Asian Journal of Empirical Research
Volume 8, Issue 6 (2018): 208-224

http://aessweb.com/journal-detail.php?id=5004

Cost efficiency of banking sector of Bangladesh: evidence using the stochastic frontier analysis

Md. Hashibul Hassan [a], Mahmudul Hassan[b]

Corresponding author

[a] Assistant Professor; Department of Finance, Jagannath University, Dhaka, Bangladesh
[b] Postgraduate Student; Department of Finance, Jagannath University, Dhaka, Bangladesh
✉ *hashibulhassan@fin.jnu.ac.bd (Corresponding author)*

ARTICLE HISTORY:

Received: 13-Apr-2018
Accepted: 25-May-2018
Online available: 15-Jun-2018

Keywords:

Intermediation approach,
Production approach,
Stochastic frontier analysis (SFA),
Trans-log cost function

ABSTRACT

Banking industry dominates the financial sector of Bangladesh with an approximate share of 74% of the total intermediation. In recent years, this industry is at high risk due to supervision gaps, overcapacity and market distortions. Therefore, measuring the efficiency of the banking industry is critically important to identify poor banks and bring stability by concentrating on their performance. This study employs single stage stochastic frontier analysis (SFA) to measure the cost efficiency in the Bangladeshi banking sector during the 2011-2015 period. Five different stochastic models are used across the 35 sample banks. Evidence suggests that the mean cost efficiency found in the Bangladeshi banking sector is 88.50%. The mean efficiency is lower among the state-owned banks than conventional (private) commercial banks and Islamic Sariah banks. From the analysis, it seems that there is a low technological advancement in the banking sector during 2011-2015. Further, the analysis indicates that non-performing loans have a significant effect in reducing the overall cost efficiency among the banks.

Contribution/ Originality

This study is an endeavour to extend the literature of stochastic frontier approach (SFA) based efficiency measurement of the banking industry of Bangladesh. Multiple models with various control and environmental variables are used to restrict the effect of heterogeneity of the sample banks. Therefore, it contributes the existing wisdom by measuring more reliable performance gap between good and bad banks.

DOI: 10.18488/journal.1007/2018.8.6/1007.6.208.224
ISSN (P): 2306-983X, ISSN (E): 2224-4425

How to cite: Md. Hashibul Hassan and Mahmudul Hassan (2018). Cost efficiency of banking sector of Bangladesh: evidence using the stochastic frontier analysis. Asian Journal of Empirical Research, 8(6), 208-224.

1. INTRODUCTION

After independence in 1971, the banks operating in Bangladesh, apart from those incorporated abroad, were nationalised. At that time, outreach and financial inclusion were the main objectives for the banks, rather operational efficiency. Since 1985 government of Bangladesh has started to denationalise the previously nationalised banks and subsequently liberalize the financial sector, which increase the number of banks and branches, bank branches have increased from 4603 in 1983 to 9753 in 2017 (BB, 2017). At present, the banking industry dominates the financial sector of the country, contributing 74% of total financial intermediation (Robin *et al.*, 2018). Industry experts opine that banking sector of Bangladesh is at high risk due to supervision gaps, overcapacity and market distortions (NewAgebd, 2018). Currently, 57 banks are operating in the country and few others in the pipeline, which might put more stress in the competition of the banking sector. Therefore, the efficiency of the banking function process of existing banks needs to be measured to provide policy implication regarding the capacity of the incumbents and level of competition of the industry.

In general, there are arguments that banking sector of Bangladesh is less cost-efficient than other countries. The cost to income ratio is 30-32% in China, 27-29% in Egypt and 28-30% in Vietnam, whereas, in Bangladesh, the cost to income ratio is 40-52% (Rahman, 2016). Which shows a significant concern regarding the cost efficiency of Bangladeshi banking sector. Researchers and bankers state that the high level of non-performing loan (NPL) in Bangladesh is reducing the cost efficiency of the banking sector. In Q1 of 2017, the overall NPL was staggering 18% of the total loans and advances or USD 1.45 billion (CPD, 2017). For this high level of NPL, the bank usually reluctant to give loan and moreover, they spend more fund in processing loan (to reduce adverse selection), which increase their cost. Banks also must maintain a high level of liquidity as per Bangladesh Bank (the central bank) guidelines regarding NPL, which reduces their investment capacity and profit earning ability and further reduces their cost efficiency. In addition, many banks especially government banks are not very adaptive to the use new technologies, which increase their operating cost and making them cost inefficient relative to other banks.

Obviously, if banks have lower cost efficiency, there will be a higher probability of failure and becoming insolvent (Podpiera and Podpiera, 2005), which may lead to depression in the country's overall economy. Even, it is commonly argued that even a single bank meltdown might hamper other banks' operation and eventually might put the whole economy into the depression. During the global financial crisis in 2008-10, many banks around the world have been taken support from the government to stay in the business, because of their inefficiency in managing operating expenses. However, being a small and developing country, Bangladesh government has little capacity to support the banking sector if some bank collapse. Therefore, it is necessary to identify the well-performing (most efficient) banks in Bangladesh and to measure the gap between the efficient and inefficient banks. Despite many empirical literatures exist on the efficiency of banking sector using frontier approach, there are very few available on Bangladesh. This study tries to fill this academic lacuna by measuring overall efficiency of the banking sector of Bangladesh using single stage stochastic frontier approach (SFA).

The rest of this paper structured as follows- the next part is the literature review that deals mainly with the past relevant studies, the third chapter is the methodology where all five SFA models are introduced, the fourth chapter explains the results of the empirical models and the final chapter concludes the paper by presenting the findings.

2. LITERATURE REVIEW

There are mainly two approaches to measure the efficiency of the banking sector. One is simple profit-cost analysis using different financial ratios and the other is frontier efficiency approach (Daley and Matthews, 2009). The conventional financial ratio approach does not consider overall bank structure and other environmental factors, which limit its ability of efficiency measurement (Dong, 2010). For this reason, the academic researchers are inclined to use frontier efficiency approach more than the financial ratio approach. The standard framework of productive efficiency is designed by Farrell (1957) who have denoted that a firm is fully efficient if it produces maximum output at minimum cost. He suggested that productive efficiency could be observed more accurately by constructing efficient frontier using sample data and by calculating the relative efficiency score of each firm in contrast to the benchmark firm. In other words, frontier efficiency approach measures the deviation of performance of each bank from the best bank on the efficient frontier, where all sample banks are facing similar market conditions.

In the literature, both parametric and nonparametric approaches have greatly used to execute the frontier efficiency analysis in banking sector around the world. Among various parametric models, the stochastic frontier is the most popular method in banking efficiency analysis. This method was first proposed by Aigner *et al.* (1977) and later enriched by Battese and Coelli (1995). On the other hand, the non-parametric approach was presented by Farrell (1957), Which was later developed by Charnes *et al.* (1978). Data envelopment analysis (DEA) is the most common non-parametric model in measuring banking efficiency. Though these two approaches differ in their assumptions and efficient frontier generation process, the relative performance of these models over each other is not clearly recognized. Few key comparative research results are discussed in the next paragraph.

Casu and Girardone (2006) have evaluated the cost efficiency, profit and productivity changes in Italian financial conglomerates during the 1990s using both parametric and nonparametric models i.e. stochastic frontier approach (SFA), distribution-free approach and data envelopment analysis (DEA). In this study, both parametric and non-parametric methods have shown similar variation in efficiency levels. Similarly, Resti (1997) has examined the efficiency of European banks using multiple frontier techniques and found a very high degree of correlation between the results estimated by the SFA and DEA approach. Berger and Humphrey (1997) have also found that cost efficiency results are similar for both parametric and non-parametric methods. They have used five different frontier models on the data collected from 130 surveys of financial institutions across 21 countries. Though they have reported that non-parametric methods show lower mean efficiency than parametric method, results are consistent across these two methods.

Past studies are inconclusive regarding the superiority of parametric or non-parametric approach. Moreover, as discussed above, many scholars found that these approaches generate indifferent results. Therefore, this study opts to use stochastic frontier analysis approach, which is parametric in nature, rather fetching unnecessary operational complicacy. Before proceeding to the discussion on operationalization of stochastic frontier approach, it is important to discuss the choice of banking function process for this study as selection of variables and models are highly dependent on this.

Generally, production and intermediation approaches are the most well-known and common approaches in explaining the banking function process (Mohamad *et al.*, 2008). According to *production approach* activities of the banks are considered as the production of services to the depositors and borrowers. Like traditional production factors, banks use capital and labour as an input to produce output such as loans and deposit services. While the *intermediation approach* primarily assumes banks do the intermediation activities by collecting funds and transforming these into loans and other assets. This approach, in fact, complements the production approach as the banks collect funds using labour and capital (inputs) and earn profits from the volume of earning assets (output). Majority of the recent empirical research of banking efficiency are based on this approach that is originally proposed by Sealey and Lindley (1977). Between these two approaches, the intermediation approach probably more appropriate for evaluating the entire financial sector as this approach includes interest and/or funding expenses, which is the significant portion of the total cost (Mohamad *et al.*, 2008). Moreover, this approach is superior for evaluating the profitability of financial institutions since the total cost is needed to minimise, not just production costs, to maximise profits (Iqbal and Molyneux, 2016). The intermediation approach t is used in this study to define the inputs and outputs.

The subsequent crucial questions arise about the choice of input and output variables and the functional form of the model. Selection of variables is a tricky task as many authors propose many ways to define the inputs and outputs for banking sector efficiency (Das and Drine, 2011; Sherman and Gold, 1985). Moreover, a model using multiple banks must produce similar products as trans-log requires non-zero variables (Daglish *et al.*, 2015). Dong (2010) shows that one can use the stochastic process to derive cost efficiency for the banking industry using panel data. He has used five stochastic models to differentiate the efficiency result obtained and to observe the heterogeneity among the banks using the intermediation approach to define the input and output variables. To make cost function linearly homogeneous and normalize total cost and inputs' prices, he has used the price of the physical asset. Fiorentino *et al.* (2006) have also used one stage SFA trans-log cost function to determine the efficiency of German banks. They have argued in favour of intermediation approach rather than the production approach in defining input and output variables. They have used the price of labour to normalize total cost and inputs' prices. Using the same methodology, Aiello and Bonanno (2013) have found high heterogeneity in results when divided banks by size, legal status and area.

In another study, Ngan (2014) has used SFA approach in 45 Vietnam commercial banks from 2007-2012 to measure the cost and profit efficiency. He has used the intermediation process in defining the inputs and outputs and the price of loanable funds to make the cost function homogeneous. The result of this study has shown that cost efficiency differs for bank concentration, bank ownership and mergers. Altunbas *et al.* (2000) have also reported that financial capital has a great effect on overall efficiency and scale economies. Moreover, production cost over time reduced by technical change during the period. Based on these notable applications of SFA and the data availability of the banking sector of Bangladesh, this study has selected several variables those are introduced in the methodology section.

Finally, regarding the functional form of SFA, researchers have mostly used trans-log cost function in determining cost efficiency. Berndt and Chistensen (1973) have proposed the trans-log format of the Cobb-Douglas production function because this form allows making a comparison amongst different empirical results across different banks. For this benefit, this study has also used a trans-log functional form of SFA.

As mentioned earlier, there are only a few literatures exist that uses stochastic analysis to measure the efficiency of Bangladeshi banks. One of the notable research using frontier approach has done by Robin *et al.* (2018), where the authors have looked into the effect of regulation on the cost efficiency during 1983 to 2012. They have found that deregulation improves the cost efficiency, but there is still scope for cost improvement. In another study, Sufian and Kamarudin (2014) have measured the efficiency and returns to scale using Slack Based Data Envelopment Analysis (SB DEA) for the period of 2004-2011. They have found only eight banks were profit efficient and evidence of diseconomies scale in Bangladeshi banking industry. This study is an endeavour to extend the frontier efficiency approach based literature of Bangladeshi banking sector by using recent data and measuring the performance gaps among the bank from the top performing bank.

3. METHODOLOGY AND DATA

3.1. Stochastic frontier analysis (SFA) model specifications

The cost efficiency in the Bangladeshi banking sector is determined in this paper by using frontier techniques, to be precise single stage Stochastic Frontier Analysis (SFA) model. In frontier techniques, cost efficiency is measured by how good a firm is performing in contrast to the performance of the top-performing bank, producing the same output under same environment (Berger *et al.*, 2009; Xiaoqing *et al.*, 2007). This means if actual firm producing Q unit at price X and efficient firm producing Q unit at price X*, then cost efficiency can be represented as the ratio of minimal cost (QX*) to actual cost (QX).

$$\text{Cost Efficiency (CE)} = \frac{minimal\ cost}{actual\ cost} = \frac{QX*}{QX}$$

Thus, it implies that it would be possible to produce Q unit with a saving in costs (1-CE)%. The stochastic frontier analysis is a parametric method to measure efficiency, proposed by Aigner *et al.* (1977), Battese and **Corra** (1977) and Meeusen and Van Den Broeck (1977) because one can make a priori assumption about production possibility set and data generation process. Moreover, SFA is a random frontier method that allows random errors to include in the functional form. Therefore, it is referred as a composed error model where the one part representing statistical noise and the other part representing inefficiency. Therefore, the deviation from the frontier occurs not only for inefficiency but also for noise in the data. In SFA, noise follows a symmetric distribution and inefficiency follows a particular one-sided distribution. The equation for stochastic cost functions for panel data is:

$$lnC_{it} = \ln C\left(y_{it,}w_{it}\right) + \varepsilon_{it} = \ln C\ (y_{it,}w_{it}) + \mathrm{v}_{it} + \mathrm{u}_{it}$$

Where C_{it} is the observed total cost for bank i-th at t-th time, y_{it} is the vector of outputs, w_{it} is the vector of inputs, v_{it} is the two-sided noise component, and u_{it} is the nonnegative disturbance which represents the individual firm's deviations from the efficient cost frontier and serves as a proxy for both technical and allocative efficiency. The v-term is for the stochastic nature of the production function and u-term is the inefficiency of the particular bank. Here, the assumption is that both $'\mathrm{v}'$ and $'\mathrm{u}'$ are independent. Furthermore, it is assumed that $'\mathrm{v}'$ follows a normal distribution and $'\mathrm{u}'$ follows half normal distribution or truncated normal distribution.

This study uses five different SFA models to estimate the cost efficiency of Bangladeshi banks. These models are based on transcendental logarithmic (trans-log) cost function introduced by Christensen *et al.* (1973), which is the most used functional form in the bank efficiency literature. Further, intermediation approach introduced by Sealey and Lindley (1977) is used to define the input and output variables of the models. Where, input variables are the price of labour, the price of total borrowed funds (deposit) and price of physical assets and the output variables are total loans, other earning assets and not-interest income. Further discussion about these variables is presented in the data and variables section. The first stochastic cost frontier model (Model 1) is:

$$\ln\left(\frac{TC}{W_3}\right) = \beta_0 + \sum_{i=1}^{3}\beta_i\, ln(Q_i) + \sum_{m=1}^{2}\chi_i\, ln\left(\frac{W_m}{W_3}\right) + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\varphi_{ij}\, ln(Q_i)\, ln\left(Q_j\right) +$$
$$\frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\eta_{mn}\, ln\left(\frac{W_m}{W_3}\right) ln\left(\frac{W_n}{W_3}\right) + \sum_{i=1}^{3}\sum_{m=1}^{2}\iota_{im}\, ln(Q_i)\, ln\left(\frac{W_m}{W_3}\right) + u_{it} + v_{it}$$

Here, $\ln(TC)$- is the logarithm of the total costs including both operating costs and financial costs for the bank. Q- are the three outputs, which are total loans, other earning assets (interbank loans, investments) and non-interest income (net fees and commissions). W- are the three inputs those are, W_1-is the price of borrowed funds (Total interest expenses/Total borrowed funds), W_2-is the price of physical capital (Other operating expenses/ Book value of fixed assets) and W_3-is the price of labour (Personal expenses/ No. of employees). This Model 1 has used the last input price W_3 in all other input variables to make the cost function linearly homogeneous, by dividing total cost and input prices with W_3. $\beta,\ \chi,\ \varphi,\ \eta\ and\ \iota$ are the parameters to be estimated. Further, to make the second order parameters to be symmetric, the standard symmetric ($\varphi_{ij} = \varphi_{ji}\ and\ \eta_{mn} = \eta_{nm}$) restrictions have applied to the cost model. In addition, the u_{it} is a half normal distribution term that capture the effects of cost inefficiency, which represents the individual firm's deviations from the efficient cost frontier and v_{it} is representing the noise and a two-sided normal disturbance term.

From the above model, cost efficiency score can be estimated through this formula:

$$CE_{it} = E[\exp(-u_{it})\,|\varepsilon_{it}] = [\frac{1-\Phi(\sigma_* - \varepsilon_{it}\gamma/\sigma_*)}{1-\Phi(-\,\varepsilon_{it}/\sigma_*)}.\exp(-\varepsilon_{it}\gamma + \frac{1}{2}\sigma_*)$$

Here,
Φ = standard normal cumulative distribution function
$\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$, $\sigma_* = \sigma_v^2 \sigma_u^2 / \sigma^2$ and $\gamma = \sigma_u^2/\sigma^2$

γ = must lie between zero and one. A value of one is explained as cost inefficiency and a value of zero is explained as pure noise.

This paper has used maximum likelihood techniques to obtain the parameters and the two error components. The second stochastic cost frontier model (Model 2) keeps the equation for total cost is same as Model 1, except the inefficiency term u_{it}, that is no longer assumed a half normal distribution rather a truncated normal distribution. Therefore, the cost efficiency formula for Model 2 is:

$$CE_{it} = E[exp(-u_{it})|\varepsilon_{it}]$$
$$= [\frac{1-\Phi(\sigma_* - (-\sigma_u^2 \varepsilon_{it} + \mu\sigma_v^2)/\sigma\sigma_*)}{1-\Phi(-\sigma_u^2\varepsilon_{it} + \mu\sigma_v^2/\sigma\sigma_*)} . \exp(-\frac{-\sigma_u^2\varepsilon_{it} + \mu\sigma_v^2}{\sigma} + \frac{1}{2}\sigma_*)]$$

In the next phase, the Model 2 is extended with some control variables to see the influence of heterogeneity. After adding three control variables- equity capital, the level of non-performing loans and a time trend- Model 3 for measuring cost efficiency is as follows:

$$\ln\left(\frac{TC}{W_3}\right) = M2 + \sum_{k=1}^{3} \rho_k \ln Z_k + \frac{1}{2} \sum_{r=1}^{3}\sum_{s=1}^{3} \xi_{rs} \ln(Z_r) \ln(Z_s) + \sum_{k=1}^{3}\sum_{i=1}^{3} \psi_{ki} \ln(Z_k) \ln(Q_i) + \sum_{k=1}^{3}\sum_{m=1}^{2} \theta_{km} \ln(Z_k) \ln\left(\frac{W_m}{W_3}\right)$$

Here,
$M2$ = Model 2
Z = level of equity capital, level of nonperforming loans and time trend.
$\xi_{rs} = \xi_{sr}$ restriction is imposed to ensure standard symmetry.

Again, to see the difference between banks cost efficiency due to the pattern of ownership, bank size, stock market listing and market share, some environmental variables are introduced and therefore, the fourth model of stochastic cost frontier (Model 4) is as follows:

$$\ln\left(\frac{TC}{W_3}\right) = M3 + \delta_1' \, STATE_{it} + \delta_2' \, Conventional\ Commercial\ Bank_{\mathrm{it}} + \delta_3' \, \mathrm{SIZE_{it}} + \delta_4' \, \mathrm{LIST_{it}} + \delta_5' \, \mathrm{HHI_{it}} + \delta_6' \, \mathrm{MS_{it}}$$

Here,
$M3$ = Model 3
$STATE$ = Dummy variable for state-owned banks (0 for the privately owned banks)
$Conventional\ Commercial\ Bank$ = Dummy variable for conventional commercial banks (0 for Islami Sariah banks)
$SIZE$ = Natural logarithm of total assets
$LIST$ = Dummy variable for stock exchange listed banks
HHI = Sum of squared market share of all banks (Herfindahl-Hirschman Index)
MS = Bank assets to total assets of all banks.
The final Model (Model 5) is based on the assumption provided by Battese and Coelli (1995) that environmental variables can be used in the inefficiency terms. Therefore, Model 5 is the same as Model 3 except the inefficiency term u_{it} now looks like as:

$$u_{it} = \delta_0 + \delta_1 \mathrm{STATE_{it}} + \delta_2 Conventional\ Commercial\ Bank_{\mathrm{it}} + \delta_3 \mathrm{SIZE_{it}} + \delta_4 \mathrm{LIST_{it}} + \delta_5 \mathrm{HHI_t} + \delta_6 \mathrm{MS_{it}}$$

3.2. Data and variables

This study uses balanced panel data consists of 35 banks in Bangladesh over the period of 2011 to 2015 and totals 175 observations. The sample of 35 banks consists of six state-owned banks, seven Islamic Sariah based commercial banks and 22 conventional commercial banks (Private Commercial Banks PCBs). Though there are 57 banks are operating in Bangladesh presently, this study uses 35 banks due to unavailability of sufficient information to measure the cost efficiency of foreign banks, specialized banks and some commercial banks. In addition, this study excludes banks who have started their operation after 2011 due to high start-up cost could make a misleading estimation of overall cost efficiency. At the end of 2015, this sample of 35 banks has collectively owned 88.13% of total assets of the Bangladeshi banking sector.

The data collected from the financial statements are mainly categorized into dependent variable, input variables and output variables. The dependent variable is the total cost (TC), which is comprised of interest paid on total deposits plus borrowings, salaries and allowances, and other operating expenses. By following the intermediation approach proposed by Sealey and Lindley (1977), this study has used three input and three output variables. Input variables are the price of borrowed funds, the price of physical capital and price of labour. The first input variable- price of borrowed funds (W_1)- is calculated by dividing total interest expenses by the total borrowed funds. Here, total borrowed fund is the sum of total deposits, which includes current deposits, saving deposit, fixed deposits, deposits from the central bank, financial institutions and agents and other borrowed funds, which includes borrowings from other banks, interbank funds, and short and long-term bonds. The second input variable- price of physical asset (W_2)- is obtained by dividing other operating expenses with the depreciation-adjusted book value of fixed assets. The third input variable- price of labour (W_3)- is estimated by dividing personal expenses with the number of employees. Above mentioned method for estimating input prices was proposed by Coelli *et al.* (2005).

Again this study has used three output variables namely total loans, other earning assets and non-interest income. The first output variable, total loans (Q_1) includes short, medium and long-term customer loans, cash credits, bills purchased and discounted, and overdrafts but exclude loan loss reserves. The second output variable, total other earning assets (Q_2) includes balance with other banks and financial institutions, money at call and on short notice, investments, trading securities, and balance with Bangladesh bank. The third output variable, non-interest income (Q_3) includes fees and commissions from exchange and brokerage, gains from investment and other operating income.

Summary statistics of dependent-, input- and output-variables are presented in Table 1. Here, the average total cost among the sample banks is BDT[1] 15,776 million, with the standard deviation of BDT 10,091 million and ranges from BDT 874 million to BDT 60,751 million. This large range indicates that there are significant differences exist among the sample banks. Therefore, together with the input and output variables, some control and environmental variables are added to the SFA models to capture the heterogeneity exist among the banks and in the environmental condition.

Table 1: Descriptive statistics of the output and input variables

Variable	Description	Mean	St. Dev	Min	Max
TC	Total Cost*	15776	10091	874	60751
$\mathbf{Q_1}$	Total loans*	125003	86031	9189	530195
$\mathbf{Q_2}$	Total other earning assets*	75105	88856	2574	646746
$\mathbf{Q_3}$	Non-Interest income*	5613	5572	70	37089
$\mathbf{W_1}$	Price of borrowed funds	0.0711	0.0165	0.0191	0.1016
$\mathbf{W_2}$	Price of physical capital	0.1187	0.1125	0.0052	0.7759
$\mathbf{W_3}$	Price of labour	0.7281	0.2523	0.3007	1.6360

*Unit: in million Bangladeshi Taka (BDT)

[1] Currency of Bangladesh

The control variables are the level of equity capital, the level of nonperforming loans and time trend. The first control variable, level of equity (Z_1) is collected from the balance sheet of the respective bank. It is used to measure the risk preferences among sample banks. The second control variable, level of non-performing loans (Z_2) is used to measure the quality of outputs and proxy for the off-balance sheet items. The third variable, time trend (Z_3) is defined as follows: T=1 for 2011, T=2 for 2012, T=3 for 2013, T=4 for 2014 and T=5 for 2015. This time trend work as a proxy for technical progress over the period from 2011-2015.

Furthermore, the environmental variables are the Banks' ownership structure, Banks' size, Herfindahl-Hirschman Index (HHI) and the Market structure. Bank ownership structure (E_1&E_2) is the dummy variable taken for state banks, Islamic Sharia banks and conventional commercial banks. Bank size (E_3) is the natural logarithm of total assets. The HHI (E_4) is used as the proxy for market concentration, which is calculated by the sum of squared market share of all banks. Market structure (E_5) is measured by the ratio of individual bank's assets to the total assets of all banks. Finally, dummy variable (E_6) is used for the stock market listing status of the respective bank. Table 2 shows the summary statistics of the control and environmental variables across 35 banks from 2011-15. The dummy variable for Islamic sharia banks is omitted from the models, so the constant coefficient will show the effects of Islamic banks.

Table 2: Descriptive statistics of the control and environmental variables

Variable	Description	Mean	St. Dev	Min	Max
Z_1	Equity*	16700	10648	4500	59579
Z_2	Nonperforming loans*	10699	18023	751	125975
Z_3	Time trend	3	1.418		
E_1	Dummy variable for state-owned banks	0.1714	0.3780		
Omitted	Dummy variable for Islamic sharia banks (as a reference group)	0.20	0.4011		
E_2	Dummy variable for conventional commercial banks	0.6286	0.4846		
E_3	Log of total bank assets	5.2048	0.3138	4.1056	6.0112
E_4	Herfindahl-Hirschman index (HHI)	0.0369	0.0016	0.0348	0.0396
E_5	Asset market share	0.0254	0.0203	0.0012	0.1183
E_6	Dummy variable for listed banks	0.8571	0.3509		

*Unit: in million Bangladeshi Taka (BDT)

4. EMPIRICAL RESULTS

4.1. Cost frontier estimates

The five trans-log SFA model describe in the previous chapter are estimated with the computer program named FRONTIER 4.1 written by Coelli (1996). All of the stochastic frontier models are estimated using maximum likelihood techniques. The maximum likelihood parameter estimates for the five models are given below in Table 3, 4 and 5. Model 1 assumes that efficiency is a half-normal distribution and only contains input and output variables, which is the base model for the other models. In Model 2, it is assumed that the efficiency terms is a truncated normal distribution. Model 3 incorporated three control variables but the efficiency terms assumption is as like Model 2. In Model 4, three environmental variables are added to capture the effects of heterogeneity across the sample banks. In Model 5, the environmental variables are used in the inefficiency term as explanatory variables.

Table 3: Maximum likelihood parameter estimates for stochastic cost frontier models

Variables	*Parameter*	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	β_0	3.4277**	3.2117**	6.4303***	11.1802***	7.4423***
lnQ1	β_1	0.9944***	1.0400***	0.6430*	-0.0436	-0.3694
lnQ2	β_2	-0.6844	-0.687	-0.7914	-1.0119	0.2096
lnQ3	β_3	0.1135	0.1048	-0.1398	-0.2407	-0.2597
ln(W1/W3)	χ_1	0.4030*	0.4132*	0.3739	0.0568	-0.0169
ln(W2/W3)	χ_2	0.0799	0.0793	-0.3074	-0.3655	0.3393**
0.5lnQ1lnQ1	φ_{11}	0.1475**	0.1344**	0.2540***	0.4172***	0.5879***
lnQ1lnQ2	φ_{12}	-0.1966	-0.1881	-0.3827	-0.4429	-0.5301
lnQ1lnQ3	φ_{13}	0.057	0.0589*	0.0496	0.0413	-0.0631
0.5lnQ2lnQ2	φ_{22}	0.3333***	0.3287***	0.2548**	0.3653**	0.3085**
lnQ2lnQ3	φ_{23}	-0.0817	-0.0873	0.0425	0.0415	0.1621**
0.5lnQ3lnQ3	φ_{33}	0.0131	0.0189	-0.0182	-0.0193	0.0309
0.5ln(W1/W3)ln(W1/W3)	η_{11}	0.1774***	0.1755***	0.0431	0.0476	0.1912**
ln(W1/W3)ln(W2/W3)	η_{12}	-0.0242	-0.0239	-0.0528	-0.0649	-0.0818
0.5ln(W2/W3)ln(W2/W3)	η_{22}	-0.0441	-0.045	-0.0189	-0.0182	0.0245**
lnQ1ln(W1/W3)	ι_{11}	0.2053***	0.2055***	0.1691***	0.1870***	0.3299***
lnQ1ln(W2/W3)	ι_{12}	-0.0311	-0.0305	-0.0314	-0.0415	-0.1593
lnQ2ln(W1/W3)	ι_{21}	-0.1543	-0.1532	0.0194	0.027	-0.0162
lnQ2ln(W2/W3)	ι_{22}	0.0049	0.0044	0.0616***	0.0706***	0.0548**
lnQ3ln(W1/W3)	ι_{31}	0.0081	0.0052	-0.0828	-0.0894	-0.1618
lnQ3ln(W2/W3)	ι_{32}	0.0105	0.0098	-0.0089	-0.0043	0.1237***

***Source:** Authors' estimation
Note: ***, ** and * indicate 1%, 5% and 10% significance levels respectively

Table 4: Maximum likelihood parameter estimates for stochastic cost frontier models (Continued with Control variables)

Variables Control variables	*Parameter*	Model 1	Model 2	Model 3	Model 4	Model 5
lnZ1	ρ_1	-	-	-0.5288	-0.5771	-1.183
lnZ2	ρ_2	-	-	0.6307***	0.7299***	1.3312***
T	ρ_3	-	-	-0.2152	0.0386	0.1484
0.5lnZ1lnZ1	ξ_{11}	-	-	-0.196	-0.1816	-0.167
lnZ1lnZ2	ξ_{12}	-	-	-0.1053	-0.0993	-0.0525
lnZ1T	ξ_{13}	-	-	-0.0265	-0.025	-0.0435
0.5lnZ2lnZ2	ξ_{22}	-	-	0.0006	0.0176	0.019
lnZ2T	ξ_{23}	-	-	0.0036	-0.0051	0.0488
0.5lnZ3T	ξ_{33}	-	-	-0.0071	0.0108	-0.0018
lnZ1lnQ1	ψ_{11}	-	-	0.0824**	0.0545	0.0935***
lnZ1lnQ2	ψ_{12}	-	-	0.3032***	0.314***	0.3012***
lnZ1lnQ3	ψ_{13}	-	-	-0.1326	-0.1237	-0.1738
lnZ2lnQ1	ψ_{21}	-	-	0.0249	0.0199	-0.013
lnZ2lnQ2	ψ_{22}	-	-	-0.0302	-0.062	-0.1276
lnZ2lnQ3	ψ_{23}	-	-	0.0443**	0.0584**	0.0641***
TlnQ1	ψ_{31}	-	-	0.0794***	0.062*	0.0355**
TlnQ2	ψ_{32}	-	-	-0.0089	-0.0104	-0.0221
TlnQ3	ψ_{33}	-	-	-0.0714	-0.0722	-0.0573
lnZ1ln(W1/W3)	θ_{11}	-	-	-0.0994	-0.0923	-0.1847
lnZ1ln(W2/W3)	θ_{12}	-	-	0.0055	0.0082	0.0433***
lnZ2ln(W1/W3)	θ_{21}	-	-	-0.0008	-0.0012	0.069*
lnZ2ln(W2/W3)	θ_{22}	-	-	-0.0148	-0.0149	-0.0737

Tln(W1/W3)	θ_{31}	-	-	-0.0862	-0.0887	-0.0698
Tln(W2/W3)	θ_{32}	-	-	0.0038	-0.0045	0.0307*

Source: Authors' estimation
Note: ***, ** and * indicate 1%, 5% and 10% significance levels respectively

Table 5: Maximum likelihood parameter estimates for stochastic cost frontier models (Continued with Environmental variables)

Variables	*Parameter*	Model 1	Model 2	Model 3	Model 4	Model 5
Environmental variables						
State-owned banks	δ'_1	-	-	-	0.1521***	-
Conventional commercial bank	δ'_2	-	-	-	0.0119	-
Size	δ'_3	-	-	-	-0.3239	-
HHI	δ'_4	-	-	-	12.1804***	-
Market share	δ'_5	-	-	-	-1.41	-
Listed	δ'_6	-	-	-	0.2547***	-
Intercept	δ_0	-	-	-	-	-0.1258
State-owned banks	δ_1	-	-	-	-	0.1188***
Conventional commercial bank	δ_2	-	-	-	-	0.1651***
Size	δ_3	-	-	-	-	-0.0583
HHI	δ_4	-	-	-	-	-2.9034
Market share	δ_5	-	-	-	-	3.299***
Listed	δ_6	-	-	-	-	0.4465**

Source: Authors' estimation
Note: ***, ** and * indicate 1%, 5% and 10% significance levels respectively

From Table 3, total loans (Q1) coefficient in Model 1 suggests that without any control and environmental variables 1% increase in total loans will increase total cost by 0.99%, which is 1.04% in case of Model 2 and 0.64% in Model 3. In Model 4 & 5 these coefficients are negative but statistically insignificant. Coefficient parameters of Model 1 and 2 is quite high compared to other countries. Dong (2010) has found that 1 % increase in the amount of total loans will increase total cost by 0.64% in his analysis on the Chinese banking sector. Further, Cavallo and Rossi (2002) have found 1% increase in total loans will increase 0.75% in total cost on European banking system. This finding is expected for Bangladeshi banks. Due to the high probability of failing to repay loan and diseconomies of scale, banks must spend significant processing cost, legal adviser fees, supervision fees and higher operating costs.

Further, In Model 5, the other earning assets (Q2) coefficient suggests that 1% increase in other earning assets will increase total cost by 0.21%. All other models show a negative relationship between Q2 and dependent variable. Non-interest income (Q3) coefficient in Model 1 suggests that 1% increase in non-interest income will increase total cost by 0.11% and 0.10% in Model 2. From the output coefficients, it seems that total loans have more significant effect on total costs than other earning assets and non-interest income.

The price of borrowed funds (W1) coefficient in Model 1 suggests that 1% increase in the price of borrowed funds will increase total cost by 0.40%, and for Model 2, that is 0.41%. The price of physical capital (W2) coefficient in Model 5 suggests that 1% increase in the price of physical capital will increase total cost by 0.34%. Again, Dong (2010) have found 1 % increase in the price of physical capital will increase the total cost by 0.11% in the Chinese banking sector. This finding supports that Bangladeshi banks are operating at diseconomies of scale compare to Chinese banking sector.

From Table 4, the coefficient of the control variable- level of equity (Z1) - shows a negative relation with total cost in Model 3 to Model 5, which suggest that increasing level of equity does not increase burden in total cost. Non-performing loans (Z2) coefficient is positive and significant in Model 3, 4 and 5. The non-performing loan has a significant effect on increasing total cost of Bangladeshi banking sector. The time trend (T) coefficient suggests that technology does not have any significant effect in reducing total costs. The coefficient of equity level and total loans suggests that 1% increase in total loans and equity level will increase total costs by about 0.05% to 0.09%, in different models. In addition, the coefficient of levels of equity and other earning assets shows a significant relationship with the total costs.

From Table 5, in case of Model 4, the coefficient of the environmental variables i.e. state-owned banks and conventional commercial bank suggests that state-owned banks have added more total costs than a conventional commercial bank. If a sample bank is conventional commercial bank total costs increase by 0.01%, but if it is a state-owned bank total costs increase by 0.15%. In Model 5, where environmental variables work as an explanatory variable in the inefficiency term, coefficient shows different explanation about state-owned banks and conventional commercial banks. The coefficients show that both state-owned banks and conventional commercial banks are added more total costs than Islamic sharia banks.

4.2. Key estimation results

Table 6 summarizes some key estimation results obtained from stochastic models using FRONTIER 4.1 (Coelli, 1996). These key estimation results determine the shape of the stochastic frontier. The μ parameter is not significantly different from zero, which tells that banks are mostly in efficient frontier. If the value of γ is zero, the deviation from efficient frontier will be for pure noise. Nevertheless, the γ parameter is statistically significant and different from zero, which tells that variation in total costs due to the inefficiency among banks. The $\sigma^2$is significant in all models except Model 2, which states that Model 2 may be biased due to truncated normal distribution. Furthermore, the log likelihood is maximum in Model 3 and Model 4.

Table 6: Key estimation results

Model Specification	μ	γ	σ^2	Log-likelihood	LR test of the one-sided error
Model 1	0	0.9696***	0.0418***	268.6324	142.0797
Model 2	-0.6585	0.9903***	0.1327	269.0503	142.9157
Model 3	-0.6730	0.9941***	0.1139***	320.5697	151.6147
Model 4	-0.5446	0.9907	0.0748***	323.4735	91.1640
Model 5	-0.1258	1.0000***	0.0041***	281.8321	74.1395

Source: Authors' estimation
Note: ***, ** and * indicate 1%, 5% and 10% significance levels respectively

4.3. Correlation between banks' rank order estimation among different SFA models

This correlation test of banks' rank order is done to know whether different model shows different banks efficient or the models represent similar interpretation about efficient banks. From the correlation coefficients of Model 1, 2, 3 and 4 exhibited in Table 7 it can be concluded that all models have picked the same set of banks as efficient and as problematic. The correlation between Model 1 and Model 2 is 0.99, which suggest a similar bank ranking order in normal and truncated efficiency distribution. Model 3 and Model 4 also show a significantly high degree of correlation between them. This suggests that introducing environmental variables as explanatory variables has a very small effect on bank ranking order. However, the correlation coefficient of Model 5 suggests a significant difference in ranking order among the sample banks with other models. This difference may arise due to the existence of heterogeneity among sample banks.

Table 7: Correlation between rank order efficiency estimates among different models

	Model 1	Model 2	Model 3	Model 4	Model 5
Model 1	1.0000	0.9974	0.8287	0.8676	0.4872
Model 2	0.9974	1.0000	0.8627	0.8847	0.4651
Model 3	0.8287	0.8627	1.0000	0.8867	0.3508
Model 4	0.8676	0.8847	0.8867	1.0000	0.5502
Model 5	0.4872	0.4651	0.3508	0.5502	1.0000

Source: Authors' estimation

4.4. Identification of good and bad banks across different models

Table 8 shows ten top performing banks in terms of cost efficiency in different stochastic frontier models. Dutch-Bangla Bank (DBBL) is in first place in Model 1, 4 and 5 and second place in Model 2 and 3. ICB Islamic Bank is in first place in Model 2 and 3 and in third place in Model 1 and 4. Which suggest that the banks' cost efficiency across different models show consistent results. However, due to different characteristics of different models, there is small variation arise in cost efficiency estimation. The average efficiency estimates of all banks are shown in the Appendix A. On the other hand, Table 9 exhibits the ten least performing banks in terms of cost efficiency in different SFA models. Model 1 and 2 depict quite consistent ranking of the worst performing banks. But Model 3, 4 and 5 rank the worst banks in pretty different ways, which indicates incorporation of control and environmental variables affect the model very differently. In other words, ill-performing banks are doing poor in different areas.

Table 8: Top 10 Best performing banks across models

Model 1	Model 2	Model 3	Model 4	Model 5
Dutch-Bangla Bank	ICB Islamic Bank	ICB Islamic Bank	Dutch-Bangla Bank	Dutch-Bangla Bank
BRAC Bank	Dutch-Bangla Bank	Dutch-Bangla Bank	BRAC Bank	BRAC Bank
ICB Islamic Bank	BRAC Bank	BRAC Bank	ICB Islamic Bank	Pubali Bank
Uttara Bank	Uttara Bank	Uttara Bank	Uttara Bank	The City Bank
Pubali Bank	Pubali Bank	Pubali Bank	Pubali Bank	Premier Bank
Rupali Bank	Rupali Bank	Rupali Bank	Mutual Trust Bank	Southeast Bank
Agrani Bank	Agrani Bank	Mutual Trust Bank	Premier Bank	Mutual Trust Bank
Sonali Bank	Islami Bank Bangladesh	First Security Islami Bank	The City Bank	IFIC Bank
Islami Bank Bangladesh	Sonali Bank	Islami Bank Bangladesh	IFIC Bank	Mercantile Bank
National Bank	Premier Bank	Premier Bank	First Security Islami Bank	Islami Bank Bangladesh

Source: Authors' estimation

Table 9: Top 10 Worst performing banks across models

Model 1	Model 2	Model 3	Model 4	Model 5
BASIC Bank	BASIC Bank	Al-Arafah Islami Bank	AB Bank	Janata Bank
BDBL	BDBL	Dhaka Bank	Al-Arafah Islami Bank	Sonali Bank
Standard Bank	Standard Bank	Standard Bank	Dhaka Bank	BDBL

Al-Arafah Islami Bank	Al-Arafah Islami Bank	Bank Asia	Standard Bank	BASIC Bank
Social Islami Bank	Dhaka Bank	AB Bank	Bank Asia	Al-Arafah Islami Bank
Dhaka Bank	Social Islami Bank	BDBL	BDBL	Shahjalal Islami Bank
Shahjalal Islami Bank	Bank Asia	Janata Bank	Sonali Bank	EXIM Bank
First Security Islami Bank	Shahjalal Islami Bank	BASIC Bank	Southeast Bank	Social Islami Bank
Bank Asia	First Security Islami Bank	Southeast Bank	Rupali Bank	Agrani Bank
Eastern Bank	Eastern Bank	Sonali Bank	Janata Bank	Trust Bank

Source: Authors' estimation

4.5. Descriptive statistics of cost efficiency by banks' ownership status

Table 10 exhibits the cost efficiency levels of the different bank by types. The mean efficiency of state-owned banks is 72.61%, the conventional commercial bank is 72.68% and Islamic sharia banks is 71.13% in Model 1. Likewise, the mean efficiency of three types of banks from SFA models 2 to 5 are presented in Table 10. Though there is no significant variation in cost efficiency by bank types, state-owned banks are lagging behind in terms of cost efficiency from the conventional commercial banks and Islamic sharia banks. Conventional commercial banks have the highest efficiency score (Model 5), whereas state-owned banks have the lowest (Model 3). This finding conforms with the findings of the previous studies conducted by Fries and Taci (2005) in Eastern Europe, Bonin *et al.* (2005) in 11 transition countries, and Wang *et al.* (2005) and Yao *et al.* (2007) in Chinese Economy. On the contrary, Bhattacharyya *et al.* (1997) have found that state-owned commercial banks are more efficient than private commercial banks in their analysis on Indian banking sector.

Table 10: Descriptive statistics of cost efficiency by different bank types

Bank Types		**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
State owned banks N=6	Mean	0.7261	0.7177	0.5347	0.7187	0.8248
	Standard Deviation	0.0833	0.0758	0.0371	0.0337	0.0359
Conventional commercial banks (PCBs) N=22	Mean	0.7268	0.7194	0.5694	0.7675	0.9142
	Standard Deviation	0.0996	0.1003	0.0669	0.0854	0.0512
Islamic sharia banks N=7	Mean	0.7113	0.7117	0.6096	0.7614	0.845
	Standard Deviation	0.126	0.1366	0.1765	0.1025	0.0341

Source: Authors' estimation

4.6. Stability of cost efficiency over time periods

The mean cost efficiency from 2011 to 2015 across different models are exhibited in Table 11. The mean efficiency estimation is increasing from year to year. Which suggest that banks are trying to reduce their cost and hence the efficiency score is becoming better year by year. Moreover, year to year increment of efficiency levels is almost same across the models. For example, in Model 1, the mean cost efficiency increases from 2011 to 2012 by (71.49% - 72.17%) 0.68%. Again in Model 2, the mean cost efficiency increases from 2011 to 2012 by (70.92% - 71.62%) 0.70%. Model 3, 4 and 5 also show almost same percentage increase from 2011 to 2012. This result suggests that all models are influenced by same technological advancement and banks are following homogeneous banking process.

Table 11: Mean cost efficiency from 2011-2015 across different models

	2011	2012	2013	2014	2015
Model 1	0.7149	0.7217	0.7284	0.7349	0.7414
Model 2	0.7092	0.7162	0.7230	0.7298	0.7364
Model 3	0.5778	0.5823	0.5868	0.5912	0.5956
Model 4	0.6682	0.6782	0.6880	0.6975	0.7069
Model 5	0.8182	0.8475	0.9087	0.9013	0.8215

Source: Authors' estimation

5. FINDINGS AND CONCLUSION

This paper examines the cost efficiency in the Bangladeshi banking sector using stochastic frontier analysis from 2011-15. The sample consists of 35 banks and the data is balanced panel data, collected from the Annual Reports of respective banks. This study employs single stage stochastic frontier model and four additional stochastic frontier models to measure the heterogeneity across the sample banks. Additionally, intermediation approach is used to define the input and output variables for one stage SFA model, and transcendental log transformation is used to construct the SFA cost function. To make the cost function homogeneously independent, input and output variables are divided by the price of labour. This study has also used control and environmental variables in different frontier models to make the results more reliable.

From the results of this study following key issues have been found. First, the overall mean cost efficiency in the Bangladeshi banking sector is 88.50%, using environmental variables in the inefficiency terms, which indicates that Bangladeshi banking sector has the scope and opportunity of further advancement in terms of cost efficiency. Second, non-performing loans decrease the cost efficiency score in the Bangladeshi banking sector significantly. Third, state-owned banks are less cost-efficient than conventional (private) commercial banks and Islamic sharia banks.

Funding: This study received no specific financial support.
Competing Interests: The authors declared that they have no conflict of interests.
Contributors/Acknowledgement: All authors participated equally in designing and estimation of current research.

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Appendix

Appendix A: Average cost efficiency of banks by different models

Bank Name	Model 1	Model 2	Model 3	Model 4	Model 5
AB Bank Limited	0.6702	0.6612	0.5102	0.6899	0.8440
Agrani Bank Ltd.	0.7888	0.7746	0.5512	0.7735	0.8397
Al-Arafah Islami Bank Limited	0.6299	0.6281	0.5084	0.6901	0.8202
Bank Asia	0.6494	0.6402	0.5099	0.6934	0.8664
BASIC Bank	0.6205	0.6219	0.5139	0.7483	0.8107
BDBL	0.6218	0.6241	0.5104	0.6935	0.8048
BRAC Bank Ltd.	0.9921	0.9879	0.7394	0.9910	0.9946
Dhaka Bank Ltd.	0.6393	0.6328	0.5097	0.6911	0.8595
Dutch-Bangla Bank Ltd.	1.0000	0.9960	0.7552	1.0000	1.0000
Eastern Bank Ltd.	0.6567	0.6475	0.5228	0.7218	0.9158
EXIM Bank	0.6646	0.6599	0.5192	0.7036	0.8259
First Security Islami Bank Limited	0.6478	0.6447	0.6001	0.7809	0.8424
ICB Islamic Bank Limited	0.9712	1.0000	1.0000	0.9817	0.8493
IFIC Bank Ltd.	0.7306	0.7237	0.5852	0.7879	0.9414
Islami Bank Bangladesh Limited	0.7827	0.7733	0.5979	0.7567	0.9187
Jamuna Bank Ltd.	0.7053	0.6974	0.5487	0.7434	0.8982
Janata Bank Ltd.	0.7442	0.7300	0.5115	0.7014	0.8007
Mercantile Bank Ltd.	0.6843	0.6745	0.5396	0.7336	0.9336
Mutual Trust Bank Ltd.	0.7025	0.6970	0.6023	0.8089	0.9428
National Bank Ltd.	0.7528	0.7419	0.5732	0.7620	0.9061
National Credit and Commerce Bank Ltd.	0.6574	0.6511	0.5339	0.7280	0.8590
One Bank Limited	0.6788	0.6767	0.5407	0.7230	0.8504
Premier Bank Ltd.	0.7528	0.7475	0.5970	0.8052	0.9759
Prime Bank Ltd.	0.6910	0.6777	0.5257	0.7093	0.8909
Pubali Bank Ltd.	0.8018	0.7924	0.6081	0.8103	0.9783
Rupali Bank Ltd.	0.7955	0.7864	0.6036	0.6985	0.8916
Shahjalal Islami Bank Limited	0.6464	0.6417	0.5243	0.7124	0.8237
Social Islami Bank Limited	0.6365	0.6339	0.5175	0.7043	0.8349
Sonali Bank Ltd.	0.7857	0.7693	0.5174	0.6972	0.8011
Southeast Bank Ltd.	0.6640	0.6514	0.5148	0.6973	0.9519
Standard Bank Limited	0.6280	0.6266	0.5098	0.6914	0.8648
The City Bank Ltd.	0.7311	0.7223	0.5832	0.7941	0.9766
Trust Bank Limited	0.6822	0.6799	0.5621	0.7502	0.8413
United Commercial Bank Ltd.	0.7078	0.6979	0.5457	0.7331	0.9182
Uttara Bank Limited	0.8117	0.8033	0.6098	0.8201	0.9027