Measuring the technical efficiency of the listed IT companies: Evidence from Bangladesh

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ABSTRACT
This study aimed to measure the technical efficiency of information technology (IT) companies listed on the Dhaka Stock Exchange (DSE) in Bangladesh. It included ten listed IT companies for the period 2016–2020. The input-oriented Data Envelopment Analysis (DEA) approach was used to measure technical efficiency. This study used two inputs, such as fixed assets and capital expenditure, and three outputs, such as return on equity, return on assets, and total income, to measure technical efficiency. All the required data were collected from publicly available annual reports, the sample companies’ websites, and the website of DSE. The study found that Bangladeshi-listed IT companies were not adequately technically efficient, with an average efficiency score of 56.6 percent, requiring a 43.6 percent improvement in efficiency during the period 2016–2020. This inefficiency was due primarily to pure technical inefficiency followed by scale inefficiency. The findings of the study are expected to provide important and useful information to the Bangladesh Association of Software and Information Services (BASIS), the Bangladesh Computer Council (BCC), the ICT Division of the Bangladesh government, and the sample companies.

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Introduction
In the twenty-first century, information technology (IT) is the world’s fastest-expanding industry (Shinkai & Hossain, 2011). The global IT industry provides services such as system architecture, networking, security, and data and information systems maintenance, as well as sells various products and services to corporations and other organizations worldwide. However, the concept of information technology has changed and expanded over time. It includes a broad range of information processing systems and computer applications used in organizations, including information systems, the internet, information and communication technologies, and their infrastructure, such as computer software, networks, and hardwires that transmit data to improve the efficiency of individuals and organizations (Onn & Sorooshian, 2013).

There is a profound relationship between the development of the national economy and the development of the IT sector because it provides quick and easy access to information, which is critical for a country’s development (Helal & Rahman, 2016). By creating employment, increasing the share of service trade, and adopting appropriate information technologies, the sector contributes to the economic development of countries (Shinkai & Hossain, 2011). In line with other countries, Bangladesh’s IT industry contributes...
to its overall economic growth by increasing efficiency across industries, lowering costs, and improving the quality of industrial output. Up until now, the IT industry in Bangladesh has generated about 300,000 job opportunities (Latifee & Hossain, 2018). The country’s domestic Information Technology and Information Technology Enabled Services (IT-ITES) market is currently worth $0.9–1.1 billion and is projected to increase to $5 billion by 2025 (Bari & Latifee, 2022). These statistics indicate that the IT industry has significantly contributed to the country’s economic growth, but not as significantly as in other South Asian economies such as India. ICT-related industries contribute roughly 13 percent of Bangladesh’s GDP, compared to about 26 percent of India’s (Hossain, 2021).

The Bangladeshi government has stated that it aspires to create a “Digital Bangladesh” in which IT will be used in governance, management, and administration to ensure transparency and accountability. The goal of “Digital Bangladesh” is to create a society driven by ICT and knowledge-based, with easy access to information online and modern technology for all conceivable tasks in the public, private, and non-profit sectors. From this vantage point, there is a policy question: is Bangladesh’s IT sector efficient enough to support the country’s desire to become a “Digital Bangladesh”?

Therefore, this study aims to measure the efficiency of the listed IT companies in Bangladesh. Measuring the efficiency of the country’s IT is inevitable. This is because it helps develop the present condition, identify loopholes in the systems or planning, and offer a solution to achieve the desired performance standard. Numerous studies in the area of efficiency measurement have been conducted to examine the performance of non-IT sectors in Bangladesh. For example, Ahmed and Liza (2012) and Abdul, Hasan, and Pananjung (2013) examined the efficiency and performance of commercial banks in Bangladesh. Nargis and Lee (2013) and Islam and Hoque (2014) investigated the efficiency of the agricultural sector, while Chowdhury, Rana, and Azim (2019) examined the efficiency of the intellectual capital of the pharmaceutical industry in Bangladesh. Similarly, Ahmed, Hasan, and MacLennan (2019) assessed the technical efficiency of public hospitals, while Baten, Kamil, and Fatama (2009) and Ahmed and Ahmed (2012) investigated the technical efficiency of the manufacturing industry, and Samad and Patwary (2003) examined the technical efficiency of the textile industry in Bangladesh. The earlier studies largely ignored the IT sector aside from the study by Shinkai and Hossain (2011), who analyzed the productivity and performance of the IT sector in Bangladesh based on a survey of 202 firms of various sizes. The study also assessed the impact of the 2008 global financial crisis on the sector. However, the current study differs from Shinkai and Hossain (2011) in that they used various financial ratios to assess the performance and productivity of the country’s IT sector. The current study used the Data Envelopment Analysis (DEA) approach, a mathematical method, particularly a linear programming technique. Unlike financial ratios, this approach provides an authentic result of efficiency and its causes.

The remainder of this paper is structured as follows. Section 2 presents the brief history of the IT sector in Bangladesh; section 3 reviews the literature; and section 4 describes the methodology employed in this study. Empirical results and discussion are presented in section 5, and section 6 draws a conclusion.

As early as the 1960s, Bangladeshi nuclear research by the Atomic Energy Centre led to the development of the information technology sector by starting the use of computers (Shinkai & Hossain, 2011). In the following decades, the use of IT in large Bangladeshi organizations increased, mainly due to the IBM mainframe computers. However, it was not until the 1990s that the industry began to receive close attention. The industry is still in its infancy today but shows signs of expansion. The sector started to bloom after 2010 as the government took huge initiatives to make this sector more vital than ever. To make the vision of “Digital Bangladesh” a success, the government of Bangladesh created a roadmap for more productive use of IT.

The rapidly expanding ICT sector has boosted the dynamism of developing new revenue streams and job opportunities. Access to and utilization of ICTs is now a key contributor to competitiveness, economic expansion, and social advancement. The sector already creates enormous employment opportunities by employing more than one million young people (Tech Observer Desk, 2021). Additionally, this industry has enormous potential to diversify exports and boost GDP. According to Latifee (2021), the industry has performed relatively well, contributing 0.76 percent to GDP by earning $1.3 billion in export revenue in FY 2020–21 and controlling a $1.4 billion market share locally. By 2025, it is anticipated that the country’s ICT exports will total $5 billion (Bari & Latifee, 2022).

However, well-developed infrastructure facilities are one of the biggest challenges in developing the IT industry, followed by power supply facilities (Karthik, Kala, Jain, & Gupta, 2017). In 2021, Bangladesh ranked 135th out of 137 countries for mobile internet speed and 98th out of 181 countries for fixed broadband speed (Dhaka Tribune, 2021). In both cases, the global average is much higher (Hasan, 2020). This clearly indicates poor internet connection facilities in Bangladesh, which is another obstacle to overcome for sustainable success in the IT sector. The unauthorized copying of software, also known as software piracy, can be another challenge for the Bangladesh IT industry. According to the BSA Global Software Survey (2018) report, the rate of unlicensed software installed in Bangladesh was 90 percent in 2011. This is worth a commercial value of $147 million. The percentage of unauthorized software installed decreased from 86 percent in 2015 to 84 percent in 2017. However, the commercial
value of this unlicensed software increased to $236 million in 2015 and $226 million in 2017. This rate is very high in the Asia-Pacific region compared to other countries. The pirated software industry is threatening the legitimate software industry as its commercial value will decrease in the global and domestic markets.

The biggest threat to the expanding IT sector of Bangladesh can be attributed to rivals in the sector like India, Vietnam, and Malaysia. Bangladesh faces a severe threat from the Indian IT industry. The Indian IT sector has experienced consistent growth since 2001 and accounted for 19.2 percent of all global IT spending in 2021 (Sun, 2021). The industry is expected to grow to $350 billion by 2025 (IBEF, 2019). On the other hand, the growth of the IT sector in Vietnam and Malaysia is impressive. As a result, the development of Bangladesh’s IT industry is threatened by IT giants like India and the quickly expanding IT sector in Vietnam and Malaysia.

Another name for the threat to Bangladesh’s IT-ITES is “cyber security.” Bangladesh has a relatively high rate of cyber vulnerability. Every year, it costs millions of dollars in damage to a number of IT and telecommunications-related industries. Cyber-attacks are destroying the computing industry and a nation’s economy. The frequency of cyber-attacks increases along with the number of internet users. The largest bank heist in the history of cyber-attacks, totaling $81 million, occurred at Bangladesh Central Bank in 2016 (Kitten, 2016). According to Kaspersky (2019), Bangladesh held the top spot from 2018 to 2019, with a rate of 13.78 percent of attacks by encryptors in Asia. A recent attack in Bangladesh in 2021 destroyed 147 branches of banks and non-banking financial institutions (Rahman, 2021). The government of Bangladesh has taken the initiative to build 25 IT and software parks across the nation to overcome this industry’s constraints. The government has pledged to exempt corporations from all taxes up until the year 2024 and to exempt rentals and utilities in this industry from taxes by 80 percent (Karthik et al., 2017). Additionally, Bangladesh is moving toward the fifth generation of internet service, which is anticipated to be available nationwide by 2026.

**Literature Review**

The literature on the efficiency of the IT sector is discussed in this section, both theoretically and empirically. The theoretical literature focuses on various dimensions of technical efficiency and how they affect the IT sector. The empirical literature reviews several prior studies that examined the IT sector’s technical, pure technical, and scale efficiency and the methodologies employed.

**Theoretical Background**

In recent years, efficiency measurements of various firms and industries have dramatically increased. This is due to the fact that maintaining competitiveness in a global business environment necessitates efficiency evaluations (Alam et al., 2020). Business organizations are constantly looking for cost-effective ways to produce high-quality goods and provide high-quality services to gain a competitive advantage over rivals. Increasing efficiency is the most effective way to achieve cost-effectiveness. Efficiency refers to achieving the maximum level of performance by using a minimum level of inputs (Banton, 2020). According to Coelli, Rao, O’Donnell, and Battese (1998), efficiency is the ability of a company to generate a higher amount of output from a given set of input levels under certain conditions. Färe, Grosskopf, Lindgren, and Roos (1992) refer to it as a DMU’s or a firm’s ability to attain its behavioral goal. However, the concept of efficiency takes into account not only the quantities of inputs and outputs but also the abilities and behavior of DMUs in converting inputs to outputs (Şişman, 2017).

Different dimensions can define the efficiency concept. The most common efficiency concept is technical efficiency, introduced by Koopmans (1952), which was later expanded to define what is now known as Pareto-Koopmans Efficiency (Cooper, Seiford, & Tone, 2006):

“The performance of a DMU is efficient if and only if it is not possible to improve any input or output without worsening any other input or output.”

That is, the effectiveness with which a particular set of inputs are utilized to generate a particular set of outputs is known as technical efficiency (Pettinger, 2020). According to Ben-Bellahsen and Womack (2002), the production of a given level of output from a minimal level of inputs, or the creation of maximal output from any given set of inputs, is referred to as technical efficiency. It is critical to assess a firm’s technical efficiency to determine how well it works toward its ultimate goals. When a company is deemed to be technically efficient, it means it is on the production frontier. This indicates that a company effectively utilizes its resources to get the intended result. A firm may be technically efficient for pure technical efficiency and for scale efficiency (Huguenin, 2012). Pure technical efficiency is linked to management performance and techniques (Taib, Ashraf, & Razimi, 2018; Jia & Yuan, 2018). It assesses how far a firm can reduce its inputs (in a fixed proportion) while remaining within the variable return to scale (VRS) frontier (Iqbal & Awan, 2015). Scale efficiency, on the other hand, refers to the relationship between the output level and average cost; thus, it is related to the size of an organization’s operation (Abel & Bara, 2017). It is a parameter that indicates a firm’s operation at an optimum scale size (Huguenin, 2012). It measures how far a firm projected to reach the VRS efficiency
frontier can reduce its inputs (in fixed proportions) while remaining within the constant return to scale frontier. Thus, scale efficiency measures the extent to which a firm can reduce inputs by shifting to a part of the frontier with higher returns to scale (Iqbal & Awan, 2015).

Technical efficiency can also be input-oriented or output-oriented. The input-oriented method of measuring technical efficiency calculates how many fewer resources a firm could use while still producing the same output (Forbes, Harslett, Mastoris, & Risse, 2010; Şişman, 2017). Efficiency in this context can be defined as a firm’s resource intensity compared to best practices. This approach is suitable for firms that can change their input usage but have limited output flexibility. For firms with budget limits, this is more likely to be the case (Forbes et al., 2010).

In contrast, the output-oriented technical efficiency measure shows how much output can be increased proportionally without altering input levels (Vincent & Charles, 2012). This definition of efficiency defines a firm’s productivity to best practices. Firms that can change their output level should use this model orientation (Forbes et al., 2010). Indeed, the orientation of output and input determines the point on the efficient frontier to use as a benchmark (Abel & Bara, 2017).

Empirical Review

There has been little research into determining the technical efficiency of the IT sector. Thus, this review section was conducted based on the limited literature. Chen, Wang, Wu, and Zhang (2011) measured the efficiency of 73 Chinese IT companies from 2005–2007 using the DEA-based Malmquist productivity index. This study measured managerial efficiency, technical efficiency, and scale efficiency. According to the findings, the Chinese IT industry has neither technical nor managerial efficiency, requiring 6.8 percent and 5.1 percent improvement in efficiency, respectively, and only four and six companies obtained technical and managerial efficiency separately. Furthermore, scale efficiency was measured, which still requires an improvement of 1.8 percent to achieve overall efficiency. The study found that only seven companies had achieved scale efficiency. Using the same model, Sahoo and Nauriyal (2014) measured the overall technical efficiency, pure technical efficiency, and scale efficiency of 72 software firms in India from 1999–2008.

The study revealed that software firms wasted 35 percent of their inputs on average, given their low overall technical efficiency. It was further revealed that, during the study period, the number of companies operating on the most productive scale size decreased. The results also found that Indian-owned companies were more efficient than foreign-owned and group-owned companies. Chiang, Cheng, and Leu (2017) conducted a study to measure the performance and technical efficiency of the top 250 companies in the ICT industry in the world, as well as companies with significant contributions to the ICT industry in Taiwan, for a total of 16 objects. The study applied the DEA and Malmquist productivity indexes to understand the efficiency problems of each firm. The study documented a mixed result. For example, among Taiwan’s ICT sector companies, only 3 can grow continuously to achieve maximum benefits, while 6 have stable efficiency and 6 have declining efficiency and rising costs. Employing the financial ratio-based DEA model, Siew, Fai, and Hoe (2012) provided evidence that 44 percent of 18 technology-based firms listed on the Malaysian Stock Exchange are efficient.

Shinkai and Hossain (2011) analyzed the productivity and performance of the IT sector in Bangladesh based on a survey of 202 listed and non-listed firms of various sizes for the period 2004–2008. The study employed various financial ratios to measure performance and productivity. Results showed high productivity in export-oriented IT firms, while e-governance investments contributed to helping older IT firms achieve greater productivity.

Research Methodology

Sample Selection and Sources of Data

Ten of eleven IT companies listed on the Dhaka Stock Exchange (DSE) were included in this study (Table 1). One company, namely eGeneration Ltd. (EGEN), was excluded from the study due to the unavailability of data. The technical efficiency of IT companies was measured using panel data for the period 2016–2020. However, two companies were listed on the DSE in 2019, and one company was listed in 2017. Accordingly, the study employed panel data for the period 2019–2020 for two companies and 2017–2020 for one company. All the necessary data were collected from the sample companies’ annual reports for the respective years. If any required data was not available in the annual reports of the companies, it was collected from the websites of the DSE and the companies.
Table 1: List of Sample IT Companies

<table>
<thead>
<tr>
<th>Companies</th>
<th>Listing Year</th>
<th>Total Assets as on 31st December 2020 (BDT in million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aamra Networks Ltd.</td>
<td>2017</td>
<td>2509.91</td>
</tr>
<tr>
<td>Aamra Technologies Ltd.</td>
<td>2012</td>
<td>2578.39</td>
</tr>
<tr>
<td>AND Telecom Ltd.</td>
<td>2019</td>
<td>2233.63</td>
</tr>
<tr>
<td>Agni System Ltd.</td>
<td>2003</td>
<td>1152.15</td>
</tr>
<tr>
<td>BDCOM Online Ltd.</td>
<td>2002</td>
<td>1121.99</td>
</tr>
<tr>
<td>Daffodil Computers Ltd.</td>
<td>2006</td>
<td>840.48</td>
</tr>
<tr>
<td>Genex Infosys Ltd.</td>
<td>2019</td>
<td>2398.66</td>
</tr>
<tr>
<td>Information Services Ltd.</td>
<td>2002</td>
<td>209.72</td>
</tr>
<tr>
<td>Intech Ltd.</td>
<td>2002</td>
<td>391.78</td>
</tr>
<tr>
<td>IT Consultants Ltd.</td>
<td>2016</td>
<td>2742.24</td>
</tr>
</tbody>
</table>

Source: Annual Reports (2016–2020) of 10 listed IT companies.

Variables and Measurements

This study measures the efficiency of the listed IT companies in Bangladesh. Typically, efficiency is concerned with the resources or inputs required to generate output for a specific task. Following the study of Malhotra and Dhanda (2020), it took two inputs and three outputs to measure the efficiency of IT companies in Bangladesh. Inputs are capital expenditures and fixed assets, while outputs are: return on equity, return on assets, and total income. The inputs and outputs were chosen based on prior studies. All the variables are defined and operationalized in Table 2.

Table 2: Variable Definition and Measurements

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measurement units</th>
<th>Definition and measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input variables</td>
<td>Capital expenditures (CAPEX)</td>
<td>Money spent by a business on purchasing fixed assets or increasing the value of an existing fixed asset with a useful life that extends beyond the taxable year (McConnell &amp; Muscarella, 1985). The current period property, plant, and equipment (PP&amp;E) on the balance sheet are equal to the prior period PP&amp;E plus capital expenditures less depreciation.</td>
</tr>
<tr>
<td></td>
<td>Fixed assets (FA)</td>
<td>Long-term tangible assets used in a business’s operations to generate revenue (Malaescu, 2015). It is determined by adding up the purchase price of all fixed assets and any additional improvements, then taking away any depreciation that has accrued.</td>
</tr>
<tr>
<td>Output variables</td>
<td>Return on equity (ROE)</td>
<td>Net income (after preferred stock, but before ordinary stock dividends) of a firm divided by its total equity at the end of its financial year (Hossain, 2020).</td>
</tr>
<tr>
<td></td>
<td>Return on asset (ROA)</td>
<td>The ratio of a company’s profitability to its total assets (Jewell &amp; Mankin, 2011).</td>
</tr>
<tr>
<td></td>
<td>Total income (TI)</td>
<td>The total income is the revenue earned from selling goods or services related to the company’s primary operations (White, 2021).</td>
</tr>
</tbody>
</table>

Model Specification

Decision-Making Units (DMUs), or the number of firms or entities that reach maximum efficiency (100 percent) when no one of their inputs or outputs can be improved without reducing some of their other inputs or outputs (Cooper, Seiford, & Zhu, 2011). When there is a single input and output, the most commonly used measure of the efficiency of a DMU is

\[
\text{Efficiency} = \frac{\text{Output}}{\text{Input}}
\]

However, measuring the overall efficiency of a DMU when there are multiple inputs and outputs is difficult. Two basic approaches are mostly used for measuring efficiency if there are multiple inputs and outputs, such as the parametric and non-parametric approaches. Both approaches compute the relative efficiency of a set of similar units, commonly known as DMUs, to determine the best practice frontier (Iqbal & Awan, 2015). The functional relationships between variables like cost, profit, and output among inputs, outputs, and other factors can be found using parametric approaches (Taib et al., 2018). In addition to being consistent with
the functional form of the production process, which Cummins and VanDerhei (1979) defined as “consistent with the organization of production at the firm,” this implicitly takes the identification of the production process into account. These approaches, however, make various assumptions about the distribution’s nature and the error or stochastic term. The most widely used parametric approach techniques are the Stochastic Frontier Approach (SFA), Data Frontier Analysis (DFA), and the Thick Frontier Approach (TFA).

In contrast, non-parametric approaches are used to measure the relative technical efficiencies of DMUs (Charnes, Cooper, & Rhodes, 1978). The Data Envelopment Approach (DEA), developed by Charnes et al. (1978), is mainly used under the non-parametric approach (Taib et al., 2018). It is also called frontier analysis. A collection of observed units is utilized to create a best practice group, and the units that are inefficient compared to the best practice group are identified using DEA (Chen et al., 2011). The DMUs use several inputs to make several outputs, and the costs of the inputs and prices of the products are considered unknown (Wang, Gopal, & Zionts, 1997). In the case of multiple inputs and outputs, DEA estimates a set of weights that places each DMU in the most advantageous position in relation to other DMUs. This method reduced the multiple-input, multiple-output model to a ratio with a single “virtual” input and a single “virtual” output. Moreover, this approach requires no functional form to measure relative technical efficiencies. However, it is not stochastic, i.e., it does not require error terms to be specified, and DMUs that do not lie on efficiency frontiers are considered inefficient (Iqbal & Awan, 2015). This study employed the DEA model to measure the technical efficiency of the listed IT companies in Bangladesh, as there are two input and three output variables. Following the study of Abel and Bara (2017), the model for measuring technical efficiency is shown in equation 1.

\[ \theta^* = \min \theta \]

Subject to
\[ \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io} \quad i = 1, 2, ..., m \]
\[ \sum_{j=1}^{n} \lambda_j y_{ij} \leq y_{io} \quad i = 1, 2, ..., m \]
\[ \sum_{j=1}^{n} \lambda_j = 1 \]
\[ \lambda_j \geq 0 \]

The model is being examined by n DMUs. The \( i^{th} \) input and the \( r^{th} \) output of the DMUo are represented by x and y, respectively. \( \lambda \) are unidentified weights, and the number of DMUs is represented by \( j = 1, 2, ..., m \). The ideal value of \( \theta^* \) displays how far away from the efficient frontiers the firms are. Thus, the most technically efficient firm will have \( \theta^* = 1 \), while the least technically efficient firm will have \( \theta^* < 1 \). Technical efficiency can be defined by two orientations in DEA. The first is input-oriented, which seeks to reduce inputs in order to achieve the desired output, while the second is output-oriented, which seeks to increase output for a given set of inputs. This study used the input-oriented approach to measure technical efficiency. Two inputs, such as total fixed assets (FA) and capital expenditure (CAPEX), and three outputs, such as return on equity (ROE), return on assets (ROA), and income (TI), were considered for measuring IT firms’ efficiency in this study. The empirical model for this study is

\[ \theta^* = 0 \]

Subject to
\[ \lambda_i FA_i + \lambda_i CAPEX_i \leq \theta x_{io} \quad i = 1, 2, ..., 3 \]
\[ ROE_i + \lambda_i ROA_i + \lambda_i TI \leq y_{io} \quad i = 1, 2, ..., m \]
\[ \sum_{i=1}^{n} \lambda_i = 1 \]
\[ \lambda_i \geq 0 \]

Where FA is total fixed assets, CAPEX is capital expenditure, ROE is the return on equity, ROA is the return on assets, and TI is total income. A value of \( \lambda=1.0 \) denotes an efficient DMU, while a value of \( \lambda < 1.0 \) denotes an inefficient DMU. A value of \( \lambda=0.80 \), for example, indicates that a company could reduce its inputs by 20 percent while producing the same output level. The basic model of the DEA approach is the CCR model, named after Charnes et al. (1978), which assumes constant returns to scale (CRS) between inputs and outputs in frontier analysis. This model is commonly known as the CRS-DEA model. Later, Banker, Charnes, and Cooper (1984) introduced the BCC-DEA model, commonly known as the VRS-DEA model, to estimate ‘pure’ technical efficiency under the assumption of variable returns to scale (VRS). The DEA calculates the overall technical efficiency (OTE), which assists in identifying inefficiencies brought on by both pure technical inefficiency and scale inefficiency (Alam et al., 2020). Therefore, technical efficiency (constant return on scale – CRS) is a product of pure technical efficiency (variable return to scale – VRS) and scale efficiency (SE) (Malhotra & Dhanda, 2020), which is as follows:

\[ TE_{CRS} = PTE_{VRS} \times SE \]
Where $TE_{CRS}$ refers to the technical efficiency (constant returns to scale), $PTE_{VRS}$ refers to the pure technical efficiency (variable returns to scale), and $SE$ denotes the scale efficiency. $TE$, $PTE$, and $SE$ were estimated based on outputs and inputs collected from the sample.

**Results and Discussion**

**Descriptive Statistics**

Table 3 presents the descriptive statistics for each input and output variable used in the study to measure the efficiency of listed IT companies in Bangladesh. Starting with the input variables, the overall average FA was BDT 0.65 billion, and the median was BDT 0.59 billion for the sample companies during the study period, with a standard deviation of 0.43. For all sample companies, the combined average CAPEX was BDT 0.07 billion, with a median of 0.02 and a standard deviation of 0.08. Regarding the output variables, the overall average ROE was 9.72 percent, and the median was 9.32 percent for the sample companies during the study period, with a standard deviation of 7.34. For all sample companies, the overall mean ROA was 9.43 percent, with a median of 7.16 percent and a standard deviation of 11.54. During the study period, the sample companies had an overall mean and median TI of BDT 0.65 billion and BDT 0.62 billion, respectively, with a standard deviation of 0.41.

**Table 3: Descriptive Statistics**

<table>
<thead>
<tr>
<th>Year</th>
<th>Measures</th>
<th>Inputs</th>
<th>Outputs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FA (BDT in billion)</td>
<td>CAPEX (BDT in billion)</td>
<td>ROE (percent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in</td>
<td></td>
<td>ROA (percent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TI (BDT in billion)</td>
</tr>
<tr>
<td>2016</td>
<td>Mean (percent)</td>
<td>0.53</td>
<td>0.07</td>
<td>9.82</td>
</tr>
<tr>
<td></td>
<td>Median (percent)</td>
<td>0.61</td>
<td>0.04</td>
<td>9.96</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.30</td>
<td>0.07</td>
<td>6.75</td>
</tr>
<tr>
<td>2017</td>
<td>Mean (percent)</td>
<td>0.60</td>
<td>0.04</td>
<td>9.60</td>
</tr>
<tr>
<td></td>
<td>Median (percent)</td>
<td>0.61</td>
<td>0.03</td>
<td>9.60</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.41</td>
<td>0.03</td>
<td>6.16</td>
</tr>
<tr>
<td>2018</td>
<td>Mean (percent)</td>
<td>0.65</td>
<td>0.07</td>
<td>10.13</td>
</tr>
<tr>
<td></td>
<td>Median (percent)</td>
<td>0.60</td>
<td>0.04</td>
<td>10.98</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.45</td>
<td>0.08</td>
<td>3.73</td>
</tr>
<tr>
<td>2019</td>
<td>Mean (percent)</td>
<td>0.69</td>
<td>0.07</td>
<td>9.54</td>
</tr>
<tr>
<td></td>
<td>Median (percent)</td>
<td>0.59</td>
<td>0.02</td>
<td>10.13</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.46</td>
<td>0.08</td>
<td>5.58</td>
</tr>
<tr>
<td>2020</td>
<td>Mean (percent)</td>
<td>0.77</td>
<td>0.06</td>
<td>7.23</td>
</tr>
<tr>
<td></td>
<td>Median (percent)</td>
<td>0.54</td>
<td>0.03</td>
<td>6.86</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.55</td>
<td>0.08</td>
<td>5.71</td>
</tr>
<tr>
<td>2016–2020</td>
<td>Overall Mean (percent)</td>
<td>0.65</td>
<td>0.07</td>
<td>9.72</td>
</tr>
<tr>
<td></td>
<td>Overall median (percent)</td>
<td>0.59</td>
<td>0.02</td>
<td>9.32</td>
</tr>
<tr>
<td></td>
<td>Overall Standard Deviation</td>
<td>0.43</td>
<td>0.08</td>
<td>7.34</td>
</tr>
</tbody>
</table>

Notes: FA is fixed assets, CAPEX is capital expenditure, ROE is the return on equity, ROA is the return on assets, and TI is total income.

Source: Authors’ calculation

**Results of Data Envelopment Analysis (DEA)**

Table 4 presents DEA estimations for the average annual technical efficiency ($TE_{CRS}$) and its decomposition into pure technical ($PTE_{VRS}$) and scale efficiency ($SE$) of listed IT companies in Bangladesh for the period 2016–2020. The results demonstrate that Bangladeshi-listed IT companies were technically efficient, with an average efficiency score of 56.6 percent during the period 2016–2020. The study also reveals that the average pure technical efficiency score for the period was 60.5 percent. The scores fell from 2016 to 2018, then rose slightly from 2019 to 2020. The results show that the average scale efficiency of IT companies in Bangladesh for the study period was 74.8 percent. The scores were not stable, as evidenced by an increase in 2017 followed by a gradual decrease from 2017.
Table 4: DEA Estimations – Input Oriented Technical Efficiency

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TE\text{CRS} (\lambda)</td>
<td>PTE\text{VRS}</td>
<td>SE</td>
<td>TE\text{CRS} (\lambda)</td>
<td>PTE\text{VRS}</td>
</tr>
<tr>
<td>Aamra Networks Ltd.</td>
<td>0.656</td>
<td>1.000</td>
<td>0.656</td>
<td>0.481</td>
<td>1.000</td>
</tr>
<tr>
<td>Aamra Technologies Ltd.</td>
<td>0.128</td>
<td>0.483</td>
<td>0.265</td>
<td>0.381</td>
<td>1.000</td>
</tr>
<tr>
<td>AND Telecom Ltd.</td>
<td>0.497</td>
<td>1.000</td>
<td>0.497</td>
<td>0.430</td>
<td>0.754</td>
</tr>
<tr>
<td>Agni System Ltd.</td>
<td>0.725</td>
<td>0.867</td>
<td>0.836</td>
<td>0.729</td>
<td>0.810</td>
</tr>
<tr>
<td>BDCOM Online Ltd.</td>
<td>0.313</td>
<td>0.416</td>
<td>0.754</td>
<td>0.303</td>
<td>0.467</td>
</tr>
<tr>
<td>Daffodil Computers Ltd.</td>
<td>0.619</td>
<td>0.668</td>
<td>0.927</td>
<td>0.624</td>
<td>0.643</td>
</tr>
<tr>
<td>Genex Infosys Ltd.</td>
<td>0.775</td>
<td>1.000</td>
<td>0.775</td>
<td>0.765</td>
<td>1.000</td>
</tr>
<tr>
<td>Information Services Ltd.</td>
<td>0.440</td>
<td>0.445</td>
<td>0.988</td>
<td>0.450</td>
<td>0.458</td>
</tr>
<tr>
<td>Intech Ltd.</td>
<td>0.969</td>
<td>0.982</td>
<td>0.987</td>
<td>0.519</td>
<td>0.621</td>
</tr>
<tr>
<td>IT Consultants Ltd.</td>
<td>0.414</td>
<td>0.998</td>
<td>0.415</td>
<td>0.540</td>
<td>0.770</td>
</tr>
<tr>
<td>Mean of individual year</td>
<td>0.554</td>
<td>0.786</td>
<td>0.710</td>
<td>0.522</td>
<td>0.752</td>
</tr>
<tr>
<td>Mean (2016–2020)</td>
<td>TE\text{CRS} (\lambda) = 0.566, PTE\text{VRS} = 0.605, SE = 0.748</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: TE\text{CRS} is the overall technical efficiency, PTE\text{VRS} is the pure technical efficiency, and SE is the scale efficiency.

Source: Authors’ calculation
Company and year-wise results show that the TE_{CRS} estimation of the Information Services company is 1 (λ=1.00) in 2016. However, the TE_{CRS} estimations of all other companies are less than 1 (λ<1.00) along with the estimations of PTE_{VRS} and SE, except for Aamra Networks Ltd. and Agni System Ltd., whose PTE_{VRS} estimation is equal to 1. These results indicate that only Information Services Ltd. had technical efficiency in 2016. In the same year, both Aamra Networks Ltd. and Agni System Ltd. had no technical efficiency because of their scale inefficiencies. On the other hand, all other companies were technically inefficient in 2016 due to pure technical inefficiency and scale inefficiency. Table 4 shows a nearly identical result in 2017 to that of 2016. Only one company, Intech Ltd., was technically efficient (TE_{CRS} (λ=1.00) in 2017. Genex Infosys Ltd. was pure technical efficient (PTE_{VRS}) in the same year but lacked scale efficiency, making it technically inefficient. In contrast, all the other companies suffered from pure technical inefficiency and scale inefficiency, which led to their being technically inefficient (λ<1.00) in 2017.

The results for 2018 show that all companies’ TE_{CRS} estimations are below 1 (λ<1.00), and their PTE_{VRS} and SE estimations are also below 1, except for Aamra Networks Ltd. and Genex Infosys Ltd., whose PTE_{VRS} estimations are equal to 1. These findings indicate that, except for Aamra Networks Ltd. and Genex Infosys Ltd., all the companies in the study suffered from technical inefficiencies in 2018 due to a lack of pure technical efficiency and scale efficiency. Scale inefficiency was the only cause of technical inefficiency at Aamra Networks Ltd. and Genex Infosys Ltd. for the year. According to the findings for 2019 and 2020, all companies have TE_{CRS} estimations below 1 (λ<1.00), and the estimations of PTE_{VRS} and SE are below 1, except for Aamra Networks Ltd., AND Telecom Ltd., and Genex Infosys Ltd., whose PTE_{VRS} estimations are equal to 1. These findings imply that, except for Aamra Networks Ltd., AND Telecom Ltd., and Genex Infosys Ltd., all companies included in the sample experienced technical inefficiency in 2019 and 2020 as a result of a lack of both pure technical efficiency and scale efficiency. The technical inefficiency of Aamra Networks Ltd., AND Telecom Ltd., and Genex Infosys Ltd. was accounted for only by scale inefficiency for the year.

### Table 5: Efficient Companies in Sample

<table>
<thead>
<tr>
<th>Year</th>
<th>Total No. of DMUs</th>
<th>No. of Efficient Companies (TE_{CRS})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>2016</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: This table summarizes the total number of companies that were found to be technically efficient based on the DEA.

**Source:** Authors’ calculation

The results reported in Table 4 show that IT companies were technically efficient, with an average efficiency score of 61.8 percent in 2016, 60 percent in 2017, 53.7 percent in 2018, 52.2 percent in 2019, and 55.4 percent in 2020. What can be seen is the continual decline in technical efficiency of the listed Bangladeshi IT companies during the period 2016–2017 and a slight improvement in 2020. This result implies that the IT companies suffered an average minimum of 38.2 percent and a maximum of 47.8 percent in technical inefficiency during the study period. In other words, it was possible to produce the same level of output with a minimum of 38.2 percent and a maximum 47.8 percent reduction in the input of IT companies. Even if the IT companies had operated at the same efficiency level as the most efficient IT company in the sample, there would have been more opportunities for them to increase their output. Finally, Table 5 shows that only one company was technically efficient in 2016 and 2017 and that no companies experienced technical efficiency throughout the study period.

### Discussion

The technical efficiency of the listed Bangladeshi IT companies was estimated using the Data Envelopment Analysis approach. To better understand the causes of efficiency and inefficiency, technical efficiency was broken down into pure technical efficiency and scale efficiency. The study found that Bangladeshi-listed IT companies were not adequately technically efficient, with an average efficiency score of 56.6 percent, requiring a 43.6 percent improvement in efficiency during the period 2016–2020. In other words, the sample companies could have cut their inputs by 43.6 percent on average while producing the same output level. As for pure technical efficiency, the findings also imply that the managerial efficiency of IT companies declined during the first three years of the study period before beginning to improve in 2019. A few companies’ average pure technical efficiency score during the study period was one, meaning those IT firms attained 100 percent pure technical efficiency while others did not. This result suggests that only a few IT companies in Bangladesh utilized their resources efficiently in exogenous environments, while the majority of them failed to show managerial efficiency in managing their resources efficiently.

To sum up, the listed IT companies are not technically efficient, i.e., they are not making the best use of their resources to achieve their goals. On average, IT companies in Bangladesh perform better in scale efficiency than in purely technical efficiency. That is, pure technical inefficiency is the most common source of technical inefficiency, followed by scale inefficiency. The findings infer that the listed IT companies are primarily experiencing issues related to management performance and techniques, followed by issues related to operating at the incorrect scale of operations. The findings are consistent with Chen et al. (2011) and Sahoo and Nauriyal (2014).
Conclusions
This study measures the technical efficiency of the listed Bangladeshi IT companies for the period 2016–2020. The technical efficiency of the sample firms was determined using an input-oriented Data Envelopment Analysis model. To measure technical efficiency, this study used two inputs, such as fixed assets and capital expenditure, and three outputs, such as ROE, ROA, and total income.

Data Envelopment Analysis results documented that the listed IT companies were not adequately technically efficient, i.e., they were not making the best use of their resources to achieve their goals during the study period. A continual decline in the technical efficiency of the companies during the period 2016–2017 was observed, with a marginal improvement in 2020. It was possible for the listed IT companies, in particular, to produce the same level of output by reducing 43.6 percent of their input. Pure technical inefficiency is the most common source of technical inefficiency, followed by scale inefficiency.

The findings of the study are expected to provide important and useful information to the Bangladesh Association of Software and Information Services (BASIS), the Bangladesh Computer Council (BCC), and the ICT Division of the Bangladesh government in taking the necessary steps in light of the state of the IT sector to help the government achieve its vision of a “Digital Bangladesh.” Moreover, the sample companies could benefit from this study by addressing inefficiencies, increasing shareholder investments, maximizing corporate wealth, and boosting customer satisfaction.

The study is not free from limitations. The main limitations were its small sample size and short time frame. This study only included IT companies listed on the Dhaka Stock Exchange, leaving out those listed on the Chattogram Stock Exchange. Furthermore, rather than using parametric approaches to measure efficiency, the study used non-parametric approaches. Therefore, future studies could include all companies listed on both stock exchanges for an extended period of time and simultaneously employ both parametric and non-parametric approaches.

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Author Contributions: Conceptualization, Methodology, Data Collection, Formal Analysis, Writing—Original Draft Preparation, Writing—Review And Editing by authors with equal participation. All authors have read and agreed to the published the final version of the manuscript.

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to that the research does not deal with vulnerable groups or sensitive issues.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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,Revenue%20is%20the%20total%20amount%20of%20income%20generated%20by%20the,not%20interchangeable

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