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Cost and Profit Efficiency of Banks: Stochastic Frontier Analysis vs Data Envelopment Analysis

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Abstract

This study compares the most widely used parametric and non-parametric techniques to measure cost and profit efficiency of banks, namely the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). We formulate the specification form of both stochastic cost and profit frontier models and constant return to scale Cost DEA and Profit DEA models and provide an empirical assessment of the cost and profit frontiers based on a panel dataset of National Commercial Banks (NCBs) and Private Banks (PBs) in Bangladesh over the 2001-2010 period. The cost inefficiency and profit efficiency are slightly higher for PBs than NCBs in case of both SFA and DEA. The coefficients of advance and off-balance sheet items are significant that positively influence the banks in stochastic cost frontier model while the advance, other earning assets, price of borrowed fund are

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significant and negative effects on the banks in stochastic profit frontier model. The average cost inefficiency and average profit efficiency are recorded with 16.3% and 91% respectively. The highest and lowest cost inefficiency are observed for Janata Bank and United Commercial Bank Limited whilst the highest and lowest profit efficiency are recorded for Eastern Bank Limited and Janata Bank respectively. The average technical and allocative efficiency are 68.8% and 35.9%, respectively in case of CRS cost-DEA model whereas they are 70.3% and 31.8% in case of CRS profit-DEA model. The average cost inefficiency is recorded 6.3% by SFA whereas it is 24.5% by DEA. The average profit efficiency is found 91% by SFA while it is 22.1% by DEA, and SFA method shows better bank efficiency than DEA.

Keywords: Cost and Profit Efficiency, Stochastic Frontier Analysis, Data Envelopment Analysis, National Commercial Banks, Private Banks, Bangladesh

Ⅰ. Introduction

The efficiency and profitability of banks constitute a very important element in the analysis of financial systems of the developing countries, for which the banking system represents the main component and which has experienced major changes in the past years. The analysis of the bank efficiency has fueled a large body of literature globally, and is of vital importance from both a microeconomic and a macroeconomic perspective (Berger and Mester, 1997). An improvement of the performance of banks indicates a better allocation of financial resources and, thus, an increase in the investments favoring economic growth. Measuring cost and profit efficiency of national commercial banks (NCBs) and private banks (PBs) by using stochastic frontier analysis (SFA) and data envelopment analysis (DEA) is important, because efficiency measures are indicators of success, by which the performance of individual banks, and the bank industry as a whole, can be judged and banks has been faced growing competition, both from other banks and from markets outside the industry (Wheelock and Wilson, 1993).

There have been surprisingly few attempts to compare cost and profit efficiency measures, and even fewer to evaluate the alternative techniques of efficiency measurement. Berger and Mester (1997) showed that profit efficiency may not be positively correlated with cost efficiency, suggesting that the profit efficiency measure may include output features that reflect higher quality. Resti (1997) and Eisenbeis et al. (1997) found very high rank-order correlations between DEA and SFA, whereas Ferrier and Lovell (1990) found rank-order correlations are not significantly different from zero. Huang and Wang (2002), using a panel of Taiwanese commercial banks, report that SFA and DEA methods are generally contradictory in ranking the sample banks based on their estimated efficiency scores. Canhoto, and Dermine (2003) considered the impact of foreign banks efficiency in Australia using both DEA and SFA, they found that foreign banks are more efficient than domestic banks. Interested readers can refer to Vu and

Turnell (2011), Baten and Kamil, (2011), Akinloye et al. (2010), Delis et al. (2009), Tahir et al. (2010), Cadet (2008), Dacanay (2007), Maudos and Poster (2001), Maudos et al. (2002), Vander (2002), Rogers (1998), Berger and Mester (1997), Lozano (1997), and Berger et al. (1993) for the works of cost and profit efficiency models.

We build on this string of the literature, but the study on banks' cost and profit efficiency is limited using efficient frontiers rather than financial ratios measuring performance (Berger and Humphrey, 1997). A few researchers (e.g. Baten and Sakera, 2014; Rahman and Islam, 2011) investigated relative cost and profit efficiency of different branches of Islamic Bank Bangladesh Limited (IBBL) using only SFA, but the comparisons with NCBs and PBs using DEA is not available in their study. In this paper, by contrast, we concentrate in estimating cost and profit efficiency of banks using both SFA and DEA simultaneously. Furthermore, we use panel data over the period 2001 to 2010 rather than cross-section data at one point in time. Because, it is argued that efficiency is better studied and modeled with panels (Kumbhakar, 1993; Coelli et al., 1999; Carbo et al., 2002), and the use of panel data over cross-section provides more degrees of freedom in the estimation of the parameters. No studies are found to be available in examining the cost and profit efficiency using both SFA and DEA. This study contributes in filling this gap.

The rationale for using two different methods is well described by Berger and Humphrey (1997), who suggest that policy and research issues that rely upon firm-level efficiency estimates may be more convincingly addressed if more than one frontier technique is applied to the same set of data to demonstrate the robustness of the explanatory results obtained. Further, it is important to measure the influencing factors on bank efficiency performance in Bangladesh. First, this study deals to estimate cost and profit efficiency of NCBs and PBs in Bangladesh. Second, it measures both Cost and Profit efficiency of banks individually by using CRS Cost DEA and CRS Profit DEA. Finally, it measures year wise technical efficiency of the banking sector by both SFA and DEA.

Ⅱ. Efficiency: Concepts and Measurement

2.1. Concepts

The focus of this study is on frontier efficiency, in other words on the distance of a decision making unit (DMU) from the best practice equivalent. Farrell (1957) placed the foundation to measure efficiency at the micro level. Inefficiency is defined as the distance of a firm from a frontier production function accepted as the benchmark. If a firm's actual production point lies on the frontier it is perfectly efficient. If it lies below the frontier then it is inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual firm or DMU. Farrell proposed efficiency consists of two components: technical efficiency and allocative efficiency. The technical efficiency reflects the ability of a DMU to minimize input use as to produce a given amount of output. The allocative efficiency reflects the ability of a DMU to use inputs in optimal proportions, given their respective prices and the production technology. Efficiency ratios take

on a value between zero and one, where one indicates that the DMU is fully efficient.

The method to implement the efficiency analysis could be either stochastic or deterministic. The stochastic allows random noise due to measurement errors. The deterministic attributes the distance between an inefficient observed bank and the efficient frontier entirely to inefficiency. A parametric approach uses econometric techniques and imposes a priori functional form for the frontier and the distribution of efficiency. A non-parametric approach relies on linear programming to obtain a benchmark of optimal cost and production-factor combinations. The most popular methods are SFA, which is stochastic and parametric, and DEA, which is deterministic and non-parametric, and both have comparative advantages and disadvantages. The DEA is a linear programming method, which does not take into account the random errors and, thus, does not require predefinition of the distribution of the error term, while the SFA integrates random errors, but also requires predefinition of the functional form. In SFA, the output of a company is a function of inputs, inefficient and random errors, and the distribution of errors. The DEA does not take into account the noise; so that the efficiency estimations can be biased if the production process of the company is characterized by stochastic elements.

This study analyses the same dataset to what extent SFA and DEA measure cost efficiency (CE) and profit efficiency (PE).

2.2. Theoretical Stochastic Cost Frontier Model

Following Aigner et al. (1977) and Meeusen and Broeck (1977), cost efficiency model can be defined as:

$$C_{it} = f(y_{it}, p_{kt}, \varepsilon_{it}),$$
$$i = 1, 2, ..., N; \quad t = 1, 2, ..., T \qquad (1)$$

where, N stands for the number of banks; C_{it} stands for the bank's total operational costs of ith banks in tth period; y_{it} represents the vector of output quantities of the ith banks in tth period; p_{kt} is the vector of price inputs of the ith banks in tth period; and ε_{it} is a composite error term in tth period, through which the cost function varies stochastically. The term ε_{it} can be partitioned into two parts as follows: $\varepsilon_{it} = v_{it} + u_{it}$. The equation (1) is represented in natural logs:

$$\ln C_{it} = f(y_{it}, p_{kt}) + \ln v_{it} + \ln u_{it} \qquad (2)$$

where, v_{it} refers to endogenous factors and u_{it} refers to exogenous factors, which impact the cost of the bank production. Thus the term v_{it} denotes a rise in the cost of bank production due to the inefficiency factor that may result from the mistakes of the management, such as non-optimal employment of the quantity or mix of inputs given their prices. u_{it} represents a temporary rise or fall in the bank's costs due to the random factor that may stem from a data/measurement error, or unexpected/uncontrollable factors such as weather, luck, labor strikes, war, etc., that are not under the influence of the management. u_{it} are assumed to be identically distributed as normal variates and inefficiency scores v_{it} are derived from a normal

distribution, $N(0,\sigma_v^2)$. The relative efficiency of a bank can be estimated by means of the ratio, $\lambda = \frac{\sigma_v}{\sigma_u}$.

The CE of ith bank in tth period is measured as the ratio between the minimum cost necessary to produce that bank's output and the actual cost:

$$CE_{it} = \frac{C_{\min}}{C_{it}} = \exp(u_{it}) \qquad (3)$$

2.3. Theoretical Stochastic Profit Frontier Model

Suppose the ith bank has a vector of x_i independent inputs that determine profit. Then, following Berger and Mester (1997) and Battese and Coelli (1995), the stochastic profit efficiency model is defined as:

$$\pi_{it} = f(x_{it}, p_{kt}, \beta) + (v_{it} - u_{it}),$$
$$i = 1,2,...,N; \quad t = 1,2,...,T \qquad (4)$$

where π_{it} is the logarithm of profit of the i^{th} bank in tth period; x_i is a vector of input quantities in tth period; β's are unknown parameters to be estimated; v_{it}'s corresponds to the random fluctuations, and is assumed to follow a symmetric normal distribution around the frontier i.e., $N(0,\sigma_v^2)$ and independent of u_{it}; for profit function, $u_{it} \le 0$ (0 for highest profit) accounts for bank's inefficiency and is assumed here to follow a truncated normal distribution i.e., $N(\mu,\sigma_u^2)$.

In log form, alternative profit function can be written as follows:

$$\ln(\pi_{it} + a) = \ln f(x_{it}, p_{kt}, \beta) + (v_{it} - u_{it}) \qquad (5)$$

where, a is a constant added to the profits of each bank so that natural log is taken of a positive number since minimum profits are typically negative; v_{it} and u_{it} represent the error terms as the same as above.

The PE is measured as the ratio between observed profit (P) to the corresponding profit frontier (P^*), i.e. $PE = P/P^*$. After obtaining the estimates of u_{it} the profit efficiency of ith bank in tth period is given by:

$$PE_{it} = p/p^* = \exp(-u_{it}) \qquad (6)$$

2.4. Empirical Stochastic Translog Cost Frontier Model

The specification of Translog cost frontier model can be expressed in terms of banks as output and multi-input banks as follows:

$$\ln C_{it} = \beta_0 + \sum_{l=1}^{3}\beta_l \ln y_{ilt} + \frac{1}{2}\sum_{l=m=1}^{3}\beta_{lm}\ln y_{ilt}\ln y_{imt}$$
$$+ \sum_{k=1}^{3}\beta_k \ln p_{ikt} + \frac{1}{2}\sum_{k=n=1}^{3}\beta_{kn}\ln p_{ikt}\ln p_{\text{int}}$$
$$+ \sum_{l<k}^{3}\sum_{k}^{3}\beta_{lk}\ln y_{ilt}\ln p_{ikt} + (v_{it} + u_{it}),$$
$$i = 1,2,...,N; t = 1,2,...,T \qquad (7)$$

where, *ln* is natural logarithm; β_l, β_{lm} are parameter to be estimated for the frontiers of output; β_k, β_{kn} are parameter to be estimated for input price of frontier model; β_{lk} is parameter to be estimated for interaction effect.

2.5. Empirical Stochastic Translog Profit Frontier Model

The specification form of alternative translog profit frontier model can be expressed as follows:

$$\ln(\pi_{it}+a)=\beta_0+\sum_{q=1}^{3}\beta_q \ln x_{iqt}+ \frac{1}{2}\sum_{q=r=1}^{3}\beta_{qr}\ln x_{iqt}\ln y_{irt}+\sum_{k=1}^{3}\beta_k \ln p_{ikt} + \frac{1}{2}\sum_{k=n=1}^{3}\beta_{kn}\ln p_{ikt}\ln p_{\text{int}}+ \sum_{q<k}^{3}\sum_{k}^{3}\beta_{qk}\ln y_{iqt}\ln p_{ikt}+(v_{it}-u_{it}), \quad (8)$$

$$i=1,2,...,N;\ t=1,2,...,T$$

where, β_q, β_{qr} are parameter to be estimated for the frontiers of input; β_k, β_{kn} are parameter to be estimated for input price of frontier model; β_{qk} is parameter to be estimated for interaction effect.

DEA is a linear Programming technique developed by Charnes, Cooper and Rhodes (1978), that allows calculating relative efficiency of a business unit without knowing whether any relationship exists among the variables. In most of them, it is very difficult to obtain the input price due to unavailability of data information whereas price data is necessary in order to perform econometric approach.

2.6. CRS Profit DEA

Let us consider $(i=1,2,...,\mathrm{N})$ DMUs (decision making unit) or banks, each one is producing different profit output $(y_j; j=1,2,3)$ and using different input quantities $(x_s; s=1,2,3)$. The profit efficiency of the bank is assumed constant return scale (CRS) can be defined as follows:

$$\begin{aligned} &Max_{u,v}(u'y_j / v'x_s),\\ &\text{subject to}\\ &u'y_j - v'x_s \le 0,\\ &u, v \ge 0\\ &j=1,2,3;\quad s=1,2,3. \end{aligned} \quad (9)$$

where x_s is a vector of sth input quantities in ith bank; y_j is a vector of bank jth profit output given the inputs in the ith bank; u is the weighted relative vector associated to output and v is the weighted relative vector associated to input quantities.

2.7. CRS Cost DEA

The dual form of the above problem can be defined as the cost inefficiency of the bank:

$$\begin{aligned} &Min_{\theta,\lambda}\theta,\\ &\text{subject to}\\ &-y_j + Y\lambda \ge 0,\ \mathrm{j}=1,2,3\\ &\theta x_s - X\lambda \ge 0,\ \mathrm{s}=1,2,3\\ &\lambda \ge 0, \end{aligned} \quad (10)$$

where X is input matrix, Y is output matrix, λ is a vector of constant and θ is a scalar. The value of θ obtained will be the efficiency score for the ith bank. It will satisfy $\theta \le 1$, with a value of 1 indicating a point on the frontier and hence a technical efficient bank.

Ⅲ. Data and Definition of Variables

This study considers two categories of banks (i) National Commercial Banks (NCBs), (ii) Private Banks (PBs) of Bangladesh over the time period from 2001 to 2010. Most of the data are collected from the annual reports of the specific banks of Bangladesh and annual accounts of Scheduled Commercial Banks published by Bangladesh Bank, the central bank of Bangladesh. All variables except for the input price and output are measured in millions of Bangladeshi Taka.

The output vectors used in this study which include (1) Advance is measured as total loan and advance minus loan, (2) Other earning assets is measured by total other assets, (3) Off-balance Sheet Items are measured by total Off-balance Sheet items including contingent liabilities under cost function, measured as total cost, is defined by all expenses of bank such as salary and allowances, rent, taxes, insurance, lighting, stationary, managing director's remuneration, depreciation cost of bank.

The inputs prices used here which include (1) Price of fixed assets is measured as total repairing cost of fixed assets, (2) Price of labors is measured as total salary and allowances, (3) Price of Borrowed fund is measured by total borrowed including inside and outside of Bangladesh under profit function, measured as total profit after tax.

The input quantities used here include (1) Fixed Assets is measured by number of fixed assets such as building, furniture, fixture, office appliance, and motor vehicles etc, multiplied by number of branch, (2) Number of labor is measured as full-time equivalents of bank's person who has agreed by contract to perform specified services for another, the employer, in exchange for money, (3) Borrowed fund is collected from inside and outside of Bangladesh under both CRS Profit DEA and CRS Cost DEA methods.

Summary statistics of output, input quantity and input prices are presented in <Table 1>.

Table 1. Summary Statistics of Output Input Quantity and Input Price variables

Variable	*Description*	*Mean*	*Std. Deviation*	*Minimum*	*Maximum*
Output					
Cost	Total Cost	3480.694	12044.072	102.46	156341
Profit	Profit after Tax	1002.206	1142.129	8.23	6860.34
ADV	Advance	29803.862	46154.689	229.383	398432.89
OEA	Other Earning Assets	11018.182	29997.426	54.2	176625.2
OBS	Off-balance Sheet items	32410.732	106807.038	923.67	987634.8
Input Price					
PFA	Price of Fixed Assets	136.596	128.3027	0.077	619.49
POL	Price of Labor	969.078	2324.091	1.61	28125.12
PBF	Price of Borrowed Fund	1724.787	2503.066	0.46	14200.44
Input Quantity					
FIA	Fixed Assets	5378.924	8821.654	157	36081
BOF	Total Borrowed Fund	998.900	1774.209	7	14040
NLA	Number of Labor	3719.465	6045.394	101	25753

Ⅳ. Empirical Results and Discussion

4.1. Estimates of Cost and Profit Efficiency

The maximum likelihood estimates of the stochastic frontier cost and profit models of the NCBs and PBs in Bangladesh are reported in <Table 2>. A significant positive or negative coefficient for any variable suggests that it increases or decreases the bank's cost and profit efficiency.

The advance and off-balance sheet items are found significant and positive effects on the cost efficiency of the banks. The coefficient of advance (0.334) is highly significant at 1% level and the coefficient of off-balance sheet items (0.339) is significant at 5% level of significant. Both results positively influenced the banks in terms of stochastic cost frontier model. These results suggest that the output variable advance is positively affected total operating cost. Other earning assets and price of borrowed fund are observed to be insignificant and negative. In case of profit frontier model, the advance (ADV), other earning assets (OEA), price of borrowed fund (PBF) are observed to be significant and have negative effects on the banks at 1% level. Besides, Off-balance sheet items (OBS), Price of fixed assets (PFA), Price of labor (POL) are found to be significant and have positive effects on the sampled banks.

4.2. Results of Likelihood-Ratio Test

The results of various hypothesis tests of the cost and profit efficiency models are presented in <Table 3>. The first null hypothesis is $H_0 : \gamma = 0$, which specifies that there is no technical efficiency effect in the cost and profit efficiency model. The hypothesis is accepted in terms of cost frontier model so we can conclude that there is no technical efficiency effect in the model. But in case of profit efficiency model, it is rejected, so it is concluded that there exists a technical efficiency effect in the model. The second null hypothesis is $H_0 : \beta_{ij} = 0$, which specifies that both Cobb-Douglas stochastic frontier cost and profit models are more preferable than Translog stochastic cost and profit frontier models. From the result it is observed that the null hypothesis is rejected so Translog Cost and Profit models are more preferable than Cobb-Douglas stochastic cost and profit frontier models.

4.3. Bank-wise Efficiency Estimates

The evaluation of technical efficiency, allocative efficiency cost efficiency and profit efficiency for the sample banks is presented in <Table 4> for both cost DEA and profit DEA. The average technical and allocative efficiency are 68.8% and 35.9%, respectively for cost DEA. The technical efficiency is always greater than allocative efficiency for the sampled banks. However, the technical efficiency is observed smaller than the allocative efficiency in case of *AB Bank, Bank Asia* and *BRAC Banks*. The results of technical efficiency and allocative efficiency are combined to provide a measure of total cost efficiency in case of cost DEA. The lowest cost efficiency is 1.8% for *AB Bank* and highest cost efficiency is 100% for both *Mutual Trust Bank* and *One Bank* in terms of cost DEA.

In case of profit DEA, the average technical

Table 2. Maximum Likelihood Estimates of Translog Stochastic Cost Frontier Model

		Cost		*Profit*	
Variable	***Parameter***	***Coefficient***	***T-ratio***	***Coefficient***	***T-ratio***
CONSTANT	β_0	0.177@	0.335	-0.771***	-4.815
ADV	β_1	0.334***	2.710	-332.398***	-371.668
OEA	β_2	-0.098@	-0.864	-1835.55***	-2133.80
OBS	β_3	0.339**	2.270	830.590***	936.419
PFA	β_4	0.139@	1.485	166.420***	372.692
POL	β_5	0.093@	1.031	917.644***	4608.146
PBF	β_6	-0.018@	-0.301	-415.021***	-1082.55
ADV^2	β_{11}	-0.067@	-0.091	0.220@	0.146
OEA^2	β_{22}	0.116@	0.158	-0.048@	-0.044
OBS^2	β_{33}	-0.052@	-0.071	0.315@	0.398
PFA^2	β_{44}	-0.006@	-0.008	0.0007@	0.001
POL^2	β_{55}	-0.103@	-0.141	-0.141@	-0.391
PBF^2	β_{66}	0.096@	0.130	-0.072@	-0.082
*ADV*OEA*	β_{12}	0.024@	0.027	0.0002@	0.0003
*ADV*OBS*	β_{13}	-0.059@	-0.067	-0.288@	-0.188
*OEA*OBS*	β_{23}	0.032@	0.036	-0.144@	-0.575
*PFA*POL*	β_{45}	-0.054@	-0.061	-0.140@	-0.161
*PFA*PBF*	β_{46}	0.044@	0.050	-0.071@	-0.085
*POL*PBF*	β_{56}	-0.003@	-0.004	-0.213@	-0.258
*ADV*PFA*	β_{14}	-0.036@	-0.041	-0.078@	-0.110
*ADV*POL*	β_{15}	-0.085@	-0.096	-0.220@	-0.304
*ADV*PBF*	β_{16}	0.014@	0.016	-0.151@	-0.179
*OEA*PFA*	β_{24}	0.055@	0.062	0.289@	0.736
*OEA*POL*	β_{25}	0.006@	0.007	0.140@	0.085
*OEA*PBF*	β_{26}	0.106@	0.119	0.226@	0.118
*OBS*PFA*	β_{34}	-0.029@	-0.032	0.018@	0.009
*OBS*POL*	β_{35}	-0.077@	-0.087	-0.119@	-0.107
*OBS*PBF*	β_{36}	0.022@	0.024	-0.045@	-0.104
SIGMA-SQUARED	σ^2	0.145	9.233	0.403	
GAMMA	γ	0.308	2.558	0.391	
Likelihood function		-66.534			

*** Significant at the 0.01 level, ** Significant at the 0.05 level, *Significant at the 0.10 level, @ means insignificant.

Table 3. Generalized Likelihood-Ratio Test of Hypothesis of Stochastic Cost and Profit Frontier Model

Null Hypothesis	Log-Likelihood Function	Test Statistic λ	Critical Value*	Decision
		Cost		
$H_0 : \gamma = 0$	-68.898	4.72	38.301	Accept H_0
$H_0 : \beta_{ij} = 0$	-70.843	21.56	5.138	Reject H_0
		Profit		
$H_0 : \gamma = 0$	-252.172	243.47	38.301	Reject H_0
$H_0 : \beta_{ij} = 0$	-117.392	22.76	5.138	Reject H_0

Notes: All critical values are at 5% level of significance.
* The critical values are obtained from Table of Kodde and Palm (1986). The null hypothesis which includes the restriction that γ is zero does not have a Chi-square distribution, because the restriction defines a point on the boundary of parameter space.

Table 4. Bank-wise Cost and Profit Efficiency by Data Envelopment Analysis (DEA)

Name of the Banks	*Serial No.*	*Cost Efficiency*			*Profit Efficiency*		
		TE	AE	CE	TE	AE	PE
AB Bank	1	0.076	0.240	**0.018**	0.068	0.201	**0.014**
Bank Asia	2	0.268	0.809	**0.217**	0.191	0.607	**0.116**
BRAC Bank	3	0.329	0.584	**0.192**	0.692	0.293	**0.202**
Dhaka Bank	4	0.306	0.199	**0.061**	0.323	0.306	**0.099**
Dutch Bangla Bank	5	0.429	0.408	**0.175**	0.450	0.473	**0.213**
Eastern Bank	6	0.458	0.236	**0.108**	0.458	0.090	**0.041**
Mercantile Bank	7	0.788	0.471	**0.371**	0.622	0.450	**0.280**
Mutual Trust Bank	8	1.000	1.000	**1.000**	0.882	0.891	**0.786**
National Bank	9	0.596	0.111	**0.066**	0.596	0.103	**0.061**
One Bank	10	1.000	1.000	**1.000**	1.000	1.000	**1.000**
Prime Bank	11	0.832	0.196	**0.163**	0.830	0.166	**0.138**
Pubali Bank	12	0.750	0.170	**0.128**	0.847	0.088	**0.074**
South East Bank	13	1.000	0.262	**0.262**	1.000	0.323	**0.323**
Sonali Bank	14	0.867	0.104	**0.090**	1.000	0.122	**0.122**
United Commercial	15	1.000	0.130	**0.130**	1.000	0.117	**0.177**
Uttara Bank	16	1.000	0.152	**0.152**	1.000	0.098	**0.098**
Janata Bank	17	1.000	0.026	**0.026**	1.000	0.077	**0.077**
	Mean	**0.688**	**0.359**	**0.245**	**0.703**	**0.318**	**0.221**

TE=Technical Efficiency, AE= Allocative Efficiency, CE= Cost Efficiency, PE= Profit Efficiency.

and allocative efficiency are 70.3% and 31.8%, respectively. The technical efficiency is observed higher than the allocative efficiency for the sampled banks expect *AB Bank, Bank Asia, Dutch Bangla Bank* and *Mutual Trust Bank.* The measurements of technical efficiency and allocative efficiency are combined to provide a measure of total profit

efficiency in case of profit DEA. The lowest profit efficiency is 1.4% for *AB Bank* and the highest profit efficiency 100% for *One Bank*. The average cost and profit efficiency are recorded at 24.5% and 22.1% respectively in case of both Cost-DEA and Profit-DEA.

4.4. Bank-wise Estimates of Cost and Profit Efficiency

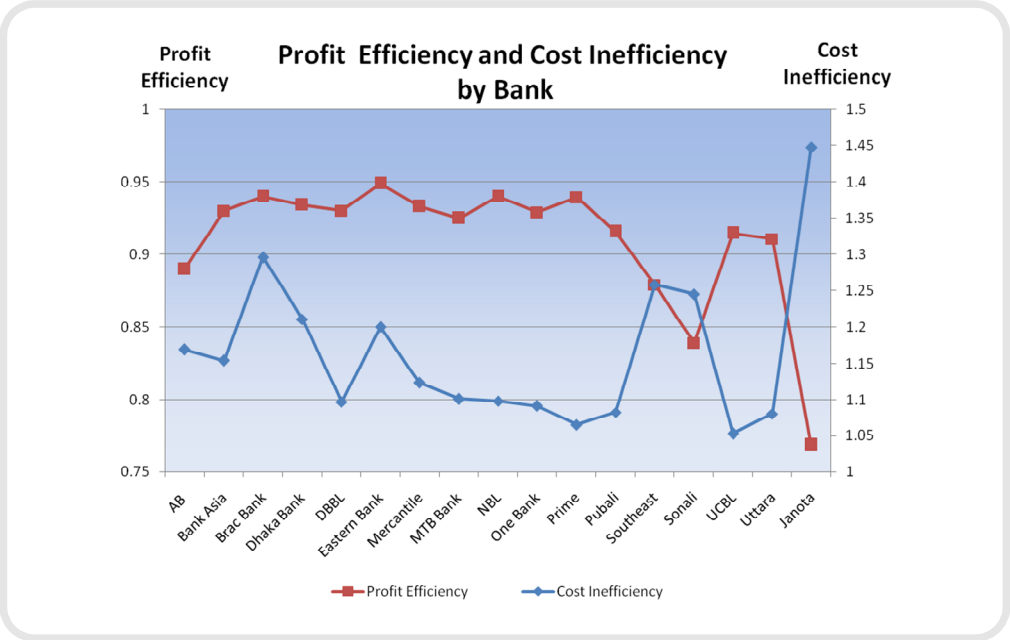
Cost and Profit efficiency comparison in between SFA and DEA are given in <Table 5>. The average cost inefficiency is found to be 6.3% by SFA while it is recorded at 24.5% by DEA, showed less efficient. No banks are shown cost efficient by SFA but *Mutual Trust Bank* and *One Bank,* are shown full efficient by DEA. The most cost inefficiency is observed for *Janata Bank* with the value of 44.7%. The less inefficiency is recorded at 5.3% for *United Commercial Bank* by SFA and less efficiency 1.8% in case of DEA for *AB Bank*. The average profit efficiency is observed 91% and 22.1% by SFA and DEA respectively, so SFA is better technique in measuring efficient than DEA. In case of SFA, *Janata Bank* is found to be less profit efficient with the value of 75.9% than all other banks and most profit efficient is recorded for *Eastern Bank* with the value of 94.9%. On the other hand in case of DEA, less profit efficient is found for *AB Bank* (1.4%) and exact efficient is for *One Bank* (100%). Most of the banks are recorded above 90% efficient by SFA while they are found below 20% efficient by DEA.

The bank wise cost and profit efficiency scores are illustrated in **Figure-1**. The average profit efficiency (91%) and average cost inefficiency (16.3%), respectively, are reported for the sampled banks. *Eastern Bank* profit

Table 5. Bank-wise Cost and Profit Efficiency Using SFA and DEA Methods

Name of the Banks	Cost		Profit	
	SFA	DEA	SFA	DEA
AB Bank	1.169	0.018	0.890	0.014
Bank Asia	1.154	0.217	0.930	0.116
BRAC Bank	1.296	0.192	0.940	0.202
Dhaka Bank	1.211	0.061	0.934	0.099
Dutch Bangla Bank	1.097	0.175	0.930	0.213
Eastern Bank	1.200	0.108	0.949	0.041
Mercantile Bank	1.123	0.371	0.933	0.280
Mutual Trust Bank	1.101	1.000	0.925	0.786
National Bank	1.098	0.066	0.940	0.061
One Bank	1.091	1.000	0.929	1.000
Prime Bank	1.065	0.163	0.939	0.138
Pubali Bank	1.082	0.128	0.916	0.074
South East Bank	1.258	0.262	0.879	0.323
Sonali Bank	1.245	0.090	0.839	0.122
United Commercial Bank	1.053	0.130	0.915	0.177
Uttara Bank	1.080	0.152	0.911	0.098
Janata Bank	1.447	0.026	0.769	0.077
Mean	1.063	0.245	0.910	0.221

Fig. 1. Average Cost and Profit Efficiency of Selected Banks by Stochastic Frontier Analysis



efficiency (94.5%) is observed higher than others banks. On the other hand *Janata Bank* profit efficiency (76.9%) is very low comparing to others banks. From Figure 1, we observed that *Janata Bank* is less efficient in case of profit model; whilst it is most inefficient for cost model. *UCBL* is less inefficient for cost model but profit efficiency is high for *Brac Bank, NBL Bank, and Prime Bank*. Cost inefficiency is (5.3%) very low for *UCBL,* on the other hand cost inefficiency (44.7%) is very high for *Janata Bank*. The profit efficiencies of *Bank Asia, BRAC Bank, Dhaka Bank, DBBL, Eastern Bank, Mercantile Bank, MTB, National Bank, One Bank, Prime Bank* and *Pubali Bank* are found almost stable, whereas *DBBL, Mercantile Bank, MTB, National Bank, One Bank, Prime Bank, Pubali Bank* and *Uttara Bank* are almost stable in terms of cost inefficiency.

4.5. Year-wise Estimates of Cost and Profit Efficiency

Year-wise cost and profit efficiency of NCBs and PBs using SFA and DEA are presented in <Table 6>. The average cost inefficiency is recorded at 34.6% for NCBs and 15.2% for PBs by SFA, on the other hand average cost efficiency is found to be 28.2% for NCBs and 82.4% for PBs by DEA. The NCBs cost inefficiency is doubled than PBs cost inefficiency in case of SFA, and PBs cost efficiency is found one third of NCBs cost efficiency by DEA.

In case of SFA, the average cost inefficiency is found to be high in the year of 2002 for NCBs while average cost inefficiency is recorded high in the year of 2003 for PBs but cost inefficiency is found less inefficint in the year of 2010 for NCBs and cost inefficiency is

Table 6. Year-wise National Commercial Bank and Private Bank Efficiency by SFA and DEA

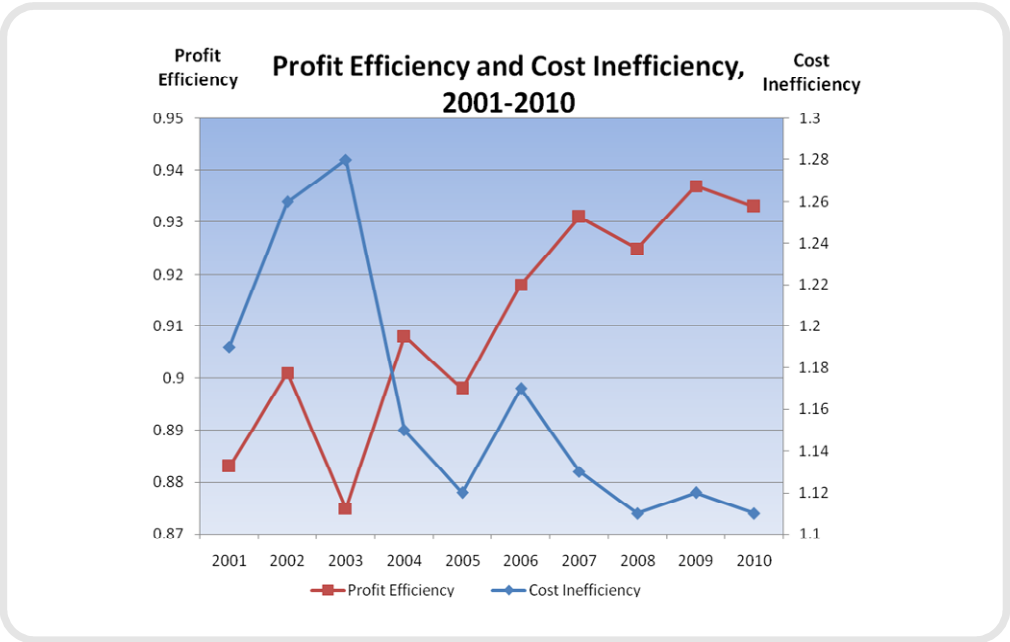
Year ↓	National Commercial Bank				Private Bank			
	Cost Efficiency		Profit Efficiency		Cost Efficiency		Profit Efficiency	
	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA
2001	1.592	0.260	0.724	0.142	1.131	0.893	0.904	0.795
2002	2.214	0.544	0.777	0.208	1.127	0.808	0.918	0.878
2003	1.351	0.244	0.756	0.118	1.267	0.869	0.890	0.778
2004	1.222	0.084	0.784	0.104	1.139	0.919	0.925	0.787
2005	1.098	0.093	0.711	0.095	1.262	0.810	0.922	0.725
2006	1.576	0.275	0.854	0.687	1.119	0.762	0.927	0.693
2007	1.292	0.325	0.875	0.403	1.111	0.776	0.939	0.732
2008	1.042	0.188	0.835	0.181	1.115	0.797	0.937	0.766
2009	1.048	0.679	0.891	0.566	1.129	0.803	0.944	0.794
2010	1.034	0.125	0.838	0.208	1.121	0.807	0.945	0.803
Mean	1.346	0.282	0.804	0.271	1.152	0.824	0.925	0.775

recorded less inefficient in the year of 2007 for PBs. In the year of 2001 cost inefficiency is observed 59.2% for NCBs and 13.1% for PBs, which are less inefficient than NCBs. In the year of 2006 the cost inefficiency is recorded 57.6% for NCBs and 11.9% for PBs, it is also less inefficient than NCBs. In case of SFA, average profit efficiency is more efficient in the year of 2009 with the value of 89.1% and less efficient in the year of 2005 with the value of 71.1% for NCBs. Average profit efficiency is more efficient in the year of 2010 with the value of 94.5% and less efficient in the year of 2003 with the value of 89% for PBs.

In case of DEA, the cost efficiency is most efficient in the year of 2009 with the value of 67.9% for NCBs and most efficient with 91.9% in the year of 2004 for PBs. It is less efficient in the year of 2004 with the value of 8.4% for NCBs and less efficient in the year of 2006 with the value of 76.2% for PBs. The average profit efficiency 80.4% for NCBs and 92.5% for PBs while the average profit efficiency 27.1% for NCBs and 77.5% for PBs. The PBs is more efficient than NCBs in case of both SFA and DEA. In case of DEA, the average profit efficiency is more efficient in the year of 2006 with the value of 68.7% and less efficient in the year of 2005 with the value of 9.5% for NCBs; on the other hand, average profit efficiency is more efficient in the year of 2002 with the value of 87.8% and less efficient in the year of 2006 with the value of 69.3% for PBs. The overall profit efficiency of PBs is more efficient than NCBs in case of both SFA and DEA.

Year-wise the profit and cost efficiency scores for the sampled banks are illustrated in **Figure-2**. From the result, we observed that the trend for profit efficiency is increasing by year. It is observed that the profit efficiency 87.5% in 2003 which increases to 93.7% in 2009, but profit efficiency decreases from 2002 to 2003. On the other hand in 2003, low profit efficiency is observed, but in 2010, it slightly decreased as compared to 2009. The trend for cost inefficiency scores increase from 19% to 28% from 2001 to 2003, and then fall down from 28% to 12% during 2003 to 2005,

Fig. 2. Year-wise Average Cost and Profit Efficiency of Banks



and then increase from 12% to 17% in 2006 and then decrease from 17% to 11% during 2008 and 2010.

Ⅴ. Conclusions

In this study we measure both the cost and profit efficiency derived by two different methodologies: SFA and DEA. To this end, we use an identical data set of NCBs and PBs in Bangladesh. We assess the sensitivity of SFA and DEA efficiency measures when the respective frontiers are based on an increasingly homogenous sample in terms of years and banking groups included. This study formulated stochastic cost and profit frontier models and CRS Cost-DEA and CRS Profit-DEA for NCBs and PBs in Bangladesh.

In cost inefficiency model, the estimated coefficient of Price of borrowed fund (PBF) with -0.018 indicated that the level of inefficiency decreased by PBF. Advance (ADV) and Off-balance sheet items (OBS) were found significant with positive values that increased the value of inefficiency. In profit efficiency model, the estimated coefficient of Advance (ADV), other earning assets (OEA) and Price of borrowed fund were recorded highly significant with negative values that decreased the level of efficiency, but Off-balance sheet items (OBS), Price of fixed assets (PFA) and Price of labor (POL) were found significant with positive values that increased the level of efficiency.

Bank wise average profit efficiency and cost inefficiency were found to be 0.910 and 1.063 respectively. Most profit efficient bank was found *Eastern Bank* with score of 0.949 and less profit efficient bank was found *Janata*

Bank with score of 0.769 for profit model. Most cost inefficient bank was *Janata Bank* with score of 0.447 and less cost inefficient bank was *United Commercial Bank* with score of 0.053 for cost model.

In case of CRS cost DEA, average bank-wise technical efficiency, allocative efficiency and cost efficiency were 0.688, 0.359 and 0.245 respectively; and in case of CRS profit DEA, average technical efficiency, allocative efficiency and profit efficiency were 0.703, 0.318 and 0.221 respectively. Bank wise average cost and profit efficiency using SFA and DEA were (6.3% and 24.5%) for cost model and (91% and 22.1%) for profit model respectively; we conclude that SFA efficiency is better than DEA efficiency. Year-wise profit efficiency of PBs is recorded most efficient (92.5%) comparing to the NCBs (80.4%). Besides, year-wise average cost inefficiency of private banks occurred with the value of (15.2%) along with NCBs (34.6%). The cost and profit efficiency of NCBs were found always less efficient than PBs in DEA.

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