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A Survey on Malaysia's Banks Efficiency: Using Data Envelopment Analysis

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Abstract: Malaysia's banking industry is undergoing changes and overall competition. Commercial banks in Malaysia not only need to become profitable, but also efficient in order to enhance the economic growth and survive against its competitors. Data Envelopment Analysis (DEA) is a well-known non-parametric technique to measure the relative efficiency of banks. There are several studies on Malaysia's bank efficiency using conventional DEA models which are not able to discriminate between technically efficient banks. This study applies a recent robust DEA model, called Kourosh and Arash Model (KAM), to measure the relative efficiency of 15 commercial banks of Malaysia in 2013 with 4 inputs and 3 outputs. Several DEA models are applied and shows how KAM logically increases the discrimination power of DEA, and identifies the most efficient banks as well as introducing the reference sets for technically efficient and inefficient banks. The results in average indicate that Malaysia's local banks are more efficient than Malaysia's foreign banks in 2013.
Keywords: Bank, Efficiency, Data envelopment analysis, Kourosh and Arash method, Radial models, Benchmarking, Ranking.

INTRODUCTION

The banking system plays a vital role in the economic growth of a country. The competitive survival banks usually depend on their profitability, efficient management, growth rate and the risk exposure which has a direct impact on its market potential [1]. Malaysia's banking industry is undergoing changes, risk transformation, regulatory requirements and enormous growth in terms of new products, services and overall competition. There are several studies on Malaysia's banks efficiency since 2005 and usually they used Data Envelopment Analysis (DEA) techniques [2-6]. DEA is a nonparametric method in operations research for assessing the relative efficiency of homogeneous Decision Making Units (DMUs). It considers two set of factors (inputs and outputs) for each DMU, and gives an efficiency score between 0 and 1 to rank DMUs as well as measuring potential decrease and increase of inputs/outputs to benchmark DMUs [7].

Charnes, Cooper and Rhodes (CCR) [7] and Banker, Charnes and Cooper (BCC) [8] models are the first two common conventional redial DEA models which have been used for measuring Malaysia's banks efficiency. For instance, Habibullah et al. [2] in 2005 investigated the relative efficiency of 37 commercial banks in Malaysia by applying CCR in DEA. Matthew and Ismail [3] in 2006 examined the technical efficiency of 30 domestic and foreign commercial banks in Malaysia using CCR and BCC models. Sufian and Majid [4] in 2007, Kamaruddin et al. [5] in 2008 and Ismail et al. [6] in 2013also applied CCR and BCC to measure the relative efficiency of Malaysia's banks. However, CCR and BCC are neither able to distinguish between technically efficient DMUs nor able to benchmark and rank all DMUs appropriately [9, 10].

Unfortunately, since the real data of most of previous studies are not available, examining the results of previous research on bank efficiency are impossible. In other words, there is no chance to represent the strengths and/or weaknesses of previous findings. Therefore, this study selected a real-life numerical example of 15 commercial banks of Malaysia inclusive 8 local and 7 foreign banks in 2013 with 7 factors (4 inputs: equity capital, deposit from customers, interest expenses and other operating expenses; and 3 outputs: loan, advances and financing , interest income and other operating income). Different conventional DEA models are applied in order to find a guideline to depict the strengths and/or weaknesses of previous studies on Malaysia's banking industry. A recent robust DEA model, called Kourosh and Arash Model (KAM) [11], is also applied to depict the discrimination power of DEA in comparison with current methodologies.

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The rest of this paper is organized in 5 sections. In Section 2, a short review on the efficiency measurement in banking is illustrated. The DEA models are demonstrated in Section 3 and their results are represented in Section 4 for a real-life numerical example on Malaysia's Banks. Section 5 concludes this study.

LITERATURE REVIEW

The essences of bank production are the ability to improve informational asymmetries between borrowers and lenders, and manage risks. These abilities are vital elements of bank output and influence the managerial incentives to produce financial services wisely and efficiently. Efficiency means using the jobs right which can be interpreted as a ratio of output/input values. Traditionally banks measures the efficiency of their branches separately at the strategic and tactical levels. In the strategic level, branch's efficiency is defined by simple operational ratios such as transactions per teller or by financial ratios such as deposits to loans or return on assets [12]. In the tactical level, industrial-engineering methods are used to measure time-and-motion efficiency.

DEA method has extensively been used to evaluate the relative efficiency of banking institutions (Table 1). Paradi and Zhu [13] found that there is a significant diversity of input and output selection among different studies, and the most widely used approaches are the Constant Returns to Scale (CRS),and radial DEA models. Most of the previous studies on the banking efficiency in Asia are different in the methodology or in the measurement of the inputs and outputs of the banks. Table 1 illustrates a short background on previous bank efficiency studies to select different factors and models.

There are four approaches as a guide in selecting input and output variables such as production approach, intermediation approach, revenue (or value added) approach and operating (or income based) approach[14-17]. Production approach suggests that the number of accounts or its related transactions is the best measure for output, while the number of employees and physical capital are considered as inputs [14]. The intermediation approach deposits total loans and securities as outputs, whereas deposits along with labour and physical capital are defined as inputs [15]. On the other hand, the operating approach defines banks' output as total revenue (interest and non-interest income) and inputs as the total expenses (interest and non-interest expenses) [16]. Under the most recent approach, revenue approach deposits and loans are viewed as outputs because they are responsible for the significant proportion of value added [17]. The appropriateness of each approach varies according to the circumstances.

Table 1: Summary of bank efficiency measurement from various authors.

Author / Year	Sample/ DMUs	Methods	Output Variables	Input Variables
Miller and Noulas [18] in 1996	201 U.S. Banks (1984-1990)	DEA CRS, VRS	1) commercial and industrial loans 2) consumer loans 3) real estate loans 4) investments 5) total interest income 6) total non-interest income	1) total transactions deposits 2) total non-transactions deposits 3) total interest expenses 4) total non-interest expenses
Luo [19] in 2003	245 Banks (2000)	DEA IO CRS, VRS	Profitability: 1) number of employees 2) assets 3) stockholders' equity Marketability: 1) revenue 2) profits	Profitability: 1) revenue 2) profits Marketability: 1) market value 2) stock price 3) earnings per share
Wai et al. [20] in 2003	35 Singaporean Banks (1993-1999)	DEA VRS OO	Model A 1) Interest income 2) Other income Model B 1) Loans Model C 1) Risk Weighted Asset	Model A 1) Interest expenses 2) Operating expenses Model B and C 1) Deposits 2) Fixed Assets
Habibullah et al. [2] in 2005	37 Malaysia Banks (1988-1993)	DEA CCR OO	1) interest income 2) non-interest income 3) total loans	1) non-interest expenses 2) transaction deposits 3) non-transaction deposits

Matthews and Ismail [3] in 2006	30 Malaysia Banks (1994-2000)	DEA, IO CRS, VRS	1) total loans 2) other earning assets 3) other operating income	1) number of employees 2) fixed assets 3) total deposits
Sufian and Majid [4] in 2007	10 Malaysia Banks (2002-2003)	DEA IO, OO VRS	1) interest income 2) non-interest income 3) net-profit	1) personnel expenses (labor) 2) interest expenses
Kamaruddin et al. [5] in 2008	14 Malaysia Banks (1998-2004)	DEA IO OO VRS	Cost efficiency model 1) earning assets 2) liquid assets 3) other income Profit efficiency model 1) profit before taxation 2) zakat	Cost efficiency model 1) personnel expenses (labor) 2) fixed assets Profit efficiency model 1) personnel expenses (labor) 2) total deposits 3) premises and fixed assets
Alkhathlan and Malik [21] in 2010	10 Saudi Arabia Banks (2003-2008)	DEA CCR,BCC IO	1) Loans and advances (net)	1) Operating expenses 2) Equity capital 3) Deposits
Thagunna and Poudel[22] in 2013	21 Nepal Banks (2007-2011)	NDRS, CRS and NIRS	1) Total loans 2) Interest income 3) Operating non-interest income	1) Total deposit, 2) Interest expense, 3) Operating non-interest expense
Ismail et al. [6] in 2013	17 Malaysia Banks (2006-2009)	DEA IO CRS, VRS	1) total loans 2) other earning assets 3) off-balance sheet items	1) personnel expenses (labor) 2) fixed assets 3) total deposits
Wang et al. [23] in 2014	16 Chinese Banks 2003-2011.	DEA ADD	1) Interest income 2) Non-interest income 3) Bad loans	1) Fixed assets 2) Labours

In the context of DEA, efficiency investigates how well the production process converts inputs into outputs, that is, it investigates how much inputs need to be decreased/increased or outputs need to be increased/decreased in order to enhance its performance [11]. DEA defines an efficient frontier based on the best available practices and calls DMUs on the frontier as technically efficient and those are not lied on the frontier as inefficient.

CCR is a radial model with Constant Returns to Scale (CRS) technology. In Input Oriented (IO) approach CCR radially minimizes the inputs values while keeping at least present output levels whereas in Output Oriented (OO) it radially maximizes the outputs values while keeping at most present input levels. BCC considers Variable Returns to Scale (VRS) by adding the convexity constraint, $\sum_{i=1}^{n}\lambda_i = 1$, to CCR. There are also two different technologies such as Non-Decreasing Returns to Scale (NDRS) and Non-Increasing Returns to Scale (NIRS) which can be measured by adding the constraints $\sum_{i=1}^{n}\lambda_i \geq 1$ and $\sum_{i=1}^{n}\lambda_i \leq 1$ to CCR, respectively. The weighted additive DEA model (ADD) [24] and Slack Based Measure (SBM)[25] simultaneously minimize inputs and maximize outputs. The score of SBM is always less than equal the score of CCR that shows the discrimination power of SBM via CCR. Unfortunately, none of these models are able to distinguish between technically efficient DMUs and proposed super efficiency models are not appropriate to discriminate between technically efficient DMUs [9]. Therefore, are recent robust DEA model was proposed by Khezrimotlagh et al. [11] which simultaneously regulates inputs and outputs of each DMU in comparison with best observed practices in the sample. It handles measurement errors, detecting outliers and easily discriminates technically efficient DMUs as well as rank and benchmark DMUs. KAM introduces a very small negligible thickness in the frontier and measures the instabilities of technically efficient DMUs in the sample. KAM in CRS where the l^{th} DMU is evaluated, is given by:

$$\max \sum_{j=1}^{m} w_j^- s_j^- + \sum_{k=1}^{p} w_k^+ s_k^+$$

Subject to

$$\sum_{i=1}^{n}\lambda_i x_{ij} + s_j^- = x_{lj} + \varepsilon_j^-, \text{ for } j = 1,2,\ldots,m,$$
$$\sum_{i=1}^{n}\lambda_i y_{ik} - s_k^+ = y_{lj} - \varepsilon_k^+, \text{ for } k = 1,2,\ldots,p,$$
$$\lambda_i \geq 0, \text{ for } i = 1,2,\ldots,n,$$
$$s_j^- \geq 0, \text{ for } j = 1,2,\ldots,m,$$
$$s_k^+ \geq 0, \text{ for } k = 1,2,\ldots,p.$$

VRS: Add $\sum_{i=1}^{n}\lambda_i = 1$.
NIRS: Add $\sum_{i=1}^{n}\lambda_i \leq 1$.
NDRS: Add $\sum_{i=1}^{n}\lambda_i \geq 1$.

The KAM best technical efficient target and score with ε degree of freedom (ε-DF) are as follows, respectively:

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$$\begin{cases} x_{ij}^* = x_{ij} - s_{ij}^{-*} + \varepsilon_j^-, \text{for } j = 1,2,\dots m, \\ y_{ik}^* = y_{ik} + s_{ik}^{+*} - \varepsilon_k^+, \text{for } k = 1,2,\dots p. \end{cases}$$

$$KA_\varepsilon^{*i} = \frac{\sum_{k=1}^{p} w_k^+ y_{ik} \ / \ \sum_{k=1}^{p} w_j^- x_{ij}}{\sum_{k=1}^{p} w_k^+ y_{ik}^* \ / \ \sum_{k=1}^{p} w_j^- x_{ij}^*}$$

IF the weights in ε-KAM are unknown, they are defined as $w_j^- = 1/x_{lj}$, $w_k^+ = 1/y_{lk}$, where $x_{lj} \neq 0$ and $y_{lk} \neq 0$, respectively, and $w_j^- = 1$ or $w_k^+ = 1$, where $x_{lj} = 0$ or $y_{lk} = 0$, respectively. The components of epsilon vector to identify the thickness of the frontier are selected as $\varepsilon_j^- = \varepsilon \times \min\{x_{lk} : x \neq 0, i = 1, 2, \dots, n\}$ and $\varepsilon_k^+ = \varepsilon \times \min\{y_{lk} : y_{lk} \neq 0, i = 1, 2, \dots, n\}$ where ε is a very small nonnegative real number. The thickness of the frontier in this case is measured by $2(\sum_{j=1}^{m}(\varepsilon_{ij}^-)^2 + \sum_{k=1}^{p}(\varepsilon_{ik}^+)^2)^{1/2}$[11].

A technically efficient DMU is called KAM efficient with ε-DF if $KA_0^* - KA_\varepsilon^* < \delta$, otherwise, it is called inefficient with ε-DF. The value of δ depends on the aim of measuring the efficiency scores of DMUs and would be defined by $\varepsilon/(m+p)$ or $\varepsilon/10$ or greater value to have at least one efficient DMU with ε-DF.

The score of KAM score is between 0 and 1 for those DMUs which require improving its inputs and/or outputs. If the score of KAM is greater than 1 for a DMU, KAM represents that the DMU has a good combination of data, shouldn't change its data except by CRS technology or highest KAM-efficient targets [11].

MATERIAL AND METHODS

Table 2 illustrates the 15 selected local and foreign Banks in Malaysia. There are 8 local banks numbered as L1-L8 and 7 foreign banks numbered as F1-F7. The financial data of these 15 selected commercial banks in 2013 inclusive 4 inputs and 3 outputs are illustrated in Table 3. Data were also taken from the financial statements of the respective banks. A combination of intermediation approach and operating approach are considered in this study.

Table 2: The 15 selected local and foreign Banks in Malaysia.

Local Banks	Code	Foreign Banks	Code
Malayan Banking Berhad	L1	Bangkok Bank Berhad	F1
Hong Leong Bank Berhad	L2	Bank of China Malaysia Berhad	F2
Affin Bank Berhad	L3	John Pierpont Morgan Chase Bank Berhad	F3
Alliance Bank Malaysia Berhad	L4	HSBC Bank Malaysia Berhad	F4
AmBank Malaysia Berhad	L5	OCBC Bank Malaysia Berhad	F5
CIMB Bank Berhad	L6	Standard Chartered Bank Malaysia Berhad	F6
Public Bank Berhad	L7	United Overseas Bank Malaysia Berhad	F7
RHB Bank Berhad	L8		

Table 3: The 15 DMUs with 4 inputs and 3 outputs (RM'000)

Banks	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3
L1	4,591,331	8,862,079	273,670,380	5,096,985	237,971,279	11,744,776	5,882,062
L2	1,630,340	1,879,909	109,168,631	3,139,893	81,835,734	5,609,243	1,222,457
L3	461,133	1,518,337	36,800,728	1,308,113	30,178,910	2,150,845	234,862
L4	473,247	600,517	30,116,637	659,456	22,907,273	1,361,593	390,734
L5	1,046,978	820,364	62,120,335	2,285,813	59,032,684	4,297,874	639,062
L6	3,679,418	4,131,410	156,115,031	3,804,657	132,833,310	8,387,957	2,042,067
L7	597,840	20,424	250,873	351,252	219,416	5,570,538	1,750,643
L8	1,467,233	2,546,910	137,741,241	1,810,022	119,542,545	3,391,467	936,947
F1	35,420	400,000	2,457,461	81,573	2,493,493	138,704	14,365
F2	50,766	304,000	3,213,514	157,323	2,796,973	256,288	29,882
F3	117,400	85,500	3,663,079	42,831	168,741	131,278	117,827
F4	1,141,676	114,500	48,883,876	882,635	35,484,730	2,322,282	166,110
F5	808,251	291,500	56,429,044	1,604,653	48,935,917	2,918,427	147,834
F6	932,069	3,778,829	34,452,038	780,454	29,163,612	1,892,673	732,387
F7	759,076	2,298,271	19,977,389	991,533	26,443,516	3,467,326	2,104,870

All data are rounded to the nearest thousands of Ringgit Malaysia (RM'000). The four inputs are overhead expenses, equity capital, deposit from customers and interest expenses, respectively. These inputs represent measures for the banks' labor, capital and operating costs and are illustrated as follows:

Input1: Overhead expenses (other operating expenses), that is, amount which generally does not depend on sales or production quantities. These include marketing expenses, rent and utilities, office expenses, operating leases, IT (software services) and other fixed costs.

Input 2: Equity capital, that is, the current market value of everything owned by the company from which the total of all liabilities is subtracted. On the balance sheet of the company, equity capital is listed as stockholders' equity or owners' equity.

Input 3: Deposit from customers, that is, money placed into a banking institution for safekeeping by customers.

Input 4: Interest expenses, that is, the cost incurred by an entity for borrowed funds. Interest expenses are non-operating expenses shown on the income statement.

The three outputs are total loans, interest income, and non-interest income, respectively. These outputs represent the banks' revenue and major business activity and are illustrated as follows:

Output 1: Loan, advances and financing, which consist of loans and lease net of unearned income. Loan generally regarded as 'credit' granted where the money is disbursed and its recovery is made on a later date. Banks grant advances largely for short-term purposes, such as purchase of goods traded in and meeting other short-term trading liabilities.

Output 2: Interest income, which includes interest and fee income on loans, income from lease financing receivables, interest, dividend income on security and other interest. It is the amount of interest that has been earned during a specific time period.

Output 3: Non-interest income (Other operating income), which includes service charges on deposit account, income from fiduciary activities and other non-interest income. Income derived primarily from fees. Examples of non-interest income include deposit and transaction fees, insufficient funds (NSF) fees, annual fees, monthly account service charges, inactivity fees, check and deposit slip fees, etc.

In the next section several DEA models are applied to discriminate between these 15 banks.

RESULTS AND DISCUSSION

Table 4 and 5 illustrate the efficiency scores of CCR, ADD and 10^{-7}-KAM in CRS and VRS, respectively. Note that, the results of models in NIRS and NDRS are not represented as they were almost completely the same as the results of models in VRS and CRS, respectively.

The value of epsilon to apply ε-KAM is selected as 10^{-7}, because in this case, the components of epsilon vector are $\varepsilon_1^- = 0.0035420$, $\varepsilon_2^- = 0.0020424$, $\varepsilon_3^- = 0.0250873$, $\varepsilon_4^- = 0.0042831$, $\varepsilon_1^+ = 0.0168741$, $\varepsilon_2^+ = 0.0131278$ and $\varepsilon_3^+ = 0.0014365$, which are very small negligible values according to the minimum values of factors. The diagonal of efficient tape in this case is around 0.0670, which is quite negligible.

The instabilities of technically efficient DMUs (those DMUs lie on the frontier) while ten millionth errors occur in the components of the frontier are examined by KAM. According to Khezrimotlagh et al. [9], a technical efficient bank can be called as KAM efficient with 10^{-7}-DF in inputs and outputs, if $1 - KA_\varepsilon^* < \delta$.In this practice, the values of $\delta$is selected as 10^{-8}.

There are eight technically efficient banks by CRS DEA models, L3, L5, L7, L8, F1, F4, F5 and F7. However, 10^{-7}-KAM suggests four of them, L7, F7, L8 and L5, as efficient with 10^{-7}-DF. As can be seen in the 5th column of Table 3, KAM is easily able to rank all banks appropriately and distinguish between technically efficient banks. The best bank is introduced as L7 with the first rank among 15 selected banks. It is a reference set for almost all banks as well as efficient Banks F7, L8 and L5 with 10^{-7}-DF. Moreover, L7 has the best technically efficient score as 1 even with 0.1-DF, which shows the strong combination of its factors in the sample.

Table 3: The results of CRS DEA models.

DMUs	CCR-IO (OO)	ADD CRS	10^{-7}-KAM CRS	Rank	Reference Sets	Decision
L1	0.9359	0.6451	0.645101437	9	L7, L8, F7	Inefficient
L2	0.8419	0.5535	0.553525107	11	L7, L8	Inefficient
L3	1	1	0.999999915	7	L3, L7, L8	Inefficient with 10^{-7}-DF
L4	0.8404	0.5415	0.541513034	12	L7, L8	Inefficient
L5	1	1.0000	0.999999990	4	L5, L7, L8, F5	Efficient with 10^{-7}-DF
L6	0.9069	0.3673	0.367293399	13	L7, L8	Inefficient
L7	1	1	1.000000000	1	L7	Efficient with 10^{-7}-DF
L8	1	1	0.999999994	3	L7, L8	Efficient with 10^{-7}-DF
F1	1	1	0.999999244	8	L8, F1, F7	Inefficient with 10^{-7}-DF
F2	0.9758	0.6172	0.617215263	10	L3, L7, L8, F1	Inefficient
F3	0.6008	0.1381	0.138080183	15	L7, L8	Inefficient
F4	1	1	0.999999951	6	L7, L8, F4, F5	Inefficient with 10^{-7}-DF
F5	1	1	0.999999968	5	L7, L8, F5	Inefficient with 10^{-7}-DF
F6	0.8584	0.3418	0.341809656	14	L7, L8	Inefficient
F7	1	1	0.999999996	2	L7, L8, F7	Efficient with 10^{-7}-DF

Table 4: The results of VRS DEA models.

DMUs	BCC-IO	BCC-OO	ADDVRS	10^{-7}-KAM VRS	Rank	Reference Sets
L1	1	1	1	1.000000000	1	L1, L7
L2	1	1	1	0.999999990	8	L1, L2, L5, L6, L7
L3	1	1	1	0.999999918	10	L3, L7, L8, F1
L4	0.8792	0.8673	0.5991	0.599135034	14	L7, L8, F2, F5
L5	1	1	1	0.999999998	5	L5, L7, L8, F5
L6	1	1	1	0.999999996	6	L1, L5, L6, L7
L7	1	1	1	1.000000000	1	L7
L8	1	1	1	0.999999999	3	L1, L7, L8
F1	1	1	1	0.999999693	13	L7, F1
F2	1	1	1	0.999999837	11	L7, L8, F1, F2
F3	1	1	1	0.999999759	12	L7, L8, F2, F3, F5
F4	1	1	1	0.999999985	9	L7, L8, F4, F5
F5	1	1	1	0.999999992	7	L7, L8, F5
F6	0.8635	0.8619	0.3730	0.373048841	15	L1, L7, L8
F7	1	1	1	0.999999999	3	L1, L7, L8, F7

It is clear that the number of technically efficient banks is increased by applying VRS instead of CRS. However, KAM is a robust model and is easily able to discriminate between DMUs. According to Table 4, L7 in VRS technology has also the first rank among other banks. Although, L1 is known as efficient with 10^{-7}-DF in VRS and has the first rank, increasing the values of epsilon shows that L7 has the score as 1 even with 0.1-DF, whereas L1 score is decreased with 10^{-5}-DF. Moreover, L7 is a reference set for all banks in VRS.

The strengths and weaknesses of the conventional DEA models which have usually been applied to measure the relative efficiency of banks industry in comparison with the results of KAM can clearly be seen in this real-life numerical example.

CONCLUSION

In this study, different DEA models are applied in order to find a guideline to depict the strengths and/or weaknesses of previous studies on Malaysia's banking industry. A real-life numerical example of 15 foreign and local banks of Malaysia in 2013 are exemplified with 7 factors. The results shows that the best technically efficient bank in 2013 was Public Bank and the local banks in average were more efficient than foreign banks. An appropriate rank for each bank was provided by applying KAM with 10^{-7}-DF. KAM is suggested to measure the relative efficiency of bank as well as benchmark and rank banks appropriately.

REFERENCES

1. Guru BK, Staunton, J, Balashanmugam B; Determinants of commercial bank profitability in Malaysia. Journal of Money, Credit, and

Banking, 2002; 17:69-82.Habibullah MS, Makmur MI, Azman-Saini WNW, Radam A, Ong HB; Bank efficiency and the efficient market hypothesis: The case for bank stock prices in KLSE. Savings and Development, 2005; 29(4):363-390.
2. Habibullah MS, Makmur MI, Azman-Saini WNW, Radam A, Ong HB; Bank efficiency and the efficient market hypothesis: The case for bank stock prices in KLSE. Savings and Development, 2005; 29(4):363-390.
3. Matthews K, Ismail M; Efficiency and productivity growth of domestic and foreign commercial banks in Malaysia. Cardiff economics working papers, 2006; No. E2006/2.
4. Sufian F, Majid MZA; Banks' efficiency and stock prices in emerging markets: evidence from Malaysia. Journal of Asia-Pacific Business, 2007; 7(4):35-53.
5. Kamaruddin BH, Safab, MS, Mohd R;Assessing production efficiency of Islamic banks and conventional bank Islamic windows in Malaysia. International Journal of Business and Management Science, 2008; 1(1):31.
6. Ismail F, Majid MSA, Rahim RA; Efficiency of Islamic and conventional banks in Malaysia. Journal of Financial Reporting and Accounting, 2013; 11(1):92-107.
7. Charnes A, Cooper WW, Rhodes E; Measuring the efficiency of decision-making units. European Journal of Operational Research, 1978; 2(6):429–444.
8. Banker RD, Charnes A, Cooper WW; Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 1984; 30(9):1078-1092.
9. Khezrimotlagh D, Salleh S, Mohsenpour Z; Benchmarking Inefficient Decision Making Units in DEA. Journal of Basic and Applied Scientific Research, 2012; 2(12):12056-12065.
10. Khezrimotlagh D, Salleh S, Mohsenpour Z; Nonlinear Arash Model in DEA. Research Journal of Applied Sciences, Engineering and Technology, 2013; 5(17):4268-4273.
11. Khezrimotlagh D, Salleh S, Mohsenpour, Z; A new method for evaluating decision making units in DEA. Journal of the Operational Research Society, 2014; 65(5):694-707.
12. Golany B, Storbeck JE;A data envelopment analysis of the operational efficiency of bank branches. Interfaces, 1999;29(3):14-26.
13. Paradi JC, Zhu H; A survey on bank branch efficiency and performance research with data envelopment analysis. Omega, 2013; 41(1), 61-79.
14. Benston GJ; Branch banking and economies of scale. The Journal of Finance, 1965; 20(2):312–331.
15. Sealey C, Lindley JT; Inputs, outputs and a theory of production and cost at depository financial institutions. The Journal of Finance, 1977; 32(4):1251-1266.
16. Leightner JE, Lovell CA; The impact of financial liberalization on the performance of Thai banks. Journal of Economics and Business, 1998; 50(2):115–131.
17. Drake L, Hall MJB, Simper R; The impact of macroeconomic and regulatory factors on bank efficiency: A non-parametric analysis of Hong Kong’s banking system. Journal of Banking and Finance, 2006; 30(5):1443–1466.
18. Miller SM, Noulas AG; The technical efficiency of large bank production.Journal of Banking and Finance, 1996; 20(3):495–509.
19. Luo X; Evaluating the profitability and marketability efficiency of large banks: An application of data envelopment analysis. Journal of Business research, 2003; 56(8):627-635.
20. Wai HL, Dollery B, Coelli T; Measuring the Technical Efficiency of Banks in Singapore for the period 1993-99. ASEAN Economic Bulletin, 2003; 20(3):195-210.
21. Alkhathlan K and Malik SA; Are Saudi Banks Efficient? Evidence Using Data Envelopment Analysis (DEA). International Journal of Economics and Finance, 2009; 2(2):53-58.
22. Thagunna KS, Poudel S; Measuring bank performance of Nepali banks: A Data envelopment analysis (DEA) perspective. International Journal of Economics and Financial Issues, 2012; 3(1):54-65.
23. Wang K, Huang W, Wu J, Liu Y; Efficiency measures of the Chinese commercial banking system using an additive two-stage DEA. Omega, 2014; 44:5-20.
24. Charnes A, Cooper WW, Golany B, Seiford LM, Stutz J; Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. Journal of Econometrics, 1985; 30(1):91–107.
25. Tone K; Several algorithms to determine multipliers for use in cone-ratio envelopment approaches to efficiency evaluations in DEA. In: Amman H, Rustem B and Whinston AB (eds). Computational Approaches to Economic Problems. Kluwer Academic Publishers: Dordrecht, The Netherlands, 1997; 91–109.