Volume 14 Number 1 & 2 December 2022

Article History
Received 21 August 2022
Accepted 10 April 2023
DOI: https://doi.org/10.57143/JBFS130104

Cost and Profit Efficiency Analysis of Commercial Banks in Bangladesh Using Stochastic Frontier Approach

Md. Asif Nawaz[1]
Tasneema Khan[2]

Abstract: This study aims to measure the efficiency of the commercial banks in Bangladesh using the Battese and Coelli (1995) model of Stochastic Frontier Analysis (SFA) approach. This is a widely used one-step model, which allows for the estimation of bank efficiency by taking the inefficiency-effecting exogenous factors into account. Using an unbalanced panel of 287 observations from 32 banks for the period 2011-2020, we found that on average the commercial banks are 91.64% cost-efficient and 79.21% profit-efficient and both cost and profit efficiency decreased during the COVID-19 period. Furthermore, we found that-private banks are more cost and profit efficient than state-owned banks; foreign banks are more profit-efficient but less cost-efficient than domestic banks; banks established between 1991-2000 are more cost-efficient while banks established between 2001-2010 are more profit-efficient when compared to their counterparts; old banks are less profit efficient than the new banks; and finally, expectedly, large banks are found to be more profit-efficient than small banks.

Keywords: Cost Efficiency, Profit Efficiency, Stochastic Frontier Analysis, Commercial banks

1.0 Introduction

A sound, functioning, and efficient banking system is essential for the development of an economy as banks safeguard the public's savings while funding the expansion of trade and commerce. Banks are also dominant in providing financial intermediation services and facilitate the capital formationprocess in an economy (Yildirimand and Philippatos, 2007). For any country's financial system to be stable and its economy to flourish sustainably, banks must operate efficiently. Studies (e.g., Fethi and Pasiouras, 2010) claim that, on one hand, an efficient banking system boosts economic growth, while on the other, bank insolvencies can trigger systemic crises. For this reason, various stakeholders,including regulators, consumers, investors, and the public are concerned about the performance of banks, especially about efficiency that subsequently ensures financial sector's stability. Therefore, researchers and bank supervisors and regulators around the

[1] Corresponding author, Assistant Professor, Department of Banking and Insurance, University of Dhaka, Email: asifnawaj13@du.ac.bd
[2] Assistant Professor, Department of Banking and Insurance, University of Dhaka

world are inclined to analyze bank efficiency, evaluate the efficiency level of different types of banks, and identify the inefficient banks.

Efficiency refers to the ability of banks to convert inputs into financial products and services in relation to the expenses they incur. In several studies, bank efficiency has been measured in terms of cost and profit together with data on country and bank-specific factors that are related to bank efficiency. A comprehensive study on bank efficiency is pioneered by Berger and Mester (1997) who measured the efficiency of the U.S. commercial banks using three efficiency concepts- cost, standard profit, and alternative profit with several measurement techniques. Market-specific, regulatory, and bank-specific aspects were examined as efficiency-determining variables in this study. In several studies, bank-specific characteristics, such as bank size, profitability, capital sufficiency, diversity, liquidity, market share, management, and asset quality have been identified as the determinants of bank efficiency (e.g. Barth et al., 2013; Tecles and Tabak, 2010; Sufian, 2009). Ownership structure has been identified as another key factor in determining bank efficiency considering whether the bank is privately or publicly held, listed or not, domestic or foreign-owned (e.g. Sufian, 2009, Casu and Molyneux, 2003). In other studies, the relationship between bank regulation, supervision, and restrictions with efficiency was also investigated (e.g. Barth et al.,2013; Pasiouras et al., 2009). Alongside, macroeconomic variables such as inflation, GDP growth, and unemployment rate have also been found as determinants of bank efficiency (e. g. Niţoi and Spulbar, 2015; Pasiouras et al., 2009).

Studies have also been conducted to compare bank efficiency among different countries (e.g. Barth et al., 2013; Casu and Molyneux, 2003; DeYoung and Nolle, 1996). The cross-country analyses of bank efficiency of Central and Eastern European countries and South-Eastern European counties are some pioneering ones (see e.g. Fang et al., 2011; Yildirim and Philippatos, 2007). In some other studies, bank efficiency of South Asian countries (Bangladesh, Sri Lanka, India, and Pakistan) were investigated (e.g. Perera et al., 2008). However, regulatory and environmental differences among different countries, inconsistency in data definitions, and distinct country-specific factors made single-country analysis highly valuable as compared to cross-country analysis (Casuand Molyneux, 2003). Hence, many studies further focused on single country analysis, specifically on developed economies such as the U.S., the U.K., Australia, and Germany (e.g. Sturm and Williams, 2004; Fiorentino et al., 2006; Berger and Mester, 1997). These studies, either used SFA and/or DEA approache to estimate the bank efficiencies.

It can be noted from the above-mentioned studies that there have been few studies on the efficiency of banks in emerging economies. Hence, we are attempting to fill this gap by analyzing the bank efficiency of one of the developing economies,

Bangladesh. The reason behind choosing Bangladesh is that the banking industry has a strong hold over Bangladesh's financial sector and there is a lack of a comprehensive research on efficiency of commercial banks in Bangladesh (Banna et al., 2017). We are analyzing the cost and profit efficiency of commercial banks in Bangladesh by using the Stochastic Frontier Analysis (SFA) model. Using an unbalanced panel of 287 observations from 32 commercial banks, the efficiency has been analyzed over a period of 2011-2020. We have compared the efficiency of banks based on cost and profit efficiency, ownership structure, bank size, bank generation and age of doing business, foreign ownership, and efficiency during crisis and non-crisis period.

We found that on average the commercial banks are 91.64% cost-efficient and 79.21% profit-efficient and both cost and profit efficiency decreased during the COVID-19 period. Furthermore, private banks are found to be more cost and profit efficient than state-owned banks; foreign banks are more profit-efficient but less cost-efficient than domestic banks; banks established between 1991-2000 are more cost-efficient while banks established between 2001-2010 are more profit-efficient when compared to their counterparts; old banks are less profit efficient than the new banks; and expectedly, large banks are more profit-efficient than small banks. The result of our study will help bank managers to understand the level of their banks' efficiency and adjust their policies to improve the current state. Alongside, as the regulator and supervisor of the Bangladeshi banking sector, the central bank, can identify poor-performing banks and take different qualitative and/or quantitative measures to improve the efficiency of the banks and make the banking sector more resilient to the shocks of crisis such as COVID-19.

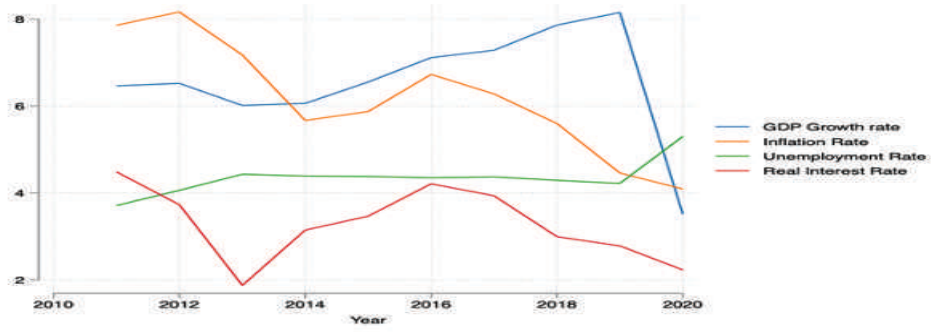
The rest of the paper is structured as follows: Section 2 presents the overview of the Bangladesh economy and the banking industry followed by Section 3 which discusses the prior literature on bank efficiency. Section 4 elaborates the empirical research design and section 5 presents the results. Finally, Section 6 concludes our findings, highlights the policy implications, and indicates the direction of further research.

2.0 Macroeconomic Overview and a Glimpse of the Banking Industry of Bangladesh

Bangladesh presently has an outstanding track record of growth and development despite being one of the poorest countries at the time of its birth in 1971. The nation's incredible tale of progress and poverty eradication is evident as the poverty rate decreased from 43.5% to 14.3% between 1991 and 2016 (World Bank Data, 2022). With the help of a demographic dividend, robust ready-made garment (RMG) exports, remittances, and stable macroeconomic conditions, it has been among the world's fastest-growing economies during the past ten years

(World Bank, 2022). Consequently, Bangladesh attained lower-middle income status in 2015 (World Bank Data, 2022). The COVID-19 pandemic, however, has had a substantial impact on Bangladesh, as well as other nations, limiting economic activity and reversing some of the advances made over the previous ten years. As evident, the GDP growth rate accelerated from 6.46% in 2011 to 8.15% in 2019 but sharply declined to 3.50% in 2020 (World Bank Data, 2022). Bangladesh has been able to maintain a steady unemployment rate with an average of 4.24% from 2011 to 2019 (World Bank Data, 2022). However, the rate increased to 5.3% in 2020. Likewise, Bangladesh has had considerable success in taming inflationary pressure from 2014 and onwards (Monetary Policy Statement, 2021-2022). Despite the global inflationary pressure during COVID-19, Bangladesh has successfully maintained its inflation rate at 4.08% (World Bank Data, 2022). Figure 1 depicts the trend of these macroeconomic determinants of Bangladesh from 2011 to 2020.

Figure 1: Graphical Presentation of the Macroeconomic Condition of Bangladesh



Source: Word Development Indicators World Bank

Bangladesh's economy depends heavily on the banking sector. Currently, 61 banks are operating in Bangladesh of which 6 are state-owned banks, 3 are specialized banks, 9 are foreign private commercial banks, 10 are Islamic banks in private ownership, and the remaining 33 are conventional commercial banks in private ownership (Scheduled Banks Statistics, 2022). Since independence, the banking sector of Bangladesh has grown very rapidly. Table 1 and figure 2 depicts the status of total assets, gross loans, total equity, LLPs, and Profit before taxes of commercial banks in Bangladesh since 2011.

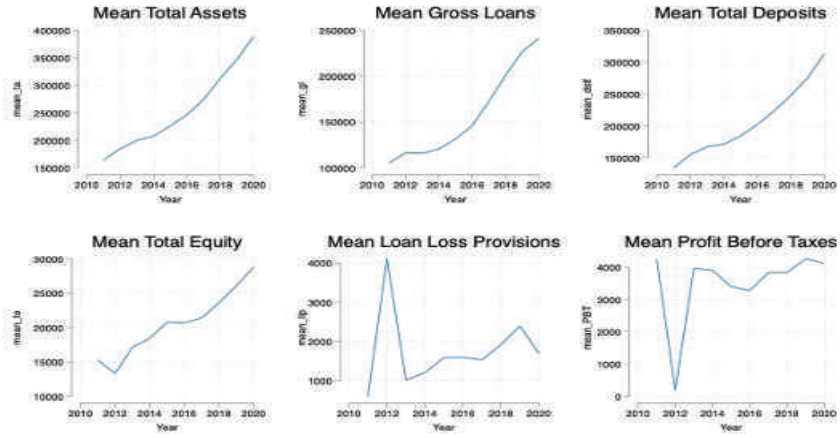
Table 1: Historical Averages of Assets, Loans, Equity, LLPs, and Profit of Banks in Bangladesh *(in million BDT)*

Year	Total Assets	Gross Loans	Total Equity	Loan Loss Provisions	Profit Before Taxes
2011	164157.8	105289.4	15233.64	605.02	4247.65
2012	184639.2	116322.1	13316.95	4105.25	201.67
2013	199944.9	115947.1	17149.65	1018.39	3958.63
2014	207736.3	120636.1	18428.41	1207.73	3903.74
2015	226301.2	131556	20775.53	1592.7	3395.16
2016	246463	146090.1	20687.05	1599.59	3274.43
2017	274389.2	172294.3	21377.88	1530.62	3833.45
2018	312468.6	201152.9	23614.66	1919.9	3835.23
2019	347134.1	226993.5	26077.94	2393.84	4259.12
2020	389110.4	241050	28800.26	1690.41	4115.25

Source: Bank Focus and Authors' own calculation

As evident from Table 1 and Figure 2, the mean total assets, gross loans and total deposits of the banking sector steadily increase over time. As reported by Bangladesh Bank, the increase in total deposits is contributed majorly by the urban deposits (Scheduled Banks Statistics, 2020). The growing gross loan over the years reflects Bangladesh Bank's policy implementation to reach out to the productive sectors in order to achieve economic growth (Monetary Policy Statement, 2020-2021). The average LLPs increased significantly in 2012, but then drastically decreased and stabilized after that. The profitability of the industry experienced a sharp decline in 2012 but recovered well in the next year. However, the COVID-19 pandemic caused a minor drop in the industry's profitability in 2020. Therefore, since the beginning of COVID-19, Bangladesh Bank has been actively stipulating the necessary policy support to lessen its negative economic effects and restore normalcy in all sectors of the economy.

Figure 2: Graphical Presentation of Banking Industry Characteristics of Bangladesh



Source: Bank Focus and authors' own calculation

3.0 Literature Review

Measuring bank performance has been an area of interest for researchers and policy-makers for many years as efficient banking system is crucial for a country's financial stability and long-term economic progress (Barth et al., 2013). Following the pioneering works of Benston (1965) and Bell and Murphy (1968), various empirical studies focused on the performance analysis of depository institutions, particularly the commercial banks (Berger and Mester, 1997). Early studies on bank performance concentrated on the analysis of scale and scope economies using a cost function in which it is implicitly assumed that all banks operate at roughly the same levels of efficiency (Yildirim and Philippatos, 2007). However, academic research on bank performance has turned to frontier efficiency, often known as X-efficiency, which assesses inefficiency as a divergence from the efficient frontier, on which best-practice firms operate (Hasan and Marton, 2003). Since the early 1990s, cost efficiency has gathered increased attention as a measure of bank efficiency (Barth et al., 2013). A lower chance of failure is associated with improved cost-efficiency, suggesting that better risk and cost management are signs of better overall management (Kraft et al., 2006). Therefore, cost optimization and efficiency have become more crucial for commercial banks in the wake of the global financial crisis (Barth et al., 2013). Moreover, the current COVID-19 outbreak calls for rethinking of bank efficiency since the overall costs of banks increased during this pandemic period. Apart from that, profit function is also considered for measuring efficiency in several studies (Berger and Mester, 1997). For certain levels of input and output prices (quantities) and other exogenous market variables, profit efficiency assesses how close a bank is to making the maximum feasible profit as a best-practice firm on the frontier (Yildirim and Philippatos, 2007).

3.1 Measurement of Bank Efficiency

To measure operational efficiency and analyze the cross-sectional drivers of efficiency differentials across banks, the existing literature used a variety of efficiency concepts and measurement methods. In terms of frontier-based efficiency estimation technique, there are both parametric and non-parametric approaches (Sturm and Williams, 2004). Farrell (1957) first established the non-parametric efficiency technique, which has since become frequently employed in the literature on bank efficiency. Among the non-parametric techniques, Data Envelopment Analysis (DEA) is the most common (e.g. Barth et al., 2013; Hauner, 2005). However, the non-parametric approach forbids stochastic error in the analysis, hence all performance deviations from the efficient frontier are attributed to inefficiency (Yildirim, 2002). In contrast, the stochastic or random error in modeling efficiency is taken into account in the parametric approach, which is based on econometric modeling. As a result, when compared to estimates

made using a non-parametric approach, parametric estimates of efficiency are unbiased (Kumbhakar and Lovell, 2003).Therefore, academics have been increasingly interested in parametric approaches such as Stochastic Frontiers Analysis (SFA) approach (e.g. Yildirim and Philippatos, 2007; Kraft et al., 2006; Hasan and Marton, 2003; Miller and Parkhe; 2002). As a branch of parametric approaches, SFA accounts for random errors and systematic differences like heterogeneity among entities within the formulated model. Moreover, SFA formulates a production, cost, revenue, or profit function in relation to the inputs, outputs, and environmental determinants (Kumbhakar and Lovell, 2003).

3.2 Bank Efficiency Studies on Developed Economies

There have been substantial numbers of cross-country and single country studies on bank efficiency, especially on developed economies. Berger and Mester (1997) conducted a comprehensive study on 6000 U.S. commercial banks over 1990-1995 with different efficiency concepts and measurement techniques, the result of which are quite robust. Sturm and Williams (2004) compared the efficiency of foreign-owned banks operating in Australia with that of local banks using Data Envelopment Analysis (DEA), Malmquist Indices and SFA approach. The goal was to see if foreign banks were more efficient than domestic banks between 1988 and 2001 after the deregulation of Australian banking system. Hauner (2005) also adopted DEA approach to measure the cost efficiency, scale efficiency and productivity change between large Australian and German banks. The cost-efficiency of Austrian banks was determined to be significantly lower than that of German banks.

3.3 Bank Efficiency Studies on Developing Economies

Perera et al. (2008) found that the average cost efficiency of Bangladeshi commercial banks was found to be 89.12% during 1997-2004. Miah and Sharmeen (2015) analyzed the relationship among capital, risk and efficiency of conventional and Islamic banks of Bangladesh during 2001-2011, where they found conventional banks to be more cost effective than Islamic banks. Shanmugam and Das (2004) adopted SFA to estimate the technical efficiency of 94 Indian banks during the reform period of 1992–1999 over four categories of banks in respect of ownership, where foreign and state banks are found to be more efficient than the private domestic banks. Thi My Phan et al. (2016) conducted a study on six emerging Asian countries (Bangladesh, India, Philippines, Malaysia, Vietnam and Indonesia) over 2005-2012 to assess the relationship between X-efficiency and market concentration and competition. They found that market concentration positively affects X-efficiency and competition does the opposite. Considering the global financial crisis, Banna et al. (2017) investigated Bangladeshi commercial banks' efficiency by adopting DEA approach and identified whether the crisis had

any impact on their efficiency level. Most recently Nawaz (2021) measured the efficiency of Bangladeshi Islamic banks and analyzed the impact of the qualities of Shariah Supervisory Board members on the cost efficiency of these banks. The author found that there is room for improving cost efficiency of Islamic banks and that the qualities of Shariah Supervisory Board members can play an important role in enhancing the cost efficiency of Bangladeshi Islamic banks.

3.4 Cross-Country Analysis of Bank Efficiency

Miller and Parkhe (2002) conducted the first ever cross-country analysis of bank efficiency, which adopted SFA approach to see if foreign banks are more efficient than host country banks in 14 different economies. Their findings revealed that efficiency of foreign banks is strongly influenced by the competitiveness they face in both home and host country. Using Stochastic Frontier Approach (SFA) and Distribution-Free Approach (DFA), Yildirim and Philippatos (2007) investigated commercial banks' cost and profit efficiency in twelve transition economies of Central and Eastern Europe (CEE) from 1993 to 2000. According to the DFA and the SFA, the average cost efficiency scores for the 12 countries were 72% and 77%, respectively. However, profit efficiency levels were shown to be much lower in comparison to cost efficiency.

3.5 Factors Influencing Bank Efficiency

Economic transition and structural changes of banking sectors set some researchers to measure the efficiency in both developed and developing economies to identify how these factors affect the bank efficiency.

3.5.1. Macroeconomic and Regulatory Changes

Fang et al. (2011) analyzed six South-Eastern European countries during the economic transition of 1998-2008 to measure the cost and profit efficiency of 171 commercial banks. The average cost and profit efficiency was 68.59% and 53.87%, respectively. In response to the regulatory and structural change in the South Asian banking, Perera et al. (2008) looked at the cost efficiency of 111 commercial banks from Bangladesh, India, Pakistan, and Sri Lanka over the period of 1997–2004. Larger banks, as well as those with widespread ownership through stock exchange listings, were found to be more cost-effective. State-owned banks, on the other hand, were less efficient. However, overall cost efficiency declined over the studied period. Analyzing 615 publicly quoted commercial banks from 74 countries, Pasiouras et al. (2009) found that banking policies that improve market discipline and provide authorities more supervisory power boost banks' cost and profit efficiency.

3.5.2. Bank Size

Large banks in Croatia, categorized by assets size, were found to be more efficient than small banks (Kraft et al., 2006). Similarly, Yildirim and Philippatos (2007) revealed that larger banks in Central and Eastern European countries were more cost efficient in their operations. On the other hand, profit efficiency did not appear to be related to asset size in their findings. The association of profit efficiency and bank size was not found in South-Eastern countries as well, but cost efficiency reduced with size of bank (Fang et al., 2011). In contrast, size was found to be positively associated with both cost and profit efficiency in Hungarian commercial banks, implying that bigger banks had better cost and profit efficiency (Hasan and Marton, 2003). However, Mendes and Rebelo (1999) could not identify any clear association between size and cost efficiency since both large and small Portuguese banks remained efficient throughout the studied years. In a recent study on banks of 72 countries, Barth et al. (2013) reveled that large banks are more efficient, which could be due to scale or scope economies. For the emerging Asian countries including Bangladesh, the size of bank had a highly substantial positive effect on X-efficiency, implying that larger banks can achieve higher levels of X-efficiency (Thi My Phan et al., 2016).Likewise, Perera et al. (2008) found that larger banks to be more cost efficient in the South Asian countries (Bangladesh, India, Pakistan, Sri Lanka). In an individual study on Bangladesh, large banks are also proved to be more efficient in Bangladesh pre and post crisis period (Banna et al., 2017).

3.5.3. Maturity

A comparison of old and new banks in respect of efficiency in Croatia revealed that new banks, established after 1990, were more efficient in majority of the studied years (Kraft et al., 2006). But contrary to expectation, new private banks could not outperform in terms of efficiency. Nevertheless, there was no significant association between the lengths of banking experience, i.e., the number of years in business with bank efficiency of Hungarian banks (Hasan and Marton, 2003).

3.5.4. Ownership

Many studies tried to evaluate whether there is any significant difference in efficiency according to ownership of banks. Kraft et al. (2006) analyzed the relative cost efficiency of state-owned, private and foreign banks of Croatia using Stochastic Frontier Analysis for the period of 1994 to 2000. Their findings revealed that until the year 2000, private banks were less efficient than state banks. This result is contrary to Barth et al. (2013), who found that government-owned banks were less efficient while observing 4050 banks of 72 countries over 1999-2007. It is, therefore assumed that state owned banks are less efficient as government tends to pursue nonprofit aims, such as providing employment and

ensuring social stability through these banks (Barth et al., 2013). According to La Porta et al. (2002), politicians control state-owned banks and utilize them to foster their own political and personal goals, such as creating jobs for political allies and bailing out underperforming state-owned firms (SOEs), which causes less efficiency. Government-owned banks in South Eastern European countries also had lower profit efficiency than private domestic banks as found by Fang et al. (2011). Similarly, Perera et al. (2008) identified that stat-owned banks of South Asian countries to be less cost efficient during 1997-2004. However, large state-owned banks of Australia and Germany were found to be more cost-effective than other banks, which is likely due to state guarantees that provide them access to cheaper capital (Hauner, 2005).

Foreign banks in Croatia consistently had higher cost efficiency rankings than all types of domestic banks (Kraft et al., 2006). Yildirim and Philippatos (2007) also found that foreign banks were more cost efficient but less profit efficient relative to domestically owned private and state-owned banks in Central and Eastern Europe. A study conducted by Hasan and Marton (2003) on Hungarian commercial banks over 1993-1998 revealed that foreign banks had both better cost and profit efficiency than that of domestic banks. Whereas, foreign banks in South-Eastern European countries had higher profit efficiency but poorer cost efficiency (Fang et al., 2011). Besides, Australian foreign banks showed better efficiency than domestic banks after the banking sector deregulation in the mid 1980's (Sturm and Williams, 2004). On contrary to that, many researchers found the opposite results. Looking at fourteen different countries, Miller and Parkhe (2002) concluded that domestic banks were more profit efficient than foreign banks. In another study on the U.S. banks, DeYoung and Nolle (1996) also identified that foreign banks remained less efficient than domestic banks during 1985-1990.

3.5.5 Capitalization

The impact of capitalization on efficiency level has been analyzed in several studies. Strong capital structure is critical for banks in transition economies since it adds to their ability to resist financial crises and increases depositor protection in times of macroeconomic instability. Furthermore, in banking, lower capital ratios suggest greater leverage and risk, as well as higher borrowing rates (Yildirim and Philippatos, 2007). As a result, with better-capitalized banks, efficiency should be higher. It is observed that higher efficiency is associated with well-capitalized banks in Central and Eastern European countries (Yildirim and Philippatos, 2007). Barth et al. (2013) also revealed that well-capitalized banks are more efficient. Conversely, Hasan and Marton (2003) found that well-capitalized banks in Hungary are less likely to be more efficient in terms of profit and cost. Likewise, well-capitalized banks in South-Eastern counties were less

cost efficient (Fang et al., 2011). According to Pasiouras et al, (2009), increasing capital requirements increase cost efficiency while lowering profit efficiency. In Bangladesh, well-capitalized commercial banks are found to be more efficient both before and after the global financial crisis (Banna et al., 2017).

While there has been a lot of research on the efficiency of banks in developed economies, a few research are found on bank efficiency in developing economies. Hence, the goal of our research is to close this gap. A study on Bangladeshi banking sector, one of the developing economies, is a vital addition to the existing literature. The current study aims to measure the cost and profit efficiency of Bangladeshi commercial banks from several dimensions, using data from the most recent year, which includes the year of the COVID-19 pandemic. It is observed that no prior study made such a thorough review of bank efficiency using data from commercial banks in Bangladesh up to the most current year. Therefore, the present study contributes to the existing literature by demonstrating the level of total cost and profit efficiency of commercial banks in Bangladesh. Besides, how the bank size, ownership structure, level of capitalization, and age of the bank affect both cost and profit efficiency would provide some meaningful insights for the policymakers.

4.0 Methodology

4.1 Sample and Data

The present analysis concentrates solely on the conventional commercial banks of Bangladesh. The Islamic banks and the specialized banks have been excluded from the investigation because of their unique characteristics. The primary sample consisted of 38 banks comprising state-owned, foreign, and private commercial banks. However, due to data unavailability, the final sample consists of 32 commercial banks producing an unbalanced panel of 287 observations over the period of 2011 to 2020. All the bank-specific data have been collected from the Orbis Bank Focus and the macroeconomic data were obtained from the World Bank database.

The summary statistics of the variables used in the cost and profit efficiency analysis are presented in Table 2. Overall, the data looks consistent. The mean, standard deviation (SD), minimum, and maximum values show that the dataset is not suffering from extreme values or any distributional disturbances.

4.2 Model Design and Specification

The present study uses the Stochastic Frontier Analysis (SFA) approach, which uses a method to estimate banks' efficiency scores in relation to the best practice frontier in terms of cost and profit. The Battese and Coelli (1995) model, which

among other SFA models allows inefficiency to depend on some exogenous variables allowing the analysis of how these factors influence inefficiency, is employed in this paper. The stochastic cost and profit frontiers in their general forms are as follows:

$$\ln TC_{it} = f(y_{it}, p_{it}; \beta) + \varepsilon_{it} \quad \text{where } i = 1, 2, \ldots\ldots N; t = 1, 2, \ldots T \quad (1)$$

$$\ln \pi_{it} = f(y_{it}, p_{it}; \beta) + \varepsilon_{it} \quad \text{where, } i = 1, 2, \ldots\ldots N; t = 1, 2, \ldots T \quad (2)$$

Here, TC_{it} is the total cost of bank *i* at time *t* and π_{it} is the profit before taxes of bank *i* at time *t*. Total cost is the summation of three input prices, including labor cost, interest expense, and other operating expenses. y_{it} and p_{it} are the vectors of outputs and the input prices respectively. β is the vector of unknown scalar parameters to be estimated. ε_{it} is the error term including two components:

$$\boldsymbol{\varepsilon}_{it} = v_{it} + u_{it} \quad \text{for cost efficiency}$$

$$\boldsymbol{\varepsilon}_{it} = v_{it} - u_{it} \quad \text{for profit efficiency}$$

Table 2: Overall Summary Statistics

Categories of Variables	Variables	Mean	SD	Min	Max
Inputs	Labour Expenses (x1)	3124.550	2730.194	67.032	14508.320
	Interest Expenses (x2)	11681.400	8699.290	52.640	47352.930
	Other Operating Expenses (x3)	2342.960	1777.797	76.887	11204.970
Outputs	Gross Loans (y1)	162285.100	113713.200	1831.430	607113.300
	Other Earning Assets (y2)	15311.660	22656.340	4.190	138241.200
	Off Balance sheet Items (y3)	91081.840	128310.100	157.880	1148178.000
Input Prices	Price of Labour (p1)	12559.140	8817.240	266.740	48108.810
	Price of Fund (p2)	0.012	0.004	0.003	0.027
	Price of Capital (p3)	0.060	0.020	0.002	0.132
Costs	Total Cost (TC)	1.068	1.348	0.116	9.638
Other and Exogenous Variables	Earnings Before Provision and Taxes	5320.539	3350.466	34.826	20683.900
	Total Equity	21079.270	14242.160	4022.710	85607.940
	Economic Growth*	6.562	1.286	3.509	8.153
	Inflation*	6.038	1.225	4.090	8.165
	Unemployment*	4.385	0.372	3.710	5.300
	Real Interest Rate*	3.239	0.780	1.872	4.484

Notes: *Variables with an asterisk are in percentages. Other values are in million BDT expressed in real 2011 terms.*

The v_{it} is the stochastic error term and u_{it} is the inefficiency term. v_{it} is assumed to be normally distributed with a zero mean and constant variance and u_{it} is time-varying and takes only nonnegative values and it follows truncated (at zero) normal distribution, where the mean, m_{it} is defined as:

$$m_{it} = \partial_0 + \partial z_{it} + w_{it} \quad \text{for cost efficiency} \ldots\ldots\ldots\ldots(3)$$

$$m_{it} = \delta_0 + \delta z_{it} + w_{it} \quad \text{for profit efficiency} \ldots\ldots\ldots\ldots(4)$$

Here, z_{it} is a (Kx1) vector of exogenous variables, which influence the inefficiency of bank *i* at time *t*. ∂ and δ is the (Kx1) vector of parameters to be estimated to determine the strength and direction of the influence of the variables under consideration.

In a single step regression model, the parameters of equations (1) and (3) are calculated for cost efficiency and equation (2) and (4) are calculated for profit efficiency using the Maximum Likelihood Estimation method. Cost efficiency is determined by estimating the frontier using the formula $CE_{it} = \exp(-u_{it})$, whereas profit efficiency is calculated by $PEFF_{it} = \exp(u_{it})$ where the results will range between 0 and 1. Scores that are closer to 1 show greater efficiency.

The Translog specification is used to specify the functional form of the cost and profit functions. The functions for this study has the following forms using three outputs, three input prices, equity, and time trend:

$$\begin{aligned} lnTC_{it} = {} & \alpha_0 + \sum_{i=1}^{3} \alpha_i lny_{it} + \sum_{j=1}^{3} \beta_j lnp_{jt} \\ & + \frac{1}{2}\sum_{i}^{3}\sum_{k}^{3} \sigma_{ik}\, lny_{it}\, lny_{kt} + \frac{1}{2}\sum_{j}^{3}\sum_{h}^{3} \gamma_{jh}\, lnp_{jt}\, lnp_{ht} \\ & + \sum_{i}^{3}\sum_{j}^{3} \delta_{ij}\, lny_{it}\, lnp_{jt} + d_1 \mathrm{lnequity} + d_2 \frac{1}{2}(lnequity * lnequity) \\ & + r_1 t + r_2 \frac{1}{2}(t * t) + v_{it} + u_{it} \end{aligned} \quad \ldots\ldots\ldots\ldots(1a)$$

$$\begin{aligned} ln\pi_{it} = {} & \alpha_0 + \sum_{i=1}^{3} \alpha_i lny_{it} + \sum_{j=1}^{3} \beta_j lnp_{jt} \\ & + \frac{1}{2}\sum_{i}^{3}\sum_{k}^{3} \sigma_{ik}\, lny_{it}\, lny_{kt} + \frac{1}{2}\sum_{j}^{3}\sum_{h}^{3} \gamma_{jh}\, lnp_{jt}\, lnp_{ht} \\ & + \sum_{i}^{3}\sum_{j}^{3} \delta_{ij}\, lny_{it}\, lnp_{jt} + r_1 t + r_2 (t * t) + d_1 \mathrm{lnequity} \\ & + d_2 \frac{1}{2}(\mathrm{lnequity} * \mathrm{lnequity}) + v_{it} - u_{it} \end{aligned} \quad \ldots\ldots\ldots\ldots(2a)$$

For linear homogeneity, the following constraints identified as equation (5) with the symmetry being, $\gamma_{j,h} = \gamma_{h,j}$; $\delta_{j,h} = \delta_{h,j}$ is usually maintained:

$$\sum_{j}^{3}\beta_j = 1,\ \sum_{j}^{3}\gamma_{j,h} = 0,\sum_{j}^{3}\delta_{i,j} = 0 \quad \ldots\ldots (5)$$

4.3 Definition of the Variables

To specify the efficiency frontier, the intermediation approach is used, where banks are viewed as financial intermediaries that use labor and physical capital to transform deposits and borrowed funds into loans and other earning assets (Sealey and Lindley, 1977). Therefore, data on total cost, total profit, input prices, and outputs are required for the measurement of both cost and profit efficiency. In this analysis, banks are thought of as multi-product businesses that use three inputs to produce three outputs. Compatible with Altunbas et al. (2000) and Pasiouras et al. (2009), the outputs include gross loans (y1), other earning assets (y2), and off balance-sheet items (y3). The cost of labor (p1), the cost of borrowing fund (p2), and the cost of physical capital (p3) are thus the input prices. The model incorporates equity to account for the variation among banks, and it uses the time to reflect the impact of technological advancements.

4.4 Determinants of Efficiency

The Battese and Coelli (1995) approach allows for a single-step analysis of the effects of determinants on cost and profit efficiency, hence this study also takes into account the determinants of efficiency. Otherwise, the estimated results would be biased (Wang and Schmidt, 2002). Since, the efficiency of commercial banks is influenced by macroeconomic stability, as demonstrated by Niţoi and Spulbar (2015), economic growth, inflation, unemployment rate, and real interest rate are therefore taken into account based on prior studies. For equations (3) and (4), the determinants for cost and profit inefficiency are specified as follows:

For Cost Efficiency

$$m_{it} = \partial_0 + \partial_1 \text{GDP Growth}_t + \partial_2 \text{Unemployment}_t + \partial_3 \text{Inflation}_t + \partial_4 \text{Interest Rate}_t + w_{it} \ldots\ldots (3a)$$

For Profit Efficiency

$$m_{it} = \delta_0 + \delta_1 \text{GDP Growth}_t + \delta_2 \text{Unemployment}_t + \delta_3 \text{Inflation}_t + \delta_4 \text{Interest Rate}_t + w_{it} \ldots\ldots (4a)$$

5.0 Results and Discussion

From the efficiency analyses we have some very interesting results for the different groups of commercial banks of Bangladesh. The results are discussed in the following paragraphs.

5.1 Results on Overall Cost and Profit Efficiency

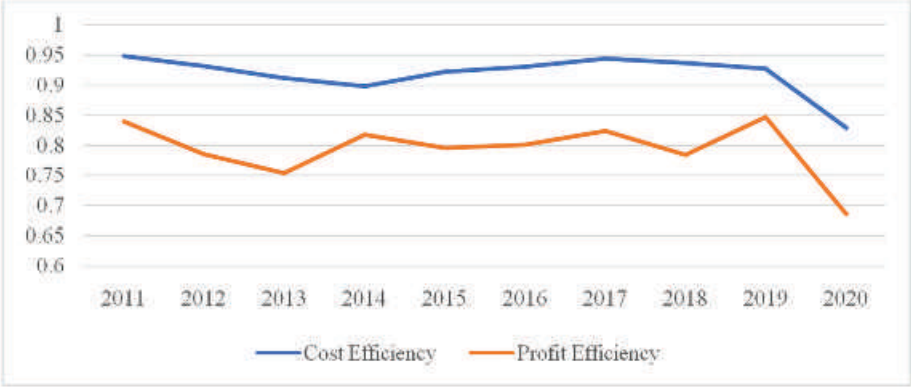
Table 3 and Figure 3 show the yearly mean cost and profit efficiency scores of Bangladeshi commercial banks. The results indicate that the cost efficiency of the studied banks is ranging between 82.89% and 94.85% and the profit efficiency is ranging between 68.58% and 84.66% during our studied period, 20211-2020. From the graphs we can also observe that the profit efficiency is more volatile than the cost efficiency. However, both cost and profit efficiency follow somewhat similar pattern, which is more observable during the COVID-19 period (2020) as both cost and profit efficiency got reduced during this period. The reason is well established that during COVID-19 crisis banks could not distribute many loans due to the reduced demands and economic shutdown. We also observe that since 2014 both cost and profit efficiencies were increasing. The reason might be the development projects and business growth in Bangladesh during this period. Furthermore, from the t-test analysis we observe that the banks are statistically significantly more cost efficient than they are profit efficient. Finally, overall, we observe that the commercial banks in Bangladesh are on average 91.64% cost efficient and 79.21% profit efficient during 2011-2020.

Table 3: Yearly Mean Cost and Profit Efficiency

Year	Mean Cost Efficiency	Mean Profit Efficiency
2011	0.9485	0.8394
2012	0.9313	0.7858
2013	0.9123	0.7536
2014	0.8978	0.8176
2015	0.9219	0.7957
2016	0.9309	0.8009
2017	0.9446	0.8237
2018	0.9368	0.7841
2019	0.9280	0.8466
2020	0.8289	0.6858
Overall	0.9164	0.7921

Source: Authors' own calculation

Figure 3: Yearly Mean Cost and Profit Efficiency



Source: Authors' own calculation

5.2 Result on Cost and Profit Efficiency according to the Ownership Structure

We found a very expected result for the cost and profit efficiency of banks with different types of ownership. The results of the cost and profit efficiency of the foreign and domestic banks in Table 4 show that foreign banks are on average 89.59% cost efficient and 80.27% profit efficient whereas domestic banks are 91.93% cost efficient and 79.05% profit efficient. The results from the t-test confirm that foreign banks are less cost efficient than the domestic banks in Bangladesh, but there is no difference between the profit efficiency of foreign and local banks. Moreover, Table 4, Figures 4 and 5, and the t-tests reveal that foreign and local banks are more cost efficient than they are profit efficient.

The results on the cost and profit efficiency of private and state-owned banks in Table 4 show that on average, private banks are 91.78% cost efficient and 81.55% profit efficient, whereas state-owned banks are 90.70% cost efficient and only 63.37% profit efficient. The result from the t-tests confirm that there is no difference between the cost efficiency of private and state-owned banks, but the profit efficiency of private banks is statistically significantly higher than that of state-owned banks. As Barth et al. (2013) mentioned in their study, that the state-owned banks help government to pursue non-profit aims; they do not care much about cost or profit efficiency. Similarly, La Porta et al. (2002) state that state-owned banks tend to be less efficient in their operations because the political parties control the state-owned banks to promote their political and personal goals and to bail-out underperforming state-owned firms. In Bangladesh also the state-owned banks have the similar kind of condition and objectives, hence we observe lower profit efficiency than that of private banks. Furthermore, the results in Table 4, Figures 6 and 7, and the t-tests on the comparison of cost and

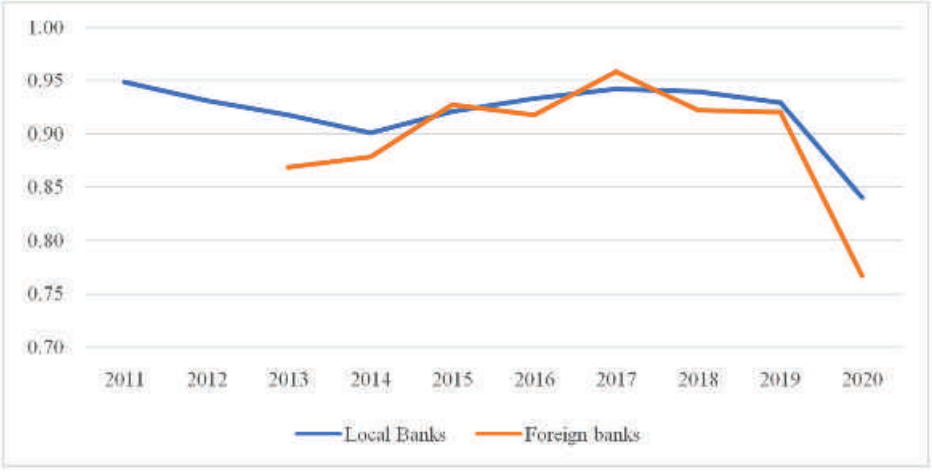
profit efficiency of state-owned and private banks reveal that both state-owned and private banks are more cost efficient then they are profit efficient.

Table 4: Yearly Average Cost and Profit Efficiency according to Bank Ownership

Year	Foreign Banks		Domestic Banks		Private Banks		State-Owned Banks	
	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency
2011			0.9485	0.8394	0.9480	0.8517	0.9510	0.7697
2012			0.9313	0.7858	0.9318	0.8019	0.9287	0.6837
2013	0.8687	0.9184	0.9178	0.7330	0.9156	0.7777	0.8936	0.6149
2014	0.8780	0.8897	0.9009	0.8065	0.9001	0.8343	0.8828	0.7092
2015	0.9271	0.8388	0.9211	0.7894	0.9248	0.8226	0.9020	0.6143
2016	0.9179	0.8137	0.9333	0.7984	0.9309	0.8395	0.9303	0.4400
2017	0.9581	0.7607	0.9421	0.8358	0.9445	0.8351	0.9459	0.7468
2018	0.9222	0.6985	0.9396	0.8006	0.9398	0.8099	0.9163	0.6102
2019	0.9200	0.8300	0.9295	0.8497	0.9283	0.8796	0.9254	0.6161
2020	0.7669	0.7428	0.8404	0.6752	0.8308	0.7080	0.8159	0.5304
Overall	0.8959	0.8027	0.9193	0.7905	0.9178	0.8155	0.9070	0.6337

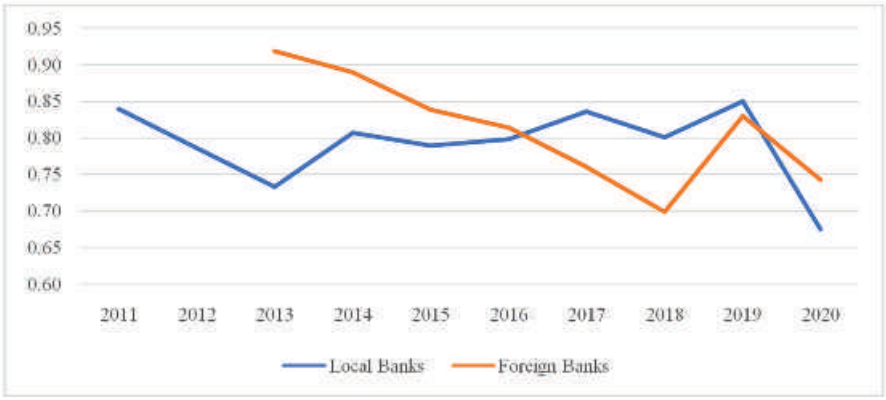
Source: Authors' own calculation

Figure 4: Cost Efficiency of Foreign and Domestic Banks



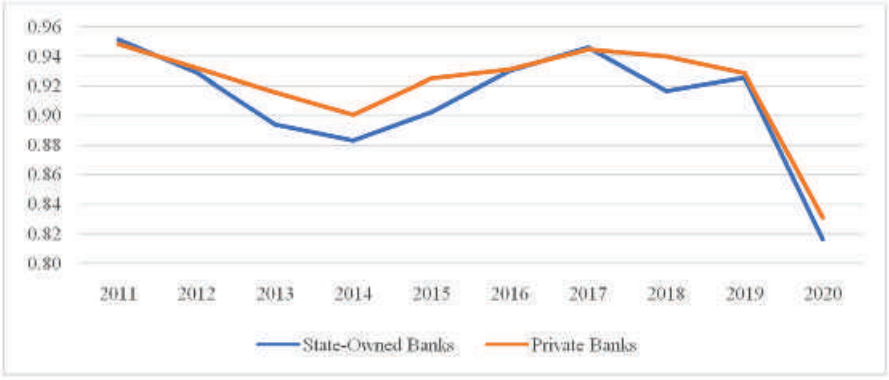
Source: Authors' own calculation

Figure 5: Profit Efficiency of Foreign and Domestic Banks



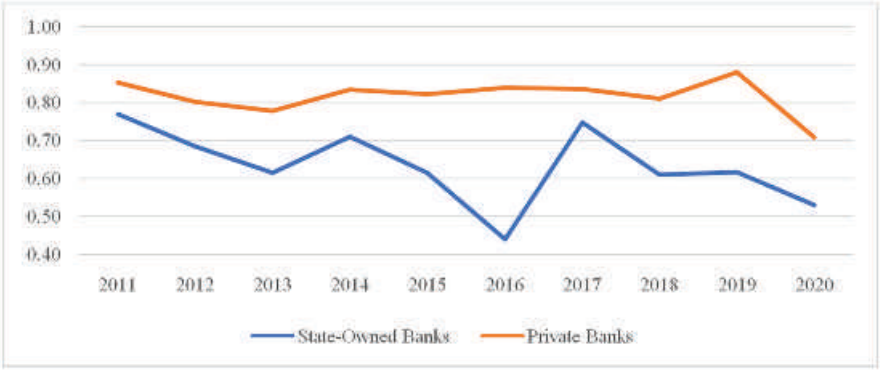
Source: Authors' own calculation

Figure 6: Cost Efficiency of Private and State-owned Banks



Source: Authors' own calculation

Figure 7: Profit Efficiency of Private and State-owned Banks



Source: Authors' own calculation

5.3 Result on Cost and Profit Efficiency according to the Bank Size

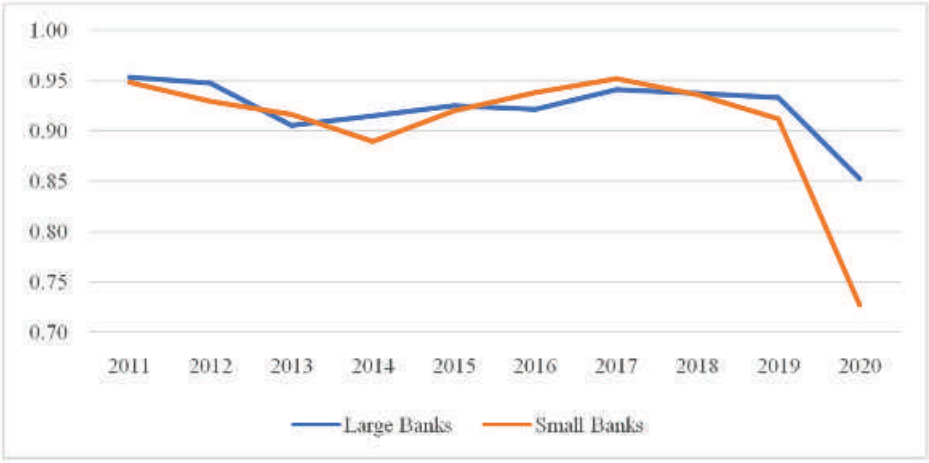
In our analysis we have also divided the banks according to their size (measured by the total assets) and analyzed their cost and profit efficiencies. The results show that large banks are on average 91.58% cost efficient and 77.63% profit efficient whereas small banks are 91.70% cost efficient and 80.79% profit efficient. The results from the t-tests confirm that there is no difference between the cost efficiency of large and small banks, but larger banks are more profit efficient than their smaller counterparts, which conforms the findings of Hasan and Marton (2003). According to Barth et al. (2013) large banks' higher efficiency can be the result of scale and scope economies. Moreover, large banks can better diversify their risks and loans and are better able to use high-end technologies and hire better staffs, which helps them to enhance their efficiency. Furthermore, the result in Table 5, Figures 8 and 9, and the t-tests on the comparison of cost and profit efficiency reveal that both large and small commercial banks in Bangladesh are more cost efficient then they are profit efficient.

Table 5: Yearly Average Cost and Profit Efficiency According to Bank Size

Year	Large Banks (Total Assets>Median Total Asset)		Small Banks (Total Assets<Median Total Asset)	
	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency
2011	0.9533	0.8847	0.9479	0.8344
2012	0.9474	0.6876	0.9288	0.8013
2013	0.9050	0.8286	0.9160	0.7161
2014	0.9149	0.8160	0.8893	0.8184
2015	0.9245	0.7816	0.9200	0.8060
2016	0.9214	0.7515	0.9377	0.8365
2017	0.9403	0.8201	0.9515	0.8294
2018	0.9372	0.7614	0.9356	0.8620
2019	0.9326	0.8380	0.9116	0.8776
2020	0.8525	0.6773	0.7267	0.7227
Overall	0.9158	0.7763	0.9170	0.8079

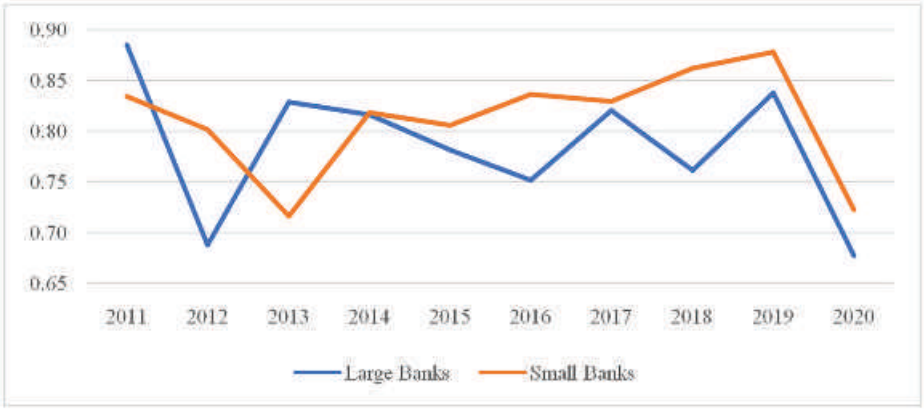
Source: Authors' own calculation

Figure 8: Cost Efficiency of Large and Small Banks



Source: Authors' own calculation

Figure 9: Profit Efficiency of Large and Small Banks



Source: Authors' own calculation

5.4 Result on Cost and Profit Efficiency according to the Level of Capitalization

Going forward, in our analysis we have also divided the banks according to the size of the capital they hold and analyzed their cost and profit efficiencies. The results show that more capitalized banks are on average 92.02% cost efficient and 78.74% profit efficient whereas less-capitalized banks are 91.16% cost efficient and 79.80% profit efficient. The results from the t-tests reveal that there is no difference between the cost and profit efficiencies of well-capitalized and less-capitalized banks. Furthermore, the result in Table 6, Figures 10 and 11, and the

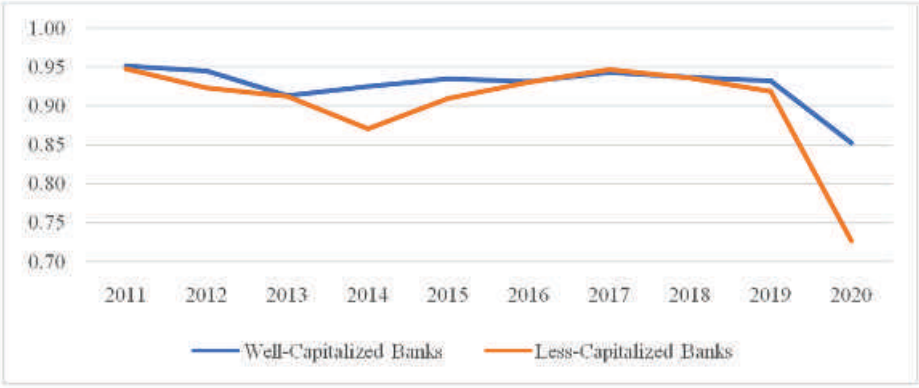
t-tests on the comparison of cost and profit efficiency of these two groups of bank sreveal that both well-capitalized and less-capitalized banks are more cost efficient then they are profit efficient.

Table 6: Yearly Average Cost and Profit Efficiency According to Bank Capitalization

Year	Well-Capitalized Banks (Capital>Median Capital)		Less-Capitalized Banks (Capital<Median Capital)	
	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency
2011	0.9513	0.8851	0.9472	0.8198
2012	0.9451	0.7914	0.9235	0.7825
2013	0.9128	0.8207	0.9119	0.6913
2014	0.9251	0.8725	0.8705	0.7627
2015	0.9349	0.8269	0.9097	0.7665
2016	0.9311	0.7671	0.9305	0.8418
2017	0.9431	0.7958	0.9465	0.8576
2018	0.9371	0.7351	0.9362	0.8731
2019	0.9317	0.8390	0.9184	0.8662
2020	0.8525	0.6773	0.7267	0.7227
Overall	0.9202	0.7874	0.9116	0.7980

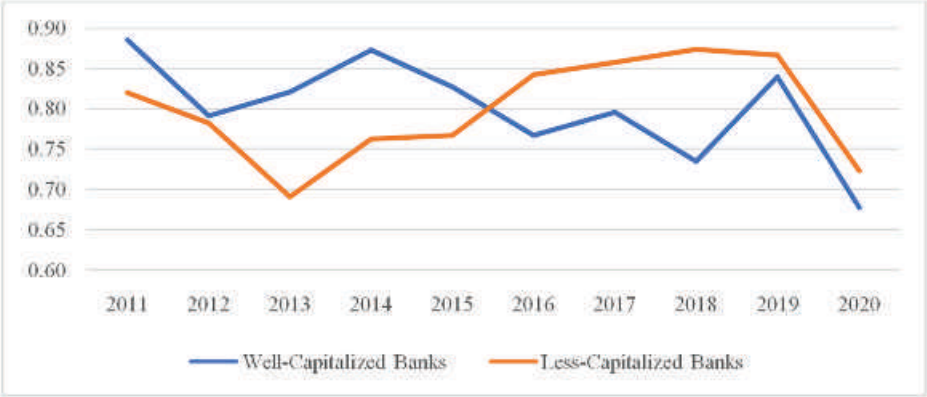
Source: Authors' own calculation

Figure 10: Cost Efficiency of Well-Capitalized and Less-Capitalized Banks



Source: Authors' own calculation

Figure 11: Profit Efficiency of Well-Capitalized and Less-Capitalized Banks



Source: Authors' own calculation

5.5 Results on Cost and Profit Efficiency of Banks Established in Different Periods

We have also grouped and analyzed the cost and profit efficiencies of banks established in different periods since liberation of Bangladesh. Our analysis reveals that the cost efficiency of these banks, ranges between 87.98% and 93.05% and the profit efficiency varies between 77.31% and 85.05%. The results from the t-tests and the Figures 12 and 13 confirm that the cost efficiency of banks established between 1971-1990, between 1991-2000, between 2001-2010, and in 2001 and onwards, is higher than their profit efficiency and the banks established between 1991-2000 are more cost efficient than their other counterparts. Finally, the banks established between 2001-2010 are more profit efficient than their other counterparts. These results establish the fact that banks with more years of business experience tend to be more cost efficient whereas, banks with less years of business experience are more focused on the profit efficiency.

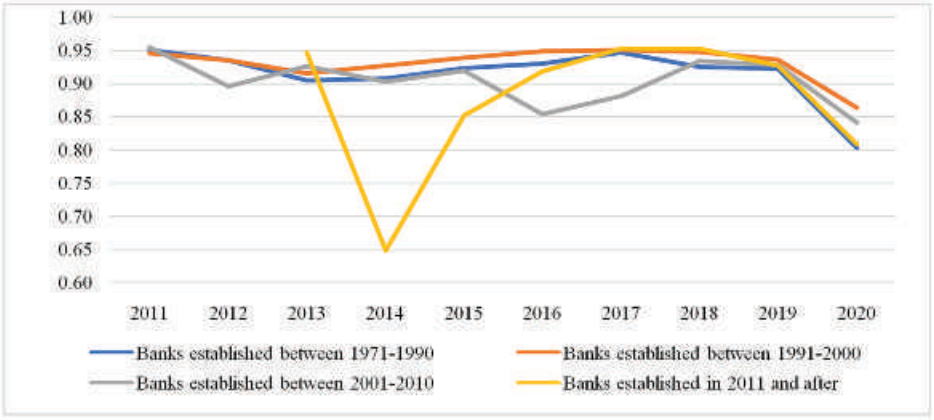
Table 7: Yearly Average Cost and Profit Efficiency According to Bank Generation

Year	Bank Established in Between 1971-1990		Bank Established in Between 1991-2000		Bank Established in Between 2001-2010		Bank Established in 2011 and Afterwards	
	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency
2011	0.9504	0.8306	0.9453	0.8326	0.9540	0.9095		
2012	0.9346	0.7959	0.9352	0.7532	0.8958	0.9195		
2013	0.9048	0.7707	0.9156	0.7659	0.9264	0.9070	0.9461	0.0888
2014	0.9077	0.8375	0.9270	0.8210	0.9030	0.8706	0.6487	0.6048
2015	0.9227	0.7886	0.9388	0.7916	0.9194	0.8304	0.8519	0.8222

2016	0.9295	0.7456	0.9483	0.8374	0.8542	0.8592	0.9185	0.8736
2017	0.9468	0.7725	0.9508	0.8557	0.8807	0.8661	0.9525	0.9062
2018	0.9248	0.7024	0.9474	0.8520	0.9340	0.7996	0.9521	0.8834
2019	0.9222	0.8254	0.9355	0.8703	0.9279	0.8422	0.9266	0.8608
2020	0.8032	0.6924	0.8639	0.6716	0.8411	0.7010	0.8090	0.6991
Overall	0.9118	0.7731	0.9305	0.8052	0.9037	0.8505	0.8798	0.7826

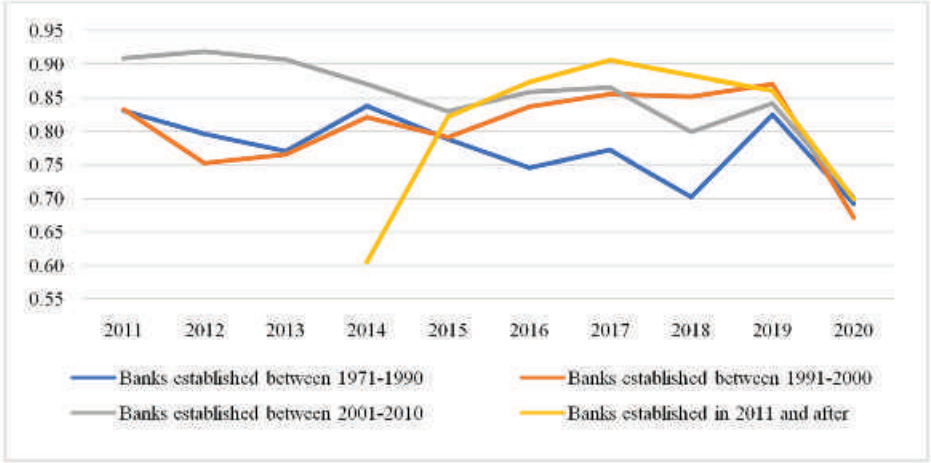
Source: Authors' own calculation

Figure 12: Yearly Mean Cost Efficiency of Banks Established in Different Periods



Source: Authors' own calculation

Figure 13: Yearly Mean Profit Efficiency of Banks Established in Different Periods



Source: Authors' own calculation

5.6 Result on Cost and Profit Efficiency according to the Age (experience) of Banks

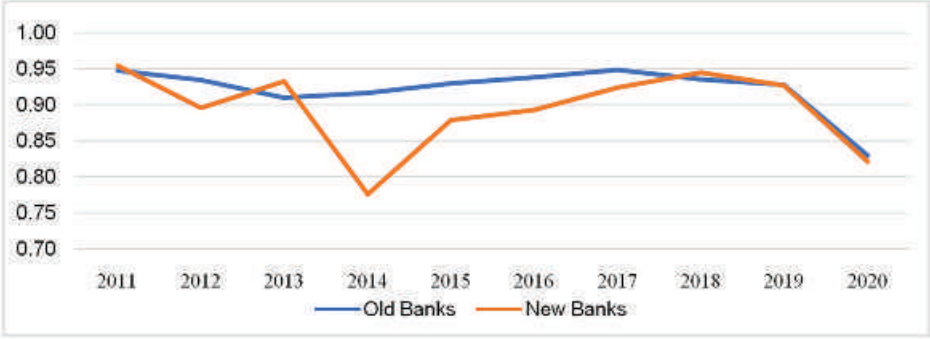
Finally, we divided our banks as new (established before 1999) and old (established after 1999) banks and found that old banks are 92.06% cost efficient and 78.81% profit efficient and new banks are 89.14% cost efficient and 81.57% profit efficient. Table 8, Figures 14 and 15, and the results of the t-tests show that old banks are less cost efficient than the new banks and there is no difference between the profit efficiencies of new and old banks. Furthermore, the results from the t-tests reveal that the cost efficiency of old and new banks is higher than their level of profit efficiency.

Table 8: Yearly Average Cost and Profit Efficiency of Old and New Banks

Year	Old Banks (Established Before 1999)		New Banks (Established After 1999)	
	Cost Efficiency	Profit Efficiency	Cost Efficiency	Profit Efficiency
2011	0.9479	0.8316	0.9540	0.9095
2012	0.9349	0.7724	0.8958	0.9195
2013	0.9098	0.7685	0.9330	0.6342
2014	0.9166	0.8299	0.7758	0.7377
2015	0.9302	0.7900	0.8789	0.8255
2016	0.9382	0.7880	0.8928	0.8678
2017	0.9487	0.8109	0.9238	0.8902
2018	0.9353	0.7715	0.9449	0.8498
2019	0.9281	0.8454	0.9271	0.8534
2020	0.8302	0.6832	0.8218	0.6999
Overall	0.9206	0.7881	0.8914	0.8157

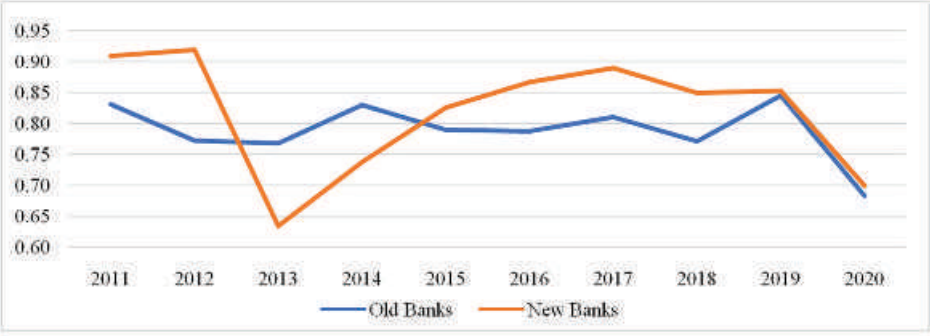
Source: Authors' own calculation

Figure 14: Yearly Cost Efficiency of Old and New Banks



Source: Authors' own calculation

Figure 15: Yearly Profit Efficiency of Old and New Banks



Source: Authors' own calculation

6.0 Summary of the Findings and Conclusion

Applying Battese and Coelli (1995) model of Stochastic Frontier Analysis (SFA) approach on an unbalanced panel of 287 observations from 32 banks for the period 2011-2020, we found that on average the commercial banks in Bangladesh are 91.64% cost-efficient and 79.21% profit-efficient and both cost and profit efficiency decreased during the COVID-19 period. Furthermore, we found that- private banks are more cost and profit efficient than state-owned banks; foreign banks are more profit-efficient but less cost-efficient than domestic banks; banks established between 1991-2000 are more cost-efficient while banks established between 2001-2010 are more profit-efficient when compared to their counterparts; old banks are less profit efficient than the new banks; and expectedly, large banks are more profit-efficient than small banks. These results will help the bank managers in trying to find the way towards improving their

efficiency by reducing costs; and banks supervisors to formulate some rules and regulations and take corrective actions to streamline the inefficient banks. This way a more resilient to shocks and efficient banking system can be established for the sake of the economy of Bangladesh. Though, one of the limitations of the present study is that the determinants of the efficiency have not been analyzed, it could serve as a subject for further analysis in this regard. Specifically, one can proceed with the analysis of the bank-specific, macroeconomic, and regulatory determinants of cost and profit efficiency of commercial banks in Bangladesh.

References

1. Altunbas, Y., Liu, M.-H., Molyneux, P. and Seth, R. (2000). Efficiency and Risk in Japanese Banking. *Journal of Banking & Finance*, 24 (10), pp. 1605–1628.
2. Banna, H., Ahmad, R. and Koh, E. H. Y. (2017). Determinants of Commercial Banks' Efficiency in Bangladesh: Does Crisis Matter?. *The Journal of Asian Finance, Economics, and Business, [online]*. 4(3), pp. 19–26. Available at: https://www.koreascience.or.kr/article/JAKO201716463831065.page.
3. Barth, J. R., Lin, C. , Ma, Y., Seade, J. and Song, F.M. (2013). Do Bank Regulation, Supervision and Monitoring Enhance or Impede Bank Efficiency?. *Journal of Banking & Finance*, 37(8), pp. 2879–2892.
4. Battese, G. E. and Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, 20(2), pp. 325–332.
5. Bell, F. W. and Murphy, N. B. (1968). *Costs in Commercial Banking: A Quantitative Analysis of Bank Behavior and Its Relation to Bank Regulation*. Research Report No. 41, Federal Reserve Bank of Boston.
6. Benston, G. J. (1965) Branch Banking and Economies of scale. *The Journal of Finance*, 20, pp. 312–332.
7. Berger, A. N. and Mester, L. J. (1997). Inside the black box: What explains differences in the efficiencies of financial institutions?. *Journal of Banking & Finance*, 21(7), pp. 895–947.
8. Casu, B. and Molyneux, P. (2003). A Comparative Study of Efficiency in European Banking. *Applied Economics*, 35(17), pp. 1865–1876.
9. DeYoung R, and Nolle, D. E. (1996). Foreign-owned Banks in the United States: Earning Market Share or Buying It?. *Journal of Money, Credit, and Banking,* 28(4), pp. 622–636.
10. Fang, Y., Hasan, I. and Marton, K. (2011). Bank Efficiency in South-Eastern Europe. *Economics of Transition*, 19(3), pp. 495–520.
11. Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General*), 120(3), pp. 253-281. DOI:10.2307/2343100.

12. Fethi, M. D. and Pasiouras, F. (2010). Assessing Bank Efficiency and Performance with Operational Research and Artificial Intelligence Techniques: A Survey. *European Journal of Operational Research*, [online] 204(2), pp. 189–198. DOI:10.1016/j.ejor.2009.08.003.

13. Fiorentino, E., Karmann, A. and Koetter, M. (2006). The Cost Efficiency of German Banks: A Comparison of SFA and DEA. SSRN Electronic Journal. DOI:10.2139/ssrn.947340

14. Hasan, I. and Marton, K. (2003). Development and Efficiency of the Banking Sector in a Transitional Economy: Hungarian Experience. *Journal of Banking & Finance*, 27(12), pp. 2249–2271.

15. Hauner, D. (2005). Explaining Efficiency Differences Among Large German and Austrian Banks. *Applied Economics*, 37(9), pp. 969–980.

16. Kraft, E., Hofler, R. and Payne, J. (2006). Privatization, Foreign Bank Entry and Bank Efficiency in Croatia: A Fourier-Flexible Function Stochastic Cost Frontier Analysis. *Applied Economics*, 38(17), pp. 2075–2088.

17. Kumbhakar, S. C. and Lovell, C. K. (2003). Stochastic Frontier Analysis. Cambridge University Press.

18. La Porta, R., Lopez-De-Silanes, F. and Shleifer, A. (2002). Government Ownership of Banks. *The Journal of Finance*, 57(1), pp. 265–301. DOI:10.1111/1540-6261.00422.

19. Mendes, V. and Rebelo, J. (1999). Productive Efficiency, Technological Change and Productivity In Portuguese Banking. *Applied Financial Economics*, 9(5), pp. 513–521.

20. Miah, Md. D. and Sharmeen, K. (2015). Relationship Between Capital, Risk and Efficiency. *International Journal of Islamic and Middle Eastern Finance and Management*, 8(2), pp. 203–221.

21. Miller, S. R. and Parkhe, A. (2002). Is There A Liability of Foreignness in Global Banking? An Empirical Test of Banks' X-Efficiency. *Strategic Management Journal*, 23(1), pp. 55–75.

22. Monetary Policy Statement, 2021-2022 (2022). Bangladesh Bank.

23. Nawaz, Md. A. (2021). Impact of the Qualities of Sharia'h Supervisory Board Members on Cost Efficiency of Bangladeshi Islamic.*Banks Journal of Banking & Financial Services*, 13(1), pp. 31-55.

24. Niţoi, M. and Spulbar, C. (2015). An Examination of Banks' Cost Efficiency in Central and Eastern Europe. *Procedia Economics and Finance*, 22, 544–551.

25. Orbis. (2021) *Orbis Bank Focus.* Available from: https://bankfocus-bvdinfo-com.ezproxy.nottingham.ac.uk/version-2021518/bankfocus/1/Companies/dashboard/Index?refreshTopPos=0&format=_standard&BookSection=PROFILE&uniqueId=True [Accessed November 02, 2021].

26. Pasiouras, F., Tanna, S. and Zopounidis, C. (2009). The Impact of Banking Regulations on Banks' Cost and Profit Efficiency: Cross-Country Evidence. *International Review of Financial Analysis*, 18(5), pp.294–302.

27. Perera, S., Skully, M. and Wickramanayake, J. (2008). Cost Efficiency in South Asian Banking: The Impact of Bank Size, State Ownership and Stock Exchange Listings. *International Review of Finance*, 7(1-2), pp. 35–60.

28. Sealey, C. W. & Lindley, J. T. (1977). Inputs, Outputs, and Theory of Production Cost at Depository Financial Institutions. *Journal of Finance*. 32(4), pp. 1251–1266.

29. Scheduled Banks Statistics, (2022). Bangladesh Bank.

30. Scheduled Banks Statistics, (2020). Bangladesh Bank.

31. Semih Yildirim, H. and Philippatos, G. C. (2007). Efficiency of Banks: Recent Evidence from the Transition Economies of Europe, 1993–2000. *The European Journal of Finance*, 13(2), pp. 123–143.

32. Shanmugam, K. R. and Das, A. (2004). Efficiency of Indian Commercial Banks During the Reform Period. *Applied Financial Economics*, 14(9), pp. 681–686.

33. Sturm, J.-E. and Williams, B. (2004). Foreign Bank Entry, Deregulation and Bank Efficiency: Lessons From the Australian Experience. *Journal of Banking & Finance*, 28(7), pp. 1775–1799.

34. Sufian, F. (2009). Determinants of Bank Efficiency During Unstable Macroeconomic Environment: Empirical Evidence from Malaysia. *Research in International Business and Finance*, 23(1), pp. 54–77. DOI:10.1016/j.ribaf.2008.07.002.

35. Tecles, P. L. and Tabak, B. M. (2010). Determinants of Bank Efficiency: The Case of Brazil. *European Journal of Operational Research*, [online] 207(3), pp. 1587–1598. DOI:10.1016/j.ejor.2010.06.007.

36. The World Bank. (2022) *World Bank Open Data.* Available from: https://data.worldbank.org/ [Accessed 2nd February, 2022].

37. Thi My Phan, H., Daly, K. and Akhter, S. (2016). Bank Efficiency in Emerging Asian Countries. *Research in International Business and Finance*, 38, pp. 517–530.

38. Wang, H. J. and Schmidt, P. (2002). One-Step and Two-Step Estimation of the Effects of Exogenous Variables on Technical Efficiency Levels. *Journal of Productivity Analysis*, 18(2), pp. 129-144.

39. Yildirim, C. (2002). Evolution of Banking Efficiency Within an Unstable Macroeconomic Environment: The Case of Turkish Commercial Banks. *Applied Economics*, 34(18), pp. 2289–2301.