Inzinerine Ekonomika-Engineering Economics, 2019, 30(4), 442–450

Efficiency of Banks in Malaysia: a Super Efficiency Approach

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crossref http://dx.doi.org/10.5755/j01.ee.30.4.19291

The stability of the economic system of a country very much depends on its banking industry. Data Envelopment Analysis (DEA) has been applied widely for measuring efficiency of banks. Limited studies, however, have employed the radial and non-radial DEA models to evaluate efficiency of banks without considering the ranking of the fully efficient banks since those banks have the same efficiency score. Considering the weakness of the radial and non-radial DEA, this paper aims to calculate the banks efficiency of nine commercial banks in Malaysia from 2004 to 2013 by adopting the two-stage of super efficiency slack-based measure (SE-SBM) model. This model can discriminate between the efficient banks and recalculate their efficiency scores. Then, the selected banks were able to be ranked according to their final efficiency scores. Moreover, comparative analyses of the efficiency of the banks and the year-wise efficiency of the selected banks were also conducted. The methodology consists of two stages. In the first stage the SBM model is run to classify efficient and inefficient banks. In the second stage the super efficiency model is run to rank the efficient banks obtained from the first stage by calculating their super efficiency scores. Our empirical results show that: (1) the efficiency status of the banks fluctuated over the examined period, the high number of the efficient banks is achieved in the years 2006 and 2008, while the year 2012 has the lowest number of the efficient banks. (2) the ranking of the banks fluctuated in the studied period. (3) most of the banks are inefficient in terms of their average efficiency scores. This paper has two limitations. First, the paper did not integrate undesirable output, despite it deals with non-interest income. Second, performance evaluation of Malaysian commercial banks was only compared among the Malaysian banks.

Keywords: *Data Envelopment Analysis; Malaysian Commercial Banks; Slack-Based Measure; Super Efficiency.*

Introduction

The bank sector represents the main source of long-term investment and achieves the economic growth (Sufian & Kamarudin, 2014). In developing countries such as Malaysia, the bank sector is strongly related to the financial system. The stability of its financial system really depends on its banking performance. Therefore, it represents the backbone of the economic development (Levine, 1998). Modern banking business has drastically transformed over the years due to globalization, and information technologies development (Titko, Stankeviciene & Lace, 2014). To be able to survive in the digital era, and to achieve a high level of economic development, the performance or efficiency of bank sector needs to be measured (Ataullah & Le, 2006). Performance of banks is related to other important issues such as competition, productivity, efficiency and profitability. The efficiency measure ensures that the banks keep profitable. In recent years, many studies have examined the efficiency of banks with parametric and non-parametric frontier approaches (Sufian & Haron, 2009; Staub, Souza, & Tabak, 2010; Ouenniche & Carrales, 2018; Baten, Kasim, & Rahman, 2015). Most of these studies used a non-parametric approach which is called Data Envelopment Analysis (DEA) (Avkiran, 2011).

DEA is a mathematical programming approach proposed by Charnes et al. (1978) for measuring the efficiency of a peer set of homogenous decision making units (DMUs), which consume multiple inputs to produce multiple outputs. There are two types of efficiency measures in DEA, radial and non-radial. The radial model assumes proportional reduction of inputs (input-oriented) or proportional expansion of outputs (output oriented) and it ignores an existence of input and output slacks in the efficiency score. These limitations of the model lead to inaccurate efficiency measures (Chiu *et al.,* 2011).

In order to obtain precise efficiency measure, non-radial models are more suitable since they simultaneously deal with input and output slacks at different rates (Charnes *et al.,* 1985; Morita *et al.,* 2005). Tone (2001) proposed a non-radial SBM model to effectively discriminate efficient and inefficient DMUs. However, Tone's (2001) model is not able to discriminate between the high performers DMUs (i.e., fully efficient). To discriminate between fully efficient DMUs, Tone (2002) constructed a super efficiency slack-based measure (SE-SBM) model by excluding the efficient DMU_o from its efficient frontier of the SBM model. The model measures the non-radial distance between an excluded efficient DMU and the efficient frontier formed by the remaining efficient DMUs; thus, it deals with slacks of input and output simultaneously (Hussain *et al.,* 2016). This feature of Tone's (2002) model made it more appropriate in dealing with real life applications. Despite the salient features of the SE-SBM model, it was not use yet in evaluating the efficiency of Malaysian banks. Hence, the aim of this paper is to evaluate efficiency of main commercial banks in Malaysia, for a period of ten years, that is from 2004 to 2013, and to identify the banks' ranks using the formulation of the SE-SBM model, thus improving the methodology of measuring the efficiency of Malaysian banks. The formulated SE-SBM calculates for the first time, input saving (i.e., maximum level of an input allowable to increase) and output surplus (i.e., minimum level of an output allowable to decrease) of the commercial banks in Malaysia. The applied methodology of this paper is based on Tone's (2002) model by discriminating among efficient and inefficient commercial banks. The discrimination process is obtained by identifying increasing in inputs (input saving) and decreasing in outputs (output surplus).

In order to achieve the aim of the paper, this paper is set out as follows: Section 2 provides literature review related to the efficiency studies in banks sector. Section 3 presents the methodology of this paper in evaluating banks' efficiency using the SE-SBM model. Section 4 discusses the results from different empirical tests, while concluding remarks are discussed in Section 5.

Literature Review

In literature of banks' efficiency, there have been many studies conducted under the two efficiency measures of DEA; i.e., radial and non-radial. The studies that used radial model as those introduced by Ataullah et al. (2004), Casu and Molyneux (2003), Favero and Papi (1995), Li (2006), and McAllister and McManus (1993). The radial model concentrates on proportional changes in input (input-oriented model) or (output-oriented model) and it cannot deal simultaneously with input and output slacks. Thus, the radial model is not able to reflect all efficiency of inefficient DMUs (Cooper *et al.,* 1999). To deal simultaneously with slacks of inputs and outputs, non-radial models have been proposed. The non-radial additive model was proposed by Charnes et al. (1985) to simultaneously deal with input-output slacks. However, its objective function cannot measure in-depth efficiency for inefficient DMUs since its value depends on measurement of inputs and outputs (i.e., non-commensurate) (Cook & Seiford, 2009). To overcome this issue, Tone (2001) proposed slack-based measure model (SBM) whose objective function is unit invariant and its value ranged from zero to one. Since then, several efficiency studies in bank sector have been conducted based on the Tone's (2001) model (e.g., Drake & Hall, 2003; Sufian & Kamarudin, 2014; Zhao & Kang, 2015; Yin, Yu, & Huang, 2018; Zha, Liang, Wu, & Bian, 2016; Wang, Hang, Sun, & Zhao; 2016; Wang, Huang, Wu, & Liu, 2014).

All these studies are unable to discriminate between efficient DMUs. To discriminate and rank efficient banks, several studies have been conducted under the super efficiency radial model such as Deng et al. (2007), Khodabakhshi et al. (2010), Rahim (2015). Rahim (2015) analysed and compared between the technical efficiency of foreign and domestic Malaysian commerical banks over the examined period 2000 to 2010. The results obtained indicate that the performance of the domestic banks is better than of the foreign banks. Since the super efficiency radial model which proposed by Andersen and Petersen (1993) suffered from the infeasibility issue under the technology of variable return to scale (VRS), Tone (2002) proposed a super efficiency slack-based measure (SE-SBM) model. The model has several salient features which are: (i) the model deals with input and output slacks simultaneously, (ii) it achieves the feasibility under the two technologies of constant return to scale (CRS) and variable return to scale (VRS) because it determines the maximum increasing in inputs (input saving) and maximum decreasing in outputs (output surplus), (iii) its objective function is invariant, and (iv) its scalar measure simultaneously deals with input excess/output shortfall (Du *et al.,* 2010; Duzakın & Duzakın, 2007; Hussain *et al.,* 2016; Taleb et al., 2018). All these features have made the model is more appropriate in evaluating the efficiency of an organization seeking both input reduction and output augmentation. Based on SE-SBM model, limited efficiency studies in bank sector have been introduced (e.g., Chiu *et al.,* 2011; Chiu *et al.,* 2008; Zhao & Kang, 2015). In addition, a new scheme of the SE-SBM model that deals with negative outputs was formed by Lo and Lu (2009), their model has been used to evaluate efficieny of financial companies in Taiwan. Hence, this paper explores the potential of the SE-SBM model in evaluating and analysing the efficiency of the Malaysian commerical banking sector. To the best of our knowledge, there has not been efficiency study used the SE-SBM model to evaluate efficiency of banks sector in Malaysia.

Methodology

This section discusses the methodology of the SE-SBM model in discriminating among efficient and inefficient DMUs and ranking them. To do that, we adopt the two-stage model of Tone (2002) to evaluate the efficiency of nine commercial banks in Malaysia from 2004 to 2013 as follows.

Slack-Based Measure (SBM) Model

To evaluate and analyse the bank's efficiency based on the SE-SBM model, we first run the SBM model of Tone (2001) to discriminate between efficient and inefficient banks. The non-radial SBM model evaluates the efficiency of DMU_j under evaluation ($j = 1, \ldots, n$) where n is the number of DMUs that need to evaluate; $x_{ij} > 0, i = 1, \ldots, m$; $y_{rj} > 0,\ r = 1, \ldots, s$ are the ith input and rth output, respectively for the jth DMU. λ_j denotes the intensity factor of the efficient DMU_o, where o denotes factor reflecting the DMU under evaluation. The production possibility set (PPS) of the model is defined as

$$P_{SBM}=\left\{(x,y)\middle| x\geq\sum_j x_j\lambda_j, y\leq\sum_j y_j\lambda_j, \lambda_j\geq 0\right\} \quad (1)$$

The fractional form of the SBM model is described as follows:

$$\min\ \varphi=\frac{1-\frac{1}{m}\left(\sum_{i=1}^{m}\frac{s_i^{-*}}{x_{io}}\right)}{1+\frac{1}{s}\left(\sum_{r=1}^{s}\frac{s_r^{+*}}{y_{ro}}\right)} \quad (2)$$

s.t.

$$x_{io}=\sum_{j=1}^{n}x_{ij}\lambda_j^{*}+s_i^{-*}, \quad i=1,\ldots,m$$

$$y_{ro}=\sum_{j=1}^{n}y_{rj}\lambda_j^{*}-s_r^{+*}, \quad r=1,\ldots,s$$

$$\lambda_j^{*}\geq 0, s_i^{-*}\geq 0, s_r^{+*}\geq 0, \quad j=1,\ldots,n$$

To construct the efficient frontier under the technology of CRS, the value of φ should be equal to one and all values of input excess s_i^- and output shortfall s_r^+ are equal to zero. Thus, the efficiency score reveals the global technical efficiency and DMU_o is SBM-efficient, otherwise the DMU_o is SBM-inefficient. To obtain the optimal solution, the fractional model, i.e., model. (2) should be transformed into linear form using Charnes and Cooper (1962) as follows:

by assuming $1/t+\frac{1}{s}\left(\sum_{r=1}^{s}\frac{s_r^{+}}{y_{ro}}\right)$,

$$\min\ \tau^{*}=t-\frac{1}{m}\left(\sum_{i=1}^{m}\frac{\hat{s}_i^{-}}{x_{io}}\right) \quad (3)$$

s.t

$$t+\frac{1}{s}\left(\sum_{r=1}^{s}\frac{\hat{s}_r^{+}}{y_{ro}}\right)=1$$

$$t\,x_{io}=\sum_{i=1}^{m}x_{ij}\hat{\lambda}_j+\hat{s}_i^{-}, \quad i=1,\ldots,m$$

$$t\,y_{ro}=\sum_{r=1}^{s}y_{rj}\hat{\lambda}_j-\hat{s}_r^{+}, \quad r=1,\ldots,s$$

$$\hat{\lambda}_j\geq 0, \hat{s}_i^{-}\geq 0, \hat{s}_r^{+}\geq 0, \quad j=1,\ldots,n$$

An optimal solution of model (3) is defined as $\tau^{*}, \hat{s}_i^{-}, \hat{s}_r^{+}, \hat{\lambda}$. Thus, an optimal solution of model (2) can be obtained as

$$\varphi^{*}=\tau^{*},\ \bar{s}_i^{*}=\hat{s}_i^{-}/t,\ s_r^{+*}=\hat{s}_r^{+}/t,\ \lambda^{*}=\hat{\lambda}\ /t.$$

Super Efficiency-SBM Model

In reality situations, it is possible that multiple DMUs achieve the fully-efficient status. To discriminate among the efficient DMUs, the super efficiency (SE) model should be employed. The SE status of an efficient DMU_o is identified by excluding the efficient DMU_o from its reference set. However, the main issue is how to identify the distance between the excluded efficient DMU_o and the efficient frontier constructed by the remaining efficient DMUs. The distance reflects the possible amount of increasing inputs (input saving) and decreasing outputs (output surplus) of the excluded efficient DMU_o The aim of the input saving and output surplus is to achieve the SE status by measuring the ability of the excluded efficient DMU_o to move on the efficient frontier. To calculate input saving and output surplus of the excluded efficient DMU_o, the SE-SBM model of Tone (2002) is a suitable solution. Based on values of input saving and output surplus, the SE score of the observed $DMU_o\,(x_{io}, y_{ro})$ is identified. Thus, the model can be presented as follows:

$$\min\quad \phi^{SE}=\frac{\frac{1}{m}\sum_{i=1}^{m}\left(\frac{x_{io}+z_{io}^{-}}{x_{io}}\right)}{\frac{1}{s}\sum_{r=1}^{s}\left(\frac{y_{ro}-z_{ro}^{+}}{y_{ro}}\right)} \quad (4)$$

s.t.

$$\sum_{j=1, j\neq o}^{n}x_{ij}\lambda_j\leq x_{i0}+z_{io}^{-}, \quad i=1,\ldots,m$$

$$\sum_{j=1, j\neq o}^{n}y_{rj}\lambda_j\geq y_{r0}-z_{ro}^{+}, \quad r=1,\ldots,s$$

$$\lambda_j\geq 0, \quad j=1,\ldots,n,\ j\neq o$$

$$z_{io}^{-}, z_{ro}^{+}\geq 0, \quad \forall_{i,r}$$

The points $(x_{io}+z_{io}^{-}, y_{ro}-z_{ro}^{+})$ represent the maximum level of the *i*th input and minimum level of the *r*th output of the DMU_o. The numerator of the objective function represents the weighted distance from x_{io} to $x_{io}+z_{io}^{-}$ $(>x_{io})$; thus, it reflects an average expansion rate of x_{io} to $x_{io}+z_{io}^{-}$ for DMU_o. The dominator reflects the weighted distance from y_{ro} to $y_{ro}-z_{ro}^{+}$ $(<y_{ro})$. Hence, it reflects an average reduction rate of y_{ro} to $y_{ro}-z_{ro}^{+}$. The objective function of model (4) can be rearranged by replacing its slacks of input saving and output surplus z_{io}^{-}, z_{ro}^{+} , respectively with $x_{io}+z_{io}^{-}, y_{ro}-z_{ro}^{+}$, respectively. Thus, model (4) becomes as

$$\min\quad \phi^{SE}=\frac{1+\frac{1}{m}\sum_{i=1}^{m}\left(\frac{z_{io}^{-*}}{x_{io}}\right)}{1-\frac{1}{s}\sum_{r=1}^{s}\left(\frac{z_{ro}^{+*}}{y_{ro}}\right)} \quad (5)$$

s.t.

$$\sum_{j=1, j\neq o}^{n}x_{ij}\lambda_j^{*}\leq x_{i0}+z_{io}^{-*}, \quad i=1,\ldots,m$$

$$\sum_{j=1, j \neq o}^{n} y_{rj}\lambda_j^* \geq y_{r0} - z_{ro}^{+*}, \qquad r = 1, . . . , s$$

$$\lambda_j^* \geq 0, \qquad j = 1, . . . , n, \; j \neq o$$

$$z_{io}^{-*}, \; z_{ro}^{+*} \geq 0, \quad \forall_{i,r}$$

Note that model (5) is a fractional form; thus, it should be transformed into a linear form to obtain an optimal solution as illustrated follows.

$$\min \quad \delta^{SE} = t + \frac{1}{m}\sum_{i=1}^{m}\left(\frac{\hat{z}_{io}^{-}}{x_{io}}\right) \tag{6}$$

s.t.

$$t - \frac{1}{s}\sum_{r=1}^{s}\left(\frac{\hat{z}_{ro}^{+}}{y_{ro}}\right) = 1$$

$$\sum_{j=1, j \neq o}^{n} x_{ij}\hat{\lambda}_j \leq t\, x_{i0} + \hat{\bar{z}}_{io}, \qquad i = 1, . . . , m$$

$$\sum_{j=1, j \neq o}^{n} y_{rj}\hat{\lambda}_j \geq t\, y_{r0} - \hat{\overset{+}{z}}_{ro}, \qquad r = 1, . . . , s$$

$$\hat{\lambda}_j \geq 0, \qquad j = 1, . . . , n, \; j \neq o$$

$$\hat{z}_{io}^{-}, \; \hat{z}_{ro}^{+} \geq 0, \quad \forall_{i,r}$$

An optimal solution of model (6) is identified as δ^{SE}, $\hat{z}_i^-$, $\hat{z}_r^+$, $\hat{\lambda}$. Thus, an optimal solution of model (5) can be obtained as

$$\phi = \delta^*, \; z_i^{-*} = \hat{z}_i^- / t, \;\; z_r^{+*} = \hat{z}_r^+ / t, \; \lambda^* = \hat{\lambda} / t .$$

For more detail (see Tone, 2002; Lo & Lu, 2009).

Using SE-SBM Model to Evaluate Performance of Malaysian Banks

Data Set

This paper utilizes a sample of nine commerical banks in Malaysian from 2004 to 2013 to evaluate the efficiency of the banks using the SE-SBM model of Tone (2002). Each bank denotes as an independent DMU. In this paper, we considered three inputs and two outputs. The inputs are: deposits, fixed assets, and capital (Chen *et al.,* 2010; Chiu *et al.,* 2008; Zhao & Kang, 2015). The two outputs are: non-interest income (Chen *et al.,* 2010; Chiu *et al.,* 2008), and investments (Asmild & Matthews, 2012). The inputs and outputs of the data set is presented in Table 1. Table 2 shows the descriptive statistics of the input/outputs.

Table 1

Definitions of the Input and Output Factors

Input factor	**Definition**
Deposits (x_1)	Demand deposit, foreign exchange deposit, time deposit
Fixed assets(x_2)	Lands, equipments, structures, etc.
Capital (x_3)	Total value utilising by banks to raise deposits
Output factor	**Definition**
Non-interest income (y_1)	Interest income subtracted from operating revenue
Investment (y_2)	The aggregate value of bonds and stocks that a bank hold

Table 2

Descriptive Statistics of the Inputs/Outputs of Nine Malaysian Banks (2004–2013)

Variables	Banks	AFIN	MYPB	AMMB	BIMB	COMBS	HOLB	HONG	MALY	RHBC
x_1	Mean	17.2133	16.9602	17.7969	16.8662	18.8326	18.0270	18.0239	19.1495	18.2260
	S.D.	0.2876	0.2591	0.3555	0.3967	0.4782	0.4517	0.4536	0.4210	0.3818
x_2	Mean	17.5487	17.2204	18.2684	17.1561	19.1718	18.2758	18.3555	19.5316	18.6115
	S.D.	0.2365	0.2159	0.2549	0.3915	0.4256	0.4363	0.4410	0.3961	0.2940
x_3	Mean	15.4605	15.0437	16.3085	14.2183	17.2423	15.8691	16.0175	17.4110	16.4651
	S.D.	0.2284	0.2692	0.2272	1.4421	0.4683	0.6014	0.5909	0.5584	0.4258
y_1	Mean	13.0148	12.7905	14.3373	12.7860	15.0333	13.4325	13.8742	15.3974	14.0653
	S.D.	0.1836	0.3111	0.2831	0.5827	0.5566	0.4306	0.3396	0.5758	0.3565
y_2	Mean	15.9163	15.5816	16.3031	15.8863	17.5595	16.5225	16.8384	17.6641	17.0427
	S.D.	0.1731	0.5443	0.2902	0.6813	0.4113	0.6147	0.5340	0.5485	0.3017

S.D refers to standard devition measure
Source: annual report of the banks. Note: AFIN: AFFIN HOLDINGS, MYPB: Alliance Financial Group, AMMB: AMMB Holdings, BIMB: BIMB Holdings, COMBS: CIMB Group Holdings, HOLB: Hong Leong Bank, HONG: Hong Leong Financial Group, MALY: Malayan Banking, RHBC: RHB Capital.

Results and Discussions

The two-stage SE-SBM model needs to be applied to calculate the efficiency scores of the banks. The first stage uses SBM model (2) to discriminate among efficient and inefficient banks during the period of evaluation, the efficiency score of each inefficient bank is less than one. In contrast to this, the efficiency score of each efficient bank is equal to one. To discriminate and rank the efficient banks resulted from model (2); super efficiency model (4) is run as the second stage. Hence, the efficiency scores of the super-efficient and inefficient banks are presented in Table 3.

Table 3 presents that the efficiency status of the banks fluctuated over the examined period, the high number of the efficient banks can be observed in the years 2006 and 2008 by six for each of which (i.e., the efficient banks are 66 %). For years 2005, 2009, 2010, and 2011, 33 % of the banks are efficient, while the year 2012 has the lowest number of the efficient banks where only two are efficient out of the nine banks.

Table 3

Efficiency Scores of Two-Stage SE-SBM Model

Banks/Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	10-year Average
AFIN	1.0005	0.9630	0.9446	0.9764	0.9716	0.9752	0.9656	0.9624	0.9502	0.9708	0.9680
MYPB	0.9600	0.9427	0.9389	0.9808	0.9734	0.9688	0.9711	1.0003	0.9723	0.9667	0.9675
AMMB	1.0132	1.0128	1.0021	1.0072	1.0069	0.9735	0.9767	0.9766	0.9712	1.0105	0.9951
BIMB	1.0072	1.0049	1.1301	1.0053	1.0029	1.0132	1.0153	1.0135	1.0229	1.0291	1.0244
COMBS	1.0037	0.9736	1.0027	1.0047	1.0061	1.0025	1.0011	0.9900	0.9856	1.0005	0.9971
HOLB	0.9608	0.9422	0.9745	0.9807	0.9880	0.9788	0.9724	0.9380	0.9603	0.9530	0.9649
HONG	1.0041	1.0186	1.0008	1.0012	1.0020	0.9870	0.9873	0.9836	0.9661	0.9609	0.9912
MALY	0.9951	0.9806	1.0031	0.9849	1.0040	1.0001	1.0009	1.0103	1.0147	1.0002	0.9994
RHBC	0.9932	0.9801	1.0040	1.0018	1.0024	0.9838	0.9729	0.9729	0.9584	0.9732	0.9843
Yearly Average	**0.9930**	**0.9798**	**1.0000**	**0.9936**	**0.9952**	**0.9869**	**0.9848**	**0.9830**	**0.9779**	**0.9849**	

We can see that BIMB has achieved the super-efficient status over the examined period; thus, its rank is the first at most of the years, i.e., six years as shown in Table 4. The banks COMBS and MALY have achieved the super-efficient status for seven years of the examined period, i.e., 77 % of the evaluation period, while the number of times that the banks AMMB, HONG, and RHBC have realized the super efficiency is six, five, and three, respectively. Only one bank which is HOLB out of the total nine banks has not realized the super-efficient status; therefore, its rank is low among other banks, this provides an indicator to low performance of the mentioned bank. Moreover, the ranking of the nine banks are fluctuated among increase and decrease except BIMB was relatively stable at first rank as presented in Table 4.

Table 4

Ranks of the Banks Based on Efficiency Scores of Two-Stage SE-SBM Model

Banks/Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AFIN	5	7	8	9	9	7	9	8	9	6
MYPB	9	8	9	7	8	9	8	3	4	7
AMMB	1	2	5	1	1	8	5	6	5	2
BIMB	2	3	1	2	4	1	1	1	1	1
COMBS	4	6	4	3	2	2	2	4	3	3
HOLB	8	9	7	8	7	6	7	9	7	9
HONG	3	1	6	5	6	4	4	5	6	8
MALY	6	4	3	6	3	3	3	2	2	4
RHBC	7	5	2	4	5	5	6	7	8	5

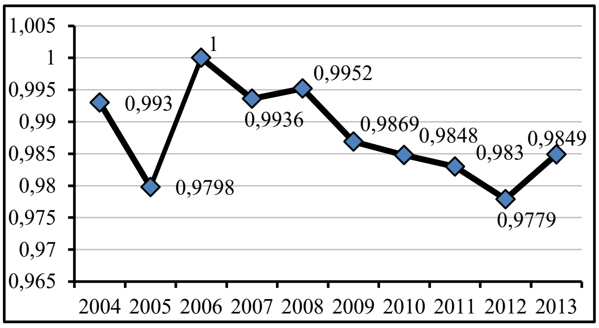

Figure 1. Yearly Average of Efficiency Scores of Nine Commercial Banks

In addition, the average of efficiency scores obtained from the two-stage model is restricted between 0.9779 and 1. About 90 % of the banks are inefficient as yearly average, this indicates that the super efficiency scores of the efficient banks are small, i.e., the non-radial distance between an excluded efficient bank to the efficient frontier is small (Lo & Lu, 2009). Regarding to the averages of the overall efficiency, Figure 1 depicts that the average efficiency of Malaysian banking sector has decreased in the year 2005 and increased at 2006, and then significantly decreased after 2006 to 2012 because of the financial crisis on the commercial Malaysian banks. However, the banks started to improve their performance in year 2013 since their trend has started to increase. In general, the figure shows that the average efficiency score decreased over the examined period, especially after 2006. To observe the average efficiency of each bank over the evaluation period, Figure 2 illustrates the ten-year average of efficiency scores of each of the bank. Clearly, BIMB is ranked first with score of 1.0244, followed by COMBS and AMMB at second and third positions, respectively, while HOLB is at the lowest position for the years 2004–2013.

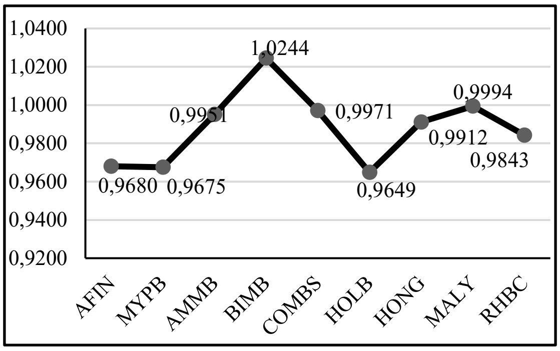

Figure 2. Ten-Year (2004–2013) Average of Efficiency Scores of Each Bank

Comparison between the Super Efficiency Radial and SE-SBM Model

The efficiency scores of Malaysian banks over the evaluation period are calculated using the super efficiency radial model proposed by Andersen and Petersen (1993) as presented in Table 5. The efficiency scores reported in Table 5 are compared to that obtained from the SE-SBM model which presented in Table 3.

Table 5

Efficiency Scores of the Super Radial Model

Banks/Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	10-year Average
AFIN	1.0017	0.9825	0.9789	0.9934	0.9859	0.9921	0.9715	0.9678	0.9566	0.9908	0.9821
MYPB	0.9683	0.9472	0.9679	0.9901	0.9812	0.9832	0.9743	1.0004	0.9776	0.9814	0.9772
AMMB	1.0301	1.0300	1.0065	1.0154	1.0179	0.9925	0.9876	0.9806	0.9742	1.0212	1.0056
BIMB	1.0193	1.0149	1.3905	1.0161	1.0088	1.0331	1.0338	1.0289	1.0406	1.0570	1.0643
COMBS	1.0080	0.9871	1.0079	1.0124	1.0113	1.0041	1.0029	0.9951	0.9918	1.0017	1.0022
HOLB	0.9704	0.9549	0.9958	0.9949	0.9983	0.9835	0.9754	0.9457	0.9712	0.9706	0.9761
HONG	1.0124	1.0204	1.0022	1.0025	1.0047	0.9907	0.9917	0.9908	0.9770	0.9839	0.9976
MALY	0.9966	0.9915	1.0063	0.9883	1.0087	1.0005	1.0022	1.0211	1.0303	1.0003	1.0046
RHBC	0.9963	0.9915	1.0115	1.0038	1.0050	0.9912	0.9793	0.9782	0.9690	0.9908	0.9917
Yearly Average for all banks	**1.0003**	**0.9911**	**1.0408**	**1.0018**	**1.0024**	**0.9967**	**0.9909**	**0.9898**	**0.9875**	**0.9997**	

The efficiency scores of the SE-SBM model are less than or equal to that of the super radial model (see Tone, 2001, p. 505; 2002, p.39). Therefore, Table 3 has shown that all efficiency scores of the SE-SBM model are less than or equal to that of the super radial model presented in Table 5. Consequently, the yearly averages of efficiency scores of the SE-SBM model for all banks are also less than of that resulted by the super radial model as shown in the mentioned tables and Figure 3. This ensures that the two super efficiency models were applied in an effective manner. The efficiency status of the efficient and inefficient banks during the period of evaluation are same for the two models since the efficiency scores obtained from the super radial model are greater than or equal to that resulted by the SE-SBM model. Due to the efficiency measurement of the non-radial SBM model determines by the values of reference set, the model can eliminate biases in its efficiency measures (Tone, 2001). Hence, the efficiency scores of the efficient and inefficient banks obtained from the SE-SBM model are more stable of that resulted by the super radial model.

The stability of the two models' results can be presented through their averages of efficiency scores as display in Figures 3 and 4. Figure 3 shows the average of efficiency scores resulted from the two models for the nine banks during the period of evaluation, while Figure 4 shows the average of efficiency scores of the two models also but for each bank over the examined period. Through the two figures, we can observe that the average of efficiency scores resulted from the SE-SBM model is more stable than of the super radial model over evaluation period, this provides another significant indicator to the robust results of the SE-SBM model.

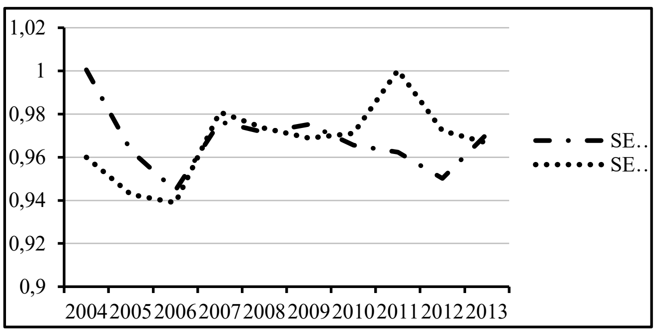

Figure 3. Yearly Average Efficiency Scores of Super Radial and SE-SBM Models

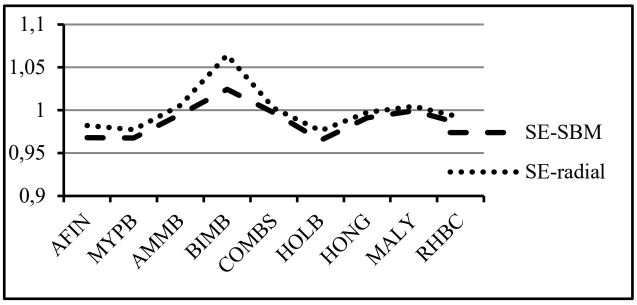

Figure 4. Ten-Year Efficiency Average Score for Each Bank

Conclusions

The non-radial SBM model measures the efficiency of DMUs in an effective manner since it deals with slacks of input and output simultaneously at different rates, which is the limitation of the radial model. However, when the radial model was used to measure the efficiency of Malaysian banks, the radial model cannot properly rank efficient banks because these banks have the same efficiency score. The performance of banks having same efficiency scores and same ranks, cannot be differentiated or discriminated. Therefore, in this paper, the SE-SBM model, proposed by Tone (2002) is utilized in ranking efficient nine Malaysian banks. The salient features of the model are its ability to discriminate the efficient and inefficient DMUs and ranking them, in addition it has the ability to identify slacks of input excess and output shortfall for each inefficient unit to improve its performance. In Malaysia; however, there have not been studies employed the SE-SBM model in evaluating Malaysian banks sector. Thus, with the aim to evaluate the efficiency of Malaysian banking sector, and to rank the efficient banks as well, this paper adopts the two stages of SE-SBM model. For the first time, the efficiency of commercial banks in Malaysia has been evaluated using the SE-SBM model of Tone (2002), and the efficient banks were able to be ranked for each year under study, which significantly contributes to the literature of banks efficiency.

The empirical results illustrate that the efficiency of the nine main Malaysian commercial banks has greatly decreased between 2006 and 2012. However, the high number of the efficient banks, with different rankings can be observed in years 2006 and 2008. The BIMB has achieved the super-efficient status for all examined years; therefore, its rank is the first in the most years of the examined period. In contrast to this, HOLB bank has achieved low rank among the other banks since its status is inefficient over the examined period. Moreover, the average efficiency scores of the most banks are inefficient; this provides an indicator that the efficiency status of the banks is greatly fluctuated over the period of evaluation. The data set of Malaysian banks were re-examined by calculating the efficiency scores using the super radial model. For this, a comparison between the results obtained from the SE-SBM and that of the super radial models is performed. The results of the SE-SBM models are more stable of that obtained from the super radial model. For the decision makers, the inefficient banks could improve their performance by calculating their real projections of inputs and outputs.

This paper has three limitations. First, performance evaluation of Malaysian commercial banks was only compared among the Malaysian banks. More accurate efficiency measures can be obtained, if other developed Asian countries such as Japan and Singapore dataset are included. Second, due to cost constraint faced by the research team to get more recent data, the study did not able to cover more recent data, for example up to 2016. However, it is believed that the ten-year study period is not that short period of time and the findings are still relevant for reference regarding the future direction of Malaysian banking industry. In upcoming research, more recent data with different categories of banks should be considered, so that more high impact findings are plausible. Third, the dataset used in this paper consists of bad output, which is non-interest income, this factor is more likely to be dealt as undesirable output. Therefore, a new SE-SBM model with undesirable output can be proposed. All these venues can be executed as future directions for this paper.

Acknowledgement

The authors wish to acknowledge the financial support provided by the High Impact Group Research Grant (PBIT) with S/O Code 12870, Universiti Utara Malaysia, Sintok, Kedah, Malaysia, for conducting this research.

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The article has been reviewed.

Received in October 2017; accepted in October 2019.