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*Research Article*

# Contribution of Co-Skewness and Co-Kurtosis of the Higher Moment CAPM for Finding the Technical Efficiency

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The objective of this paper is to present the technical efficiency of individual companies and their respective groups of Bangladesh stock market (i.e., Dhaka Stock Exchange, DSE) by using two risk factors (co-skewness and co-kurtosis) as the additional input variables in the Stochastic Frontier Analysis (SFA). The co-skewness and co-kurtosis are derived from the Higher Moment Capital Asset Pricing Model (H-CAPM). To investigate the contribution of these two factors, two types of technical efficiency are derived: (1) technical efficiency with considering co-skewness and co-kurtosis (WSK) and (2) technical efficiency without considering co-skewness and co-kurtosis (WOSK). By comparing these two types of technical efficiency, it is noticed that the technical efficiency of WSK is higher than the technical efficiency of WOSK for the individual companies and their respective groups. As per available literature in the context Bangladesh stock market, no study has been conducted thus far to measure technical efficiency of companies and their respective groups by using the risk factors which are derived from the H-CAPM. In this research, the link between H-CAPM and SFA is established for measuring technical efficiency and it is believed that the findings of this study may be applied to other emerging stock markets.

## 1. Introduction

In the finance literature, CAPM is one of the most important developments which predicts that the expected return on an asset is linearly related to systemic risk. But, because of the large number of empirical evidence against the CAPM, the financial researchers started to search for a substitute model to describe the risk-return relationship of risky assets. This searching had led the researchers to the extension of the CAPM. The higher moment CAPM was initially proposed by Rubinstein [1] and sequentially developed by Kraus and Litzenberger [2], Fang and Lai [3], Hwang and Satchell [4], and Harvey and Siddique [5]. Rubinstein [1] noted that when the market returns are not normal (but skewed or leptokurtic), the standard CAPM is not enough to price equity returns. So, he recommended for the addition of higher moments. Kraus and Litzenberger [2] extended the Sharpe-Lintner CAPM model by introducing the third moment "skewness" and examined the effect of skewness in return distributions. They found that the systematic skewness (co-skewness) is capable of explaining the behavior of asset returns which was not fully explained by the traditional CAPM. Fang and Lai [3] showed that in the presence of skewness and kurtosis in asset return distribution, the expected excess rate of return is related not only to the systematic variance but also to the systematic skewness and systematic kurtosis in the U.S. stock market. Hwang and Satchell [4] investigated whether the emerging markets are better explained with the additional risk factors such as higher moments (skewness and kurtosis). They tested the higher moment CAPM by using the generalized method of moment (GMM) and found that the higher moment CAPM is better explained than the conventional mean-variance CAPM in emerging markets. Harvey and Siddique [5] tested the extended CAPM model which was proposed by Kraus and Litzenberger [2] and found that the model incorporating co-skewness is helpful in explaining some of the nonsystematic components in cross-section variation of equity returns. Brunnermeier et al. [6]

concluded in his study that the desire for skewness can also impact the market return. Very recently, the study of Kostakis et al. [7] examined the preferences of the higher moments of returns' in the asset pricing model of London Stock Exchange during the period of 1986–2008. The final results of their study fully confirmed that co-skewness and co-kurtosis premia are priced in the UK market. Young Chang et al. [8] investigated whether the market skewness and kurtosis risks affect the cross section of stock returns. The results of their study were contributed to the existing literature which highlights the importance of higher-moment risk in asset pricing. Carmichael and Coen [9] studied the effect of co-skewness on asset valuation and found the contribution of idiosyncratic co-skewness in asset pricing.

So, a number of studies have tested higher order CAPM model for developed stock markets, but there has been little work in the emerging stock markets. However, there are only a few studies in the Bangladesh context which are related to CAPM or higher moment CAPM. Alam et al. [10] investigated whether or not the CAPM model is working in the DSE market by using the daily data of market index and returns for the period of 1994 to 2005. They found that CAPM is not working in the market. Ali et al. [11] also tested the validity of the CAPM in the DSE market. They concluded that the invalidity of CAPM in the market is because of finding nonlinear relationship between risk and return and not finding beta as a complete measure of risk. Mollik and Bepari [12] examined the nature of instability of CAPM's beta and found that beta instability increases with an increase in holding (sample) periods. To the best of our knowledge, no research has been done to measure the technical efficiency of companies listed in the Bangladesh stock market by using the risk factors which are derived from higher moment CAPM.

According to Berger and Humphrey [13], many of the researchers used either parametric approach: SFA or non-parametric approach: Data Envelopment Analysis (DEA) for investigating the technical efficiency of financial institutions, for example, banking industry [14–18] and insurance industry [19, 20]. In this study, SFA was used instead of DEA for measuring the technical efficiency. The reason of using SFA was that it has the advantage of dealing with stochastic noise, allowing for statistical tests of hypotheses concerning production structure and degree of inefficiency. The reason of not using DEA was that DEA does not impose any assumptions about production functional form and also does not take into account random errors; hence, the efficiency estimates may be biased if the production process is largely characterized by stochastic elements [21].

SFA employs a composed error model in which inefficiencies are assumed to follow an asymmetric distribution, usually the half-normal or the truncated-normal, while random errors are assumed to follow a symmetric distribution, usually the standard normal [22]. Most past studies used the half-normal or the truncated-normal distribution as assumption about inefficiency effects model because of the ease of estimation and interpretation [23]. Application of different distributions, like gamma and exponential, can also be significant sometimes [24–26].

## 2. Materials and Methods

*2.1. Data Sources.* The paper focused on DSE market of Bangladesh, because it is not only the country's oldest stock exchange but also one of the fast growing emerging stock markets in South Asia. In fact, when most of the world stock markets declined during the last global financial crisis in 2008, stock prices in DSE market experienced a continuous rise [27]. The reasons behind this were that DSE was isolated from the global financial markets and Bangladesh Bank (BB) took prompt actions to safeguard the banks and other financial institutions from the crisis. That is why DSE has significant implications for the performance of financial sector, and even the economy as a whole [28].

The data which was collected from DSE market belongs to 71 nonfinancial companies for the period of 2002–2011. Recently, the DSE market included 22 categories of companies, of which the following 10 categories were covered in this analysis: engineering, food and allied products, fuel and power, textiles, pharmaceuticals and chemicals, service and real estate, cement, tannery industries, ceramic industry, and miscellaneous.

*2.2. Variables Construction.* For this study, individual company's return was taken as a dependent variable. Market return market capitalization, book to market ratio, and market value were taken as the independent variables. We also introduced the co-skewness and co-kurtosis terms as independent variables in the final analysis of SFA, as we know that one of the main objectives of this study was to check the contribution of co-skewness and co-kurtosis (which was derived from H-CAPM) for finding the technical efficiency of the studied companies and their respective groups in the DSE market.

*2.3. Estimating the Co-Skewness and Co-Kurtosis from the Higher Moment CAPM.* According to the CAPM, returns can be explained through the following equation:

$$R_{it} = R_{ft} + \beta_i \left(R_{mt} - R_{ft}\right), \tag{1}$$

where, $R_{it}$ is the rate of return on security $i$ at time $t$, $R_{ft}$ is the rate of return on a risk free asset at time $t$, $R_{mt}$ is the rate of return on the market index at time $t$, and $\beta_i$ is the beta of security $i$, which can be also expressed as $\mathrm{Cov}(R_i, R_m)/\mathrm{Var}(R_m)$

The above CAPM model would be in the following shape after introducing the higher moments [29]:

$$\begin{aligned} R_{it} - R_{ft} = \alpha_i + \beta_i \left(R_{mt} - R_{ft}\right) + \delta_i \left(R_{mt} - R_{ft}\right)^2 \\ + \kappa_i \left(R_{mt} - R_{ft}\right)^3 + e_{it}, \end{aligned} \tag{2}$$

where $\delta_i$ represents co-skewness as

$$\delta_i = \frac{\mathrm{Cov}\left(R_i, R_m^2\right)}{E\left[\left(R_m - E\left(R_m\right)\right)^3\right]}, \tag{3}$$

where $\kappa_i$ is co-kurtosis as

$$\kappa_i = \frac{\left(R_i, R_m^3\right)}{E\left[\left(R_m - E\left(R_m\right)\right)^4\right]}. \quad (4)$$

According to Fama and McBeth [30], the above equation (2) of H-CAPM was estimated by using the OLS (Ordinary Least Squares) method to estimate the OLS estimates of the systematic risk, co-skewness risk, and co-kurtosis risk contained in a particular company $i$.

*2.4. Stochastic Frontier Model.* Initially, SFA was developed by Aigner et al. [22] and Meeusen and van Den Broeck [31] as the tool to measure the efficiency. In our analysis, the following model [32] was used where efficiency effects were separated from stochastic element. This model was preferred because in this study no explanatory variables were associated with technical inefficiency effects. So, the model is

$$Y_{it} = \exp\left(x_{it}\beta + V_{it} - U_{it}\right) \quad i = 1, 2, \ldots, N;\ t = 1, 2, \ldots, T, \quad (5)$$

where $Y_{it}$ denotes the output for the $i$th company in the $t$th time period; $x_{it}$ is a $(1 \times k)$ vector whose values are functions of inputs for the $i$th company in the $t$th time period; and $\beta$ is a $(k \times 1)$ vector of unknown parameters to be estimated. The error term comprises two separate parts; $V_{it}$s are assumed to be independently and identically distributed two-sided $(-\infty < V_{it} < \infty)$ random errors which have mean zero and unknown variance $\sigma_v^2$ [22] and also independent of $U_{it}$s, which is defined by Battese and Coelli [32] as follows:

$$U_{it} = \left\{\exp\left[-\eta\left(t - T\right)\right]\right\} U_i, \quad (6)$$

where $U_i$s are one-sided $(U_i \geq 0)$ random variables associated with the technical inefficiency and assumed to be distributed half-normal [33], exponential [31], truncated-normal [22], and gamma [34] distributions. According to Bauer [35], a distributional assumption has to be made because of the separation of efficiency effects from the stochastic element. In our analysis, we selected the half-normal distribution for the inefficient component, since we found from the result of the hypothesis test in our study that half-normal distribution is more preferable than truncated-normal distribution for the data of DSE market.

In the above equation (6), $\eta$ is an unknown scalar parameter which determines whether inefficiencies are time-variant or time-invariant. If $\eta$ is positive, then the technical inefficiencies of companies decline over time. If $\eta$ is zero, then the technical inefficiencies of companies remain constant. However, if $\eta$ is negative, then the technical inefficiencies of companies increase over time. Finally, according to Battese and Coelli [36], the technical efficiency level of company $i$ at time $t$ is the ratio of the actual to the potential output as follows:

$$\mathrm{TE}_{it} = \frac{\exp\left(\beta_0 + x_{it}\beta + V_{it} - U_{it}\right)}{\exp\left(\beta_0 + x_{it}\beta + V_{it}\right)} = \exp\left(-U_{it}\right). \quad (7)$$

This measure was 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 [37].

*2.5. Selecting the Functional Form of the Stochastic Frontier Model.* Generally, two types of model (Cobb-Douglas or Translog) are used in the SFA analysis. Actually, Cobb-Douglas production function is a special form of the Translog production function, where the coefficients of the squared and interaction terms of input variables are assumed to be zero. Both production functions have some limitations as follows: Cobb-Douglas function has a unitary elasticity of substitution, whereas Translog function losses the degree of freedom and a serious problem occurs when the number of firms considered in the analysis is small [38]. The researchers [39–41] concluded that the choice of functional form might not have a significant impact on measured efficiency levels. But we need to find which functional form is appropriate in our SFA analysis. So, in order to select the best specification (Cobb-Douglas or Translog) of the given data set, we conducted a hypothesis test by using the generalized likelihood-ratio (LR) statistic as follows:

$$\lambda = -2\left\{\mathrm{In}\left[L\left(H_0\right)\right] - \mathrm{In}\left[L\left(H_1\right)\right]\right\}, \quad (8)$$

where $L(H_0)$ and $L(H_1)$ are the values of the log-likelihood function for the frontier model under the null and alternative hypotheses.

By using the above test statistic in (8), the null hypothesis $H_0 = \beta_{ji} = 0$ (i.e., the coefficients of the squared and interaction terms of input variables are zero) against the alternative hypothesis $H_0 = \beta_{ji} \neq 0$, (i.e., the coefficients of the squared and interaction terms of input variables are not zero) was tested. We got the value of LR statistic which was compared with the critical value of Kodde and Palm [42] table and concluded that the null hypothesis, $H_0 = \beta_{ji} = 0$, is accepted which indicates that Cobb-Douglas production function is more preferable than Translog production function in our analysis.

*2.6. Empirical Stochastic Frontier Model.* The empirical version of stochastic frontier model (5) can be expressed with the specification of Cobb-Douglas functional form as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 \ln X_{4it} + \left(V_{it} - U_{it}\right), \quad (9)$$

where the subscripts $i$ and $t$ represent the $i$th company and the $t$th year of observation, respectively, and $i = 1, 2, \ldots, 71$ and $t = 1, 2, \ldots, 10$. $Y_{it}$ represents the individual return, $X_{1it}$ the market return, $X_{2it}$ market capitalization, $X_{3it}$ book to market ratio, and $X_{4it}$ market value. "ln" refers to the natural logarithm; the $\beta_i$s are unknown parameters to be estimated; $V_{it}$ follows $N(0, \sigma_v^2)$ and $U_{it}$ follows half-normal distribution.

The above model in (9) was extended by introducing the two risk factors co-skewness and co-kurtosis as input

Table 1: The OLS estimates without (with) considering co-skewness and co-kurtosis.

| Variables | Parameters | WOSK | | | WSK | | |
|---|---|---|---|---|---|---|---|
| | | Coefficients | S.E | $t$-value | Coefficients | S.E | $t$-value |
| Constant | $\beta_0$ | 0.0524[@] | 0.2117 | 0.24 | 0.2548[@] | 0.4269 | 0.59 |
| Market return | $\beta_1$ | 0.5244[*] | 0.0385 | 13.60 | 0.5251[*] | 0.0389 | 13.49 |
| Market capitalization | $\beta_2$ | −0.0062[@] | 0.0109 | −0.56 | −0.0063[@] | 0.0109 | −0.57 |
| Book to market ratio | $\beta_3$ | −0.0742[*] | 0.0179 | −4.13 | −0.0735[*] | 0.0179 | −4.08 |
| Market value | $\beta_4$ | 0.0085[@] | 0.0076 | 1.12 | 0.0081[@] | 0.0076 | 1.05 |
| Co-skewness | $\beta_5$ | | | | −0.05993[***] | 0.0436 | −1.72 |
| Co-kurtosis | $\beta_6$ | | | | 0.0227[***] | 0.0357 | 1.65 |
| Sigma-squared | $\sigma^2$ | 0.2083 | | | 0.2081 | | |

[*],[**],[***]Significance level at 1%, 5%, and 10% consecutively, [@]means insignificant, S.E: standard error.

variables which were derived from H-CAPM. The extended model becomes

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_4 \ln X_{4it} + \beta_5 \ln X_{5it} + \beta_6 \ln X_{6it} + (V_{it} - U_{it}), \quad (10)$$

where $X_{5it}$ denotes the co-skewness term and $X_{6it}$ denotes co-kurtosis term in the above equation.

*2.7. Tests of Hypothesis.* A series of formal hypotheses were obtained using the generalized likelihood ratio test statistic which was given in (8). Taymaz and Saatçi [43] stated that this test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with a degree of freedom equal to the number of restrictions involved. The null hypotheses are rejected when the test statistic ($\lambda$) exceeds the critical value of Kodde and Palm [42].

The following hypotheses will be tested in paper.

(i) $H_0 : \gamma = 0$, it expresses that technical inefficiency effects are not present in the model.

(ii) $H_0 : \mu = 0$, it means that the half-normal distribution is preferable to the truncated-normal distribution for technical inefficiency effect.

(iii) $H_0 : \eta = 0$, this hypothesis means that there is no change in the technical inefficiency effects over time.

## 3. Results and Discussion

*3.1. Ordinary Least Square Estimation.* The ordinary least square (OLS) estimates of the parameters of Cobb-Douglas stochastic frontier production model were obtained by grid search in the first step and then these estimates were used to estimate the maximum likelihood estimates of the parameters of the model. The ordinary least square estimates which show the average performance of the sample companies without (with) considering co-skewness and co-kurtosis were presented in Table 1. From the analysis, it was observed that the coefficients of market return and book to market ratio were statistically significant at 1% level of significance in the stock market in both conditions. Also, the results indicated that the additional input variables co-skewness and co-kurtosis were significant at 10% level of significance and they affected the individual company's return significantly. The parameter $\sigma^2$ was positive in both cases, which indicated that the observed output differed from frontier output owing to factors which were within the controls of the stock market.

*3.2. Estimation of Stochastic Frontier Model.* The maximum likelihood estimates (MLE) for the parameters of Cobb-Douglas stochastic frontier production model without (with) considering co-skewness and co-kurtosis were presented in Table 2. The results in Table 2 showed that the estimates of the parameters without (with) considering co-skewness and co-kurtosis were respectively 0.5118 and 0.5272 for market return input, −0.0052 and −0.0135 for market capitalization input, −0.0724 and −0.0806 for book to market ratio input, and 0.0132 and 0.0129 for market value input. The MLE of market return and book to market ratio in both conditions were significant at 1% level of significance which were similar to the findings of OLS estimation. We also found that the additional two input variables co-skewness and co-kurtosis were significant at 5% and 10% level of significance respectively. These results indicated that the four input variables (market return, book to market ratio, co-skewness, and co-kurtosis) significantly affect the amount of return in the individual companies and their respective groups listed in the DSE market.

In both cases, an insignificant negative relationship was observed between share returns and market capitalization, which contradicts some findings [44, 45]. The studies of Perera [44] and Claessens et al. [45] showed a significant positive relationship between market capitalization and share returns. There was a significant negative relationship between book-to-market ratio and stock returns in both conditions which also contradicts the emerging market research findings of Claessens et al. [45]. Claessens et al. [45] found that a significant positive relationship exists between book-to-market ratio and share returns. In our study, the market return showed a significant relationship with the stock returns which means that if the overall market rises, then the return of individual companies will increase, and if the overall market falls, then the return of individual companies will decrease.

Table 2: The MLE estimates without (with) considering co-skewness and co-kurtosis.

| Variables | Parameters | WOSK | | | WSK | | |
|---|---|---|---|---|---|---|---|
| | | Coefficients | S.E | $t$-value | Coefficients | S.E | $t$-value |
| Constant | $\beta_0$ | 0.0496[@] | 0.2137 | 0.23 | 0.3118[@] | 1.0027 | 0.31 |
| Market return | $\beta_1$ | 0.5118[*] | 0.0371 | 13.78 | 0.5272[*] | 0.1221 | 4.31 |
| Market capitalization | $\beta_2$ | −0.0052[@] | 0.0110 | −0.47 | −0.0135[@] | 0.0184 | −0.73 |
| Book to market ratio | $\beta_3$ | −0.0724[*] | 0.0178 | −4.06 | −0.0806[*] | 0.0203 | −3.97 |
| Market value | $\beta_4$ | 0.0132[@] | 0.0084 | 1.56 | 0.0129[@] | 0.0088 | 1.45 |
| Co-skewness | $\beta_5$ | 0 | | | −0.0719[**] | 0.0730 | −1.98 |
| Co-kurtosis | $\beta_6$ | 0 | | | 0.0464[***] | 0.0687 | 1.67 |
| Sigma-squared | $\sigma^2$ | 0.2027[*] | 0.0110 | 18.41 | 0.2027[*] | 0.0112 | 18.05 |
| Gamma | $\gamma$ | 0.0185[@] | 0.0149 | 1.23 | 0.0095[@] | 0.0092 | 1.02 |
| Mu | $\mu$ | 0.1225[*] | 0.0385 | 3.17 | 0.0878[*] | 0.0294 | 2.98 |
| Eta | $\eta$ | −0.2157[*] | 0.0435 | −4.95 | −0.1639[*] | 0.0135 | −12.08 |

[*],[**],[***] Significance level at 1%, 5%, and 10% consecutively, [@] means insignificant, S.E: standard error.

The other input variable, namely, the market value, showed insignificant relationship with the stock returns.

For the case WOSK and WSK, the estimated values of $\gamma$ were 0.0185 and 0.0095, respectively, which were positive and insignificant. The estimate of $\sigma^2$ was significantly different from zero, indicating a good fit. Since the estimates for $\eta$ parameter were negative and significant in both conditions, the technical inefficiency effects tend to increase over time in the context of Bangladesh stock market.

*3.3. Company's Mean Efficiency.* The mean wise technical efficiency of the studied 71 individual companies without (with) considering co-skewness and co-kurtosis showed a more clear perception about the performance of an individual company. The result was displayed in the Appendix. There was a variation in the technical efficiencies among the different companies in DSE market, it ranged from a low of 0.9305 (WOSK) and 0.9444 (WSK) for company Meghna Cement, to a high of 0.9529 (WOSK) and 0.9598 (WSK) for company Tallu Spinning. The actual range was found to be 0.0224 for the case of WOSK and 0.0154 for the case of WSK. The most five efficient companies during the study period were found to be Tallu Spinning, Desh Garmants, Shyampur Sugar, Renwick Jajneswar, and Stylecraft. On the contrary, the most five inefficient companies during the data period were Meghna Cement, Aftab Automobiles, Confidence Cement, Samata Leather, and National Tubes. From the investigation, it was observed that the mean efficiency of all individual companies was higher in the case of considering co-skewness and co-kurtosis as additional input variables than in the case of non-considering that two input variables in the ten years data period.

*3.4. Year-Wise Mean Efficiency of Individual Companies.* The year-wise average efficiency of 71 companies in DSE market without (with) considering co-skewness and co-kurtosis was presented in Table 3 and Figure 1. It was observed that the mean efficiency values were in the range of 0.8811 to 0.9794 for the case of WOSK and 0.9135 to 0.9818 for the case of WSK.

Table 3: Year-wise mean efficiency of companies without (with) considering co-skewness and co-kurtosis.

| Year | WOSK | WSK |
|---|---|---|
| 2002 | 0.9794 | 0.9818 |
| 2003 | 0.9758 | 0.9775 |
| 2004 | 0.9715 | 0.9722 |
| 2005 | 0.9656 | 0.9666 |
| 2006 | 0.9575 | 0.9607 |
| 2007 | 0.9476 | 0.9539 |
| 2008 | 0.9355 | 0.9460 |
| 2009 | 0.9207 | 0.9368 |
| 2010 | 0.9028 | 0.9260 |
| 2011 | 0.8811 | 0.9135 |
| Mean | 0.9438 | 0.9535 |

The mean technical efficiency of the companies during the period 2002–2011 was 0.9438 for the condition of WOSK and 0.9535 for the condition of WSK. This implies that 94 percent and 95 percent of potential outputs were being realized by the companies of DSE market by not considering (considering) the additional two input variables. From the investigation, the highest mean efficiency was observed in the year 2002 for both cases.

From Figure 1, it can be concluded that the technical efficiency decreased in both cases over the period 2002–2011. In the whole study period, the technical efficiency in the condition of WSK was higher than the technical efficiency in the condition of WOSK for the DSE market. These findings were supportive to the findings of Hasan et al. [46], where they also found that the technical efficiency rate is gradually decreasing over the period 2000–2008 in the stock market of Bangladesh. Islam and Gomes [47] argued that a combination of factors like insufficient financial information, thin and discontinuous trading, trust on price momentum, and manipulation by the market makers create the conditions that lead to the decreasing trend of efficiency in the emerging stock market. Uddin and Nabiul Khoda [28]

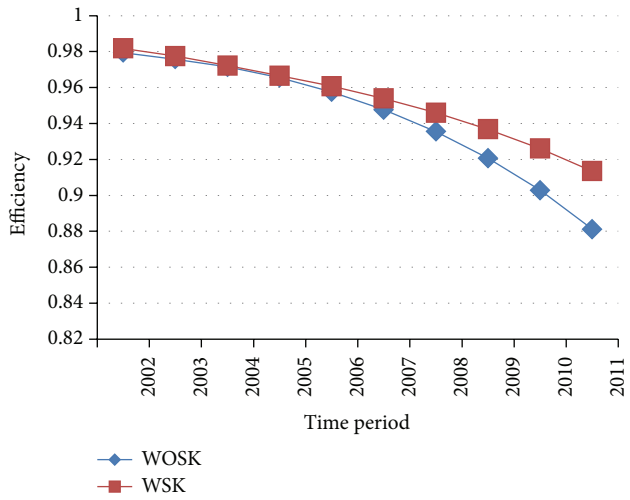


Figure 1: Year-wise mean efficiency of companies by considering (not considering) co-skewness and co-kurtosis.

concluded in their study that the reasons of the declining trend of efficiency in the DSE market are also the poor institutional infrastructure, weak regulatory framework, lack of supervision, poor corporate governance, slow development of the market infrastructure, and lack of transparency of market transactions.

*3.5. Group-Wise Technical Efficiency.* Group-wise technical efficiency of both cases was shown in Table 4 and Figure 2. The technical efficiency varied among different groups of DSE market. For the case WOSK, the technical efficiency ranged from a minimum of 0.8807 for Cement-group to a maximum of 0.9998 for Ceramic-group. Similarly, for the case of WSK, it ranged from a minimum of 0.9048 for Cement-group to a maximum of 0.9999 for Ceramic-group. Based on these results, it was concluded that the value of technical efficiency was high for Ceramic-group and low for Cement group, in comparison to other groups in DSE market. It was further observed that the technical efficiencies of all the studied groups were greater in the case of WSK than the case of WOSK.

*3.6. Results from Hypothesis Test.* Formal tests of various hypotheses were carried out using the Likelihood Ratio (L-R) statistics and the results were presented in Table 5. The first null hypothesis, $H_0 : \gamma = 0$, specifies that there are no technical inefficiency effects in the model. Having rejected the hypothesis, it was concluded that there were technical inefficiency effects in the model. This implies that the technical inefficiency effects associated with the companies of Bangladesh stock market were significant.

The technical inefficiency effects, having half-normal distribution, were tested by the null hypothesis $H_0 : \mu = 0$. In this study, this hypothesis was accepted, which indicated that the half normal distribution was preferable to the truncated-normal distribution for technical inefficiency effect.

The hypothesis $H_0 : \eta = 0$, which indicates that the technical inefficiency effect does not vary significantly over time,

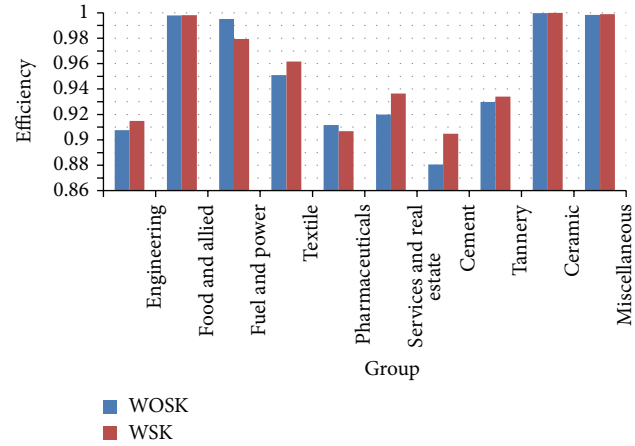


Figure 2: Group-wise mean efficiency by considering (without considering) co-skewness and co-kurtosis.

Table 4: Group-wise mean efficiency without (with) considering co-skewness and co-kurtosis.

| Group | WOSK | WSK |
|---|---|---|
| Engineering | 0.9077 | 0.9149 |
| Food and allied products | 0.9979 | 0.9982 |
| Fuel and power | 0.9793 | 0.9951 |
| Textiles | 0.9509 | 0.9616 |
| Pharmaceuticals and chemicals | 0.9069 | 0.9116 |
| Services and real estate | 0.9200 | 0.9365 |
| Cement | 0.8807 | 0.9048 |
| Tannery industries | 0.9298 | 0.9340 |
| Ceramic industries | 0.9998 | 0.9999 |
| Miscellaneous | 0.9984 | 0.9989 |

Table 5: Generalized likelihood ratio test of hypothesis of the stochastic frontier production model.

| Null hypothesis | Test statistic | Critical value* | Decision |
|---|---|---|---|
| $H_0: \gamma = 0$ | 74.52 | 7.05 | Reject |
| $H_0: \mu = 0$ | −70.92 | 5.14 | Accept |
| $H_0: \eta = 0$ | 4.22 | 2.71 | Reject |

*All critical values are at 5% level of significance and the critical values are obtained from table of Kodde and Palm [42].

was also rejected. So, the technical inefficiency effect varied significantly over time in the DSE market. The above all findings regarding the hypothesis test were fully supportive to the findings of Hasan et al. [46].

## 4. Conclusion

The results suggested that the input variables, such as market return, book-to-market ratio, co-skewness, and co-kurtosis had significant influence on share returns. This indicated that the above input variables were important for companies in the DSE market. For technical inefficiency effect, half normal distribution was found to be preferable to truncated-normal distribution. It was found that the technical efficiency

Table 6

| Firm's name | WOSK | WSK |
|---|---|---|
| ACI Limited. | 0.9406 | 0.9514 |
| Aftab Automobiles | 0.9305 | 0.9447 |
| Alltex Ind. Ltd. | 0.9460 | 0.9550 |
| Ambee Pharma | 0.9461 | 0.9545 |
| AMCL (Pran) | 0.9435 | 0.9534 |
| Anwar Galvanizing | 0.9436 | 0.9537 |
| Apex Adelchy Ft. | 0.9452 | 0.9550 |
| Apex Foods | 0.9430 | 0.9532 |
| Apex Spinning. | 0.9470 | 0.9559 |
| Apex Tannery | 0.9453 | 0.9549 |
| Aramit Cement | 0.9466 | 0.9549 |
| Atlas Bangladesh | 0.9365 | 0.9483 |
| Aziz Pipes | 0.9449 | 0.9544 |
| Bangas | 0.9452 | 0.9543 |
| Bangladesh lamps | 0.9446 | 0.9541 |
| Bata shoe | 0.9430 | 0.9526 |
| Batbc | 0.9452 | 0.9544 |
| BD.autocars | 0.9481 | 0.9563 |
| Bd. welding elec. | 0.9448 | 0.9547 |
| BDCOM online Ltd. | 0.9382 | 0.9493 |
| Beach Hatchery Ltd. | 0.9471 | 0.9556 |
| BEXIMCO | 0.9406 | 0.9519 |
| Beximco Pharma | 0.9401 | 0.9513 |
| Beximco Synthetics | 0.9465 | 0.9556 |
| BOC Bangladesh | 0.9429 | 0.9528 |
| Confidence Cement | 0.9335 | 0.9467 |
| Delta Spinners | 0.9464 | 0.9557 |
| Desh Garmants | 0.9522 | 0.9591 |
| Dulamia Cotton | 0.9461 | 0.9552 |
| Eastern Cables | 0.9415 | 0.9520 |
| Fu-Wang Ceramic | 0.9458 | 0.9551 |
| Glaxo SmithKline | 0.9439 | 0.9536 |
| H.R. Textile | 0.9473 | 0.9540 |
| Heidelberg Cement | 0.9433 | 0.9533 |
| Information services | 0.9413 | 0.9514 |
| Kay & Que | 0.9431 | 0.9527 |
| Legacy Footwear | 0.9478 | 0.9561 |
| Libra Infusions Ltd. | 0.9499 | 0.9578 |
| Meghna Cement | 0.9305 | 0.9444 |
| Meghna Condensed | 0.9464 | 0.9551 |
| Meghna Pet Ind. | 0.9420 | 0.9516 |
| Metro Spinning | 0.9422 | 0.9524 |
| Monno Ceramic | 0.9440 | 0.9537 |
| Monno Jutex | 0.9486 | 0.9565 |
| Monno Stafflers | 0.9486 | 0.9563 |
| National Polymer | 0.9421 | 0.9526 |
| National Tea | 0.9461 | 0.9550 |
| National Tubes | 0.9342 | 0.9470 |
| Olympic Industries | 0.9456 | 0.9553 |
| Orion Infusion | 0.9436 | 0.9533 |
| Padma Oil Co. | 0.9385 | 0.9499 |
| Pharma Aids | 0.9447 | 0.9545 |
| Prime Textile | 0.9487 | 0.9574 |
| Quasem Drycells | 0.9440 | 0.9536 |
| Rahima Food | 0.9496 | 0.9577 |
| Rangpur Foundry | 0.9416 | 0.9517 |
| Reckitt Benckiser | 0.9421 | 0.9523 |
| Renata Ltd. | 0.9451 | 0.9551 |
| Renwick Jajneswar | 0.9501 | 0.9582 |
| Saiham Textile | 0.9369 | 0.9490 |
| Samata Leather | 0.9346 | 0.9469 |
| Samorita Hospital | 0.9452 | 0.9544 |
| Shaympur Sugar | 0.9506 | 0.9586 |
| Singer Bangladesh | 0.9384 | 0.9498 |
| Sonargaon Textiles | 0.9439 | 0.9539 |
| Square Pharma | 0.9376 | 0.9498 |
| Square Textile | 0.9405 | 0.9514 |
| Stylecraft | 0.9502 | 0.9580 |
| Tallu Spinning | 0.9529 | 0.9598 |
| The Ibn Sina | 0.9420 | 0.9524 |
| Zeal Bangla Sugar | 0.9481 | 0.9567 |

Table 6: Continued.

rate in Bangladesh stock market decreased gradually over time. In this study, group-wise technical efficiency of the DSE market was also analyzed. The Ceramic group gave the highest technical efficiency and the Cement group gave the lowest technical efficiency. It was also noticed that the technical efficiencies of individual companies and their respective groups were higher if we introduce the two risk factors: co-skewness and co-kurtosis, which were derived from higher moment CAPM. So, the link between CAPM and SFA was established in this paper for measuring the technical efficiency.

Dhaka stock market seems to be like some other emerging stock markets such as the Indian market, the Johannesburg Stock Exchange, the Kuwaiti stock market, and some of the Middle Eastern markets, because of the similar types of characteristics such as thin trading, volatility, small number of securities listed, and investors' attitude towards investment strategy. So, it is believed that the findings of this research may be applied to other emerging stock markets.

## Appendix

See Table 6.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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