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Efficiency analysis by combination of frontier methods: Evidence from unreplicated linear functional relationship model

Omar Sharif,[1] Md Zobaer Hasan,[2] Chang Yun Fah,[1] Mahboobeh Zangeneh Sirdari[1]

[1] Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Malaysia
[2] School of Science, Monash University, Malaysia

corresponding e-mail: omarsharif[at]1utar(dot)my
address: Universiti Tunku Abdul Rahman, 43000 Kajang, Selangor, Malaysia

Abstract: This study proposes a new efficiency measurement technique CDS as combination of data envelopment analysis (DEA) and stochastic frontier analysis (SFA) and compares the CDS efficiency score with the DEA and SFA efficiency scores. The financial companies listed in Malaysian Stock Exchange for the period 2007-2016 are used to estimate the different types of efficiency score. Besides, linear regression analysis and ULFR (unreplicated linear functional relationship) analysis are used to analyze the performance of this CDS technique with the DEA and SFA techniques. The result suggests that the most efficient model is CDS which has a significant positive correlation with profit risk. Among the CDS, DEA and SFA techniques, the recommended technique (CDS) shows higher coefficient of determination values for both ULFR (0.9994) and linear regression (0.292) analysis. Also, based on the results of CDS, this study postulates that the most efficient firm is ACSM (Aeon Credit Service (M) Bhd) and the least efficient firm is MAY (Malayan Banking Bhd).

JEL Classifications: C61, G20

Keywords: Malaysian Stock Exchange, data envelopment analysis, stochastic frontier analysis, unreplicated linear functional relationship model

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1. Introduction

In the stock market, it is challenging to identify the most efficient company as many of variables are related to measuring the companies' performance. The investors sometimes earn excess profits by exploiting any observable trends in stock price series. These days it is very difficult to identify the most efficient company by observing only the stock price. Many techniques are applied by investors to optimize their return and minimize the risk of their investment (Saad et al., 2011). Particularly in policy making, the efficiency measurement is important because it assists an efficient allotment of capital across versatile productive sectors in an economy. The investors get an accurate signal from the stock price if the market or company is efficient. In this way, efficiency helps to boost

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stock market liquidity and economic growth as well as stimulates long-term investment. Reversely, inefficiency creates higher costs and fluctuations in stock price (Hubbard, 2008).

In current years, the academic research on the performance of financial institutions has increasingly focused on frontier efficiency analysis. For performance evaluation, ample change occurred in the past two decades. Nowadays, performance evaluation is critical as a large number of variables (input and output) are involved in the measurement of the corporate performance (Adrienn, 2014). Performance analysis gives opportunities to investors, particularly private equity shareholders, to find the extra value for their non-financial performance (Patrícia & Balazs, 2014).

There are many methods in the frontier analysis to evaluate performance such as parametric methods and non-parametric methods, stochastic method (Fenyves et al., 2015). The stochastic frontier analysis (SFA) model becomes the most frequently used procedure because it segregates statistical noise from the effect of inefficiency (Kumbhakar & Lovell, 2003). In spite of this, SFA model speculates a distinct probability distribution for the efficiency level. However, if the selection of input-output variables or decision making units is erroneous then the finding score will incorporate error (Coelli et al., 2005). The data envelopment analysis (DEA) model skips this sort of specification error and it does not need a prior postulation regarding the associate analytical type of an assumed likelihood distribution or the production function for efficiency (Dong et al., 2014). DEA does not allow random errors in the optimization which is its main drawback. Therefore, if any noise exists, this may exaggerate the common inefficiency. Consequently, two methods (DEA and SFA) have their advantages as well as drawbacks (Huang & Wang 2002).

Many researchers (e.g. Casu et al., 2004; Delis & Papanikolaou, 2009; Weill, 2004) find that the consistency of efficiency derived from DEA and SFA is not significant. For this reason, this study concentrates on finding the combination of the DEA and SFA efficiency scores which will be a new experiment in literature perspective. For the justification of model effectiveness this study analyzes the impact of profit risk (return on asset) on efficiency as theoretically we know that a most profitable company should be efficient. Moreover, Fernandes et al. (2018) and Altunbas et al. (2007) find that there is a strong connection between efficiency and profit risk; because inefficient financial firm tends to take less risk by investing and hold more capital. Fernandes et al. (2018) find that profit risk has a positive effect on the efficiency of peripheral European domestic banks. More precisely, profit risk can be well-defined as a proportion of net income over the total asset. However, the selected data may contain some error due to imputation of some missing value by maximum likelihood method or balance sheet data sometimes make some manipulation by the company. For this reason, this study concentrates to find error-free technical efficiency by applying the unreplicated linear functional relationship model (ULFR) that first introduced by Adcock in the year 1877 (Sprent, 1990).

This study is a new idea for the estimation of the financial firm's efficiency by using the combination of DEA and SFA by utilizing the unique data set especially in respect to stock market related input output variable's data set. The study provides a unique setting to calculate financial efficiency matric and finds the effect of profit risk on efficiency by using regression analysis and ULFR. This analysis will help to find technical efficiency sores that error-free and more effective. Moreover, these findings could provide useful and important signal in case of decision making for management.

Given the above, this study's aim is four-fold. First, DEA and SFA utilized to find technical efficiency. Second, the combination of DEA and SFA that is measured by averaging DEA and SFA scores to find technical efficiency. Third, examination of the influence of efficiency on profit risk to find the most efficient method. Finally, ULFR model will be applied to find error-free efficiency.

This paper is structured as follows. Section 2 describes the background of this study (review of literature), Section 3 presents the methodology of the study. Next, Section 4 is about result and discussion and Section 5 illustrates the limitation of the study. Finally, Section 6 presents the conclusion.

2. Review of literature

In many pieces of literature, various efficiency approaches have been applied to find banking efficiency. Only a relatively few studies have used two or more frontiers for estimating financial firm efficiency for the same data set. Aigner et al. (1977) suggest the parametric approach (SFA), Charnes et al. (1978) suggest the non-parametric (DEA) further developed to non-constant returns (NCR) by Banker et al. (1984).

Bauer (1990), Lovell (1993), Greene (1993), and Coelli et al. (2005) provide the extensive reviews and contributions for the two methods.

Resti (1997), Eisenbeis et al. (1997), and Huang & Wang (2002) extend comparative study on SFA and DEA in financial firms. In their studies, the two approaches provide relatively close mean efficiencies. Resti (1997) and Eisenbeis et al. (1997) find very high rank-order correlations between DEA and SFA.

Ferrier & Lovell (1990) identify rank-order correlation that is approximate to zero (0.02). In contrast, the inefficiency scores measures from the DEA approach are more than two times greater than those calculated using SFA by Eisenbeis et al. (1997). Dong et al. (2014) find out SFA efficiency scores which are slightly higher than DEA efficiency scores. The findings of the SFA exercise discover lower mean inefficiency than those of the DEA (Delis, 2009). Huang & Wang (2002) estimate 22 Taiwanese commercial banks' economic efficiency for the period 1982 to 1997 by using SFA and DFA (distribution-free approach) as well as DEA. The result shows that the mean efficiency scores derived from the three methods (DEA, SFA, and DFA) are the same. On the other hand, the Spearman's rank correlation coefficients for SFA, DFA, and DEA efficiency measures are quite minor indicating that these techniques are not consistent in their efficiency rankings. Weill (2004) also investigates in European countries' (Italy, France, Germany, Switzerland and Spain) banking data to find the consistency of efficiency frontier techniques (DEA, SFA, and DFA). He describes that the efficiency rank order correlations among the methods are generally poor. More recently, Fernandes et al. (2018) have evaluated the efficiency of European peripheral domestic banks. They have made the linear regression analysis of bank-risk determinants and their performance over the period 2007 to 2014 and have found that profit risk and efficiency have a positive relation. Fah et al. (2007) utilized ULFR model to find error value from dependent and independent variables' simple linear regression: as conventional regression models are not suitable for global versus localized measure, perfect reference and bivariate case. They have found that coefficient of determination (COD) of ULFR better than COD of simple linear regression.

Ismail (2005) has concentrated on Malaysian commercial bank to find efficiency over the period 1994 to 200 and postulates that DEA technique shows higher efficiency scores than the parametric methods and scores are positively related to each other. Sufian et al. (2016) have found with DEA approach that banks from Asian countries are comparatively more efficient rather than external banks. Davies (2017) postulates that technical efficiency of Malaysian commercial banks is 71.33%. He suggests that domestic banks have been inefficient in controlling their costs due to their size.

Janang et al. (2013) with SFA approach have found that remuneration is positively linked to the efficiency of government-linked companies. Suhaimi et al. (2012) have confirmed that 7 banks are efficient among the 9 banks in Malaysia. Hasan et al. (2012) have found that Malaysian internal banks have the mean efficiency of 94% and the most efficient bank is RHBANK while the least efficient bank is PBK.

From the best of our knowledge, virtually nothing has been published to critically examine the impact of profit risk on technical efficiency (derived from DEA, SFA, and CDS) in the field of the financial sector of the Bursa Malaysia. Despite studying of efficiency by different method, no research shows the combination of both methods and finds the impact of efficiency and profit risk. Most importantly, no article is recognized that shows the error-free technical efficiency by applying ULFR model. In light of these knowledge gaps, this article proposes a model CDS that can measure efficiency more efficiently.

3. Research methodology

3.1. Data envelopment analysis

The data envelopment analysis is defined as a mathematical programming method that measures the efficiency of a firm or decision-making unit (DMU). It also measures the similar DMUs with the simple restriction that all DMUs lie below or on the efficiency frontier (Seiford & Thrall, 1990). The DEA method suggested by Charnes et al. (1987) and further developed to non-constant returns (NCR) explain how to design the production possibility set without guessing a production function from given a set data of input, output variables. The DEA approach is based on the MPI (Malmquist Productivity Index) to investigate how the productivity of each company changes through time. This is done by following an output-oriented DEA approach described by Färe et al. (1994). The best way to introduce DEA is via the ratio form. For each DMU needs to obtain a measure of the ratio of all outputs over all inputs, such as

$$\theta = \frac{p_i y_{it}}{q_i x_{it}}$$

Where, p_i is an M×1 vector of output weights for i^{th} firm and q_i is a K×1 vector of input weights of i^{th} firm. To select optimal weights we specify the mathematical programming problem:

$$\left.\begin{aligned}
&\quad\quad Max_{\theta,\lambda}\theta \\
&St, \\
&\sum_{j=1}^{n}\lambda_j x_{ij} \le x_{it} \; i = 1,2,....m \\
&\sum_{j=1}^{n}\lambda_j y_{ij} \ge \theta y_{rt} \; r = 1,2,....\mathrm{s} \\
&\lambda \ge 0
\end{aligned}\right\} \tag{1}$$

Where, for each DMU (decision making unit) s is output observation, m is input observation, r is s^{th} output, i is m^{th} input, y_{r1} is r^{th} output for time period t, x_{it} is i^{th} input for time period t, n is DMU observation, j is n^{th} DMU, λ is no-negative scalar, x_{ij} is m^{th} input for n^{th} DMU, y_{ij} is s^{th} output for n^{th} DMU, θ is a scalar representing the value of efficiency score for each DMU. A firm is assumed to be technically efficient if it is impossible to increase output without altering input. To measure the technical efficiency, the software DEAP version 2.1 is used, though this study does not discuss about productivity except technical efficiency.

3.2. Stochastic frontier analysis

A firm is called efficient if it is able to attain its objectives, otherwise it is called inefficient. It is assumed that a firm's main goal is to minimize production cost that means any excess of inputs is to be avoided so that there is no unnecessary use of capitals. It is often considered, in the production theory, which firms are behaving efficiently in an economic response. The production theory is proposed by Cobb & Douglas (1928). They develop the production theory by using of labour, capital, production, value, and wages for the manufacturing firms. The firms are capable to effectively assign all supplies relative to the inputs, outputs and constraints executed by the framework of the production function. Moreover, the firms are able to effectively assign all supplies relative to whatever behavioural aims presented to the manufacturers (Fare et al., 1985).

Additionally, Berger & Humphrey (1997) modified the production function model to concentrate on financial sector's efficiency. The efficiency of the financial sector means the efficient allocations of financial resources that are imperative to increase productivity. This shows that the economy has the upper hand to transfer the input of saving resources for more productive output. In order to measure statistical noise, Aigner et al. (1977) added symmetric error term to the deterministic frontier. The model expressed as:

$$Y_{it} = X_{it}\beta + (V_{it} - U_{it}), i = 1, 2, ...N, t = 1, ..., T \quad (2)$$

Where, Y_{it} is (the logarithm of) the production of the i^{th} firm in the t^{th} time period; X_{it} is a k×1 vector of (transformations of the) input quantities of the i^{th} firm in the t^{th} time period; V_{it} are random variables which are assumed to be iid $N(0, \sigma_i^2)$; β is an vector of unknown parameters.

$$U_{it} = U_i e^{-\eta(\mathrm{t}-\mathrm{T})} \quad (3)$$

Where, U_i is the inefficiency level of the i^{th} producer at time T and η is an unknown parameter.

The term TE_{it} is technical efficiency for the i^{th} firm in the t^{th} time period define by using stochastic frontier model (2) as follows (Battese & Coelli, 1988):

$$TE_{it} = e^{-U_{it}} \quad (4)$$

Here, U_{it} is the stipulation of the inefficiency model in equation (3). The maximum-likelihood estimates are used to measure the parameters of the stochastic frontier model.

3.3. Empirical form of stochastic frontier model

The Cobb-Douglas stochastic frontier production model's functional form is defined as:

$$\begin{aligned}\ln(\mathrm{ROE}_{it}) = \beta_0 + \beta_1 \ln(\mathrm{TV}_{it}) + \beta_2 \ln(\mathrm{DPS}_{it}) + \beta_3 \ln(\mathrm{MC}_{it}) + \beta_4 \ln(\mathrm{PV}_{it}) + \\ \beta_5 \ln(\mathrm{FL}_{it}) + (V_{it} - U_{it})\end{aligned} \quad (5)$$

Where, the subscripts t and i represents the t^{th} year and i^{th} firm of the observations, and i = 1,2,….26; t = 1,2,…10; ROE, TV, DPS, MC, PV, FL are defined in the Table 2; "ln" represents the natural logarithm.

3.4. Combination of DEA and SFA (CDS)

The average of DEA and SFA efficiency scores is considered as the combination of DEA and SFA (CDS).

$$CDS = \frac{Efficiency\, score\, of\;\, DEA + Efficiency\, score\, of\;\, SFA}{2}$$

3.5. Linear regression

In this study, the linear regression model is utilized to investigate the impact of profit risk on efficiency score (derived from DEA, SFA and CDS) in the financial sector of Bursa Malaysia. So, the three models take the following forms:

$$Ef\,(\mathrm{DEA})_i = \beta_0 + \beta_1 Pr_i + \varepsilon_i \qquad (6)$$

$$Ef\,(\mathrm{SFA})_i = \beta_0 + \beta_1 Pr_i + \varepsilon_i \qquad (7)$$

$$Ef\,(\mathrm{CDS})_i = \beta_0 + \beta_1 Pr_i + \varepsilon_i \qquad (8)$$

Where, $Ef\,(\mathrm{DEA})_i$, $Ef\,(\mathrm{SFA})_i$, $Ef\,(\mathrm{CDS})_i$ are the average technical efficiency scores of the company i derived from DEA, SFA and CDS respectively*;* Pr_i is the average profit risk of i^{th} firm; β_0 is constant and represents the slope parameter; represents error term.

3.6. Unreplicated linear functional relationship model

Suppose that $EF(\mathrm{CDS})$ and PR are two linearly related unobservable variables, then the functional form is

$$Q_i = \;\; EF(\mathrm{CDS})_i = \beta_a + \beta_f\, PR_i \qquad (9)$$

and the two corresponding random variables are observed with error d and e, respectively as

$$\left.\begin{aligned} Ef(\text{CDS})_i &= EF_i + d_i \\ \text{Pr}_i &= PR_i + e_i \end{aligned}\right\} i = 1, 2....., n \tag{10}$$

The following conditions are assumed:

$$\left.\begin{aligned} &E(\text{d}_i) = E(\text{e}_i) = 0, \text{Var}(d_i) = \sigma^2{}_d, \text{Var}(\text{e}_i) = \sigma^2{}_e, \forall i \\ &Cov(\text{d}_i, \text{d}_j) = Cov(\text{e}_i, \text{e}_j) = 0, \quad \text{i} \neq \text{j} \\ &Cov(\text{d}_i, \text{e}_j) = 0, \forall \text{i, j} \end{aligned}\right\} \tag{11}$$

Hussin (1997) defined the model (9) and (10) as the unreplicated linear functional relationship (ULFR) model when there is only the variables $EF(\text{CDS})$ and PR. Where, d_i and e_i are random variables that are mutually independent and normally distributed. When the ratio of the error variance is known, that is $\frac{\sigma^2{}_e}{\sigma^2{}_d} = \lambda$, then the maximum likelihood estimators of parameters $\beta_a, \beta_f, \sigma^2{}_d$ *and* PR_i are:

$$\hat{\beta}_a = \overline{Ef} - \hat{\beta}_f \overline{\text{Pr}}$$

$$\hat{\beta}_f = \frac{(\text{S}_{yy} - \lambda \text{S}_{xx}) + \{(\text{S}_{yy} - \lambda \text{S}_{xx})^2 + 4\lambda \text{S}^2{}_{xy}\}^{\frac{1}{2}}}{2S_{xy}}$$

$$\hat{\sigma}^2_d = \frac{1}{n-2}[\sum(\text{Pr}_i - PR_i)^2 + \frac{1}{\lambda}\sum(\text{Ef}_i - \hat{\beta}_a - \hat{\beta}_f \text{PR}_i)^2]$$

$$\text{PR}_i = \frac{\lambda \text{Pr}_i + \hat{\beta}_f(\text{Ef}_i - \hat{\beta}_a)}{\lambda + \hat{\beta}_f},$$

Where, $\overline{\text{Ef}} = \frac{\sum Ef_i}{n}$, $\overline{\text{Pr}} = \frac{\sum \text{Pr}_i}{n}$, $S_{yy} = \sum(\text{Ef}_i - \overline{\text{Ef}})^2$, $S_{xx} = \sum(\text{Pr}_i - \overline{\text{Pr}})^2$, $S_{xy} = \sum(\text{Pr}_i - \overline{\text{Pr}})(\text{Ef}_i - \overline{\text{Ef}})$.

And the coefficient of determination of ULFR ($R^2{}_f$) for any value of λ:

$$R^2{}_f = \frac{SS_r}{S_{yy}},$$

Where, $SS_r = \dfrac{\hat{\beta}_f(\mathrm{S}_{yy} - \mathrm{S}_{xx}) + 2\hat{\beta}_f \mathrm{S}_{xy}}{1+\hat{\beta}_f^2}$.

3.7. Data collection

There are 30 listed financial companies in Bursa Malaysia. This study concentrates on balance data of 26 listed companies. The sample is panel data which covers 26 financial companies listed in Bursa Malaysia over the period of 2007 to 2016. There are total 260 observations. Data are collected from Bloomberg. All the company names are shown in the Table 1.

TABLE 1. COMPANIES LISTED IN BURSA MALAYSIA

COMPANY NAME	SHORT NAME IN THE BURSA MALAYSIA	BLOOMBERG TICKER NUMBER (MK EQUITY)
Malayan Banking Bhd	MAYBANK	MAY
Public Bank Bhd	PBBANK	PBK
CIMB Group Holdings Bhd	CIMB	CIMB
Hong Leong Bank Bhd	HLBANK	HLBK
RHB Bank Bhd	RHBBANK	RHBBANK
Hong Leong Financial Group	HLFG	HLFG
AMMB Holdings Bhd	AMBANK	AMM
BIMB Holdings Bhd	BIMB	BIMB
Affin Holdings Bhd	AFFIN	AHB
LPI Capital Bhd	LPI	LPI
Syarikat Takaful Malaysia	TAKAFUL	STMB
Allianz Malaysia Bhd	ALLIANZ	ALLZ
MNRB Holdings Bhd	MNRB	MNRB
Manulife Holdings Bhd	MANULFE	MHBS
Pacific & Orient Bhd	P&O	PO
Malaysia Building Society	MBSB	MBS
Bursa Malaysia Bhd	BURSA	BURSA
Aeon Credit Service (M) Bhd	AEONCR	ACSM
INSAS Bhd	INSAS	INS
RCE Capital Bhd	RCECAP	RCE
Apex Equity Holdings Bhd	APEX	APX
Johan Holdings Bhd	JOHAN	JOH
ECM Libra Financial Group Bhd	ECM	ECML
Hong Leong Capital Bhd	HLCAP	HLG
TA Enterprise Bhd	TA	TAE
MAA Group Bhd	MAA	MAA

Source: Bloomberg terminal and Bursa Malaysia.

For this study, five inputs and an output have been selected. The input and output variables are selected based on Ismail et al. (2012) and other major studies on the efficiency of the financial sector. The five input variables are market capital, total volume, dividend per share, financial leverage, price to book ratio. The output variable is return on equity. The dividend per share is included to the study as it has relation with stock returns. On the other hand, it furnishes signaling effect to stock prices and previous empirical proof found dividend per share has anticipating power for stock returns (Campbell et al., 1988). The total volume is chosen as it has important signal tool and it is an instructive variable for stock returns. Moreover, the market capital effect appears to have a persistent explanation on stock returns (Fama & French, 1992; Ismail et al., 2012). The software package DEAP Version 2.1 and the software package FRONTIER 4.1 of Coelli (1996a, 1996b) were used in order to carry out the SFA and DEA estimations.

4. Result and discussion

Summary statistics of the data are shown in Table 2. Currency is measured in USD. Total market capital is shown in millions of USD. Dividends per share are also shown in USD. All the variables' maximum and minimum value are also shown in Table 2. The values of financial leverage, price to book ratio, return on asset and return on equity are in ratio form.

TABLE 2. SUMMARY STATISTICS OF INPUT AND OUTPUT VARIABLES

VARIABLES	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
ROA	-5.24	26.13	2.6349	3.31450
ROE	-27.74	54.75	12.9440	10.27505
TV	770400.0	3761712400	459870978.71	726230640.93
DPS	0.00	1.34	.0481	0.09293
MC	18.09	26844.15	2868.5974	5378.04424
PB	0.18	9.60	1.4813	1.23367
FL	1.01	32.19	8.4594	6.39369

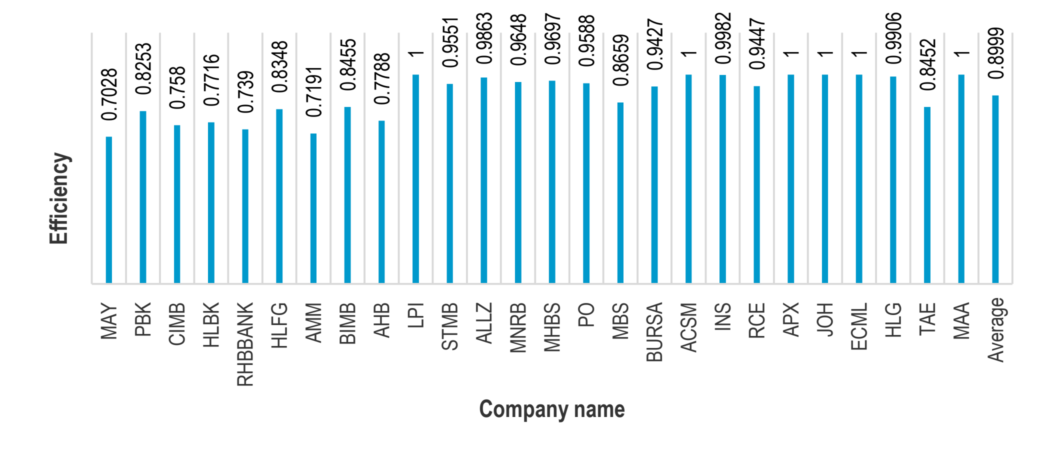
Source: Bloomberg Terminal.

However, this section presents the estimated results of DEA, SFA, and CDS. A firm will be said technically efficient if it can reduce inputs used in producing given outputs. The efficiency score of value 1 states that a firm is on the best practice frontier. A value of less than 1 indicates inefficient use of resources.

4.1. Efficiency derived from DEA

The efficiency scores are presented in Figure 1. It is seen that the average technical efficiency of financial companies listed in Bursa Malaysia was 0.8999. This means that companies were less than 10% inefficient in using their existing resources. Moreover, Siew et al. (2017) found average efficiency score 0.5865 in the financial company listed in Malaysia. It is also obvious that companies LPI, ACSM, APX, JOH, ECML, and MAA were efficient for all time period. The result is approximately similar to Siew et al. (2017) which state that LPI, BURSA, ACSM, APX were fully efficient. The results also depict that MAY was the least efficient company with 70.28% efficiency. Moreover, the efficiency scores of HLG, ALLZ, and INS were approximately same as they were around 0.98. Among the banks in Malaysia, Sufian et al. (2016) found that RHB was the most efficient bank with the efficiency score 0.937 and the least efficient bank was WAH TAT bank (0.288). On the other hand, in this study BIMB bank (0.8455) was the most efficient bank and MAY bank (0.7028) was the least efficient bank. However, in this study the RHB bank's efficiency score was 0.739.

FIGURE 1. EFFICIENCY SCORE DERIVED FROM DEA

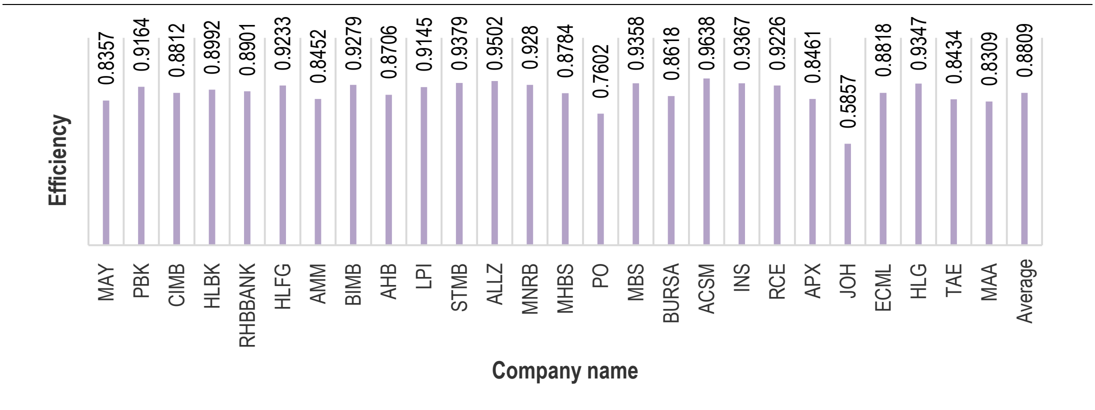


Source: Data from historical data of Bloomberg terminal.

4.2. Efficiency derived from SFA

The average technical efficiency derived from SFA was 0.8809 which means that the financial companies listed in Bursa Malaysia were 12% efficiency behind to get maximum outputs from given inputs. The efficiency scores are presented in Figure 2.

FIGURE 2. EFFICIENCY SCORE DERIVED FROM SFA



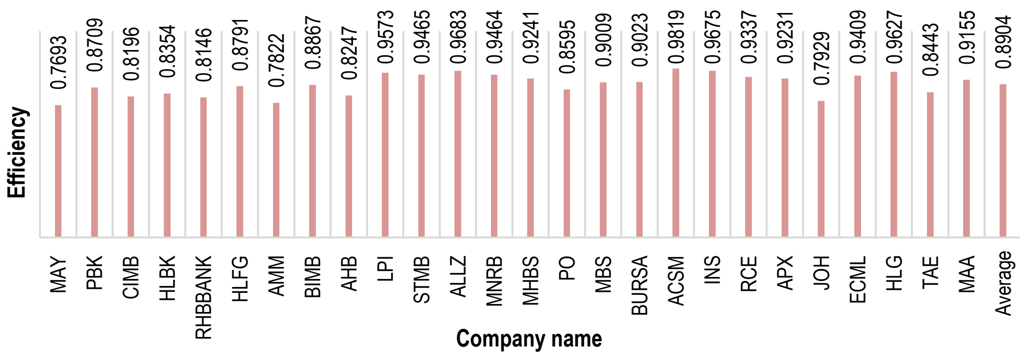
Source: Data from historical data of Bloomberg terminal.

The company ACSM seemed to be more efficient in controlling efficiency, as its efficiency score stands at 0.9637. But, the company JOH was the least efficient company as its efficiency score was 0.5857. Hasan et al. (2012) applied the SFA approach for finding the efficiency of the domestic banks listed in Bursa Malaysia over the period 2005-2010. He found that PBK (0.918) was the least efficient bank and RHBBANK (0.986) was the most efficient bank. On the other hand, in this study efficiency scores of PBK and RHBBANK were 0.9164 and 0.8901 respectively. The result of Hasan et al. (2012) differs from our study as they used different inputs and outputs.

4.3. Combination of DEA and SFA (CDS)

The technical efficiency scores derived from the combination of DEA and SFA are shown in Figure 3. The average technical efficiency was 0.8904, that means financial companies listed in Bursa Malaysia were 11% efficiency behind to get maximum outputs from given inputs. The company ACSM seemed to be more efficient in controlling efficiency, as the efficiency score stands at 0.9819. Whereas, the company MAY was the least efficient as its efficiency score is 0.7693. Average efficiency of companies ALLZ, INS and HLG were around 0.96. Among the 26 companies, 15 companies were less than 10% inefficient. However, only 2 companies were more than 20% less efficient.

FIGURE 3. EFFICIENCY SCORE DERIVED COMBINATION OF DEA AND SFA



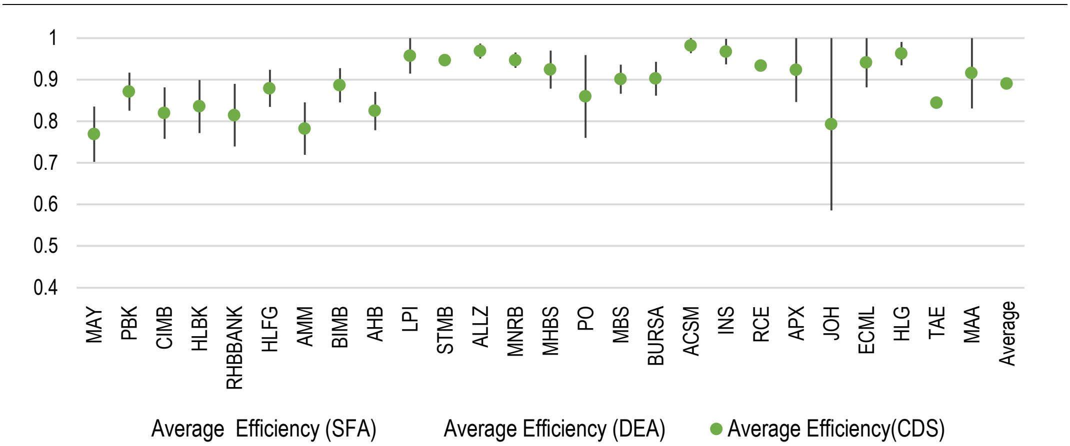
Source: Data from historical data of Bloomberg terminal.

4.4. Comparison of DEA, SFA and CDS efficiency scores

The empirical findings of efficiency scores are presented in Figure 4. It is clear that the DEA average efficiency score (0.8999) was greater than the SFA average efficiency score (0.8809). Moreover, CDS average efficiency was 0.8904 that is greater than SFA. However, such types of differences are not surprising because SFA allows DMUs to depart from the frontier due to inefficiency as well as statistical noise. But, DEA method cannot measure statistical noise. These results coincide with the results of Sufian et al. (2016), Ismail (2005), Isik & Hasan (2002). However, Dong et al. (2014) have found the opposite result in their study of cost efficiency of the Chinese banks.

In three methods, only DEA shows around similar efficiency scores. Furthermore, this study examined that there was a lesser difference among efficiency scores of financial companies estimated by DEA, SFA and CDS (SFA scores < CDS scores < DEA scores). The study suggests that the three models tend to have limited continuity in selecting the most efficient and the least efficient financial companies in terms of efficiency score.

FIGURE 4. EFFICIENCY DERIVED FROM DEA, SFA AND CDS



Source: Data from historical data of Bloomberg terminal.

4.5. Selection of most efficient method by regression analysis and ULFR

From Table 3, it is found that the relationship between efficiency and profit risk was statistically significant at the 5% level of significance by DEA and CDS since the p-value was less than 0.05.

TABLE 3. RELATIONSHIP BETWEEN EFFICIENCY
(derived from DEA, SFA and CDS) and profit risk

MODEL	CONSTANT (β_0)	COEFFICIENTS (β_1)	S.E	R^2	$R_f^{\ 2}$	*p*-value
DEA	-1.765	0.461^*	4.317	0.2130	0.9983	0.018
CDS	-10.591	0.54^*	6.687	0.2920	0.9994	0.004
SFA	0.307	0.273	6.386	0.0750	0.9991	0.177

Source: SPSS and Microsoft Excel.
Note: * - 5% significant.

This depicts that the profit risk positively affected the efficiency of the financial company listed in Bursa Malaysia. That means more profitable financial company or less leveraged company was higher efficient and would face a lesser cost of going insolvent over the period 2007 to 2016. Fernandes et al. (2018) applied the DEA method and also found that the profit risk positively affects the efficiency of European peripheral domestic banks. They found the coefficient score was 0.216. However, in this study, the relation between SFA and profit risk was insignificant (p-value was more than 0.05). Furthermore, its coefficient value was the lowest (0.273) among the three methods. The coefficient value of CDS was 0.54 and that was the highest among the three methods. The result postulates that 1% increase in profit risk can increase the efficiency by 0.54 %. Finally, from the regression results of three models, it can be concluded that the best way to measure efficiency is CDS model. Moreover, the coefficient of determination value **(R^2)** value was better in the CDS model than other methods.

The sixth column of Table 3 displays that the coefficient of determination for ULFR; it is seen that a strong relationship between profit risk and efficiency is derived from CDS. Among the three methods' COD value of ULFR, the highest value shows that CDS is more reliable than other two methods. Fah et al. (2007) found COD of ULFR (0.4408) and COD of simple linear regression (0.1231) in the study of causation with Malaysian road accident data; this explains that variability of dependent variable in ULFR is better than in the simple linear regression. Our study also shows that COD of ULFR (0.9994) is higher than COD of simple linear regression (0.292); this means that ULFR model in the measuring the relationship between profit risk and efficiency is better than linear regression.

4.6. Error-free efficiency scores of financial companies

The efficiency derived from CDS may contain measurement error as it is the method combining DEA and SFA models. Moreover, CDS may contain an error due to some missing values imputation. To remove error we applied ULFR model. From the column three of Table 4, it is seen the error-free efficiency derived from CDS. The amount of error was minimal for all the companies.

TABLE 4. ERROR-FREE EFFICIENCY SCORES DERIVED FROM CDS

COMPANY NAME (short form)	EFFICIENCY DERIVED FROM CDS	ERROR-FREE EFFICIENCY
ACSM	0.9819	0.9910
LPI	0.9573	0.9768
INS	0.9675	0.9760
ALLZ	0.9683	0.9668
HLG	0.9627	0.9625
MNRB	0.9464	0.9457
STMB	0.9465	0.9441
ECML	0.9409	0.9401
RCE	0.9337	0.9389
APX	0.9231	0.9304
BURSA	0.9023	0.9238
MHBS	0.9241	0.9208
MAA	0.9155	0.9183
MBS	0.9009	0.8973
BIMB	0.8867	0.8816
HLFG	0.8791	0.8740

TABLE 4. ERROR-FREE EFFICIENCY SCORES DERIVED FROM CDS

COMPANY NAME (short form)	EFFICIENCY DERIVED FROM CDS	ERROR-FREE EFFICIENCY
PBK	0.8709	0.8675
PO	0.8595	0.8568
TAE	0.8443	0.8455
HLBK	0.8354	0.8312
AHB	0.8247	0.8199
CIMB	0.8196	0.8155
RHBBANK	0.8146	0.8098
JOH	0.7929	0.7823
AMM	0.7822	0.7781
MAY	0.7693	0.7648

The highest amount of error that was less than 2%, in companies ACSM, LPI, INS, and BURSA. On the other hand, companies HLG, MNRB, RCE, MAY encountered less than 0.05% error. Fernandas et al. (2018) applied Double Bootstrapped Truncated Regression to obtain bias-corrected scores but they did not show bias-free each company scores. Hasan et al. (2012) applied the SFA approach for finding the efficiency of the domestic banks listed in Bursa Malaysia over the period 2005-2010 but did not find error-free efficiency. These error-removed efficiency score will help to identify the most efficient company (ACSM) and the least efficient company (MAY).

5. Research Limitations

Our study only concentrates on two most popular efficiency models (parametric and non-parametric). However, in the future study, other efficiency models such as DFA (Distribution Free Approach), Cobb-Douglas model (1995) could be used. Additionally, the analysis only focused on yearly data, and in future research this model can be justified with daily data.

6. Conclusion

The study has concentrated on three methods, SFA, DEA, and combination of DEA and SFA (CDS) to identify the most efficient method to measure technical efficiency on sample data of financial companies that are listed in Bursa Malaysia. This study is conscious that this is the sole empirical measure that uses market data of financial companies' listed in Bursa Malaysia to compare different efficiency frontier techniques. The empirical results have depicted that there were no consistency between the efficiency scores derived from DEA and SFA. More generally, the first consistency case has revealed that the average efficiency scores derived from SFA are slightly shorter than those of the DEA and CDS.

After that, this study has analysed the relationship between efficiency and profit risk to find the most efficient method as theoretically it is known that profitable company should be most efficient. The results of linear regression and ULFR have shown that CDS has the most significant relationship with profit risk by linear regression COD. In the data set, some missing data were imputed by the maximum likelihood method, for this reason the measurement can encounter some error. To find error-free efficiency we have applied ULFR model and found error-free efficiency. The most efficient company was ACSM and the least efficient company was MAY. Considering no consistency on different efficiency scores across the different methods, this study will help to measure the error-free efficiency by CDS model. This type of empirical analysis could be applied in many other sectors of stock market.

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