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Evaluation of Information Technology Impact on State-owned Commercial Banks' Efficiency: The Case of Bangladesh*

Shakera BEGUM[1], Md. Azizul BATEN[2], Rahmat ALI[3]

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Abstract

Purpose: This study measures the effect of Information Technology (IT) on both cost and profit efficiency of State-owned Commercial Banks (SOCBs) in Bangladesh. **Research design, data and methodology:** Yearly Non-IT and IT data are collected from the annual report of SOCBs of Bangladesh from 2008 to 2017. Variable Return to Scale (VRS) cost Data Envelopment Analysis (DEA) and Profit DEA are employed to measure the efficiency of SOCBs and Ordinary Least Square (OLS) is used to investigate the impacts of ICT components on operating cost and profit efficiency for SOCBs. **Results:** The average cost efficiency (74.4%) was noticed higher than the average profit efficiency (20.6%) for SOCBs. SOCBs were more affordable and less profitable for both cost and profit efficiency. Rupali bank was the most cost efficient while Sonali bank was the most profit efficient. IT Investment and IT personnel expenses were positively significant for cost efficiency. IT income, IT personnel, IT personnel expenses, ATM expenses, and Credit card expenses were negatively significant for profit efficiency. **Conclusion:** The further studies can combine DEA with machine learning algorithms to study the impact of IT on banks' performances. The results could aid government to remove the hindrance of progress in Bangladesh.

Keywords: IT Efficiency in Bangladesh, Cost & Profit DEA, SOCBs

JEL Classification Code: H21, M15, C61, G21

1. Introduction

Organizations such as banks operate Information Technology (IT) to ameliorate their competitive advantage (Appiahene, Ussiph, & Missah, 2018). The impact of IT on performance has been studied within firms, industries, and individual information systems (e.g., Bakos & Kemerer, 1992; Kauffman & Weill, 1989). According to (Chen, Liang, Yang, & Zhu, 2006), IT firms has created most business transaction and assessed its impact on firm's performance. Many studies pointed that there was an assortment of problems in evaluating the impact of IT on firm performance. The productivity paradox i.e., a positive relationship between IT investment and firm performance by the researchers (Brynjolfsson & Hitt, 1996, 1998; Brynjolfsson, Erik, & Hitt, 2000); and Carr (2003) postulate that IT provides no significant competitive advantage. Conversely, Dewan and Kraemer (2000), and Brynjolfsson et al. (2002) acknowledge that the IT strategic business effort is dependent upon the factors such as the type of IT being deployed, infrastructural, customer service, etc.

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1 Department of Statistics, Sylhet Commerce College, Sylhet, Bangladesh, Email: shakerabgm@gmail.com
2 Corresponding Author, Department of Statistics, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh, Email: baten-sta@sust.edu
3 Department of Statistics, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh, Email: ralistat@sust.edu

Researchers have begun to use Data Envelopment Analysis (DEA) as an alternative approach to measure the IT impact on firm performance, because DEA does not need a priori assumption on the functional form characterizing the relationships between IT investment and firm performance measures (Zhu, 2002). The researchers applied DEA technology to measure the impact of IT and found positive impact on firms' performance (e.g., Chen, Liang, Yang, & Zhu, 2006; Madjid, Mohammad, & Mohsen, 2009; Cao & Yang, 2013). Dash, Yang, and Liang (2006) integrated DEA and neural networks (NNs) to analyze the relative branch efficiency of a big Canadian bank and compared with the normal DEA results. Banking efficiency evaluation has been conducted along with IT investment (for example, Chen, Liang, Yang, & Zhu, 2006; Madjid, Mohammad, & Mohsen, 2009). Other researchers applied DEA approach in the measurement of efficiency within the banking sector and reported positively about the use of DEA as an efficient method of deciding the efficiency and performance of banks (for example, Halkos & Salamouris, 2004; Dalgleish, Williams, & Golden, 2007; Ascarya, Yumanita, Achsani, & Rokhimah, 2008; Nii, Aboagye, & Gemegah, 2012; Sarifuddin, Ismail, & Kumaran, 2015; Nand & Archana, 2015; Adusei, 2016; Aggelopoulos & Georgopoulos, 2017).

Application of DEA technology in measuring efficiency of banks in Bangladesh are available (for example, Khanam & Nghiem, 2003; Yasmeen, 2011; Hoque & Rayhan, 2012; Hossian, Sobhan, & Sultana, 2016; Islam & Kassim, 2015; Islam, Sabur, & Khan, 2017). There is a fair number of researches that studied cost, revenue and profit bank efficiency (for example, Vander, 2002; Isik & Hassan, 2002_b; Maudos & Pastor, 2003; Fries & Taci, 2005; Carvallo & Kasman, 2005; Bader, 2007; Ariff & Can, 2008; Bader, Mohamed, Ariff, & Hassan, 2008; Kristina, 2014; Gulati & Kumar, 2016; Tuškan & Stojanovi´c, 2016). Despite the significant importance of this area, documented studies that address the cost, and profit efficiency of State owned commercial banks along with IT investment are rare.

The goal of this study is to investigate the IT investment on State-owned Commercial Banks (SOCBs) in the context of both cost and profit efficiency in Bangladesh by Variable Return to Scale (VRS) cost DEA and profit DEA models. Examining the role of IT components on SOCBs with the efficiency of both cost and profit by using Ordinary Least Square (OLS) method is a concern. In addition, the year-wise and bank-wise cost and profit efficiency comparison are made for the SOCBs.

2. Literature Review

The DEA model initially developed by Charnes, Cooper and Rhodes (1978) was based on the assumption of Constant Return to Scale (CRS) and this model modified by Banker, Charnes, and Cooper (1984) was based on the assumption of Variable Return to Scale (VRS). In particular, (Maudos & Pastor, 2003; Färe et al., 2004), they established the cost efficiency model, the standard profit efficiency model, and the alternative profit efficiency model, respectively.

A lot of studies has been performed over the past decade in measuring efficiency of firm companies, banks and other decision making units. Noulas (2001) employed both DEA model and the traditional approach to examine the effect of banking deregulation on private and public owned banks. Sanjeev (2006) studied efficiency of private, public and foreign banks operating using DEA in India. DEA approach is very popular and has been applied widely in different areas of measuring efficiency of Indian banks by Pramodh et al. (2008). Savi´c, Radosavljevi´c, and Ilievski (2012) used the DEA window analysis technique to measure the profit efficiency and the operating efficiency of commercial banks in Serbia. To measure bank efficiency researchers (for example, Fethi & Pasiouras, 2010; Titko et al., 2014; Paradi & Zhu, 2013; Asmild & Zhu, 2016; Tuškan & Stojanovi´c, 2016; Cvetkoska & Savi´c, 2017) used different application of DEA. Chen, Matousek and Wanke (2017) examined Chinese bank efficiency with a combined approach using DEA and Support Vector Machines. Diallo (2018) analyzed the effect of bank efficiency on value-added growth of industries across countries using DEA. Violeta and Čiković (2021) measured the relative efficiency of commercial banks in two developing countries, the Republic of North Macedonia and the Republic of Croatia by using DEA.

Studies regarding the efficiency of banks in Bangladesh using the DEA approach are not very common. There are a few studies assessing the efficiency of banks with DEA (for example, Yasmeen, 2011; Hoque & Rayhan, 2012; Bhuia et al., 2012; Haque, 2013; Ahmed & Liza, 2013; Islam & Kassim, 2015; Hossain et al., 2016; Islam et al., 2017; Fatema et al., 2019; Azad et al., 2020). A few researchers conducted the efficiency analysis in cost and profit in Bangladesh (Uddin & Suzuki, 2011). With the exclusion of the study by Miller and Noulas (1996), profit efficiency is observed lower than cost efficiency. Violeta and Cikovi´c (2020) assessed the profit efficiency of commercial banks in North Macedonia using DEA technique window analysis. Besides, there are several studies available on the analysis of cost and / or profit efficiency of both Turkish and Spanish banking (Isik & Hassan, 2002a, 2002b; Maudos & Pastor, 2003); in U.S. banking (Berger & DeYoung, 2001; Clark & Siems, 2002; Berger & Mester, 2003; Färe, Grosskopf, & Weber, 2004); in European banking (Maudos et al., 2002; Vander-Vennet, 2002; Bos & Schmiedel, 2003; Weill, 2004); in Croatia

banking (Jemric & Vujcic, 2002); in Taiwan Banking (Chen, 2004); in Latin American and Caribbean Banking (Carvallo & Kasman, 2005); banks in Post Communists' Countries (Fries & Taci, 2005); in Malaysian banking (Bader, 2007); in OIC countries (Bader et al., 2008); in Latvian banking (Titko et al., 2014); in Slovak banking (Grmanova´ & Ivanova´, 2018); and in the banking sectors of developing countries (Bonin, Hasan, & Wachtel, 2005a; Sohrab & Suzuki, 2011).

DEA has been one of the most popular tools to assess the impact of IT on organizational efficiency and firm's performance, some of which have been discussed in this study. Banker et al. (1990) combined DEA and non-parametric production frontier to measure the productivity achievements from IT in complex managerial environment. Sigala (2003) conducted a study for measuring Information and Communication Technology (ICT) productivity impact with a DEA approach. Chen and Zhu (2004) used DEA model on banks and found a positive impact of IT on the bank's efficiency and performance. Chen et al. (2006), Cao and Yang (2011), and Madjid et al. (2009), they used DEA to evaluate the impact of IT on firms' performance and found a positive impact of IT on the firms' performance. Appiahene, Missah, & Najim (2019) evaluated IT impact on Ghanaian bank branches using a two-stage DEA model and found IT had significant impact on the banks' overall performance. Studies were conducted regarding the link between productivity and IT investments to explain the ineffectiveness of information technology in improving the performance of banks (Loveman, 1994; Oluwagbemi, Abah, & Achimugu, 2011). In addition, the works of Brynjolfsson and Hitt (1996, 1998), Prasad and Harker (1997), and Brynjolfsson, Erik and Hitt (2000) have found a positive relationship between IT investment and the productivity of a banking firm. A few researchers (Licht & Moch, 1999; Prasad & Harker, 1997) showed the effects of IT investments on profitability and concluded that there was no link between IT investments and bank profitability.

3. Research Methods and Materials

3.1. Data Description and the Variables

In this study the yearly data such as Non-IT and IT are used are described in *Table 1*.

Table-1: Definitions of the Variables for DEA (Outputs, Input Quantity, Output and Input Prices Variables) and IT Variables

Variables	Definition
Dependent Variables	
Operating cost	Total cost comprises the income salaried to investor, staffs expenditures, and other functioning expenditures.
Profit after tax	Total profit is subtracted of the entire cost from entire income.
Output Quantity	
Loan	The sum of long-term and short term loan, trade bills and reduced bills and other loans.
Off balance Sheet item	Off-balance Sheet Items measures the sum of guarantees, commitment and financial derivative instrument
Output Price	
Price of Loan	Price of Loan measures the net interest income or net interest expenditures divided by total loan
Price of off balance sheet items	Price of off balance sheet items is defined the ratio of total operating expenses and the total securities
Input quantity	
Total fund	Total Funds measures the sum of deposit and non-deposit funds at the end of the respective years
Fixed assets	Fixed assets measure the book, the value of premises and fixed capital.
Labor	The quantity of labor measures the number of bank staff members.
Input Price	
Price of Fund	Price of Fund is defined by the ratio of total interest expenditures toall deposits.
Price of Fixed Assets	Price of fixed assets measures the ratio of non-interest expenditures to fixed assets.
Price of Labor	Price of Labor calculates the ratio of personnel expenses to the numberof bank staffs.
IT Variables	

IT Expenses	The total IT refers to the expenses of the maintenance and repair, rent, depletion of IT equipment and information sourcing services.
IT Income	The total income from IT sector in Bank.
IT Investment	IT investment is total IT budget of the bank which included hardware, software, network, security training and other IT purpose
IT Personnel	The total no of IT staff member in the bank.
IT personnel Expenses	IT personnel expenses are designed as total salaries of IT staff expenses.
ATM Transaction	The total amount of deposit withdraw by ATM Card.
ATM Expenses	The conduct of Banking Service Charge by using ATM Card.
Credit Card Transaction	The total amount of deposit withdraw by Credit Card.
Credit Card Expenses	Credit card service charge is calculated price of credit card.

3.2 VRS Cost Minimization DEA Model Specification

The specification of VRS cost DEA model is followed by (Coelli, Rao, O´Donnell, & Battese, 2005) as follows:

$$\text{Min} \quad h_k = \sum_{i=1}^{m} w_{iq} x_{iq}^*$$

$$\text{st} \quad \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{iq}^* \qquad ; i = 1,2,\ldots\ldots\ldots\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \le y_{rq} \qquad ; r = 1,2,\ldots\ldots\ldots\ldots,s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0 \qquad ; j = 1,2,\ldots\ldots\ldots\ldots,n$$

where w_{iq} is a vector of input prices such as (Price of fund, Price of fixed assets and Price of labor) of j^{th} bank; x_{iq}^* is the vector of input quantities such as (Total fund, Fixed assets and labor) of j^{th} bank; y_r are the rth output such as (Loan, Off-balance sheet items) of j_{th} bank. The overall cost efficiency (CE_q) is defined as

$$CE_q = \frac{\sum_{i=1}^{m} w_{iq} x_{iq}^*}{\sum_{i=1}^{m} w_{iq} x_{iq}}$$

The cost efficiency is the product of technical and allocative efficiency and the value of cost efficiency is restricted by zero and one.

3.3 VRS Profit Maximization DEA Model Specification

The profit maximization DEA model is specified as follows:

$$Max \quad \sum_{r=1}^{s} p_{rq} y_{rq}^* - \sum_{i=1}^{m} w_{iq} x_{iq}^*$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rj}^* \qquad ; r = 1,2,\ldots\ldots\ldots\ldots,s$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{rj}^* \qquad ; i = 1,2,\ldots\ldots\ldots\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0 \qquad ; j = 1,2,\ldots\ldots\ldots\ldots,n$$

where p_r are the r_{th} output price (Price of Loan, Price of off-balance sheet items); y_r^* are the r_{th} output (Loan, Off-balance sheet items) of j_{th} bank; w_i are the i_{th} input price (Price of fund, Price of fixed assets and Price of labor) of j_{th} bank; x_i^* are the i_{th} input (Total fund, Fixed assets and labor) of j_{th} bank.

The profit efficiency (PE_q) is calculated by the ratio of observed profit to maximum profit for the Decision Making Unit $(DMU)_q$ (Coelli, Rao, O´Donnell, & Battese, 2005):

$$PE_q = \frac{\sum_{r=1}^{s} p_{rq} y_{rq} - \sum_{i=1}^{m} w_{iq} x_{iq}}{\sum_{r=1}^{s} p_{rq} y_{rq}^* - \sum_{i=1}^{m} w_{iq} x_{iq}^*}$$

The profit efficiency measure is not bounded by zero and one as well as it is negative if a profit is negative, or it is undefined if profit is zero (Coelli, Rao, O´Donnell, & Battese, 2005).

3.4 Empirical Specification of Ordinary Least Square Method

The specification of the Ordinary Least Square Method is defined as

$$E_{it} = \phi_0 + \phi_1 ITE_{it} + \phi_2 ITI_{it} + \phi_3 ITIN_{it} + \phi_4 ITP_{it} + \phi_5 ITPE_{it} + \phi_6 ATMT_{it} + \phi_7 ATME_{it} + \phi_8 CCT_{it} + \phi_9 CCE_{it} + \xi_{it}.$$

where E_{it} represents both the cost and profit efficiency scores estimated by VRS Cost DEA and profit DEA respectively for the i-th bank in period t; ITE_{it} is the IT expense of bank; ITI_{it} is the IT income of bank; $ITIN_{it}$ is the IT investment of bank; ITP_{it} is the IT personnel of bank; $ITPE_{it}$ is the IT personnel expenses of bank; $ATMT_{it}$ is the ATM transaction of bank; $ATME_{it}$ is the ATM expenses of bank; CCT is the Credit Card Transaction of bank; CCE is the Credit Card Expenses of bank. ξ_{it} is the error term.

4. Results and Discussion

4.1 Yearly Average Cost and Profit Efficiency of SOCBs with DEA

Both the efficiency of cost and profit for SOCBs using DEA are presented in *Figure 1*. The average cost efficiency (74.4%) was higher than profit efficiency (20.6%) score suggests that SOCBs were more affordable and less profitable. These results show that the banks were 74% cost efficient in the year of 2008 and 2009 then it increased slightly at 1% to 5% until 2013 after then it has been fallen and steady at 65% on the next year. Finally, it increased dramatically 91.8% in the last year. The profit efficiency scores were very low during the study period. In these years of 2010, 2014 and 2016, the profit efficiency score had 30% above and the SOCBs had 10% to 20% profit efficiency score for the rest of the years. These results are supported by (Mariani, David, & Giuliana, 2011; Ariff & Can, 2008; Kristina, 2014) who showed that SOCBs were the most cost efficient.

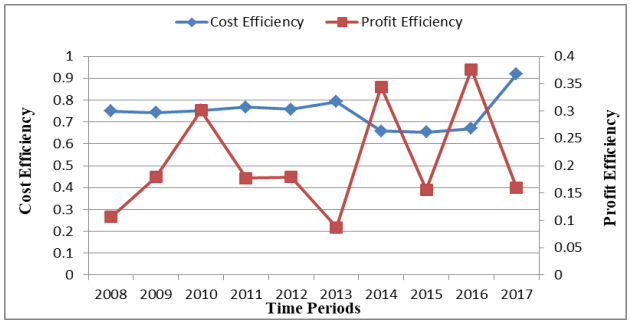

Figure 1: Yearly Average Cost and Profit Efficiency of SOCBS with DEA
Source: Author's calculation

4.2 Bank-wise VRS Cost Efficiency of SOCBs using DEA

The results of VRS cost efficiency of SOCBs are shown in *Table 2*. The average technical, allocative and cost efficiency scores were 81.4%, 91.8%, and 74.4% respectively. Rupali bank was the most cost efficient (91.7%) and the technical and allocative efficiency scores were 94.5% and 97% respectively which implies that Rupali bank can save 8.3% of their potential costs by using their inputs in optimal combination. Sonali bank was the less cost efficient with the score of 59% and the technical and allocative efficiency scores were 62.8%, and 93.3% respectively. These results are found similar with the work of Majid (2012) who measured the efficiency of Indian commercial banks by DEA.

Table 2: Bank-Wise VRS Cost Efficiency of SOCBS using DEA

Name of Banks	Cost DEA Model		
	Cost Efficiency	Technical Efficiency	Allocative Efficiency
Rupali	0.917	0.945	0.970
Sonali	0.590	0.628	0.933
Janata	0.724	0.860	0.852
Mean	0.744	0.811	0.918

Source: Author's calculation

4.3 Bank-wise VRS Cost and Profit Efficiency of SOCBs

Bank-wise cost and profit efficiency of SOCBs using DEA is presented in *Figure 2*. The bank-wise average cost and profit efficiency scores were recorded 74.5% and 20.6%. Rupali bank was the most cost efficient (91.6%) where

Sonali bank was the less cost efficient (59%). Conversely, Sonali bank was the most profit efficient bank (30.7%) and Rupali bank was recorded less profit efficient (14.9%). These results are supported by the study of Fiorentino, Karmann and Koetter (2006).

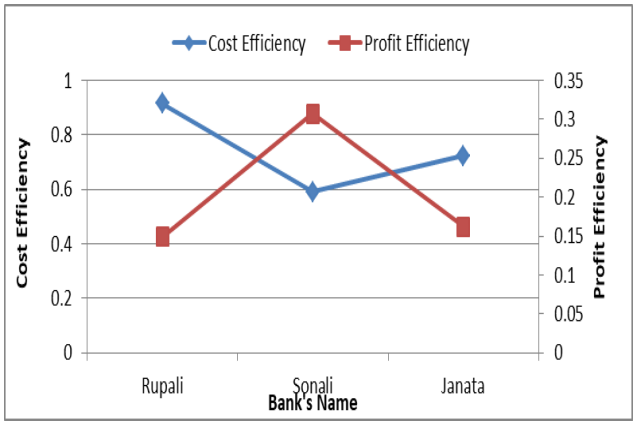

Figure 2: Yearly average cost and profit efficiency of SOCBS with DEA

4.4 IT Determinants on Cost DEA Efficiency for SOCBs by OLS Method

Table 3 represents the results of IT determinants on cost DEA efficiency of SOCBs during 2007-2018. The IT Investment ϕ_3 (0.00032) and IT personnel expanses ϕ_5 (0.00154) were positively significant for the cost efficiency of SOCBs. The ATM transaction ϕ_6 (-0.0012) was negatively significant and credit card expenses ϕ_9 (-0.002) was insignificant but had negative effect on the cost efficiency of SOCBs. This result is contradicted to the work of Syrine (2013) who assessed the impact of IT investments (hardware, software and IT services) on banks' cost efficiencies and suggested that "the Productivity Paradox" did not affect all IT investments.

Table 4 represents the results of IT determinant on profit DEA efficiency of SOCBs from 2007 to 2018. The IT income ϕ_2 (-0.0004), IT personnel ϕ_4 (-0.002), IT personnel expenses ϕ_5 (-0.0005), ATM expenses ϕ_7 (-0.019), and credit card expenses ϕ_9 (-0.025) were recorded negatively significant for the profit efficiency of SOCBs. These results are contradicted to the study of Loveman (1994) who used Ordinary Least Square method to assess the productivity effect of IT on manufacturing firms.

Table 3: It Determinants of Cost DEA Efficiency for SOCBS by OLS Method

Variable	Parameters	Coefficient	P-value
Intercept	ϕ0	0.6***	0.000
IT Expenses	ϕ1	0.00007	0.868
IT Income	ϕ2	0.001	0.059
IT Investment	ϕ3	0.00032**	0.001
IT Personnel	ϕ4	0.002	0.874
IT Personnel Expenses	ϕ5	0.00154**	0.006
ATM Transaction	ϕ6	-0.0012***	0.0001
ATM Expenses	ϕ7	0.008	0.092
Credit Card Transaction	ϕ8	0.002	0.508
Credit Card Expenses	ϕ9	-0.002	0.845

Source: Author's calculation

4.5 IT Determinants of Profit DEA Efficiency for SOCBs by OLS Method

Table 4: IT Determinants of Profit DEA Efficiency for SOCBs by Ordinary Least Square Method

Variable	Parameters	Coefficient	P-value
Intercept	ϕ0	0.220*	0.0260
IT Expenses	ϕ1	0.0002	0.8568
IT Income	ϕ2	-0.0004	0.7735
IT Investment	ϕ3	-0.0002	0.2889
IT Personnel	ϕ4	-0.002	0.3214
IT Personnel Expenses	ϕ5	-0.0005	0.6469
ATM Transaction	ϕ6	0.0010	0.1160
ATM Expenses	ϕ7	-0.019	0.0645
Credit Card Transaction	ϕ8	0.000	0.3143
Credit Card Expenses	ϕ9	-0.025	0.2321

Source: Author's calculation

5. Conclusions

IT plays a pivotal role to improve the competitiveness of the bank by providing its existing customers with satisfactory services, while at the same time bringing about a significant reduction in cost. This study examined the role of IT on the cost and profit efficiency of SOCBs in Bangladesh during 2007-2018 employing VRS cost DEA and profit DEA. Tobit regression model did not apply for estimating the IT determinants of both VRS cost DEA and profit DEA models because Tobit model usually used when the dependent variable was bounded by [0,1]. So, the IT determinants of both VRS cost DEA efficiency and profit DEA efficiency on SOCBs with Ordinary Least Square method is estimated in this study. Among SOCBs, the

average cost efficiency (74.4%) was found higher than profit efficiency (20.8%). Rupali bank was the most cost efficient with (91.6%) where Sonali bank was the less cost efficient with (59%). Sonali bank was the most profit efficient bank with (30.7%) and Rupali bank was the less profit efficient with (14.9%). The IT Investment ϕ_3 (0.00032) and IT personnel expanses ϕ_5 (-0.00154) have found positively significant for the cost efficiency of SOCBs while the ATM transaction ϕ_6 (-0.0012) was negatively significant on the cost efficiency of SOCBs. On the other hand, this study does not have any significant estimates of IT factors with profit DEA efficiency for SOCBs. This study shapes a new measure of efficiency because this study employs the IT data for gauging the role of IT components on Bangladeshi banking industry with cost DEA and profit DEA efficiency which is different from other studies. The results obtained from this efficiency studies can be used to help government, regulators and investors to remove the hindrance of progress in Bangladesh economy. This type of study could be applied in another sector of the economic market.

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