**Investigating the Role of ICT Determinants of Private Commercial Banks with Stochastic Frontier models in Bangladesh**

**Abstract**

In global terms, ICT has been emerged as one of the biggest catalysts in banking sectors that is a blithe for Bangladesh banking industry and ICT metes out no exclusion here. This study measures the impact of ICT determinants on 17 private commercial banks (PCBs) in Bangladesh employing Stochastic Cobb-Douglas and Trans-log cost and profit efficiency models considering a panel data set during 2008-2017. The average cost efficiency score is made up to 65.8% and the average profit efficiency score has been made to 50.5% for PCBs for Cobb-Douglas cost and profit frontier analysis models while in Translog stochastic cost and profit frontier analysis models the average cost efficiency score and the average profit efficiency score have been made to 66.3% and 53.9% respectively. The IT personnel expenses (0.0018) and Credit Card Transaction (0.0013) are found positively significant for profit efficiency of Stochastic Cobb-Douglas profit frontier model while the IT personnel expanses ɸ5 (0.00087), ATM Card expenses ɸ7 (0.00306) and credit card transaction ɸ8 (0.00005) have impacted positively on the cost efficiency of Stochastic Cobb-Douglas cost frontier model . The ICT factors have positive impact on private commercial banks so it can be concluded that the Private commercial banking system are technologically more advanced.

**Keywords:** ICT, Stochastic frontier model, Private Commercial Banks, Bangladesh.

1. **Introduction**

In the modern age, ICT is a crucial resource of an organization like land, labor, and capital. The banking industries is being heavily influenced by technology in this context. Due to the development of technology, the traditional banking system is disappearing. New markets, good products, proper services and efficient delivery channels for the banking industry are all these lead to a more competitive market environment (https://pdfs.semanticscholar.org/5228/b537074311cea1a0a0bc511553f4706908e8.pdf).Technology is the new door of banking and financial services to conduct their activities; such as a popular delivery mechanism ATM reduces the hassle to get the money at any time. The bank has changed its transaction system, rationalize its branch network strategy, and widen the range of delivery option by advanced technology (https://www.sciencedirect.com/science/article/pii/S1877042811018283). So, people get large facilities through an internet bank. As a result, investors are increasing day by day (https://investorplace.com/2020/06/market-share-lower-fees-boosting-spot-stock/). In this continuation, information technology environment changes rapidly and the number of internet users is increased in Bangladesh (https://www.essaysauce.com/geography-essays/essay-bangladesh-microfinance-self-help-groups/). Most of the transactions are conducted via e-banking channels, online internet bank, and m-banking services due to a decrease in the physical branches of banking. So, the customer demands are fulfilled easily in banking activities electronically. Some researchers asserted that ICT investments can really promote the enterprises operational performance by reducing costs, raising profit margin, upgrading production levels, enhance service quality, progressing customer satisfaction and successful overall operations. In contrast, other researchers do not demonstrate the positive effect of ICT investments and concluded that ICT spending brought no significant contributions to the enterprise’s operations, and so the ICT has been an issue of continuous debate for decades. (require the exact citations in this regard). (Beccalli 2007; Lee & Menon 2000; Romdhane 2013; Safari & Yu 2014; Surulivel et al. 2013) used parametric method (SFA) for estimating the banking efficiency and showed that ICT components (Software Investment, IT services, Hardware Investment) had a great impact on the bank efficiency but they did not use variables related to ICT (https://www.researchgate.net/publication/256967758\_An\_analysis\_of\_factors\_that\_influence\_the\_technical\_efficiency\_of\_Malaysian\_thermal\_power\_plants). Similarly, (Abdul-Majid, Saal & Battisti 2011; Altunbas et al. 2000; Carvallo & Kasman 2005; Casu & Molyneux 2003; Christopoulos, Lolos & Tsionas 2002; Christopoulos & Tsionas 2001; Duygun et al. 2015; Fries & Taci 2005; Košak, Zajc & Zorić 2009; Shen, Liao & Weyman-Jones 2009; Thi & Ngan 2014), used SFA method to analyze the impact on cost & profit efficiency but were unable to measure the impact of ICT variable (http://www.scienpress.com/Upload/JAFB/Vol%204\_3\_13.pdf). Moreover, one of the researchers (Chu-Fen li; 2007) made an estimate of the technical efficiency of individual banks and group banks through the use of whole ICT oriented variable on analyzed DEA and SFA method and he also measured the correlation and regression analysis among the IT variables. He showed that the technical efficiency of banks had been significantly influenced by using the ICT component significantly but he was not able to measure the impact of ICT variable on the cost and profit efficiency of banks. The financial institutions in Bangladesh seem to increasingly adopt ICT banking and improve banking capabilities. Though the increasing competition among the banks creates problems of losing their customers yet ICT enhances efficiency at all levels of banking industry value chain by facilitating service definition and new product diversity, both minimizing risk and prducing quality competitive advantages. However increasing competition among the banks leading to losing their customers, but information and technology by facilitating, service definition and new product (diversity and enhances efficiency at all levels of banking industry value chain, both reducing risk and creating quality competitive advantages). In Bangladesh, some studies using Stochastic frontier analysis and Data envelopment analysis are available solely on banking cost and profit efficiency (Ara 2016; Baten, Kasim & Rahman 2015; Hassan & Hassan 2018) and there have been some empirical studies about the impact of ICT on banking in Bangladesh (Sadekin & Shaikh 2015) asserted that ICT investments are becoming an important factor in the future development of Bangladesh banking industry. There are no studies available about the impact of ICT in the banking sector on the cost and profit efficiency (https://www.sciencedirect.com/science/article/pii/S0939362518305399).(Ariff & Can, 2008; Casu & Molyneux, 2003; Girardone et al., 2004; Sadekin & Shaikh, 2015) used TOBIT-regression method to examine the determinants of bank efficiency. In this study, TOBIT-regression model is used to reveal the determinants of cost and profit efficiency of banks in Bangladesh given the fact that the efficiency scores are constrained between zero and one (https://www.researchgate.net/publication/312647412\_THE\_EFFICIENCY\_OF\_BANKS\_IN\_INDONESIA\_SHARIA\_VS\_CONVENTIONAL\_BANKS). This study undertakes to investigate the use and development of some classes of ICT applications (e.g., ATM, Credit cards, IT personnel Expenses and IT investment) from selected 17 PCBs and analyses the impact of ICT factors on the efficiency of PCBs in Bangladesh Banking industry based on the estimated cost and profit efficiency scores.

1. **Methodology**
2. Empirical Stochastic Cobb-Douglas Cost Frontier Model

The specification of Cobb-Douglas stochastic frontier cost model (Battese & Coelli 1995) is defined as:

(1)

where, ln is natural logarithm (that is log to base e, where e = 2.718) (https://www.varsitytutors.com/hotmath/hotmath\_help/topics/natural-logarithm). Yit represent the total cost of ith bank in period t LOAit is the loan of bank i in period t; OBSit is the off-balance sheet items of bank i in period t; ; POFit is the price of fund of bank i in period t; POFAit is the price of fixed assets of bank i in period t; POLit is the price of labour of bank i in period t; v is a two-sided error term assumed to be identically and independently distributed, u is a non-negative technical inefficiency component of the error term and β’s are unknown parameters to be estimated (https://www.researchgate.net/publication/321322235\_Exploring\_the\_Future\_Potential\_of\_Jute\_in\_Bangladesh). Having obtained the parameters for each variable by banks using equation (1), the technical efficiency level for PCBs is predicted with equation (2).

(2)

1. Empirical Stochastic Cobb-Douglas Cost Frontier Inefficiency Effects Model

The empirical cost inefficiency effects model can be written as:

where uit is defined as the inefficiency term in the cost function; NIIit is the non- interest income of bank i in period t; NPLit is the non-performing loan of bank i in period t; ROAit is the return on assets of bank i in period t; ROEit is the return on equity of bank i in period t; CARit is the capital adequacy ratio of bank i in period t; ωit is the error term (https://www.sciencedirect.com/science/article/pii/0165410190900272).

1. Empirical Stochastic Cobb-Douglas Profit Frontier Model

The specification of Cobb-Douglas stochastic frontier profit model (Battese & Coelli 1995) is defined as:

Where ln is natural logarithm (that is log to base e, where e = 2.718). Whereis the profit after tax of ith bank in period t measured by revenues minus costs; is a constant to ensure the natural log of profits to be positive. All the independent variables are the same line as the described in the equation (1). Having obtained the parameters for each variable by banks using equation (5), the technical efficiency level for firms is predicted as like as the equation (2). The profit inefficiency effects model can be estimated as the same line as the equation (3) with the exception on the dependent variable of profit inefficiency.

1. Empirical Stochastic Translog Cost Frontier Analysis Model

The specification of Stochastic Translog Cost frontier model is defined by

where Cit is defined as the total cost. All the independent variables are the same line as the described in the equation (1). The empirical cost inefficiency effects model can be estimated as the same line as the equation (3) with the exception on the dependent variable of cost inefficiency in Tanslog case.

1. Empirical Stochastic Translog Profit Frontier Model

The specification form for stochastic Translog profit frontier model can be written as:

Where  is the profit after tax of ith bank in period t measured by revenues minus costs; is a constant to ensure the natural log of profits to be positive. All the independent variables are the same line as the described in the equation (5). The empirical profit inefficiency effects model can be estimated as the same line as the equation (3) with the exception on the dependent variable of profit efficiency in Translog case.

1. Empirical Tobit Regression Model

The specification of the Tobit regression model can be written as:

where Eit is defined as the Stochastic Cobb-Douglas and Translog cost and profit efficiency scores of the i-th bank in period t; ITEit is the IT expanse of bank i in period t; ITIit is the IT income of bank i in period t; ITINit is the IT investment of bank i in period t; ITPit is the IT personnel of bank i in period t; ITPEit is the IT personnel expenses of bank i in period t; ATMTit is the ATM transaction of bank i in period t; ATMEit is the ATM expenses of bank i in period t; CCT is the Credit Card Transaction of bank i in period t; CCE is the credit card expenses of bank i in period t. ξit is the error term.

1. **Results and Discussion**
2. *Cost and Profit Efficiency Results Based on Cobb-Douglas and Translog Stochastic Frontier Models*

The results of maximum likelihood estimates using stochastic Cobb-Douglas and Translog cost and profit frontier models of the PCBs are given in Table 1. In the Cobb-Douglas cost frontier model, the loan with β1 (0.554) was positively significant implies that bank reduce their cost from loan given to the customer by making proper collection efforts. The input, price of fixed assets β4 (0.09) was positively significant implying that they had been a positive influence on the bank’s cost model (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016SC0377). On the other hand, only the output variable off-balance sheet item was found negatively significant with β2 (-2.767) implied that off-balance sheet item had not a great influence on the bank’s cost. The square of inputs, the price of fund β33 (-0.106) was negatively significant and the price of fixed assets β44 (0.623) was positively significant. The interaction term of input price and outputs, loan & off-balance sheet items β12 (0.284), loan & price of fixed assets β14 (0.244), loan & price of labor β15 (0.619) were positively significant where off-balance sheet item & price of labor β25 (-0.753), price of fund & price of labor β35 (-0.152) and price of fixed assets & price of labor β45 (-0.442) were found negatively significant for the cost model. In Cobb-Douglas cost frontier model, the input price variable, price of fund was found negatively significant with the coefficient of β3 (-0.149) seems to suggest that the price of fund have impacted negatively to total operating cost. In Cobb-Douglas profit frontier model, only the price of labor was negatively significant with β5 (-0.153) suggest that banks may be overstaffed. In the Translog Stochastic profit frontier model, the variable off-balance sheet items β2 (-1.156) was negatively significant and the inputs, the price of fund β3 (2.295) was positively significant. The square input price of labour β55 (-0.325) shown highly negatively significant and also the mixed product, off-balance sheet items & price of fund β23 (-0.212), off-balance sheet items & price of fixed assets β24 (-0.237) were negatively significant and loan & off-balance sheet items β12 (0.148) and Price of fixed assets & price of labor β45 (0.449) were found positively significant. These results were supported by (Abdul-Majid, Saal & Battisti 2011; Ara 2016; Baten & Begum 2014; Baten, Kasim & Rahman 2015; Christopoulos, Lolos & Tsionas 2002; Duygun et al. 2015; Hassan & Hassan 2018; Košak, Zajc & Zorić 2009) (https://quizlet.com/24211440/test-1-flash-cards/).

1. *Results of Cost and Profit Inefficiency Effects for Private Commercial Banks in Cobb-Douglas and Translog Stochastic Frontier Models*

The cost and profit inefficiency estimates of PCBs for both the stochastic Cobb-Douglas and Translog cost and profit frontier model are given in Table 2.The variable of non-interest income was found negatively significant for both Cobb-Douglas and Translog cost inefficiency model indicates a negative impact on the bank inefficiency and therefore a positive effect on cost efficiency (https://www.researchgate.net/publication/5018599\_Labour\_Cost\_Efficiency\_in\_UK\_and\_Irish\_Credit\_Institutions). That means the banks were able to reduce the cost by non-interest income and saving their revenue.Top of Form A negative coefficient of non-performing loan (δ2 -0.039, -0.045, -0.572\*, -0.467) indicates a negative impact on the bank inefficiency and therefore a positive effect on cost efficiency. We found that there is a consistent view among scholars on the relationship between non-performing loan ratio and banking inefficiency (https://www.cogentoa.com/article/10.1080/23322039.2018.1510719). All studies applied by (Altunbas et al. 2000; Carvallo & Kasman 2005; Girardone, Molyneux & Gardener 2004; Košak, Zajc & Zorić 2009; Mertens & Urga 2001), agree that non-performing loan ratio had positive influence on inefficiency (https://www.mdpi.com/2071-1050/12/1/325/htm). Return on assets had the negatively insignificant for the cost model and negatively significant for the profit model implied that banks gained profit but could not reduce cost using their total assets with the coefficient of δ3(-0.344, -0.229, -1.704\*, -2.513\*\*). These findings were in contrary to the findings of (Andries 2011; Thangavelu & Findlay 2010; Yildirim & Philippatos 2007) They did not find a significant association between ROA and bank efficiency but support (Anwar; 2018). The highly positive coefficient of return on equity δ4 (0.871\*, 0.341\*, 2.38\*\*\* & 2.868\*\*\*) indicate that bank could not reduce cost efficiency and increase profit efficiency by properly implementing the investments. Bank capital, which is represented by the CAR, also had a positive impact on the cost efficiency of banks, with a positive direction in the model of cost, and it is negatively significant in the profit model assets with the coefficient of δ5 (0.356, 0.961\*\*\*, -1.75\*, -2.806\*\*). These findings indicate that capital adequacy is crucial for banks to support their management in order to be more profitable. It is worth noting that the high compliance of Bangladesh banks in terms of capital adequacy supply has adversely affected their level of cost efficiency. Some studies that match this finding (Andries 2011; Thangavelu & Findlay 2010; Yildirim & Philippatos 2007). The Sigma squared was positively significant. The estimated gamma was close to unity implies that the strong impact of inefficiency score to bank’s cost variance. These results were supported by (Thi & Ngan 2014).

1. *Result of Test of Hypothesis for Stochastic Cost and Profit Frontier Model*

Table 3 reports the results of hypothesis tests conducted on the cost and profit frontier models. The hypothesis tests were obtained using the generalized likelihood-ratio statistic (http://www.icommercecentral.com/open-access/stochastic-frontier-model-for-cost-and-profit-efficiency-ofislamic-online-banks.php?aid=37952).

The 1st null hypothesis is H0: ρ=0 which specifies that the Cobb-Douglas stochastic frontier model is more preferable than the Translog stochastic frontier model for cost and profit efficiency model of PCBs. It was observed that the null hypothesis is rejected in both cases of cost and profit efficiency models. So, the Translog model was more preferable than the Cobb-Douglas for both cost and profit efficiency models of PCBs.

The 2nd null hypothesis is H0: γ=0, which specify that there is no technical inefficiency effect in the Cost efficiency model. The hypothesis is accepted for the PCBs. So, there is no technical inefficiency effect in the cost model. In profit model, the hypothesis is rejected for PCBs, implied that there is a technical inefficiency effect in PCBs.

The 3rd null hypothesis is H0: βij=0, which specifies that there is an interaction effects on Translog Stochastic cost and profit frontier model. It is observed that the null hypothesis is rejected for both cost and profit efficiency, imply that there is an interaction effect in both Translog Stochastic Cost and profit frontier models for the PCBs. This result was supported by (Baten & Begum 2014; Thi & Ngan 2014).

1. *Year-wise Average Cost and Profit Efficiency Scores of Stochastic Cobb-Douglas and Translog Frontier Models*

The year-wise average cost and profit efficiency scores for PCBs are illustrated in Figure 1. It is observed that the efficiencies were varied year by year in both cases of cost and profit. In Stochastic Cobb-Douglas Cost frontier model, the cost efficiencies were around 49.9 %-74.4% from 2008-2012, and it attained the peak percentage amount of 74.8% in 2013. After that, it has been a little drop of 71.5% in 2015 and 2016. In the last year of the study period, it has been slightly increased by 73.1%. Conversely, in Stochastic Translog cost Frontier Model, the cost efficiencies were around 51.1 % to 72.1% from 2008-2013, and then it has been slightly decreased by 71.2 %. It remained steady at 70.1% in 2015 and 2016. In the last year of the study period, it was a little drop of 69.8%. On the other hand, in Stochastic Cobb-Douglas profit frontier model, the profit efficiency of PCBs was recorded 45.5% in the year of 2008, and then slightly decreased at 31.7% in the next year. It remained constant at 47% in 2011 and 2012. Again, it declined slowly and after 2014 it was gradually increasing and reached the highest value at 66.7% in the year of 2017. Moreover, in Stochastic Translog profit frontier model, the profit efficiency score of PCBs were 50% in 2008, then it decreased moderately at 32.8% in the following year. It remained 50% in 2011 and 2012. Again, it declined slowly at 40.7% and finally, it was an upward trend and reached the highest value at 66.7% in the last year of 2017. This result was supported by (Ara 2016; Baten & Begum 2014; Casu & Molyneux 2003; Hassan & Hassan 2018) who measured the PCBs were the most cost efficient rather than profit efficiency.

1. *Bank-wise Average Cost and Profit Efficiency Scores of Stochastic Cobb-Douglas and Translog Frontier Models*

The average cost and profit efficiency scores of individual commercial banks from 2008-2017 are reported in Figure 2. As presented the result, the Brac bank was the most cost efficient bank with an average efficiency score of 89.3% and Al-arafah was the less cost efficient (37.4%) among the other banks in Stochastic Cobb-Douglas cost frontier model and social islami bank was the most cost-efficient with an average efficiency score of 88% and Exim bank was the less cost efficient (31.1%) bank in Stochastic Translog cost frontier model. On the other hand, IBBL was the most profit efficient with an average efficiency score of 73.8% and mercantile bank was the less profit efficient (33.6%) bank in Stochastic Cobb-Douglas profit frontier model and the Southeast and Eastern banks were the most profit efficient bank with an average efficiency score of 68% and Mercantile was the less profit efficient (33.3%) banks in Stochastic Translog profit frontier model. Furthermore, in Stochastic Cobb-Douglas cost and profit frontier model, Southeast, Al-Arafah, Brac, and Prime bank had 60% above profit efficiency scores and Mercantile, One Southeast, Eastern, IBBL had cost efficiency scores more 70%. This result confirms that the majority of the PCBs are around 40% to 50% regarding profit efficiency and around 60% to 70% in terms of cost efficiency. Conversely, in Stochastic Translog cost and profit frontier models, the IBBL and Prime bank had 60% above profit efficiency scores and the Brac, Mercantile, One, Prime, Premium and Shahjalal banks had cost efficiency scores more than 70%. This result confirms that the majority of the PCBs were around 40% to 50% regarding profit efficiency and around 60% to 70% in terms of cost efficiency. These results were supported by (Ara 2016).

1. *Results of IT Determinants with Cost and Profit Efficiency Estimates using Tobit Regression Model*

Table 4 represents the results of IT determinants of cost and profit efficiency of Stochastic Cobb-Douglas and Translog cost and profit frontier models for PCBs. As can be seen that the IT income ɸ2 (-0.00018) and credit card expanses ɸ9 (-0.00013) were negatively significant implied that it could not reduce the banks cost and the IT personnel expanses ɸ5 (0.00087), ATM Expenses ɸ7 (0.00306) and credit card transaction ɸ8 (0.00005) had positive impact on the cost efficiency of Stochastic Cobb-Douglas cost frontier model that means banks can reduce operating costs by installing more automated teller machines, employing credit card transaction and increasing IT person whereas in Translog cost frontier model, the IT personnel expenses ɸ5 (0.0006) and credit card transaction ɸ8 (0.000006) were positively significant but IT income ɸ2 (-0.0002) and credit card expenses ɸ9(-0.0001) were negatively significant for the cost efficiency of PCBs. On the contrary, in IT determinant profit efficiency of Stochastic Cobb-Douglas profit frontier model, the IT investment ɸ3 (-0.0003), IT income ɸ2(-0.0032), IT personnel ɸ4(-0.004), and ATM transaction ɸ6 (-0.0008) were found negatively significant but the IT personnel expenses ɸ5(0.0018) and Credit Card Transaction ɸ8 (0.0013) were positively significant of PCBs. Besides, in IT determinants with profit efficiency of Stochastic Translog profit frontier model, the IT investment ɸ3 (-0.000008), and credit card expenses ɸ9 (-0.0002) were found negatively significant. This result supports the study of (Safari & Yu 2014; Surulivel et al. 2013).

1. **Conclusion**

The cost and profit efficiency are examined for the 17 PCBs in Bangladesh using panel set of data. The stochastic Cobb-Douglas and Translog frontier model are used individually for estimating cost and profit efficiency. Then the IT components are assessed using a Tobit regression model for both stochastic Cobb-Douglas and Trans-log models (https://documents.worldbank.org/curated/en/980771468193748295/text/568910NWP0RPED10Box353743B01PUBLIC1.txt). In the Cobb-Douglas stochastic frontier analysis, the average cost efficiency score was 65.8% and the average profit efficiency score was 50.5%. In the PCBs, IBBL was the most profit efficient with an average efficiency score of 73.8% and the Brac bank was the most cost-efficient bank with an average efficiency score of 89.3%, Al-Arafah was the less cost efficient (37.4%) and Mercantile bank was the less profit efficient (33.6%) respectively. In the Translog stochastic frontier analysis, the average cost efficiency score was 66.3% and the average profit efficiency score was 53.9%. Social Islami bank was the most cost-efficient with an average efficiency score of 88% and the Southeast and Eastern banks were the most profit efficient bank with an average efficiency score of 68%. Exim bank was the less cost efficient (31.1%) and Mercantile bank was the less profit efficient (33.3%) respectively. Translog Stochastic frontier model was more preferable than the Cobb-Douglas Stochastic frontier model. The ICT factors had a positive impact on the PCBs. In IT determinants with cost and profit efficiency of Stochastic Translog frontier model, the IT personnel expenses ɸ5 (0.0006) and credit card transaction ɸ8 (0.000006) were positively significant but IT income ɸ2(-0.0002) and credit card expenses ɸ9(-0.0001) were negatively significant for the cost efficiency of PCBs on the other hand, the IT investment ɸ3 (-0.000008), and credit card expenses ɸ9 (-0.0000007) were found negatively significant for the profit efficiency of Stochastic Translog profit frontier model (https://www.insightsonindia.com/wp-content/uploads/2020/06/GS3\_final.pdf). The IT income ɸ2 (-0.00018) and credit card expanses ɸ9 (-0.0001) were negatively significant for the cost efficiency of the Stochastic Cobb-Douglas cost frontier model. In IT determinants with profit efficiency of Stochastic Cobb-Douglas profit frontier model, the IT investment ɸ3 (-0.0003), IT income ɸ2 (-0.0032), IT personnel ɸ4 (-0.004), and ATM transaction ɸ6 (-0.0008) were found negatively significant for the profit efficiency but the IT personnel expenses ɸ5(0.0018) and Credit Card Transaction ɸ8 (0.0013) were positively significant. Although, there are limited ICT factors are used in this study because banks are unwilling to disclose data bothering on these issues for competitive reasons, but this study is different from other studies because of measuring the impact of ICT component on cost and profit efficiency of Bangladesh banking industry using Tobit regression model. The PCBs system has to be internally efficient and technologically advanced. The information obtained from efficiency studies can be used to help government, regulators, and investors to remove the hindrance of progress in Bangladesh economy.

**Acknowledgements**

We published already one research article on stochastic frontier models in efficiency and productivity analysis with important application to Islamic Banking Industries in the Journal of Internet Banking and Commerce. Then we would like to extend this research together with other banking industries, productivity, technical efficiency measurements and determining the important ICT factors using a stochastic frontier production function model. The previous study has helped us to enhance and clarify our work.

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**Notes**

1 According to the BIBM report, PCBs are large in terms of shares in assets and number of branches; they could cover around 99.5 per cent of their branches in present under computerization.

2 Koop (2008) specifies that the TOBIT model is a regression model that has the dependent variable which is censored at zero. In revealing the ICT factors affecting cost and profit efficiency levels of Bangladesh banks, this study uses TOBIT regression considering the efficiency scores have the features of censored value between 0 and 1.

3 Specifically the study undertakes to investigate the use and development of some classes of ICT applications because most of the banks are unwilling to disclose data bothering on these issues for competitive reasons. So, data obtained from published reports and banks officials are expected to serve as the basis for this analysis.

**Tables and figures**

**Table 1** Results of both Cost and Profit Efficiencies with Cobb-Douglas and Translog Stochastic Frontier Models

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | Coefficient of Cost | | | Coefficient of Profit | |
| Variable | Parameter | Cobb-Douglas | | Translog | Cobb-Douglas | Translog |
| Constant | β0 | 2.66\*\*\* | 15.18\* | | 5.21\*\*\* | 18.42\*\*\* |
| LOA | β1 | 0.554\*\*\* | 0.666 | | -0.008 | -1.03 |
| OBS | β2 | -0.042 | -2.767\*\* | | -0.004 | -1.156\*\* |
| POF | β3 | -0.149\*\*\* | 0.299 | | -0.021 | 2.295\* |
| POFA | β4 | 0.09\* | -1.368 | | 0.043 | 1.301 |
| POL | β5 | -0.063 | -0.489 | | -0.153\* | -0.908 |
| (LOA)2 | β11 |  | -0.230 | |  | -0.152 |
| LOA \* OBS | β12 |  | 0.284\* | |  | 0.148\* |
| LOA \* POF | β13 |  | -0.092 | |  | 0.019 |
| LOA \* POFA | β14 |  | 0.244\* | |  | -0.006 |
| Loan \*POL | β15 |  | 0.619\*\*\* | |  | 0.057 |
| (OBS)2 | β22 |  | -0.060 | |  | -0.050 |
| OBS \* POF | β23 |  | 0.037 | |  | -0.212\* |
| OBS \*POFA | β24 |  | -0.021 | |  | -0.237\* |
| OBS\*POL | β25 |  | -0.753\*\*\* | |  | 0.177 |
| (POF)2 | β33 |  | -0.106\* | |  | 0.124 |
| POF \* POFA | β34 |  | -0.049 | |  | -0.115 |
| POF \*POL | β35 |  | -0.152\* | |  | 0.183 |
| (POFA)2 | β44 |  | 0.623\*\*\* | |  | -0.503 |
| POFA \*POL | β45 |  | -0.442\*\*\* | |  | 0.449\*\* |
| (POL)2 | β55 |  | -0.076 | |  | -0.325\*\*\* |

**Table 2** Cost and Profit Inefficiency Estimates for Private Commercial Banks of Cobb-Douglas Stochastic Frontier Model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | Coefficient of cost | | Coefficient of Profit | |
| Variable | Parameter | Cobb-Douglas | Translog | Cobb-Douglas | Translog |
| NII | δ1 | -0.32\*\*\* | -0.305\*\*\* | -0.244 | 0.058 |
| NPL | δ2 | -0.039 | -0.045 | -0.572\* | -0.467 |
| ROA | δ3 | -0.344 | -0.229 | -1.704\* | -2.513\*\* |
| ROE | δ4 | 0.871\*\* | 0.341\* | 2.38\*\*\* | 2.868\*\*\* |
| CAR | δ5 | 0.356 | 0.961\*\*\* | -1.75\* | -2.806\*\* |
| Sigma Sq | б2 | 0.26\*\*\* | 0.121\*\*\* | 3.41\*\*\* | 2.704\*\*\* |
| Gamma | γ | 0.862\*\*\* | 0.669\*\*\* | 1.00\* | 0.999\*\*\* |

**Table 3** Results of Likelihood-Ratio Test of Stochastic Cost and Profit Frontier Models for Private Commercial Banks

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | Null Hypothesis | Log-Likelihood Function | Test Statistics λ | Critical Value | Decision |
| Cost |  |  | -54.96 | 38.301 | Reject H0 |
| Cobb-douglas | -65.61 |
| Translog | -38.13 |
|  | -33.64 | 1.3172 | 35.827 | Accept H0 |
|  | -64.82 | 48.9 | 5.138 | Reject H0 |
| Profit |  |  | 16.31 | 35.83 | Reject H0 |
| Cobb-douglas | -165.32 |
| Translog | -157.17 |
|  | -165.93 | 88.654 | 35.827 | Reject H0 |
|  | -165.32 | 112.54 | 5.138 | Reject H0 |

Note: all critical values are at a 5% level of significance and the critical values are obtained from a table of (Kodde et al. 1986)

**Table 4** IT Determinants of Cost and profit Efficiency Scores by Tobit Regression Model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | Coefficient of Cost | | Coefficient of Profit | |
| Variable | Parameter | Cobb-Douglas | Translog | Cobb-Douglas | Translog |
| Intercept | ɸ0 | 0.580\*\*\* | 0.619\*\*\* | 0.304\*\*\* | 0.42\*\*\* |
| IT. Expenses | ɸ1 | 0.00002 | -0.00003 | 0.0009 | -0.00002 |
| IT. Income | ɸ2 | -0.00018\* | -0.0002\*\* | -0.0032\*\* | 0.00003 |
| IT. Investment | ɸ3 | -0.0000009 | -0.000002 | -0.0003\* | -0.000008\* |
| IT. personnel | ɸ4 | 0.0002 | 0.0003 | -0.004\*\* | 0.0006 |
| IT personnel expanses | ɸ5 | 0.00087\* | 0.0006\* | 0.0018\*\* | 0.0009 |
| ATM.Transaction | ɸ6 | -0.00004 | -0.00005\* | -0.0008\* | 0.00005 |
| ATM.expeses | ɸ7 | 0.00306\* | 0.0002 | -0.009 | 0.00002 |
| Credit. Card. Transaction | ɸ8 | 0.00005\* | 0.000006\*\* | 0.0013\*\*\* | -0.0000007 |
| Credit. Card. expenses | ɸ9 | -0.00013\*\* | -0.0001\* | -0.0012 | -0.0002\*\*\* |

**Appendix 1** Year-wise Cost and Profit Efficiency of Cobb-Douglas, Translog Stochastic Frontier Analysis and VRS- Data Envelopment Analysis for Private Commercial Bank

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Cobb-Douglas | | Translog | |
| Cost Efficiency | Profit Efficiency | Cost Efficiency | Profit Efficiency |
| 2008 | 0.499 | 0.454 | 0.518 | 0.503 |
| 2009 | 0.530 | 0.319 | 0.559 | 0.328 |
| 2010 | 0.567 | 0.470 | 0.643 | 0.545 |
| 2011 | 0.643 | 0.471 | 0.676 | 0.512 |
| 2012 | 0.690 | 0.468 | 0.694 | 0.510 |
| 2013 | 0.748 | 0.444 | 0.721 | 0.473 |
| 2014 | 0.744 | 0.566 | 0.712 | 0.600 |
| 2015 | 0.715 | 0.578 | 0.701 | 0.620 |
| 2016 | 0.715 | 0.615 | 0.704 | 0.631 |
| 2017 | 0.731 | 0.667 | 0.698 | 0.664 |
| Mean | 0.658 | 0.505 | 0.663 | 0.539 |

**Appendix 2** Bank-wise Cost and Profit Efficiency of Cobb-Douglas, Translog Stochastic Frontier Analysis and VRS- Data Envelopment Analysis for Private Commercial Bank

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Banks Name | Cobb-Douglas | | Translog | |
| Cost Efficiency | Profit Efficiency | Cost Efficiency | Profit Efficiency |
| DBBL | 0.618 | 0.341 | 0.552 | 0.389 |
| Brack | 0.893 | 0.549 | 0.712 | 0.678 |
| City | 0.668 | 0.489 | 0.675 | 0.514 |
| Mercantile | 0.712 | 0.336 | 0.727 | 0.333 |
| Mutual | 0.473 | 0.398 | 0.527 | 0.397 |
| One | 0.746 | 0.425 | 0.714 | 0.477 |
| Premium | 0.678 | 0.463 | 0.703 | 0.406 |
| Prime | 0.694 | 0.591 | 0.721 | 0.628 |
| Southeast | 0.797 | 0.691 | 0.66 | 0.68 |
| Eastern | 0.738 | 0.717 | 0.779 | 0.68 |
| UCB Limited | 0.613 | 0.455 | 0.590 | 0.585 |
| IFIC | 0.588 | 0.449 | 0.663 | 0.482 |
| IBBL | 0.726 | 0.738 | 0.824 | 0.674 |
| Al-arafah | 0.374 | 0.608 | 0.461 | 0.566 |
| Social | 0.823 | 0.486 | 0.88 | 0.507 |
| Exim | 0.393 | 0.428 | 0.311 | 0.567 |
| Shahjalal | 0.658 | 0.426 | 0.761 | 0.595 |
| Mean | 0.658 | 0.505 | 0.662 | 0.539 |

**Figure 1** Year-wise Average Cost and Profit Efficiency Scores of Stochastic Cobb-Douglas and Translog Frontier Models

**Figure 2** Bank-wise Average Cost and Profit Efficiency Scores of Stochastic Cobb-Douglas and Translog Frontier Models