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Estimating Stock Market Technical Efficiency for Truncated Normal Distribution: Evidence from Dhaka Stock Exchange

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ABSTRACT

This study analyzes the technical efficiency of selected groups of companies of Bangladesh Stock Market that is Dhaka Stock Exchange (DSE) market using a stochastic frontier production function approach. This research considers Cobb-Douglas Stochastic frontier model with truncated normal distribution and both the time-variant and time-invariant inefficiency effects are estimated. The studied input variables-market return, market capitalization, book to market ratio and market value show significant relationship with the stock returns. The estimated average technical efficiency of DSE market is 95.42% of potential output for the truncated normal distribution over the period 2000-2008. The results show that technical efficiency gradually decreases over the reference period. The value of technical efficiency is high for investment group and low for bank group in time-variant situation whereas the value of technical efficiency is high for investment group also but low for ceramic group in time-invariant situation.

Key words: Technical efficiency, Cobb-Douglas stochastic frontier, truncated normal distribution, time-variant, time-invariant, Dhaka stock exchange

INTRODUCTION

Recently, all over the world many researches go on about the stock markets (such as, for French's stock market, Rhaiem *et al.* (2007a, b), for Spanish stock market, Ferruz *et al.* (2007), for Istanbul stock exchange, Senol and Ozturan (2008) and Kaplan (2008) for Nigerian stock market, Chigozie (2010), for Malaysian stock market, Angabini and Wasiuzzaman (2011), for Vietnam stock market, My and Truong (2011), for Taiwan stock market, Lin and Liang (2011), for Indian stock market, Gunasekaran and Ramaswami (2011) and for US stock market, Ravichandran and Bose (2012) but in Bangladesh, studies related to stock market are few (for example, Rahman *et al.*, 2006a, b; Uddin and Alam, 2007; Hasan *et al.*, 2011a).

Two major methods are often used for investigating the technical efficiency of financial institutions, parametric Stochastic Frontier Analysis (SFA) and non-parametric Data Envelopment Analysis (DEA). There is no accord which of the major approach is superior (Berger and Humphrey, 1997). It is a controversial matter to choice SFA approach or DEA approach for measuring efficiency (Olesen *et al.*, 1996). In addition, there are several studies that had been compared parametric and non-parametric techniques to check efficiency of financial institutions

(Altunbas *et al.*, 2001; Maudos *et al.*, 2002; Weill, 2004). This study considered the SFA to measure the technical efficiencies of selected groups of companies in Dhaka Stock Exchange (DSE) market in Bangladesh instead of DEA; because of the advantage of SFA which deals with stochastic noise and allows statistical tests of hypotheses about production structure and degree of inefficiency. This research did not consider the DEA, because it does not entail any assumptions about production functional form and does not consider the random error (Kasman and Turgutlu, 2008). The half-normal and truncated normal distribution were often used as assumption on the inefficiency effects model because of the simplicity of estimation and interpretation (Kirkley *et al.*, 1995). This study used the truncated normal distribution as an assumption because it is more appropriate than half-normal (Greene, 1993).

The way of applying SFA on measuring the technical efficiency of DSE market, DSE can play the desired role in the process of economic development of the country and would draw policy conclusions conducive to economic growth of Bangladesh. That is why this research is important for academics, policy makers and different capital market participants such as investors, managers and regulatory authorities.

MATERIALS AND METHODS

Data description and variables construction: Dhaka Stock Exchange has significant implications on the financial sector performance as well as the entire economy (Uddin and Khoda, 2009) and it is the oldest stock exchange of Bangladesh. The data has collected from DSE market consisting 94 companies in Bangladesh for the period of 2000-2008. This study has covered 13 types of category of company as: Banks, Investment, Engineering Food and Allied Products, Fuel and Power, Textile, Pharmaceuticals and Chemicals, Services and Real Estate, Cement Industry, Tannery Industry, Ceramic Industry, Insurance and Miscellaneous.

Dependent variable: This study takes individual company's return as a dependent variable. The formula is:

$$\text{Individual company's return (Y)} = \ln (P_t) - \ln (P_{t-1})$$

where, P_t = closing price at period t; P_{t-1} = closing price at period t-1 and \ln = natural log.

The reasons to take logarithm returns are justified by both theoretically and empirically. Theoretically, logarithmic returns are analytically more tractable when linking returns over longer intervals. Empirically, logarithmic returns are more likely to be normally distributed which is an earlier condition of standard statistical techniques (Strong, 1992). In order to obtain the individual company's return, company's dividend, bonus and right issues are not adjusted since, many researchers confirmed that their conclusions remained unchanged whether they adjusted their data for dividend, bonus and right issues or not (Lakonishok and Smidt, 1988; Fische *et al.*, 1993).

Independent variables: Here, market return, market capitalization, book to market ratio and market values are taken as independent variables. The formulas are given below:

$$\text{Market return (X}_1) = \ln (P_t) - \ln (P_{t-1})$$

where, P_t = price index at period t; P_{t-1} = price index at period t-1 and \ln = natural log. The name of the index is "All Share Price Index". DSE prepares daily price index from the daily transaction of each stock:

Market capitalization (X_2) = (Previous day's closing share price × shares in issue)

Book to market ratio (X_3) = (Book value/Market value)

Here, the company's net asset value per share is chosen as a book value of that company. The market value is the share value in the current market price:

Market Value (X_4) = (Share price × No. of securities traded)

Theoretical stochastic frontier model: The stochastic frontier model, sometimes also referred as the econometric frontier model was developed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). The present study has used the model proposed by Battese and Coelli (1992) which explicitly accounts for statistical noise. The specification of the model may be expressed as:

$$Y_u = \exp(x_u\beta + V_u - U_u) \quad I = 1, 2, \dots, T \quad (1)$$

where, Y_u denotes the output for the i th company in the t th time period; x_u denotes the $(1 \times k)$ vector whose values are functions of inputs for the i th company in the t th time period; β is a $(1 \times k)$ vector of unknown parameters to be estimated; V_u is the error components of random disturbances, distributed i.i.d. $N(0, \sigma_v^2)$ and independent from U_u . U_u is non-negative random variables associated with the technical inefficiency of production and it can be expressed following Battese and Coelli (1992) as:

$$U_{it} = \{\exp[-\eta(t-T)]\} U_i \quad (2)$$

where, η is an unknown scalar parameter to be estimated which determines whether inefficiencies are time-variant or time-invariant; and U_i is assumed to be i.i.d. and truncated at zero of the $N(\mu, \sigma_u^2)$ distribution. Following Battese and Coelli (1988), the technical efficiency for the i th company in the t th year can be defined as follows:

$$TE_{it} = \exp(-U_{it}) \quad (3)$$

U_{it} denotes the specifications of the inefficiency model in Eq. 2. This is done with the calculation of maximum likelihood estimates for the parameters of the stochastic frontier model by using the computer program FRONTIER Version 4.1 (Coelli, 1996).

Empirical stochastic frontier model: Since the sample number is not very high, Cobb-Douglas stochastic frontier production function with the distributional assumption as a truncated normal distribution is selected in this study. Furthermore, the Cobb-Douglas production function is looked as a simple tool which can be handled easily and can handle multiple inputs in its generalized form (Murthy, 2002). The functional form of the Cobb-Douglas stochastic frontier production model with the decomposed errors is defined as:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 \ln X_{4it} + (V_{it} - U_{it}) \quad (4)$$

where, the subscripts i and t represent the i th company and the t th year of observation, respectively; $I = 1, 2, \dots, 94$; $t = 1, 2, \dots, 9$; Y_{it} represents the individual return; X_{1it} represents the market return; X_{2it} represents market capitalization; X_{3it} represents book to market ratio; X_{4it} represents market value. "ln" refers to the natural logarithm; the β_i 's are unknown parameters to be estimated; V_{it} follows $N(0, \sigma_v^2)$ and U_{it} follows a truncated normal distribution at zero and guarantees inefficiency to be positive only.

Hypothesis test: We test the following three hypotheses. They are:

$H_0: \gamma = 0$, expressing that the technical inefficiency effects are not present in the model

The half-normal distribution is a special case of the truncated normal distribution and implicitly involves the restriction $H_0: \mu = 0$.

The hypothesis that efficiency is invariant over time, that is $H_0: \eta = 0$ will be tested. These are tested through imposing restrictions on the model and using the generalized likelihood-ratio statistic (λ). The generalized likelihood ratio statistic is defined by:

$$\lambda = -2\{\ln [L(H_0)] - \ln [L(H_1)]\} \tag{5}$$

where, $\lambda = \{\ln [L(H_0)]\}$ and $\lambda = \{\ln [L(H_1)]\}$ are the values of the log-likelihood function for the frontier model under the null and alternative hypotheses.

RESULTS AND DISCUSSION

Maximum-likelihood estimates of Cobb-Douglas production function with time-variant and time-invariant situation: The Maximum-likelihood Estimates (MLE) for the parameters of Cobb-Douglas stochastic frontier production function with time-variant and time-invariant situations were presented in Table 1. The results showed that the maximum-likelihood estimate of the parameter for market return input is 0.3873 and 0.4559, for market capitalization input is -0.1651 and -0.1555, for book to market ratio input is -0.0771 and -0.0621, for market value input is 0.2925 and 0.2308 for the time-varying and time-invariant situation, respectively. The MLE of

Table 1: Estimates of maximum-likelihood of the Cobb-Douglas production function with time-variant and time-invariant situation

Variables	Parameters	Time-variant			Time-invariant		
		Coefficients	SE	t-value	Coefficients	SE	t-value
Constant	β_0	-1.3776*	0.3830	-3.597	-0.4332 [@]	0.3945	-1.098
Market return	β_1	0.3873*	0.0449	8.630	0.4559*	0.0531	8.587
Market capitalization	β_2	-0.1651*	0.0368	-4.486	-0.1555*	0.0373	-4.166
Book to market ratio	β_3	-0.0771*	0.0145	-5.336	-0.0621*	0.0147	-4.230
Market value	β_4	0.2925*	0.0335	8.740	0.2308*	0.0333	6.932
Variance parameters							
Sigma-squared	σ^2	0.3286*	0.0722	4.548	0.0990*	0.0260	3.811
Gamma	γ	0.7632*	0.0605	12.6053	0.1572 [@]	0.2428	0.6475
Mu	μ	-1.0015**	0.4504	-2.224	-0.2495 [@]	0.5387	-0.4631
Eta	η	-0.4964*	0.0919	-5.402	0	0	0
Log-likelihood		-149.0902			-157.1236		

*, **, *** Significance level at 1, 5 and 10% consecutively, @ means insignificant, SE: Standard error

market return, market capitalization and book to market ratio in time-invariant situation were found higher than time-varying situation; and only the MLE of market value in time-invariant situation was estimated smaller than time-varying situation. However, the estimated values of the parameters of the Cobb-Douglas frontier production function obtained with the two different environments were almost similar. The log likelihood functional values for the two situations were relatively the same to each other. For the time-variant case, γ is estimated at 0.7632 which was significant and for the time-invariant case, γ is estimated at 0.1572 which was insignificant. This could be interpreted that 76% variations in output among the companies were due to the differences in technical efficiency for truncated normal distribution. It was evident from Table 1 that the estimates of σ was 0.3286 and 0.0990 for time-variant and time-invariant case were significantly different from Zero, indicated a good fit. The estimates for the parameters for the time varying inefficiency model indicated that the technical inefficiency effects tend to increase over time since the estimates for the η parameter was observed negative.

For the time-variant and time-invariant environment, the maximum-likelihood estimates of the coefficients of market return, market capitalization, book to market ratio and market value were found significant at 1% level of significance. These results indicated that these input variables significantly affect the amount of return in individual companies listed in the DSE market. There was a significant negative relationship between shares return and market capitalization which was supportive to some studies (Banz, 1981; Chan *et al.*, 1991; Fama and French, 1992) and contradict some studies (Perera, 1995; Claessens, 1996) because, later studies showed that there is a positive relationship between market capitalization and share return. Also, there was a significant negative relationship between the book-to-market ratio and stock returns which contradict in the emerging market research. Claessens (1996) found a significant positive relationship between the book-to-market ratio and share returns. The market return showed significant relationship with the stock returns which meant that if the overall market raises then the return of individual companies will increase and if the overall market falls then the return of individual companies will decrease. Rahman *et al.* (2006a) also showed in his research that market return is not only the factor to determine the stock return but the other variables (market capitalization, book to market) also significantly important. The other input variable, market value also showed significant relationship with the stock returns which intended that if the market value of individual company shows upper trend then the return of that company will increase whereas if it shows lower trend then the return of that company will decrease.

Year-wise mean efficiency of companies: The year wise mean efficiency of 94 companies in DSE market was displayed in Table 2. From this investigation, the values of mean efficiency showed the range between 0.8467 and 0.9966 during the study period. The technical efficiency had decreased over the study period which is supportive to the research of Hasan *et al.* (2011b), where he also found that the technical efficiency rate is gradually decreasing over time in the stock market in Bangladesh. The mean technical efficiency of the companies during the period 2000-2008 was 0.9542 which implied that 95% of potential output was being realized by the companies of DSE market.

Group-wise mean efficiency of companies: Group-wise mean efficiency of both time-variant and time-invariant cases were given in Table 3. For the time-variant situation, there was a variation in the technical efficiencies among the different groups in DSE market: it ranged from

Table 2: Year-wise mean efficiency of companies in Dhaka stock exchange

Year	Mean efficiency
2000	0.9966
2001	0.9944
2002	0.9909
2003	0.9851
2004	0.9757
2005	0.9607
2006	0.9371
2007	0.9007
2008	0.8467
Mean	0.9542

Table 3: Group-wise mean efficiency of companies with time-variant and time-invariant in Dhaka stock exchange

Group	Mean efficiency	
	Time-variant	Time-invariant
Bank	0.9259	0.9605
Investment	0.9727	0.9653
Engineering	0.9512	0.9501
Food and allied	0.9560	0.9516
Fuel and power	0.9591	0.9610
Textile	0.9519	0.9439
Pharmaceuticals and chemicals	0.9587	0.9601
Services and real estate	0.9489	0.9506
Cement	0.9499	0.9490
Tannery	0.9697	0.9640
Ceramic	0.9429	0.9433
Insurance	0.9635	0.9572
Miscellaneous	0.9605	0.9585

a low of 0.9259 for Bank-group, to a high of 0.9727 for Investment-group while in case of time invariant environment; it ranged from a low of 0.9433 for Ceramic-group, to a high of 0.9653 for Investment-group. The actual range was 0.0468 and 0.0220 for time-variant and time-invariant cases, respectively.

RESULTS OF HYPOTHESIS TEST

Formal tests of various hypotheses were obtained using the Likelihood Ratio (L-R) statistics (5) presented in Table 4. The first null hypothesis, $H_0: \gamma = 0$ was rejected, so, it can be concluded that there were technical inefficiency effects in the model. This implied that the technical inefficiency effects associated with the companies of Bangladesh Stock Market were significant. The second hypothesis was tested by the null hypothesis $H_0: \mu = 0$. In this study this hypothesis was also rejected which indicated that the truncated (at zero) normal distribution was found to be preferable to the half normal distribution for the technical inefficiency effect. The hypothesis $H_0: \eta = 0$ was rejected, indicating that the technical inefficiency effect varied significantly over time. The above findings were fully supportive to the findings of Hasan *et al.* (2011b).

Table 4: Generalized likelihood-ratio test of hypothesis

Null hypothesis	Log-likelihood function	Test statistic	Critical value	Decision
$H_0: \gamma = 0$	-157.6330	17.0856	2.706	Reject
$H_0: \mu = 0$	-152.3256	6.4708	2.706	Reject
$H_0: \eta = 0$	-157.1236	16.0668	2.706	Reject

All critical values are at 5% level of significance, Critical values are obtained from table of Kodde and Palm (1986)

CONCLUSION

The study identifies the determinants which influence the share prices in DSE and the level of influential. The results suggest that the variables such as market return, market capitalization, book-to-market ratio and market value have a significant influence on share returns. Through the several tests, it is observed that technical inefficiency effects associated with the companies of Bangladesh Stock Market are significant, the truncated normal distribution is found to be preferable to the half normal distribution for the technical inefficiency effect and the technical efficiency rate is found gradually decreasing over time in the stock market in Bangladesh.

This study is important, because it would examine not only the capital market behavior of Bangladesh over the period 2000-2008 but also predict the technical efficiencies for the selected groups of companies and would draw policy conclusions conducive to economic growth of Bangladesh. The investment group gives highest technical efficiency and the bank group gives lowest technical efficiency in the situation of group-wise technical efficiency with time-variant. In the context of group-wise technical efficiency with time-invariant, the investment group also gives highest technical efficiency and the ceramic group gives lowest technical efficiency for the distribution. Thus, this study provides significant insights into the level of company's group-specific technical efficiency.

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