance using the DEA approach, focusing on assets, research and development expenditures, employees, and energy consumption. They found that operational performance is related to company age and business model, while location is associated with environmental performance. [17] examined the efficiency of restaurants and hotel sectors in Greek regions using the DEA model, finding that Attica and the South Aegean are moving efficiently, while Thessaly, Central Macedonia, Central Greece, and Empires are falling further. Liang, Yang [18] applied a three-stage DEA model with ratios to measure efficiency in China's manufacturing industry from 2016 to 2019. The efficiency of all 30 regions showed an upward tendency, and policy implications were given to boost low-carbon production efficiency at national and regional levels. Raheman, Qayyum [19] measured the total factor productivity growth of the 21 sugar industries in Pakistan using DEAP software. The results showed that the industry improved technological progress, but managerial efficiency change negatively affected productivity, potentially affecting financial viability. Hossain, Rahman [20] studied the most influencing input-output factors for enhancing efficiency in Bangladesh's garment sectors. CRS-based DEA was applied to estimate efficiency, finding two garments efficient, while the high cost of material and labour was responsible for the inefficiency of the other three garments.

## 3. Objective of the Study

The main objective of the study is to measure the efficiency

and total factor productivity change of gas marketing companies in Bangladesh. The specific objectives are as follows:

1. To identify the factors(inputs) affecting the performance of the natural gas marketing companies in Bangladesh;
2. To find out the efficient gas marketing companies in Bangladesh using financial and non-financial inputs;
3. To evaluate the total factor productivity growth over the time of the natural gas marketing companies in Bangladesh;
4. To suggest some recommendations those are followed to improve the efficiency of the gas marketing companies in Bangladesh.

## 4. Concepts of the Related Items

*Data Envelopment Analysis (DEA)*: Data Envelope Analysis (DEA) is a multifactor productivity analysis model that analyzes the relative efficiency of a uniform set of decision-making units(DMUs) [21]. It is based on an efficiency ratio of output/inputs, while the organizations or entities that are responsible for the transformation of inputs to outputs are called decision-making units(DMUs) [17]. The Efficiency Score may be on the following

$$\text{Efficiency} = \frac{\text{Weighted sum of output}}{\text{Weighted sum of input}}$$

The DEA that reduces inputs to improve efficiency is input orientation, and the DEA that increases output to enhance efficiency is output orientation [21, 22].

### *Inputs*

The resources that a decision-making unit uses to carry out its operations are known as inputs [9].

### *Outputs*

The outputs represent the desired level of outcome from the use of input resources [9].

*Decision-Making Units (DMUs)*: DMUs are the companies that assess within the context of the DEA study. Hospitals, universities, schools, and colleges also be DMU, where the DEA is used for assessment [21].

### *Pure efficiency*

Pure efficiency refers to the ability of managers to utilize the resources of the company [23].

### *Scale efficiency*

Scale efficiency is the amount by which productivity can be increased by moving to the most productive scale size. A unit is said to be scale efficient when its size of operation is optimal, and any modification on its size will be less efficient [23].

### *Technical efficiency*

Technical efficiency is the product of pure efficiency and scale efficiency [24, 25]. Technical efficiency can be estimated using an input-oriented or output-oriented approach. Input-oriented technical efficiency measures address how much input quantities can be proportionally reduced without

changing the output quantities produced. Output-oriented technical efficiency measures by addressing the question -How much can output quantities be proportionally expanded without altering the input quantities used? [23]

### *Technological change*

Technology change is the second significant driver of growth in total factor productivity. The establishment of new items or technologies to advance and move the production frontier upward is known as technology change [26].

### *Malmquist Total Factor Productivity index*

Malmquist productivity index is derived from three components, i.e. efficiency change, technological change, and total factor productivity growth (TFPG). TFPG is the geometric mean of technological change and efficiency change [19].

## 5. Methodology of the Study

The research study measures the technical, technological, and productivity efficiency of selected natural gas distribution companies in Bangladesh.

### *Selection of the companies and study period*

The sample decision-making units of the natural gas marketing companies, five companies have been selected conveniently as TGTDC (established in 1964), JGTDSL (established in 1986), PGCL (established in 2000), KGDCL (established in 2010), SGCL (established in 2009), out of 6 companies covering the data of 10 years from 2013-14 to 2022-2023.

### *Selection of Input-Output Variables*

For the measurement of efficiency, both financial and non-financial inputs are considered. Non-financial indicators Sales (MMCM) [8, 12, 15-17, 20, 27] is output where Purchase (MMCM) [12, 20, 27], No. of manpower [13, 16-18, 27-29], No. of the customers, and the length of the distribution pipeline (K. M.) [27] are treated as input for measuring technical efficiency by DEA (Data Envelopment Analysis). Financial indicators, cost of sales (material) [12, 20], operating expenses [8, 9, 13, 20, 30], total equity capital [9, 12, 15, 17, 25, 31], and total assets [8, 9, 13, 16, 18, 25] are considered inputs, and net profit [8, 9, 13, 16, 18, 25, 30, 32] is output for the measurement of technical efficiency in financial DEA.

### *Variables Selection for the measurement of total factor productivity growth*

Expenditures associated with selling merchandise or rendering services to clients are the cost of sales [33]. It is what the seller must pay for the products they sell to customers [34]. Bangladesh's gas distribution companies' cost of sales includes gas purchase costs, gas transmission charges, gas development fund charges, BAPEX margin, LNG charges, VAT, Gas production charges, etc. Cost of goods sold is considered as input [12, 15, 19, 25]; Operating expenses are those costs incurred during regular business operations (excluding cost of goods sold) [34]. In the gas distribution companies in Bangladesh, it includes salary, administrative expenses, de-

preciation, bad debts, etc. Operating expenses (labour costs) are taken as input by [12, 15, 19, 31]; The shareholder's interest in a company is treated as equity capital. It includes funds invested by owners and accumulated retained earnings of the company [34, 35]. Equity capital is taken input by [12, 15, 19, 25, 31], A resource that the business owns as a result of past events and from which the entity anticipates receiving future financial benefits [36]. The resources are investments that are expected to generate future earnings through operating activities [35]. Total assets include current and long-term assets (long-term investments, Intangible assets, property, plant, and types of equipment). Assets are an important element in measuring efficiency growth [19, 25]. Net profit refers to the company's earnings. The company makes a net profit if its revenues for a given period are higher than its expenses for the same period and vice versa [34]. It is the

amount derived after deducting all costs and before taxes from the sales revenue of a particular period [25]. Net profit is taken as output by [25]. Sales revenue is treated as output by some researchers [12, 15, 19]. However, sales revenue is not considered output because gas is sold without modification, the government fixes the sales price per unit of gas, and it also has little impact on efficiency.

#### *Sources of Data*

Both financial and nonfinancial data are taken from the selected companies' annual reports, audit reports, Petrobangla reports, the Ministry of Power Energy and Mineral Resources reports, and Bangladesh economic reviews.

#### *Techniques of analysis of data*

Tools and techniques like DEA and Malmquist DEA have been used to serve the purpose of analysis and interpretations.

## 6. Results and Discussion

**Table 1.** Pearson Co-efficient of Correlation of Sales (MMCM) with each non-financial Input Variable.

Particulars	Sales (MMCM)	Purchase (MMCM)	Workforce	Customers	Length of Pipeline (K. M.)
Sales (MMCM)	1	1.00**	0.99**	0.97**	0.97**
Purchase (MMCM)	1.00**	1	0.99**	0.97**	0.97**
Workforce	0.99**	0.99**	1	0.95**	0.97**
Customers	0.97**	0.97**	0.95**	1	0.96**
Length of Pipeline	0.97**	0.97**	0.97**	0.96**	1

Source: Data compiled from the annual reports of the selected natural gas distribution companies in Bangladesh; N=5, \*, \*\* indicate the level of significance correlation at 5% and 1% (2-tailed), respectively, using SPSS version 24, K. M. = Kilometer, MMCM=Million cubic meters.

Table 1 explains the correlation between sales (MMCM) and purchases (MMCM), the workforce, customers, and the distribution line length. The estimated associations for each variable are 100\*\*, 0.99\*\*, 0.97\*\*, and 0.97\*\*, respectively, indicating that all the input variables significantly positively impact Sales (MMCM) at the 1% significance level.

**Table 2.** Pearson Co-efficient of Correlation of Net Profit before tax with each financial Input Variables.

Cost of Sales	Operating expenses	Total assets	Total equity capital
0.33*	0.51**	0.41**	0.57**

Source: Data compiled from the annual reports of the selected natural gas distribution Companies in Bangladesh; N=5, \*, \*\* indicate the level of significance correlation at 5% and 1% (2-tailed), respectively, using SPSS version 24.

Table 2 explains the correlation of net profit before tax with the cost of sales, Operating expenses, Total assets, and Total capital. The estimated associations for each variable are 0.33\*\*, 0.51\*\*, 0.41\*\*, and 0.57\*\*, respectively, indicating that all the input variables significantly positively impact net profit at the 1% significance level.

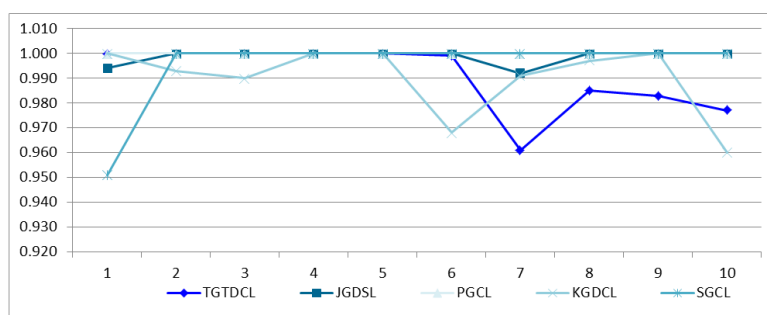
**Table 3.** The Technical efficiency scores of the selected natural gas distribution companies in Bangladesh based on non-financial data.

Particulars	Distribution Companies				
	TGTDCL	JGTDSL	PGCL	KGDCL	SGCL
2013-2014	1.000	0.994	1.000	1.000	0.951
2014-2015	1.000	1.000	1.000	0.993	1.000
2015-2016	1.000	1.000	1.000	0.990	1.000
2016-2017	1.000	1.000	1.000	1.000	1.000
2017-2018	1.000	1.000	1.000	1.000	1.000
2018-2019	0.999	1.000	1.000	0.968	1.000
2019-2020	0.961	0.992	1.000	0.991	1.000
2020-2021	0.985	1.000	1.000	0.997	1.000
2021-2022	0.983	1.000	1.000	1.000	1.000
2022-2023	0.977	1.000	1.000	0.960	1.000
Times of efficiency	5	8	10	4	9
Mini	0.961	0.992	1.000	0.960	0.951
Max	1.000	1.000	1.000	1.000	1.000
Mean	0.991	0.999	1.000	0.990	0.995
S. D	0.014	0.003	-	0.014	0.015
C. V	1.37%	0.30%	0.00%	1.45%	1.56%

Source: Data compiled from the annual reports of the selected natural gas distribution companies in Bangladesh; DEA analyzed using DEAP version 2.1. Inputs: purchase (MMCM), No. of manpower, No. of customers, Length of pipeline, Output: Sales (MMCM)

The non-financial input variables, the Purchase of gas (MMCM), employees, customers, and the length of the distribution line (K. M.), and the output variable, Sales of gas (MMCM), are taken for measuring technical efficiency in input-oriented DEA. The statistically significant correlation coefficient between inputs and output at a 1% significance level indicates the appropriateness of the variables selected for the study. Input-oriented technical efficiency measures how much input quantities can be proportionately reduced without changing the output quantities produced.

Table 3 exhibited that during the study period, KGDCL, TGTDCL, JGTDSL, SGCL, and PGCL showed efficient conditions 4, 5, 8, 9, and 10 times, respectively. Moreover, KGDCL, TGTDCL, JGTDSL, and SGCL were 6, 5, 2 and 1 years inefficient over the period of ten years. This indicates that the PGCL Company's management efficiently uses the non-financial input variables. The inefficient company could reduce its excessive use of inputs to become an efficient company and attain the position of an efficient one.



Source: Table 3.

**Figure 1.** Line chart of Technical efficiency based on non-financial data.

Figure 1 indicates the efficiency line of the selected natural gas distribution companies in Bangladesh. TGTDCCL, PGCL and KGDCL start from the efficient and SGCL and JGDSL start from the inefficient one. It's a remarkable position that SGCL attained the desired efficiency from 2<sup>nd</sup> year of the

study period. The efficient TGTDCCL and KGDCL fail to sustain the efficient performance level, and their trend is up and down. Only PGCL is able to efficiently use its non-financial resources.

**Table 4.** The technical efficiency scores of the selected natural gas distribution companies in Bangladesh based on financial data.

Particulars	Distribution Companies				
	TGTDCCL	JGDSL	PGCL	KGDCL	SGCL
2013-2014	0.630	0.347	0.347	1.000	0.275
2014-2015	0.488	0.405	0.451	1.000	0.610
2015-2016	0.527	0.337	0.460	1.000	0.393
2016-2017	0.507	0.372	0.498	1.000	0.225
2017-2018	0.296	0.529	0.545	1.000	0.961
2018-2019	0.424	0.543	0.725	1.000	1.000
2019-2020	0.220	0.690	0.983	1.000	1.000
2020-2021	0.294	0.813	0.979	1.000	1.000
2021-2022	0.081	0.291	0.357	1.000	0.624
2022-2023	0.000	0.606	1.000	0.716	1.000
Time of efficient	0	0	1	9	4
Mini	0.000	0.291	0.347	0.716	0.225
Max	0.630	0.813	1.000	1.000	1.000
Mean	0.347	0.493	0.635	0.972	0.709
S. D	0.205	0.172	0.265	0.090	0.323
C. V	59.00%	34.89%	41.78%	9.24%	45.64%

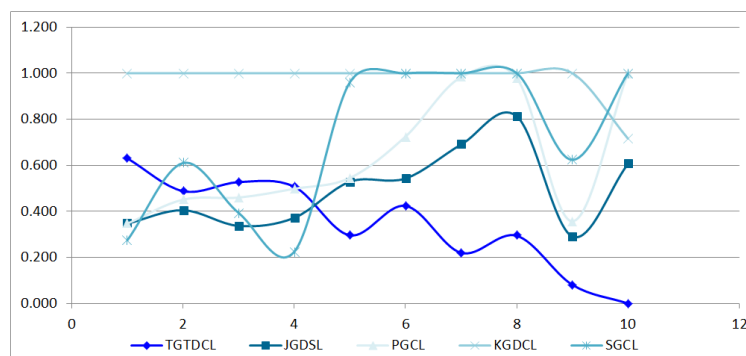
Source: Data Compiled from the Annual Reports of the selected natural gas distribution Companies in Bangladesh; DEA analyzed using DEAP version 2.1 where Input variables (cost of sales, operating expenses, equity capital, total assets), and output net profit.

In input-oriented DEA, technical efficiency is measured using the financial input variables—the cost of goods sold (Material), operating expenditures, total assets, and equity capital—and the output variable, Net profit. The statistically significant correlation coefficient between inputs and output at the 1% level of significance (Table 2) indicates that the variables chosen for the study were appropriate.

Table 4 represents KGDCL, SGCL, and PGCL each exhibited efficient conditions nine, four, and one time over the study period, and the efficiency varied is similar to the result [27]. Additionally, it is noted that TGTDCCL and JGDSL are

inefficient under the study. It is reported that comparatively, new and small-size companies' efficiency is better than that of large and old companies' performance, which is similar to the result [37]. None is efficient throughout the study period, and the result is similar to [38]. This indicates that the management of KGDCL effectively uses the input variables, but other companies fail, and SGCL has improved its efficiency over the years. To become more productive and move up to the position of an efficient company, the inefficient one should cut down on its excessive input consumption.





Source: Table 4.

**Figure 2.** Line chart of technical efficiency based on financial data.

Figure 2 indicates the efficiency position of the selected natural gas distribution companies in Bangladesh based on financial indicators. Only KGDCL starts from an efficient one, and other companies, TGTDCL, JGDSL, PGCL and SGCL, begin from an inefficient one. It's remarkable that SGCL and PGCL attain the desired efficiency but do not sustain it for a long time, and their efficiency is up and down during the study period. During the study period, TGTDCL and JGDSL fail

to attain efficiency levels in a single year. In the last year of the study period, only SGCL and PGCL achieved an efficiency position, and the rest of the companies failed to achieve the desired target. The inefficient position of TGTDCL is higher than that of any other company during the periods and focuses the management inefficiency to utilize its resources.

**Table 5.** Total factor productivity growth in selected natural gas distribution companies in Bangladesh.

Particulars	Distribution Companies					Mean
	TGTDCL	JGDSL	PGCL	KGDCL	SGCL	
Technical Efficiency change (EC)	0.283	1.064	1.125	0.964	1.154	0.823
Technological Efficiency change (TEC)	0.924	0.912	0.872	0.879	0.949	0.907
Pure efficiency change (PEC)	0.730	1.084	1.000	1.000	1.000	0.954
Scale efficiency change (SEC)	0.388	0.981	1.125	0.964	1.154	0.862
Total factor productivity change (TFPC)	0.261	0.970	0.981	0.847	1.095	0.746

Source: Data Compiled from the Annual Reports of the selected natural gas distribution Companies in Bangladesh; DEA analyzed using DEAP version 2.1, where Input variables (cost of sales, operating expenses, equity capital, total assets), and output-net profit.

Table 5 exhibits the company's total factor productivity (TFP) growth, technical efficiency change (EC), technological efficiency change (TEC), pure efficiency change (PEC), and scale efficiency change (SEC) according to the Malmquist Index. Bangladesh's natural gas distribution companies had an overall significant negative TFP growth over the study period, at 25.4%, similar to the result [19]. This indicates a substantial increase or decrease in total factor productivity growth. The analysis of gas distribution companies revealed that technical efficiency change, technological

efficiency change, pure efficiency change, and scale efficiency changed by 17.7%, 9.3%, 4.6%, and 13.8 %, respectively, over the period. On average, SGCL has the highest growth in total factor productivity (TFP) (9.5%) and has been treated as the most efficient among those selected, and all other companies TFP growth declined by PGCL (1.9%), JGDSL (3%), and KGDCL (015.3%). However, TGTDCL's TFP growth declined by -73.9% over time, indicating the worst position and inefficiency also increased over the period of time, similar to the result [39].

**Table 6.** Malmquist Index of Yearly means for the selected natural gas distribution companies.

Year	Efficiency change				
	EC	TEC	PEC	SEC	TFPC
2014-2015	1.211	0.926	1.009	1.201	1.121
2015-2016	0.900	0.772	0.991	0.908	0.694
2016-2017	0.920	0.776	0.997	0.923	0.714
2017-2018	1.312	1.019	0.802	1.636	1.337
2018-2019	1.153	0.996	1.282	0.899	1.148
2019-2020	0.978	1.093	0.788	1.241	1.069
2020-2021	1.093	0.864	1.141	0.959	0.945
2021-2022	0.468	2.468	0.663	0.706	1.154
2022-2023	0.228	0.316	1.076	0.211	0.072
Mini	0.228	0.316	0.663	0.211	0.072
Max	1.312	2.468	1.282	1.636	1.337
Mean	0.823	0.907	0.954	0.862	0.746

Source: Data Compiled from the Annual Reports of the selected natural gas distribution Companies in Bangladesh; Malmquist DEA analyzed using DEAP version 2.1; where EC= Efficiency change, TEC= Technical Efficiency change, PEC= Pure efficiency change, SEC= Scale efficiency change, TFPC= Total factor productivity change, Mini=Minimum, Max=Maximum, Mean= Geometric mean; where Input variables (cost of sales, operating expenses, equity capital, total assets), and output-Net profit.

Table 6 presents TFP growth over the period. Moreover, it is unpredictable and missing an identified pattern. The years 2017-18, 2021-22, 2018-19, and 2014-15 have the most significant rises in total factor productivity, 33.7%, 15.4%, 14.8%, and 12.1%, respectively, and show a positive relation with the growth of technological efficiency and technical efficiency and similar to the result of [19]. The TFP growth (0.072) was lowest in 2022-23, which indicates a 92.8% decline. According to the technological efficiency change

growth, efficiency rose by 146.8% in 2021-22 and declined by 68.4 % in 2022-22. Based on technical change, it increased by 31.2% during 2017-18, where the TFP growth is maximum (33.7%), and dropped by 77.2% during 2022-23, where the TFP growth is lowest (Negative). Similarly, when technological efficiency change is negative, TFP growth is also negative in the years 2015-16, 2020-21, and 2022-23, and there is an exception in 2018-19 and 2014-15.

**Table 7.** Rank of natural gas distribution companies based on Malmquist TFP and its elements.

Rank	Company	TFP change	Company	TE change	Company	TEC change
1	SGCL	1.095	SGCL	1.154	SGCL	0.949
2	PGCL	0.981	PGCL	1.125	TGTDCL	0.924
3	JGTDSL	0.970	JGTDSL	1.064	JGTDSL	0.912
4	KGDCL	0.847	KGDCL	0.964	KGDCL	0.879
5	TGTDCL	0.261	TGTDCL	0.283	PGCL	0.872

Source: Compiled from Table 5 based on data collected from the annual reports of the selected natural gas distribution Companies in Bangladesh; DEA analyzed using DEAP version 2.1 FTP= Total factor productivity; TE=Technical efficiency; TEC=technological efficiency

Table 7 presents all selected natural gas distribution companies are ranked based on their total factor productivity (TFP)



growth, technical efficiency change, and technological change. SGCL ranked first in TFP growth, technical change, and technological change. PGCL ranked 2<sup>nd</sup> in TFP growth and technical change and 5<sup>th</sup> in technological change. JGTDSL stood third in TFP growth, technical change, and technological change. KGDCL ranked fourth in TFP growth, technical change, and technological change. TGTDCCL stood in the ranking of TFP growth and technical change in the fifth position, though it stood in the second position in technological change. From the above, it is noted that technical change has a more significant impact on total factor productivity growth than technological change, with similar results with [19].

## 7. Major Findings

Based on the analysis and interpretation of financial and non-financial data, the major findings are as follows:

Based on non-financial input-out variables in measuring DEA, PGCL is technically the most efficient company, while all other companies are inefficient.

Based on financial input-out variables in measuring DEA, KGDCL is technically the most efficient company, followed by SGCL, while the rest of the other companies are inefficient. It is noted that new and small companies are technically more efficient compared to old and large ones.

The Malmquist index revealed significant changes in technical efficiency, technological efficiency, pure efficiency, scale efficiency, and total factor productivity growth. SGCL had the highest TFP growth, and TGTDCCL's growth declined by 73.9%.

The TFP growth in Bangladesh's natural gas distribution companies increases in 2014-15, 2017-18, 2018-19, and 2021-22. Technical and technological efficiency changes showed a positive relation with TFP growth. The TFP growth declined in 2022-23 by 92.8%.

SGCL ranked highest in average TFP growth with efficiency change exceeding 1.00 more than five out of nine years, and KGDCL ranked second. The PGCL's TFP growth is more static.

Concerning the average value of technical efficiency, SGCL remained the top performer, followed by PGCL and JGTDSL.

Based on the result of technological change, TGTDCCL is the best performer, while the best chance is in 2021-22, and the worst position is in 2022-23 for all the selected natural gas distribution companies.

## 8. Suggestions and Recommendations

To be an efficient company, the management should follow the following instructions:

The management of the TGTDCCL, JGTDSL, and SGCL should take the necessary steps to optimize the use of em-

ployees and the distribution network (pipeline) and purchase gas to enhance sales. The distribution network should be renovated with new technology to avoid loss due to leakage, and customers should be well-informed and motivated to use gas according to their load.

The management of TGTDCCL should investigate the reason behind the decrease in technical efficiency over the past several years and take steps to improve technical efficiency because it significantly affects total factor productivity, which is essential for sustainable growth.

All companies in the gas sector should renovate modern technology and develop infrastructure such as AI systems for operation, leakage finding, pressure control, online metering systems, and metering for all types of customers to improve technological efficiency and reduce system loss.

The total productivity of all natural gas distribution companies is unstable and facing problems. All companies should address this and take steps to achieve a smooth increase in productivity.

## 9. Conclusion

The study measures the efficiency of the natural gas marketing companies in Bangladesh. Overall, the efficiency of the gas marketing sectors is not satisfactory. Based on the analysis, considering non-financial indicators, TGTDCCL and KGDCL are inefficient, and these companies can't supply sufficient gas to their customers, and distribution network remain idle. Based on the financial indicators, all the companies incurred excessive operating expenses and cost of sales. Capital and assets are not efficiently utilized to generate profit. Considering total factor productivity growth, only SGCL has performed upwardly, but the rest of the companies failed to achieve the desired change. The summarized results indicate that new companies are more efficient than old ones due to introducing modern innovative technology. Management should control the operating expenses and cost of sales and utilize their capital and assets in the productive sectors. Natural gas marketing companies will be reached in an efficient position to reduce the excessive use of these components at the optimum level and introduce new technology.

## Abbreviations

TGTDCCL	Titas Gas Transmission and Distribution Company Limited
JGTDSL	Jalalabad Gas Transmission and Distribution System Limited
PGCL	Pashchimanchal Gas Company Limited
KGDCL	Karnaphuli Gas Distribution Company Limited
SGCL	Sundarban Gas Company Limited

## Authors Contributions

**Md. Nazmul Huda:** Conceptualization, Data collection, Methodology, Software, Writing – original draft

**Md. Abdus Sabur:** Formal analysis, Software, Supervision, Writing – review & editing

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## Data Availability Statement

Annual reports and audit reports are available in the following link of the company:

<https://titasgas.gov.bd/site/page/122cb7f4-5f94-4224-ade2-f3133fda71972/->

<https://titasgas.gov.bd/site/page/6845103c-d648-4f82-8cbb-f225bc0cc63b/->

[https://jalalabadgas.portal.gov.bd/site/view/annual\\_reports/-](https://jalalabadgas.portal.gov.bd/site/view/annual_reports/-)  
<https://jalalabadgas.portal.gov.bd/site/page/a793a7ac-7627-4164-9e92-e0d5e749588e/->

<https://pgcl.portal.gov.bd/site/page/43501176-4019-4368-ae55-923b75f7e9b1>

<https://pgcl.portal.gov.bd/site/page/dc0862dc-e849-4344-8460-b1bdeefc9e48/->

[https://kgdcl.gov.bd/site/view/annual\\_reports/-](https://kgdcl.gov.bd/site/view/annual_reports/-)

<https://kgdcl.gov.bd/site/view/reports/%E0%A6%85%E0%A6%A1%E0%A6%BF%E0%A6%9F-%E0%A6%AA%E0%A7%8D%E0%A6%B0%E0%A6%A4%E0%A6%BF%E0%A6%AC%E0%A7%87%E0%A6%A6%E0%A6%A8/->

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<https://sgcl.org.bd/site/view/reports/%E0%A6%85%E0%A6%A1%E0%A6%BF%E0%A6%9F-%E0%A6%AA%E0%A7%8D%E0%A6%B0%E0%A6%A4%E0%A6%BF%E0%A6%AC%E0%A7%87%E0%A6%A6%E0%A6%A8/->

## Conflicts of Interest

The authors declare no conflicts of interest.

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## Biography



Md. Nazmul Huda is an Assistant Professor at Islamic University in Bangladesh's Department of Accounting and Information Systems. He has been an instructor at a Bangladeshi public university for almost six years. Mr. Huda worked in various fields, including banking in the foreign exchange department, teaching at a private university, and serving as deputy manager of a natural gas distribution company in Bangladesh for nearly ten years. Without that, it should be noted that Mr. Huda earned his BBA and MBA with a major in Accounting and Information Systems from the Department of Accounting and Information Systems at Islamic University in Bangladesh, where he also placed first in the faculty and department for the MBA program and received a gold medal. The Institute of Bankers Bangladesh awarded him a JAIBB banking diploma as well. Additionally, He was successfully admitted to the National Board of Revenue of Bangladesh as an Income Tax Practitioner (ITP). He entered as a fellow under the Ph.D. fellowship program 2021–2022, of the University Grants Commission of Bangladesh, and is currently a Ph.D. fellow in the Department of Accounting and Information Systems, Islamic University, Bangladesh under the supervision of Prof. Dr. Md. Abdus Sabur. More than 20 national and international training/seminar programs have been attended, and more than 19 research articles have already been published in national and international journals.



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