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STOCHASTIC FRONTIER MODEL AND DATA ENVELOPMENT ANALYSIS FOR COST AND PROFIT EFFICIENCY OF BANKS IN BANGLADESH

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Abstract : This study formulates the specification form of both stochastic cost and profit frontier models and constant return to scale Cost and Profit data envelopment analysis (CRS Cost-DEA and CRS Profit-DEA) models. It examines the cost and profit efficiency of National Commercial Banks and Private Banks in Bangladesh. The cost inefficiency and profit efficiency are observed slightly higher for private banks than national commercial banks in case of both stochastic frontier analysis (SFA) and DEA type models. The coefficients of advance and off-balance sheet items are found significant that positively influence the banks in stochastic cost frontier model. The advance, other earning assets, price of borrowed fund are observed significant and negative effects on the banks in stochastic profit frontier model. The average cost inefficiency and average profit efficiency were recorded with 16.3% and 91% respectively. The lowest cost inefficiency is observed for *United Commercial Bank Limited* while the highest cost inefficiency is found for *Janata Bank.* The lowest profit efficiency is recorded for *Janata Bank* while the highest profit efficiency is observed for *Eastern Bank Limited.* The average technical and allocative efficiency (*inefficiency*) are 68.8% (*45.3%*) and 35.9% (*178.5%*), respectively in case of CRS cost-DEA model. The average technical and allocative efficiency are 70.3% and 31.8% respectively in case of CRS profit-DEA model. The average cost inefficiency is recorded 6.3% by SFA whereas average cost efficiency is recorded 24.5% by DEA, that showed less efficient. The average profit efficiency is found 91% by SFA while average profit efficiency is found 22.1% by DEA, so SFA method shows better efficiency than DEA in terms of banks in Bangladesh.

Key Words: Cost and Profit efficiency models, Stochastic Frontier Analysis, Data Envelopment Analysis, National commercial banks and Private Banks, Bangladesh.

1. Introduction

The banking industry of Bangladesh is a mixed one comprising nationalized, private and foreign commercial banks. These banks are the main vehicles for mobilizing invisible funds and channeling those funds to faster the growth of the productive sectors of the economy. After the liberation war 1971, Bangladesh Government nationalized all the commercial banks and financial institutions functioning in the East Pakistan. But during 1982-83, the government allowed commercial banks to operate in private sector side by side with the public sector banks to start a meaningful and constructive competition in the banking sector. About two decades in Bangladesh that banks are operating under both public and private sector. Question arises how successfully the national and private commercial banks are serving the country, how far they have achieved their desired goals? To measure cost and profit efficiency of national commercial banks and private banks using stochastic frontier analysis and data envelopment analysis is important for at least two reasons. First, efficiency measures are indicators of success, by which the performance of individual banks, and the bank industry as a whole, can be gauged. Second, banks has been faced growing competition, both from other banks and from firms and markets outside the industry (Wheelock and Wilson, 1993) and presumably banks will be more successful in maintaining their business if they operate efficiently.

Stochastic frontier analysis (SFA) has become a popular tool for production analysis. One particular advantage of SFA is the ability to model the production relationship and the determinants of inefficiency in one stage. The original specification of stochastic frontier production for cross-section

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data was independently proposed by Aigner, Lovell and Schmidt (1977), Battese and Corra (1977) and Meeusen and van den Broeck (1977). DEA is a linear Programming technique developed by Charnes, Cooper and Rhodes (1978), that allows calculating relative efficiency of a business unit without knowing (*a prior)* whether any relationship is exist among the variables. In most of them, it is very difficult to obtain the input price due to unavailability of data information (price data is necessary in order to perform econometric approach). Essentiality for that reason, this study uses the non-parametric approach (DEA) to investigate the efficiency of banks.

There has been a widespread discussion about lack of cost and profit efficiency of banks in developing countries compare to the world wide by using stochastic frontier cost and profit models. Favero and Papi (1995) measured technical efficiency and scale efficiency in the Italian banking sector using a non-parametric approach. Canhoto, and Dermine (2003) considered the impact of foreign bank entry on banking efficiency in Australia using DEA and SFA, they found foreign banks more efficient than domestic banks, which however did not result in superior profits. The measurement of bank technical efficiency and scale efficiency studies are available using DEA by several researchers (for eg., Wahida, 2011; Bengul and Ergec, 2010; Pardeep and Gian, 2010; Delis et al., 2009; Tahir et al., 2009; Al-Delaimi and Al-Ani, 2006; Lyroudi and Angelidis, 2006; Dilruba, 2005; Shanmugam and Dasz, 2004). Interested readers can refer to Vu and Turnell (2011), Akinloye et al. (2010), Tahir et al. (2010), Cadet (2008), Dacanay (2007), Vander (2002), and Berger et al. (1993) for works of cost and profit efficiency models.

We build on this string of the literature, but study the effects on banks' cost and profit efficiency, using efficient frontiers rather than financial ratios measuring performance (Berger and Humphrey, 1997). Some of above researchers summarize the existing literature on cross-country comparisons of banking efficiency using SFA and DEA independently. 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. A few studies are available in measuring bank efficiency using only SFA in Bangladesh (Baten and Kamil, 2010, 2011). Rahman and Islam (2011) investigated relative cost and profit efficiency of different branches of Islamic Bank Bangladesh Limited (IBBL) using only parametric technique, but the comparisons with NCBs and PBs using non-parametric technique like DEA is not available at their study. Moreover, Maudos and Poster (2001) and Maudos et al., (2002) pointed out that the estimation of profit efficiency and its comparison with cost efficiency, where the available evidence on bank efficiency is very limited. This study contributes in filling this gap.

This study deals to estimate first cost and profit efficiency of National Commercial Banks and Private Banks in Bangladesh. Second, it measures year wise technical efficiency of the banking sector in Bangladesh by SFA. Third, it measures both Cost and Profit efficiency of banks individually by using CRS Cost DEA and CRS Profit DEA. Finally, it compares cost and profit efficiency by using both SFA and DEA.

2. Methodology

2.1 Stochastic Cost Frontier Model

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

$$C_i = f(y_i, p_k, \varepsilon_i), \quad i = 1, \ldots\ldots\ldots \ldots, N \quad \ldots\ldots\ldots(1)$$

where, N stands for the number of banks; C_i stands for the bank's total operational costs of i-th banks; y_i represents the vector of output quantities of the i-th banks; p_k is the vector of price inputs

of the i-th banks; and ε_i is a composite error term, through which the cost function varies stochastically. The term ε_i can be partitioned into two parts as follows: $\varepsilon_i = v_i + u_i$ …….(2)
The equation (1) is represented in natural logs:

$$\ln C_i = f(y_i, p_k) + \ln v_i + \ln u_i \quad \text{…….(3)}$$

where, v_i refers to endogenous factors and u_i refers to exogenous factors, which impact the cost of the bank production. Thus the term v_i 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 price. u_i 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_i are assumed to be identically distributed as normal variates and inefficiency scores 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 specification of translog cost frontier model can be expressed in terms of banks as multi-output and multi-input banks as follows:

$$\ln C_i = \alpha_0 + \sum_i^4 \beta_i \ln y_i + \frac{1}{2}\sum_i^4\sum_j^4 \beta_{ij} \ln y_i \ln y_j + \sum_k^3 \beta_k \ln p_k$$
$$+\frac{1}{2}\sum_k^3\sum_m^3 \beta_{km} \ln p_k p_m + \sum_i^4\sum_k^3 \beta_{ik} \ln y_i \ln p_k + v_i + u_i \text{..........(4)}$$

where, ln is natural logarithm; β_i , β_{ij} are parameter to be estimated for the frontiers of output; β_k , β_{km} are parameter to be estimated for input price of frontier model; β_{ik} is parameter to be estimated for interaction effect.

2.2 Stochastic Profit Frontier Model

Suppose the ith bank has a vector of x_i independent inputs that determine profit. Then, the stochastic profit efficiency model is defined as:

$$\pi_i = \beta x_i + v_i - u_i, \qquad i = 1,2,\text{..........}, N; \qquad (5)$$

where π_i is the logarithm of profit of the i^{th} bank; x_i is a vector of input quantities; β_i's are unknown parameters to be estimated; v_i'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_i; for profit function, $u_i \le 0$ (0 for highest profit) accounts for bank's inefficiency and is assumed here to follow a truncated normal distribution i.e., $N(\mu, \sigma_u^2)$.

The profit efficiency 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_i the profit efficiency of i-th bank industry is given by:

$$PE_i = {p}/{p^*} = \exp(-u_i) \quad ..(6)$$

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

$$\ln(\pi_i + a) = \ln\ f(x_i, p_k, \beta) + v_i - u_i \cdots (7)$$

where, π_i represent net profit after tax of the i-th banks; x_i represent vector of input quantity of i-th banks; 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; p_k represent vector of k-th input price of banks.

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

$$\ln(\pi_i + a) = \beta_0 + \sum_{i=1}^{4}\beta_i \ln x_i + \sum_{k=1}^{3}\beta_k \ln p_k + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4}\beta_{ij} \ln x_i \ln x_j$$
$$+\frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\beta_{kl} \ln p_k \ln p_l + \sum_{k=1}^{3}\sum_{i=1}^{4}\beta_{ki} \ln p_k \ln x_i + v_i - u_i \cdots\cdots\cdots (8)$$

where, β_i , β_{ij} are parameter to be estimated for the frontiers of input; β_k , β_{kl} are parameter to be estimated for input price of frontier model; β_{ki} is parameter to be estimated for interaction effect.

2.3 Data Envelopment Analysis Method

CRS Profit DEA

Let us consider n DMUs (decision making unit) or banks, each one producing different output (y) and using different inputs (x). The profit efficiency of the bank assuming constant return scale (CRS), is measured as follows:

$$\begin{aligned}
&Max_{u,v}(u'y_i / v'x_i),\\
&\text{Subject to}\\
&u'y_j - v'x_j \le 0, \qquad j = 1, 2, \ldots\ldots\ldots\ldots, N, \quad ...(9)\\
&u, v \ge 0.
\end{aligned}$$

where x_i is a vector of i-th bank inputs. y_j is a vector of bank j-th output given the inputs. u is the weighted relative vector associated to output. v is the weighted relative vector associated to input.

CRS Cost DEA

Imperfect competition, constrain in finance, etc. may cause a bank to be not operating at optimal scale, in this case the CRS assumption is not appropriate because it assumes that banks are operating at optimal scale. In this case, Banker, Charnes and Cooper (1984) suggested an extension of the above model to take into account the variable return to scale (VRS). The dual form of the above problem is:

$$\begin{aligned}
&Min_{\theta,\lambda}\theta,\\
&\text{St} \quad -y_i + Y\lambda \ge 0,\\
&\qquad \theta x_i - X\lambda \ge 0, \qquad \ldots\ldots\ldots\ldots\ldots\ldots(10)\\
&\qquad \lambda \ge 0,
\end{aligned}$$

where X is $m \times n$ input matrix, Y is $s \times n$ output matrix, λ is an $n \times 1$ vector of constant and θ is a scalar. The value of θ obtained will be the efficiency score for the i-th bank. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technical efficiency bank.

3. Data and Definition of Variables

We consider 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 include (1) Cost is 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. (2) Profit is measured as total profit after tax. (3) Advance is measured as total loan and advance minus loan. (4) Other earning assets is measured by total other assets. (5) Off-balance Sheet Items are measured by total Off-balance Sheet items including contingent liabilities.

All input prices 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. All input quantity includes (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.

4. Results and Discussion

Summary statistics of output, input quantity and input prices are presented in **Table 1.** The maximum likelihood estimates of the stochastic frontier cost and profit models of the selected bank 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 β_1 (.334) is highly significant at 1% level and the coefficient of off-balance sheet items β_3 (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.

The results of various hypothesis tests of the cost and profit efficiency models were presented in **Table-3**. The first null hypothesis is $H_0 : \gamma = 0$, which specify 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.

The evaluation of technical efficiency, allocative efficiency cost efficiency and profit efficiency for the selected 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 allocotive efficiency for the selected banks. However, in the selected banks, 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, these two measures 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 *Mutual Trust Bank* and *One Bank* in terms of cost DEA.

In case of profit DEA, the average technical and allocative efficiency are 70.3% and 31.8%, respectively. The technical efficiency is observed higher than the allocative efficiency for all sample 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* in case of profit DEA. The average cost and profit efficiency is recorded at 24.5% and 22.1% respectively in case of both Cost-DEA and Profit-DEA.

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 and average cost efficiency 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 exactly 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% by SFA and average profit efficiency is found 22.1% by DEA, 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* and exact efficient is for *One Bank* with the values of 1.4% and 100% respectively. Most of the banks are recorded above 90% efficient by SFA on the other hand most of the banks 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 selected banks. *Eastern Bank* profit 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; on the other hand this *Janata Bank* 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, on the other hand *DBBL, Mercantile Bank, MTB, National Bank, One Bank, Prime Bank, Pubali Bank* and *Uttara Bank* are almost stable in terms of cost inefficiency.

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

In case of SFA, the average cost inefficiency is found to be high in the year of 2002 for NCB while average cost inefficiency is recorded high in the year of 2003 for PB but cost inefficiency is found less inefficint in the year of 2010 for NCB and cost inefficiency is recorded less inefficient in the year of 2007 for PB. In the year of 2001 cost inefficiency is observed 59.2% for NCB and 13.1% for PB, which are less inefficient than NCB. In the year of 2006 the cost inefficiency is recorded 57.6% for NCB and 11.9% for PB, it is also less inefficient than NCB. 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 NCB. 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 PB.

In case of DEA, the cost efficiency is most efficient in the year of 2009 with the value of 67.9% for NCB and most efficient with 91.9% in the year of 2004 for PB. It is less efficient in the year of 2004 with the value of 8.4% for NCB and less efficient in the year of 2006 with the value of 76.2% for PB. The average profit efficiency 80.4% for NCB and 92.5% for PB while the average profit efficiency 27.1% for NCB and 77.5% for PB. The PB is more efficient than NCB 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 NCB; 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 PB. The overall profit efficiency of PB is more efficient than NCB in case of both SFA and DEA.

Year-wise the profit and cost efficiency scores for the selected 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 increase to 93.7% in 2009, but profit efficiency decreases from 2002 to 2003. On the other hand in the year 2003, low profit efficiency is observed, but in the year 2010, it slightly decrease compared to the year 2009. The trend for cost inefficiency scores increase from 19% to 28% from 2001 to 2003, and then jump from 28% to 12% during 2003 to 2005, and then increase from 12% to 17% in 2006 and then decrease from 17% to 11% during 2008 and 2010.

5. Conclusion

This study formulated stochastic cost and profit frontier models and CRS Cost-DEA and CRS Profit-DEA to examine cost and profit efficiency of National Commercial Banks and Private Banks in Bangladesh.

In cost inefficiency model, the estimated coefficient of Price of borrowed fund (PBF) with -0.018 indicated that the level of inefficiency was decreased by price of borrowed fund. Advance (ADV) and Off-balance sheet items (OBS) were found significant with positive values that showed increasing 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 represented decreasing 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 represented increasing 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, 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, 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 private banks is recorded most efficient (92.5%) comparing to the national commercial banks (80.4%). Besides, year-wise average cost inefficiency of private banks occurred with the value of (15.2%) along with national commercial banks (34.6%). National commercial banks cost and profit efficiency were found always less efficient than private banks in case of DEA.

Appendix

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

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 Statistics 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 value 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.

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

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

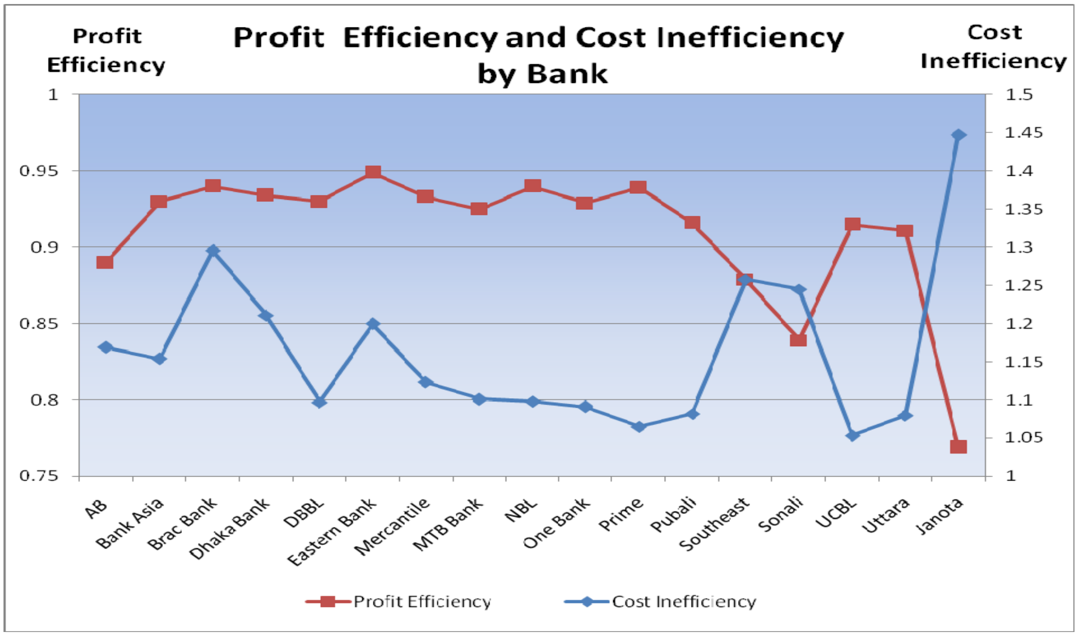

Figure-1: Average Cost and Profit Efficiency of Selected Banks for Stochastic Frontier Analysis

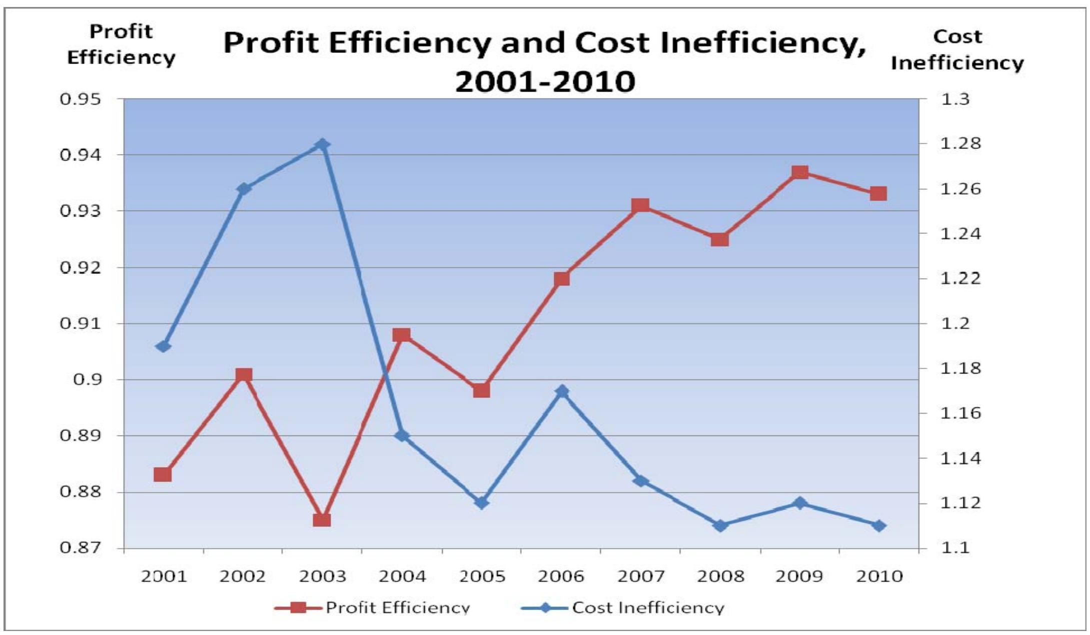

Figure-2: Year-wise Average Cost and Profit Efficiency of Banks

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