MEASUREMENT OF INEFFICIENCIES IN BANGLADESH BANKING INDUSTRY USING STOCHASTIC FRONTIER PRODUCTION FUNCTION

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ABSTRACT

This paper examines inefficiencies of Bangladesh banking industry using the stochastic frontier production function model and the time invariant cross-sectional data. The measure of ith bank technical efficiency indicates that the efficiency of Bangladesh commercial banks lies between 12.7 and 94.7 percent; the industry average is 69.5 percent. The model suggests that about 30 percent of the commercial banks in Bangladesh are below the industry average.

JEL: C12, C13, C24

INTRODUCTION

The study of efficiency in manufacturing industry in the developing countries has been an important topic in developmental literature (Pitt and Lee, 1981). In the past, the study of efficiency—technical and allocative—has also been a topic of considerable interest in agriculture. Several authors have conducted numerous studies for estimating technical inefficiencies including Battese and Coelli, 1988 and 1992. Huang and Liu (1994), Reifschneider and Stevenson (1991), and Kumbhakar, Ghose and McGuckin (1991) have also introduced models for technical inefficiency effects in the stochastic function. The interest in efficiency studies is no longer limited to agriculture and industry as it has been in the past. The interest has now entered into the banking industry.

Although there are a number of studies relating to bank efficiencies, the survey of literature done for this paper demonstrates that all of the studies applied non-parametric approaches in measuring the efficiency. All of the studies relating to bank efficiency followed Data Envelope Analysis (DEA). The DEA analysis does not provide enough credibility to the statistical significance of efficiency measure. Because "DEA assumes all deviations from the frontier are due to inefficiency" (Collie, Rao and Battese, 1998, p.219). In this respect the stochastic frontier production model, independently developed by (ALS) Aigner, Lovell, and Schmidt (1977) and (M&B) Meesuen and van den Broeck (1977), and then later modified and applied by Battese and Corra (1977) and Battese and Coelli (1995, is the most appropriate tool for measuring firm level inefficiency. The reason to use the stochastic model is because if there is any noise, like measurement errors, strikes, this "may influence the placement of the DEA frontier more than would be the case with the stochastic frontier approach" Collie, Rao and Battese,1998, p.219). There are other relative advantages for using the stochastic frontier approach. Tests of the hypothesis for the existence of inefficiency and the structure of production technology can also be performed in a stochastic frontier analysis.

This paper applies the stochastic frontier production function approach to the banking industry in Bangladesh. A stochastic frontier production function is defined for panel data, in which the non-negative technical inefficiencies of firms are assumed to be dependent on firm specific variables and time (Battese and Coelli, 1995). The stochastic production frontier model measures firm's technical efficiency which is the ratio of its mean output (subject to the level of its inputs and firm effects) to the corresponding mean production obtained by utilizing its factor inputs most efficiently.

The function also postulates the inefficiency effects in producing a firm output that are independently distributed as truncations of normal distributions with a constant variance. The parameters of the stochastic frontier and the efficiency model are estimated simultaneously with a given distributional assumption associated with cross-sectional data on the sample firm.

This paper is organized as: A brief survey of literature is outlined in Section 2. Section 3 provides a description of technical inefficiency and the frontier model with panel data. The estimate of the model and conclusion are provided in Section 4

LITERATURE REVIEW

There are numerous studies for measuring inefficiencies (efficiencies) at firm and industry level. In measuring inefficiencies, there are two prominent approaches. The one is the data envelopment analysis (DEA) known as nonparametric approach. The other is the stochastic frontier production function known as parametric approach.

DEA method was developed by Farrell (1957) and extended by Fare, Grasskopf, and Lovell (1994). This methodology is used in the banking studies of the United States by a number of authors as Farrier and Lovell (1990), Miller and Noulas (1996), Fixler and Zieschange (1993). Drake and Howcroft (1994) and Athanassopoulos (1995) used the DEA methodology for the banking industry in U.K. Lovell and Pastor applied this methodology in measuring efficiencies for the Spanish banking industry. Hassan, Al-shakas, and Samad (2004) used this method in investigating the relative efficiency of the banking industry in Bahrain.

The stochastic frontier production function, proposed and independently by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), then later developed and applied in numerous studies. Battese and Corra (1977), Kaliranjan (1982) used the stochastic frontier production function. Pitt and Lee (1981) measured the technical inefficiency in the Indonesian weaving industry with a time series cross-sectional data. Battese, Coelli and Colby (1989) applied this model for measuring efficiencies of Indian rice farms using panel data. Battese and Coelli (1992) used the frontier production function in estimating technical efficiencies of the paddy farmers of India. A generalized production frontier approach was used by Kubhakar, Ghose and McGuckin (1991) in estimating determinants of inefficiency of the United State dairy farm.

Technical Inefficiency (Efficiency)

Technically, a production function is efficient if a firm produces a maximum quantity of the output attainable with given inputs. Thus, production frontier is the locus of the technically efficient input-output combination. Inefficiency arises when a firm produces a quantity of output which is below the production frontier. That is, the output is below the maximum quantity of the attainable output. The real problem comes from estimating the production frontier. In this regards, early attempts were made by Farrell (1957) and subsequently by Aigner and Chau (1968) and Richmond (1974) to determine the frontier. These studies used linear and quadratic programming methods for estimating the production frontier. Several shortcomings became apparent. The most important, among the disadvantages, is that the production frontier does not incorporate the effect of random shocks which are outside the firms' control. As a result, "a few extreme measured observations determine the frontier and exaggerate the maximum possible output given inputs" (Pitt and Lee, (1981, p.44).

This problem is overcome by the application of the stochastic frontier production model which was developed independently by ALS (1977) and M&B (1977) by explicitly incorporating the inefficiency component, the error term, in the estimated production function. In the frontier production functions involving cross-sectional data on sample firms, the technical efficiency of a given firm was defined as the ratio of its mean observed production, given its realized firm effect, to the corresponding mean production, if the firm effect was zero (Battese and Coelli (1988). The technical efficiency of ith firm is:

$$TEi = \frac{E(Yit^* \mid Uit, xit, t = 1,2,..)}{E(Yit^* \mid Uit = 0, xit = 1,2,..)} \quad (1)$$

Where Y*it is the value of i^{th} firm production at t^{th} time and 0≤TE≤1. If TE=1, technical inefficiency = 0, on the other hand, if TE=0, technical inefficiency of ith firm is 100 percent.

Frontier Model for Panel Data

The important subject concerning the frontier production function is the component of the firm specific technical efficiency. The following is the frontier production function used for estimating inefficiencies of Bangladesh commercial banks:

$$Y_{it} = \exp\,(X_{it}\beta + V_{it} - U_{it}) \quad (2)$$

Where Y_{it} = quantity of output for i-th firm (i=1, 2,….N) at t-th time (t=1,2,…T)

X_{it} is a (1x k) vector of inputs and other explanatory variables used for the quantity of output of ith firm and t-th observation.

β is a (k x 1) vector of unknown parameters to be estimated.

V_{its} are random error variables and assumed to be independent and identically distributed as $N(0,\sigma_v 2)$ random variables, independent of U_{it} . $\sigma_v 2$ is independent of $U_{it.}$

Uits are non-negative random variables associated with ith firm technical inefficiency of production and assumed to be independently and identically distributed truncations (at zero) of the $N(\mu, \sigma 2)$.

The ratio of the observed output of the ith firm to potential output determined by the frontier function, given the input vector xi provides the definition of ith firm technical efficiency (TEi):

$$TEi = \frac{yi}{ecp(xiB} = \frac{\exp(xiB - ui}{\exp(xiB)} = \exp(-u_i). \quad (3)$$

(3) is the measure of technical efficiency for the ith firm. The mean technical efficiency of firms in the industry which corresponds to (3),according to Battese and Coelli, can be expressed and estimated as:

$$TE = \{\frac{1 - \Phi[\sigma - \mu / \sigma]}{1 - \Phi(-\mu / \sigma}\}\exp(-\mu + \tfrac{1}{2}\sigma^2) \quad (4)$$

Thus, when μ = 0, the mean technical efficiency provided in (4) equals to what derived by Lee and Tylor (1978) which is:

$$TE = 2[1-\Phi(\sigma)]\exp(1/2\,\sigma^2) \quad (5)$$

The method of maximum likelihood estimated proposed by Battese and Coelli (1993) is used for simultaneous estimation of the parameters of the stochastic frontier and the model of technical inefficiency effects. The likelihood function expressed in terms of variance parameters is:

$$\sigma^2_s = \sigma^2_v + \sigma^2 \text{ and } \gamma = \sigma^2 / \sigma^2_s \tag{6}$$

DATA AND METHODOLOGY

Data concerning Bangladesh commercial banks are considered for an empirical application of the model defined above. The data used in this paper is taken from Banks and Financial Activities, publication of the Ministry of Finance, Finance Division, Peoples' Republic of Bangladesh. Data is cross-sectional for the 44 commercial banks in Bangladesh for the year 2000.

In many industries, physical measures of output and input are readily available. There are no differences of opinion about it. For examples, in agriculture, the output is paddy, wheat or corn and is measured in tons or kg. Inputs are land, labor, and capital. In electricity, the output is kilowatt-hours of electricity. Inputs are the number of workers, tons of fuels used, and the value of electric generators.

There is no agreement in the physical measures of output in the banking sector. Moreover, there is no consensus with regard to the definition of input and output for a banking firm. Banks are multi-product firms and produce a variety of products and services as loans to customers, safekeeping, intermediation and accounting services for deposits (Benston and Smith, 1976). Some have argued that a bank's primary product is loans. From an asset point of view, the production of deposit services is essentially viewed as inputs which are used to make loans (Sealey and Lindley, 1977). This study looks at bank loans as an output of the bank. Lack of employee expenditure data, this paper uses the number of employees and deposits as inputs to generate outputs such as loans. The stochastic frontier production function is estimated as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(Dep_{it}) + \beta_2 \ln(Emp_{\,it}) + V_{it} - U_{it} \tag{7}$$

where

Y is the total loans, Dep is total deposits, and Emp is the total number of employees working for the bank $_{it}$. ln is natural log. The stochastic frontier production function in (7) is viewed as a linear version of the logarithm of the Cobb-Douglas production function. Maximum-likelihood estimates of the parameters of the model (7) are obtained by purpose specific computer software (Frontier 4.1, Coelli, 1996).

RESULTS

The estimated parameters of the frontier model are provided in (7) and are reported in Table 1.

Table: 1 Para meter Estimates for Frontier Production Function for Bangladesh Commercial Banks

Method of Estimate	**Intercept**	**Variables**		**Variance Parameters**			**Log-likelihood**	**Mean Technical Efficiency**
	β_0	$\beta_1$ln Dep	$\beta_2$lnEmp	σ_s^2	γ	μ		
M.L. (μ=0)	0.14	0.60	0.32		0.83	0.0	-33.2	
M.L. (final)	0.48	0.89	0.68	1.7	0.97*	-0.25	-25.3	0.69
(μ≠0)	(0.53)	(0.11)	(0.095)	(0.7)	(0.013)	(0.11)		

** Significance level is 0.001 percent. Table 2 provides estimated parameters of the stochastic frontier model where γ represents inefficiency. Log-likelihood ratio test provides whether γ, the measure of randomness is present and significant*

The estimated value of the parameter, μ, which defines the distribution of the bank effects for the different banks is –0.25, with an estimated standard error of 0.11. The distribution of the bank effects is found to be significantly different from the half-normal distribution in which $\mu = 0$.

A test on the significance of the random variable U_i , in the frontier model (7) is obtained from the likelihood ratio, LR. To determine if the random variable is absent from the model (i.e. $\mu = \gamma = 0$) a test can be performed for the significance of LR.

The LR value is obtained as = -2(URLLF – RLLF).

Where

URLLF = unrestricted log likelihood function
URLLF = restricted log likelihood function

Substituting the value from Table 1, LR= -2(-33.2 – (-25.3) = 15.8. The LR value has approximately chi-square distribution with parameter equal to two. According to Battese & Coelli, "the negative of twice the logarithm of the generalized log likelihood ratio has approximately chi-square distribution with parameter two" (1988, p.396).To determine if the estimated LR statistics = 15.8 is statistically significant can be tested by calculating the p-value with the number of restriction = 2.

Since the calculated p-value corresponding to LR = 15.8 with df =2 is 0.00038, LR is statistically significant at .001 percent level of significance. This means that the inefficiency effect as measured by γ is significantly different from zero. Thus, $H_0 : \gamma = 0$, is rejected. The result ($\gamma = 0.97$) indicates that the vast majority of residual variation, about 93 percent, is due to inefficiency effects, U_i , the bank specific factors. The random error, V_i , which accounts for the present measurement error in outputs, explains only 3 percent of the inefficiency.

The estimator β_1, is the coefficient for the deposit and is statistically significant. The test statistics for β_1 = 8.09 (=0.89/0.11) is higher than $t_{,.0005,42}$ = 3.50. Thus, H_0: $\beta_1 = 0$ is rejected at a significance level = 0.001. The estimator β_2, as the coefficient for employees is not statistically significant. The predicted efficiencies for the individual commercial bank of Bangladesh are presented in Table 2.

Tables 2 show that the average (mean= μ) technical efficiency of the banking industry in Bangladesh is 0.696 i.e.69.6 percent. It appears from Table 3 that 29.53 percent of the Bangladesh commercial banks are operating below the industry (banking) average. This means that about 70 percent of the commercial banks have technical efficiency higher than the industry average of 0.695. The frequency of predicted efficiencies in different ranges is presented in Table 3.

Table 3 shows that 11.35 percent of Bangladesh commercial banks have technical efficiency less than 0.5 (50%) in issuing loans. 68.11 percent of the commercial banks have technical efficiencies in the range between 0.70 and 0.9 in issuing loans with labor and deposits. 29.53 percent of the banks in Bangladesh had a technical efficiency less than 0.70 in 2000. Only one bank in this study had a technical efficiency higher than 0.9 i.e. 90 percent.

Table 2: Predicted Efficiencies for Sample Banks of Bangladesh

Bank	Estimated efficiencies	Bank	Estimated efficiencies
1	0.78	23	0.56
2	0.80	24	0.38
3	0.82	25	0.76
4	0.81	26	0.62
5	0.81	27	0.74
6	0.77	28	0.41
7	0.85	29	0.39
8	0.12	30	0.62
9	0.77	31	0.76
10	0.78	32	0.81
11	0.80	33	0.27
12	0.88	34	0.89
13	0.85	35	0.83
14	0.83	36	0.79
15	0.75	37	0.75
16	0.80	38	0.57
17	0.77	39	0.50
18	0.83	40	0.59
19	0.61	41	0.81
20	0.57	42	0.94
21	0.77	43	0.70
22	0.80	44	0.83
Mean efficiency for 44 banks			=0.695

Numbers, in Table 2, below the bank variable i.e. in column 1 and 3 are individual commercial bank and their respective estimated efficiencies are provide in column in 2 and 4.

Table 3 Frequency Distribution of Predicted Efficiencies for the Bangladesh Commercial Banks

Range of efficiencies	*Frequency of occurrences*	*Relative frequency (%)*	**Cumulative relative frequency (%)**
Less than 0.3	2	4.55	4.54
0.30 – 0.50	3	6.81	11.35
0.50 – 0.70	8	18.18	29.53
0.70 – 0.90	30	68.11	97.64
0.9 and above	1	2.27	100.0
Total	44	100.0	

CONCLUSION

The application of the stochastic frontier production function to the banking industry in Bangladesh indicates that the average technical efficiency for the industry is 0.695. About 30 percent of the commercial banks in Bangladesh have less than the industry average for technical efficiency and 70 percent of the banks have technical efficiency higher than the industry average.

The application of the model indicates that 0.97 of the residual variation of outputs (loans) are explained by the bank specific inefficiency factors, U_i . A proper bank management policy at the bank and national level may be perused to address these residual variations of outputs.

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