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Conventional versus Islamic bank efficiency: A dynamic network data-envelopment-analysis approach

Md Abul Kalam Azad[a], Muzalwana Binti Abdul Talib[b], Kian-Teng Kwek[c] and Paolo Saona[d,*]
[a]*Department of Business and Technology Management, Islamic University of Technology, Board Bazar, Gazipur, Bangladesh*
[b]*Department of Applied Statistics, Faculty of Economics and Administration, University of Malaya, Kuala Lumpur, Malaysia*
[c]*Department of Economics, Faculty of Economics and Administration, University of Malaya, Kuala Lumpur, Malaysia*
[d]*Richard A. Chaifetz School of Business, Saint Louis University, Madrid Campus, Av. Del Valle, 34, 28232, Madrid, Spain; Faculty of Economics and Business Administration, Universidad Pontificia Comillas, C/Alberto Aguilera, 23, 28015, Madrid, Spain & Faculty of Economics and Administrative Sciences, Universidad Católica de la Santísima Concepción, Alonso de Ribera 2850, Concepción, Chile*

Abstract. This study compares the efficiency of conventional and Islamic banks in Malaysia by engaging in a dynamic three-step (production, intermediation, and profitability) network data envelopment analysis (DEA). The inputs and outputs for the DEA model are selected based on the CAMELS rating. The major contributions of this study are threefold. First, this study investigates the efficiency of Malaysian banks using a novel dynamic network DEA model. Second, the Malaysian banking industry is found to be efficient in creating earning assets rather than in creating loans or profit. The results reveal that only a few banks in Malaysia have been efficient in converting deposits and equities into profit. Third, Islamic banks, in general, have been performing efficiently in the production and profitability approaches. Conventional banks, in contrast, are found to have been efficient in the intermediation approach. Policy implications are derived from the main conclusions.

Keywords: Data envelopment analysis, efficiency, network DEA, Malaysia

1. Introduction

Data envelopment analysis (DEA)—a nonparametric technique for benchmarking—has turned out to be the most interesting research area in the more than three decades' time since its inception [1]. Paradi and Zhu [2] reviewed 225 DEA papers from 1997 to 2010 and found that both institutional and branch-level studies are dominating the research work. Despite this popularity, applications of DEA in bank-efficiency studies have limitations. For instance, the inability to explain the process taking place within a decision-making unit (DMU) is one of the most commonly cited criticisms of the traditional DEA technique [3, 4]. In a traditional DEA, the inputs enter a 'black box' to produce outputs. The banking operation is not so simple that a black box can evaluate its operations [5]. The three most used approaches for studying banking operations are production (converting deposits and equities into earning assets),

*Corresponding author. Paolo Saona, Saint Louis University – Madrid Campus, Business and Economics Department, Avda. del Valle, 34 28003 Madrid, Spain & Universidad Católica de la Santísima Concepción, Faculty of Economics and Administration, Avda. Alonso de Ribera 2850, Concepción, Chile. E-mail: paolo.saona@slu.edu.

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profitability (converting loans into net income), and intermediation (converting earning assets into loans). Azad and Kian-Teng [5] used all these approaches in an additive model using a network DEA to explain a bank's complete operation and efficiency. A network DEA explains the internal structure of a DEA black box [4]. This study uses the three-stage network DEA proposed by Azad and Kian-Teng [5]. In addition to that, this study examines the efficiency of banks over the years by applying a dynamic approach. Hence this study not only explains the efficiency of each approach (production, profitability, and intermediation) separately while revealing total efficiency but also evaluate banks' progress or regress in efficiency over the course of years.

The Malaysian economy is one of the top five economies in the world as measured by Islamic Syariah-compliant assets [6]. Comparative studies of conventional and Islamic banks in Malaysia have been common. The initial studies mainly concentrated on applying basic DEA models for evaluating cost, revenue, or profit efficiency [7–10]. Another wave of studies focused on the economy before and after the global economic crisis [11, 12]. Since the Malaysian banking sector has faced forced mergers recently, a good number of bank-efficiency studies have focused on mergers while examining the comparative efficiency of conventional and Islamic banks [13–16]. However, some recent comparative studies have focused on model development and prediction using the multicriteria decision-making approach [12, 17–19]. To the best of our knowledge, only one study has examined Malaysian bank efficiency using network DEA [5]. This study examines comparative bank efficiency in Malaysia using the emerging application of network DEA [1, 4, 20].

This study contributes to the current literature in three ways. First, it applies the DEA technique to measure bank efficiency using the network DEA approach. This application of network DEA opens the black box of traditional banking studies and provides bias-free benchmarking. Specifically, we provide novel insights on banks' efficiency in creating earning assets, loans, and profits. Analysis of efficiency has not previously been conducted at these three levels in the Malaysian banking industry. Second, findings indicate that the Malaysian banking industry is more efficient in creating earning assets than in creating loans or profit. Additionally, we find that only a few banks performed well in converting deposits and equities into profits and in minimizing loan loss provisions. Third, this paper closes the gap in the empirical literature by working with a complete set of bank data from the Malaysian banking sector by using this proposed model. Previous studies of Malaysia worked with samples of banks where extrapolation of results are systematically done cautiously [8, 15, 21]. Islamic banks, in general, have performed efficiently in the production and profitability approaches. Conventional banks, in contrast, have been efficient in the intermediation approach.

This paper is organized in six sections. The following section presents a brief literature review. Section 3 describes the methodology and empirical model used in this study. Section 4 presents data and variables. A discussion of the results follows in section 5. The final section discusses conclusions and policy implications.

2. Literature review

It is of great importance to examine banking-sector efficiency because sustainable economic growth relies on it [21]. The Malaysian banking sector remains a priority research topic because of the enormous growth in banking assets (particularly growth in Islamic financial assets), the economic growth of Malaysia, and the Asian crisis in 1970 [22–24]. Moreover, the Malaysian government imposed a forced merger on the banks to strengthen the sector, which brought more attention from academics [14, 15, 25]. In particular, the growth in Islamic banking assets in Malaysia has raised a question among researchers: are Islamic banks more efficient than conventional banks?

Comparative studies of conventional and Islamic banks in Malaysia using efficiency techniques are not scarce. However, these studies have missed some major research questions. For instance, studies that applied the stochastic-frontier approach to examine efficiency among these banks did not recognize that a ratio of only two variables (input and output) cannot explain a bank's total operations [26]. Since the stochastic-frontier approach is a parametric statistical tool, it cannot take more variables as inputs and outputs. Later on, most studies examined bank efficiency in Malaysia using DEA, which is a nonparametric statistical tool that can take any number of variables as inputs and outputs [27].

Among the DEA studies on bank efficiency in Malaysia, only a few issues have been discussed while many remain unexplored [1, 4, 5, 23]. The common applications of DEA in the Malaysian bank-

Table 1
Literature on bank efficiency in Malaysia

Reference	Method	Major findings
Kamarudin and Sufian [6]	Two-stage DEA with OLS	Domestic Islamic banks are worse performers than foreign Islamic banks
Azad and Munisamy [43]	Malmquist metafrontier DEA	Islamic banks have outperformed conventional banks in the profitability approach
Kamarudin and Hue [40]	Malmquist metafrontier DEA	Foreign Islamic banks have higher productivity than domestic ones
Azad and Kian-Teng [5]	Network DEA	Islamic banks have higher efficiency in the production and intermediation approaches
Du and Sim [25]	DEA	Bank M&A can lead to efficiency improvements
Ghroubi and Abaoub [37]	SFA and metafrontier analysis	Conventional banks seem to be more efficient compared to Islamic banks because of their managerial excellence
Sufian and Kamarudin [42]	Two-stage DEA	Domestic banks are more efficient than foreign banks
Wanke and Azad [12]	Dynamic slacks-based model	Foreign Islamic banks' efficiency is higher than domestic ones'
Wanke and Azad [17]	Two-stage	Variables related to cost structure reduce efficiency levels
Wanke and Azad [19]	Two-stage	Country origin and cost structure impact efficiency
Chan and Koh [44]	Two-stage DEA	Foreign ownership, political stability, and regulatory quality are significant drivers of efficiency
Hasan and Kamil [33]	SFA	Malaysian local banks are more efficient than foreign banks
Salami and Adeyemi [45]	Malmquist DEA	Islamic banks are more efficient than conventional banks
Sufian [46]	Two-stage DEA	Productive efficiency is positively related to bank size, capitalization, and foreign ownership
Sufian and Habibullah [47]	DEA	Domestic banks have been relatively more efficient than their foreign counterparts
Lai, Ling [36]	DEA	M&As have no significant impact on Malaysian bank efficiency
Muhmad and Hashim [41]	Pooled Ordinary Least Squares	Capital adequacy, asset quality, earning quality, and liquidity have a significant impact on bank efficiency
Sufian and Kamarudin [38]	DEA	Foreign Islamic banks are revenue-efficient
Sufian and Habibullah [35]	Malmquist DEA and OLS	Bank efficiency has a negative relation with inflation and credit risk
Ahmad and Rahman [10]	DEA	Islamic banks are less efficient

efficiency literature are conventional versus Islamic banks [7, 10, 28–30], domestic versus foreign banks [31–34], performance before and after the economic crisis [11, 12], and mergers and acquisitions [15, 25, 35, 36]. Again, most studies have examined either banks' cost, profit, or revenue efficiency [9, 16, 37, 38] or their productivity [8, 30, 39, 40]. Only a few studies have applied multicriteria decision-making techniques along with DEA to predict Malaysian bank efficiency. Thus, there is a large gap in the application of network DEA to Malaysian bank efficiency to explore the internal structure of efficiency. Table 1 presents a list of recent publications and their major findings on bank efficiency in Malaysia.

3. Methodology

The production-possibility set of any DMU can be shown to be the following:

$$\left\{\left(X^k, Y^k, Z^{(k,h)}\right)\right\}$$

Subject to;

$$X^k \geq \sum_{j=1}^{n} X_j^k \lambda_j^k \,(k = 1, \ldots, K)\,,$$

$$Y^k \geq \sum_{j=1}^{n} Y_j^k \lambda_j^k \,(k = 1, \ldots, K)\,,$$

$$Z^{(k,h)} \geq \sum_{j=1}^{n} Z_j^{(k,h)} \lambda_j^k \,(\forall\,(k,h) = \textit{out puts from } k)\,, \tag{1}$$

$$Z^{(k,h)} \geq \sum_{j=1}^{n} Z_j^{(k,h)} \lambda_j^k \,(\forall\,(k,h) = \textit{in puts to } h)\,, \sum_{j=1}^{n} \lambda_j^k = 1\,(\forall k)\,, \lambda_j^k \geq 0\,(\forall j,k)$$

Equation 1 presents K divisions (that is, nodes) in the proposed network DEA model ($k = 1, \ldots, K$) by upgrading the earlier production set in Equation 1. Here, the number of DMUs is n ($j = 1, \ldots, n$), where m_k and r_k are, respectively, the numbers of inputs and outputs for any node k. The link between node k and node h is represented as (k, h), and L represents the set of links. So, the data set for the input set in node k is $\left\{X_j^k \in R_+^{m_k}\right\}(j = 1, \ldots, n; k = 1, \ldots, K)$, the output set from node k is $\left\{Y_j^k \in R_+^{r_k}\right\}(j = 1, \ldots, n; k = 1, \ldots, K)$, and the intermediate set for a link between node k and

node h is $\left\{Z_j^k \in R_+^{t_{(k,h)}}\right\}(j = 1, \ldots, n; (k, h) \in L)$, where $t_{(k,h)}$ is the number of items in the link. Finally, $\lambda^k \in R_+^{m_k}$ is the intensity vector, which corresponds to node $k\,(k = 1, \ldots, K)$. This indicates that this is a variable return to scale (VRS) model and suitable for explaining banking activities. The last constraint $\sum_{j=1}^{n} \lambda_j^k = 1\,(\forall k)$ is a VRS application.

Slack vectors $S^{K-}\left(S^{k+}\right)$ for input (output) within the DMUs can be represented by

$$x_0^k = \mathrm{X^k}\lambda^{\mathrm{k}} + S^{K-}\,(k = 1, \ldots, K), \tag{2}$$

$$y_0^k = \mathrm{Y^k}\lambda^{\mathrm{k}} - S^{K+}\,(k = 1, \ldots, K),$$

$$\lambda^{\mathrm{k}} = 1\,(k = 1, \ldots, K),$$

$$\lambda^{\mathrm{k}} \geq 0,\ S^{K-} \geq 0,\ S^{K+} \geq 0,\ (\forall k),$$

In Equation 2,

$$X^k = \left(X_1^k, \ldots, X_n^k\right) \in R^{m_k \times n}$$

and

$$Y^k = \left(Y_1^k, \ldots, Y_n^k\right) \in R^{r_k \times n}.$$

If the output-oriented efficiency is denoted as τ_0^*, the linear equation is

$$1/\tau_0^* = \max_{\lambda^{\mathrm{k}}, S^{K+}} \sum_{\mathrm{k}=1}^{\mathrm{K}} \mathrm{W^k}\left[1 + \frac{1}{\mathrm{r_k}}\left(\sum_{\mathrm{r}=1}^{\mathrm{r_k}} \frac{\mathrm{S_r^{k+}}}{\mathrm{Y_{r0}^k}}\right)\right] \tag{3}$$

subject to

$$x_0^k = \mathrm{X^k}\lambda^{\mathrm{k}} + S^{K-}\,(k = 1, \ldots, K),$$

$$y_0^k = \mathrm{Y^k}\lambda^{\mathrm{k}} - S^{K+}\,(k = 1, \ldots, K),$$

$$\lambda^{\mathrm{k}} = 1\,(k = 1, \ldots, K),$$

$$\lambda^{\mathrm{k}} \geq 0,\ S^{K-} \geq 0,\ S^{K+} \geq 0,\ (\forall k),$$

$Z^{(k,h)}\lambda^{\mathrm{h}} = Z^{(k,h)}\lambda^{\mathrm{k}},\ (\forall\,(\mathrm{k}, \mathrm{h}))$ if link between nodes are free, OR

$\mathrm{Z_0^{(k,h)}} = Z^{(k,h)}\lambda^{\mathrm{h}},\ (\forall\,(\mathrm{k}, \mathrm{h}))$ if link between nodes are fixed, where $\sum_{k=1}^{K} W^k = 1,\ W^k \geq 0\,(\forall k)$, and W^k is the relative weight of node k, which is determined corresponding to its importance. So, the overall efficiency score for an output-oriented production set (the banking sector in this case) is the weighted harmonic mean of an individual node's efficiency scores.

$$1/\tau_0^* = \sum_{k=1}^{K} \frac{W_k}{\tau_k} \tag{4}$$

For an optimal solution to Equation 4, the projection onto the frontier is

$$\begin{aligned} X_0^{k*} &\leftarrow X_0^k - S^{K-*}\,(k = 1, \ldots, K), \\ Y_0^{k*} &\leftarrow Y_0^k + S^{K+*}\,(k = 1, \ldots, K). \end{aligned} \tag{5}$$

For a free type link between the nodes, the projection is

$$Z_0^{(k,h)*} \leftarrow Z^{(k,h)}\lambda^{h*}\,(\forall\,(k, h)) \tag{6}$$

To define a reference set of any node k for the DMUs as

$$R_0^k = \left\{\mathrm{j}|\lambda_{\mathrm{j}}^{\mathrm{k}*} > 0\right\}(\mathrm{j} \in \{1, \ldots\ldots, \mathrm{n}\}) \tag{7}$$

4. Data, variables, and research model

Data are collected from the Thomson Reuters Eikon database and publicly available reports from 2009 to 2015. Earlier publications on bank efficiency reveal that the selection of variables for the three approaches included in this study (production, profitability, and intermediation) is very important [4]. We select variables for three approaches similar to [5]. Apart from this, we select variables in line with the CAMELS rating. CAMELS stands for capital adequacy (C), asset quality (A), management expertise (M), earnings strength (E), liquidity (L), and sensitivity to market risk (S). Applying these indicators helps managers and regulators to evaluate banks' overall performance [41]. Figure 1 depicts the yearly changes of the selected variables for this study. The left chart depicts the yearly changes of deposits and short-term funding, earning assets, liquid assets, loans, equity, and non-earning assets. The right one presents values for interest expenses, loan loss provisions, net income, and non-interest expenses. Figure 1 reveals that Malaysian banks have substantially improved in earning assets, deposits, loan approvals, and equity. Compared to total deposit growth, liquidity has not progressed that much, which proves managers are aggressively engaging in banking operations. Malaysian banks also have succeeded at reducing non-earning assets. However, in terms of net income and loan loss provisions, they were

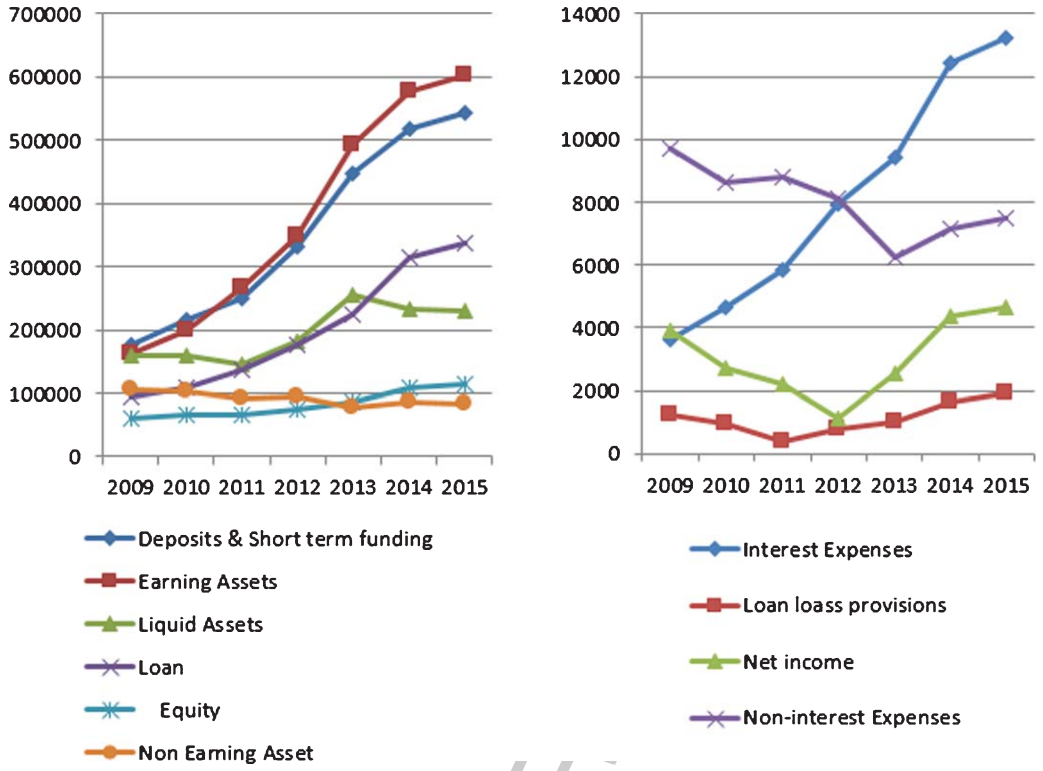

Fig. 1. Yearly changes in the variables (2009–15).

harmed by forced mergers and the global financial crisis in 2009–12 [11, 13, 14]. Figure 1 also shows that Malaysian banks successfully reduced non-interest expenses, which is linked to either forced merger or technical efficiency [16].

Figure 2 exhibits the model proposed by Azad and Kian-Teng [5] in a dynamic condition so that we can examine efficiency and productivity to estimate banks' yearly progress or regress. In the first node (production approach), a bank first concentrates on capital and deposits (total liability), which allows it to determine how much growth (loan creation) it can afford in long-term business (Node 1). From capital and deposits, theoretically, a bank produces earning assets, which in turn become loans (Node 2). In the final stage (Node 3), a bank creates net income from these loans. Along with desirable output, banks also produce undesirable output. We considered loan loss provision as undesired output. All these yearly activities (for example, $i = 1$) carry forward to the next year (for example, $i = 2$) and so on until year n. Thus, the proposed dynamic network model is expected to consider determinants of bank efficiency with a higher level of accuracy and significance.

5. Results and analysis

Major findings are described in this section. Bank efficiency defines banks' relative performance by keeping the best performer as the benchmark. Banks are compared with the benchmark to determine their relative score, which varies from 0 to 1. A score of 1 refers to the best performers within the sample; hence, banks with efficiency 1 are on the frontier. Performance of all other banks would be surpassed by those on the frontier. For our analysis, we first test bank efficiency of all forty-three commercial banks under study on a yearly basis from 2009 to 2015 (cf. Table 2). The results reveal that bank-efficiency scores have no unique pattern. Even with some ups and downs, eight banks are found to have no changes in their efficiency scores over this period. A list of the banks' names is provided in the appendix. Efficiency progress over the period is found for nineteen banks, and sixteen banks regressed during the period. One significant finding of Table 2 is that most of the banks' efficiency scores regressed during 2014 and 2015. This could be the result of a recent economic slowdown in Malaysia and partially because the exchange rate fell [34, 42]. However, no specific

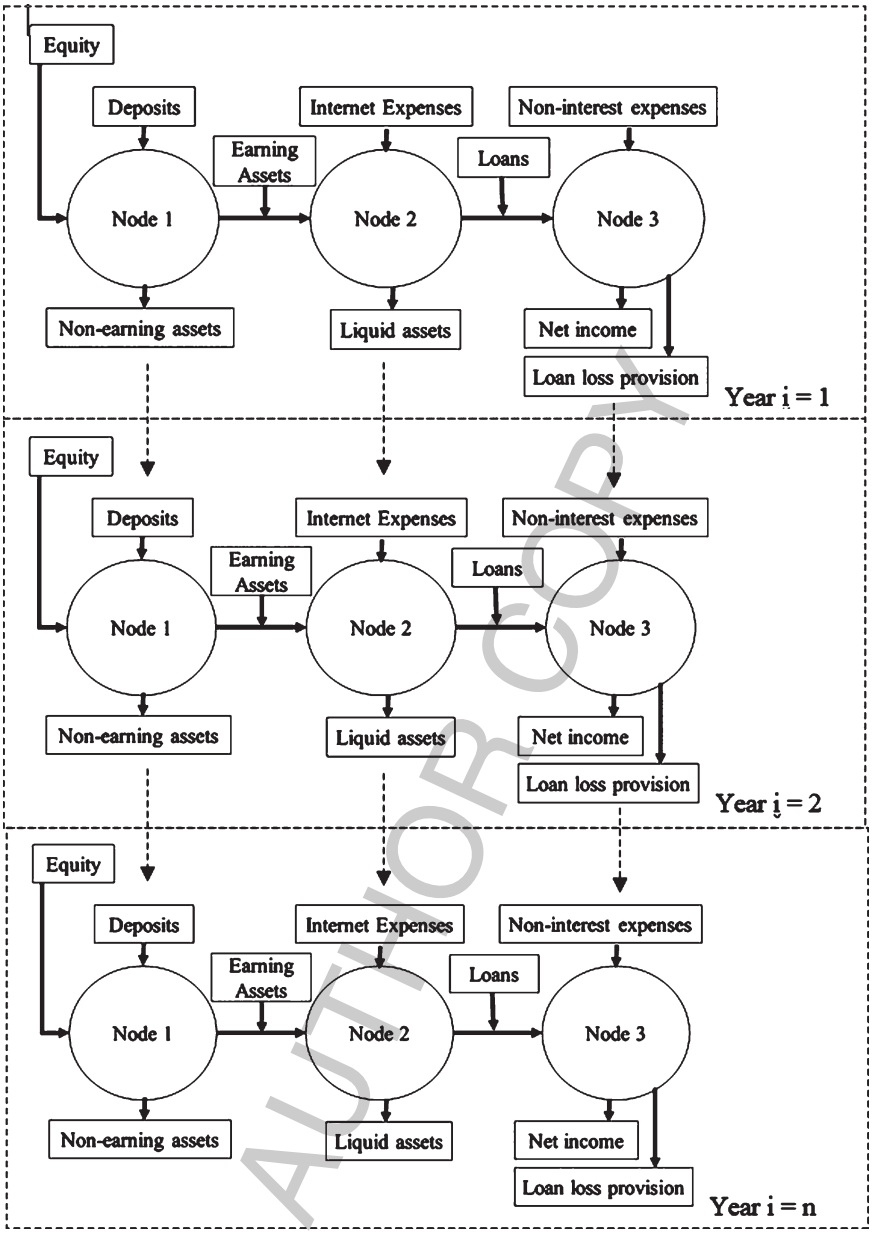

Fig. 2. Dynamic network DEA.

pattern is observed for public versus private, Islamic versus conventional, or local versus foreign banks.

Productivity is the efficiency of a DMU over time. It measures efficiency progress or regress over the years of performance. Table 3 shows the productivity scores of forty-three banks for all Node 1, Node 2, and Node 3 of the proposed model. Since productivity is the measure of changes in efficiency in DMU during two consecutive years, the productivity score can range from 0 to more than 1. Here, efficiency is calculated not only based on peer groups, but also based on peer groups from two consecutive years. The results reveal that although these banks have been operating in the same region, their efficiency varies. In the proposed network model, Node 1 explains a bank's capacity to convert its liabilities and owners' equity into earning assets. This proposed model drops non-earning assets in Node 1 since these assets will not help a bank anyway. Results from this table provide several critical points for discussion.

Table 2
Efficiency estimation of Malaysian banks (2010–15)

DMU	2009	2010	2011	2012	2013	2014	2015
FC1	0.18866	0.18308	0.11048	0.24921	0.48309	0.27242	0.12008
FC2	1.00000	0.12190	0.28047	0.55073	0.04458	0.30260	0.21679
FC3	0.16340	0.17662	0.04931	0.16088	0.06244	0.08806	0.08273
FC4	0.06720	0.05237	0.03177	0.11507	0.17038	0.16040	0.10087
FC5	1.00000	0.13572	0.08712	0.04769	0.05166	0.10804	0.10777
FC6	0.27895	0.28244	0.25314	0.26853	0.70775	0.72047	0.53933
FC7	0.24184	0.24123	0.23453	0.17510	0.20170	0.26644	0.25275
FC8	0.71482	0.81019	0.54933	0.40572	0.38214	0.25758	0.27826
FC9	0.79604	0.88861	0.34742	0.31010	0.24519	0.33916	0.33039
FC10	0.06843	0.07985	0.10114	0.07728	0.25126	0.22312	0.12168
FC11	0.03371	0.03608	0.21599	0.19506	0.24832	0.09595	0.07661
FC12	1.00000	0.74112	1.00000	0.59918	1.00000	1.00000	1.00000
FC13	1.00000	0.32471	1.00000	1.00000	1.00000	1.00000	1.00000
FC14	0.22531	0.21627	0.30561	1.00000	1.00000	0.13171	0.24682
FC15	0.89731	1.00000	0.06959	1.00000	0.74003	0.64958	0.60548
FC16	1.00000	0.15978	0.28577	0.47465	0.49343	0.42973	0.34536
FC17	0.22088	0.21492	0.24184	0.22731	0.37081	0.37805	0.23441
FC18	1.00000	0.35424	0.37039	0.42708	0.15557	0.22739	0.20096
FC19	0.10923	0.10280	0.05428	0.21875	0.27214	0.33904	0.12507
FI1	0.12707	0.11895	0.17004	0.54476	0.67905	0.25748	0.35205
FI2	1.00000	0.28870	0.31966	0.25858	0.26326	0.32965	0.13404
FI3	0.24696	0.25130	0.18258	0.13067	0.22139	0.10950	0.08111
FI4	0.33775	0.31304	0.34154	0.34248	0.43278	0.36357	0.21428
FI5	1.00000	0.48214	0.76958	1.00000	0.71091	0.71354	0.71274
FI6	0.87000	0.91521	0.82951	0.67323	0.54174	0.52958	0.49492
LC1	0.02877	0.01504	0.01756	0.08436	0.02932	0.27526	0.32428
LC2	0.27556	0.28631	0.26253	0.14527	0.30927	0.43657	0.30701
LC3	0.26502	0.25403	0.33516	0.33606	0.12247	0.26322	0.19810
LC4	0.20838	0.20857	0.22059	1.00000	0.15578	0.18587	0.17124
LC5	0.47915	0.48741	0.55998	0.32271	0.77654	0.19264	0.78389
LC6	1.00000	0.74772	0.74792	0.61660	0.05534	0.01963	0.08312
LC7	0.15279	0.14561	0.09019	0.00332	0.15290	0.17993	0.10148
LC8	0.17629	0.16225	0.17681	0.20755	0.36665	0.34823	0.28522
LI1	1.00000	0.41324	0.31419	0.68744	0.57583	0.55597	0.25191
LI2	0.35648	0.36355	0.31999	0.33453	0.49782	0.29584	0.18349
LI3	0.16428	0.15227	0.19321	0.26070	0.19599	0.28401	0.18242
LI4	0.17699	0.18329	0.23559	0.17510	0.17783	0.23104	0.16055
LI5	0.21865	0.21524	0.22996	0.20704	0.41979	0.37347	0.30847
LI6	0.23841	0.24474	0.47682	0.22929	0.33269	0.16639	0.20679
LI7	1.00000	0.79784	0.35212	0.64819	1.00000	0.03229	0.39156
LI8	0.03757	0.02371	0.10707	0.28985	0.49508	0.61622	0.52202
LI9	0.88849	1.00000	1.00000	0.71355	0.82689	1.00000	1.00000
LI10	0.28946	0.23112	0.27693	0.15219	0.35874	0.29317	0.24855

This result clearly signifies that for every year in the period of analysis, the Malaysian banking industry has had a few banks that perform at their optimal level and score in the top tier for unit efficiency. Figure 3 summarizes the earlier results from Table 3 to compare the performance at each Node.

Out of nineteen foreign conventional banks, only one bank, the Royal Bank of Scotland Berhad (FC18), has been optimal in converting its total source of funds into total earning assets. On average, foreign conventional banks scored unit efficient. Thus, high competition among the foreign conventional banks is expected. Particularly, Deutsche Bank Malaysia Berhad (FC7) consistently is very inefficient at converting capital into earning assets. This also means that most of its capital remains as non-earning assets. Interestingly, even though Deutsche Bank Malaysia Berhad (FC7) shows profit in almost every year, its very poor efficiency scores in all the estimated years signifies that compared to the best performers, such as the Royal Bank of Scotland Berhad (FC18), Deutsche Bank Malaysia Berhad (FC7) has the lowest capacity to convert capital into earning assets.

Of the six foreign Islamic banks, all have an annual average efficiency greater than 71%. The highest average yearly efficiency is recorded for OCBC Al-

Table 3
Efficiency estimation of Malaysian banks (2010–15)

	Node 1						Node 2						Node 3					
DMU/Year	2010	2011	2012	2013	2014	2015	2010	2011	2012	2013	2014	2015	2010	2011	2012	2013	2014	2015
FC1	0.92	0.62	0.85	1.47	0.93	1.37	1.00	0.41	0.64	1.82	0.78	0.87	0.54	1.19	0.97	0.47	1.22	0.83
FC2	1.00	1.00	0.96	2.100	1.07	0.90	1.00	0.72	1.00	0.52	1.12	0.51	1.00	0.97	1.21	2.72	0.93	0.59
FC3	2.50	0.95	1.16	1.02	1.00	0.79	1.20	1.02	1.42	1.13	1.00	0.91	1.47	0.74	1.10	1.17	1.00	1.00
FC4	1.00	1.26	0.97	0.95	1.08	1.22	1.00	1.72	1.04	1.03	1.34	1.22	1.00	2.03	0.96	0.10	7.42	0.23
FC5	1.00	0.99	1.01	0.95	1.10	1.00	1.00	0.72	1.00	0.52	1.12	1.12	1.00	0.97	1.21	2.72	0.93	0.20
FC6	0.89	0.96	0.11	1.37	1.00	1.00	0.45	0.73	1.40	0.89	1.00	1.00	0.60	0.89	0.94	1.00	1.00	1.00
FC7	0.93	1.00	0.96	2.10	1.07	1.65	0.94	1.00	1.89	0.72	1.32	5.31	0.43	1.00	2.97	2.39	1.88	5.65
FC8	0.92	0.83	0.60	0.92	0.58	0.87	0.86	0.77	1.08	0.70	0.91	0.97	0.76	1.20	1.06	0.94	1.04	0.98
FC9	0.97	0.99	0.62	1.10	1.12	0.62	1.12	1.12	0.40	1.29	0.96	1.74	1.00	0.95	0.32	1.00	1.49	1.57
FC10	0.97	0.99	1.01	0.95	1.00	1.00	0.72	1.00	0.52	1.12	1.00	1.00	0.97	1.21	2.716	0.93	1.00	1.00
FC11	1.00	2.32	0.87	1.10	1.10	0.55	1.00	2.03	2.67	2.01	1.72	1.26	1.00	0.68	0.59	13.50	2.02	0.77
FC12	0.78	0.61	6.58	0.97	3.91	0.97	0.98	1.28	1.26	1.24	1.00	0.66	1.11	1.64	0.94	1.64	1.39	0.79
FC13	0.97	1.00	0.08	4.89	1.00	1.10	0.36	1.00	4.41	1.32	1.00	1.17	0.67	1.00	0.95	1.79	1.00	1.01
FC14	1.00	1.01	1.00	0.98	1.00	1.16	1.00	1.17	0.85	0.70	1.00	1.06	1.00	0.95	0.89	1.19	1.00	0.92
FC15	0.97	0.99	1.01	0.95	1.00	0.96	0.97	0.86	0.99	0.59	1.00	0.92	0.81	1.07	0.80	0.99	1.01	0.84
FC16	0.97	1.00	0.08	0.98	1.00	1.10	1.00	0.52	0.85	0.70	1.12	0.72	0.95	1.00	2.97	2.39	1.88	1.00
FC17	0.37	0.90	0.08	4.89	1.00	2.71	0.95	1.53	0.99	0.59	1.00	0.04	0.49	0.84	1.00	0.95	1.00	0.72
FC18	1.00	1.03	0.62	1.11	0.80	1.31	1.00	1.13	0.62	1.75	0.93	1.20	1.00	0.51	0.82	0.20	1.00	0.86
FC19	0.90	0.43	0.61	0.90	0.95	1.00	0.40	0.49	2.28	0.59	1.08	1.00	0.77	1.07	1.02	0.99	1.01	1.00
FI1	1.01	1.03	1.00	1.03	0.97	1.02	1.26	1.20	0.29	1.11	1.12	0.88	0.14	3.32	0.22	1.72	1.41	0.64
FI2	1.11	0.83	0.84	0.66	1.22	2.27	0.73	0.70	0.69	0.55	0.89	0.71	0.38	1.00	1.56	1.43	1.14	0.75
FI3	0.97	1.02	0.31	3.80	1.00	1.07	0.63	0.93	1.97	0.15	1.00	0.68	0.85	1.13	1.03	0.97	1.00	0.93
FI4	0.99	0.96	1.02	1.00	0.92	0.98	0.91	0.63	3.19	0.55	0.74	0.90	1.00	0.63	1.61	0.93	1.10	0.96
FI5	1.01	1.03	1.71	1.01	0.97	1.02	1.00	0.52	27.32	0.93	0.57	0.72	1.10	0.99	1.31	0.80	1.15	1.61
FI6	1.11	0.96	1.00	1.01	0.95	0.81	2.23	0.31	1.06	0.46	0.91	0.27	0.72	0.86	0.91	0.31	2.63	1.06
LC1	0.96	0.99	1.01	0.85	0.98	0.91	0.39	0.88	2.53	0.33	0.50	0.45	0.13	1.40	1.49	0.40	1.00	0.37
LC2	0.93	1.00	1.01	1.00	1.02	0.92	0.86	1.00	0.81	0.92	0.91	0.87	0.27	1.00	3.98	0.50	1.24	0.74
LC3	1.00	0.96	0.99	1.01	1.01	1.03	0.91	0.79	2.39	1.29	0.80	0.91	0.82	0.97	1.21	2.72	0.93	0.77
LC4	0.98	1.02	1.00	0.94	0.99	0.95	0.54	1.68	0.53	0.64	0.93	1.54	4.74	0.49	0.99	0.94	1.00	0.74
LC5	1.00	0.97	0.95	0.96	0.72	0.78	1.00	0.66	0.65	1.02	0.81	0.70	1.00	0.91	0.75	0.76	5.88	0.22
LC6	0.86	0.38	0.20	4.88	0.81	0.79	0.91	0.95	1.55	1.50	0.97	0.31	1.07	1.64	1.01	1.03	1.09	0.54
LC7	1.47	0.88	0.77	1.15	1.60	2.07	0.91	0.78	1.13	1.04	0.85	1.86	1.10	0.99	0.99	1.21	1.15	1.61
LC8	1.08	1.02	0.90	1.01	0.99	1.23	1.24	1.09	0.22	1.22	0.72	0.81	0.80	0.84	0.85	1.04	1.06	0.74
LI1	0.84	0.77	0.98	0.93	0.72	1.08	0.63	0.53	1.57	0.62	0.23	0.84	0.65	1.33	0.13	1.13	0.88	0.20
LI2	0.87	0.96	0.95	1.30	1.19	0.87	0.72	0.67	0.59	1.62	1.19	0.64	0.59	0.58	0.81	0.96	1.05	0.76
LI3	0.97	1.01	0.97	1.01	1.10	1.31	0.78	1.00	0.57	1.10	1.32	0.66	0.97	0.94	0.94	1.01	1.00	0.87
LI4	1.00	0.91	1.00	1.00	1.00	0.86	1.00	0.52	1.86	0.66	0.76	0.72	1.00	1.60	0.63	2.30	1.07	1.15
LI5	0.96	1.00	0.97	0.95	1.02	0.97	0.60	1.00	0.80	0.22	1.15	0.92	15.40	1.00	0.99	2.67	0.49	0.50
LI6	0.98	0.99	1.01	0.82	1.11	0.82	0.97	0.46	0.58	0.30	0.77	0.46	1.00	0.62	0.79	0.81	0.94	0.93
LI7	0.79	0.83	0.78	0.80	0.95	0.54	0.43	0.34	0.42	0.43	0.73	0.60	0.42	0.89	0.90	0.78	1.00	0.34
LI8	0.72	0.98	0.29	1.40	0.77	1.57	0.46	0.62	0.88	0.90	0.80	0.50	0.46	1.11	0.97	0.95	1.17	0.34
LI9	0.76	1.00	0.55	1.26	0.66	0.92	0.85	1.00	2.81	0.86	0.57	0.93	1.78	1.00	2.08	1.01	0.65	1.02
LI10	1.00	1.06	0.67	0.94	1.00	0.92	1.00	7.70	0.21	0.83	1.00	1.12	1.00	1.68	0.14	11.25	1.00	0.20

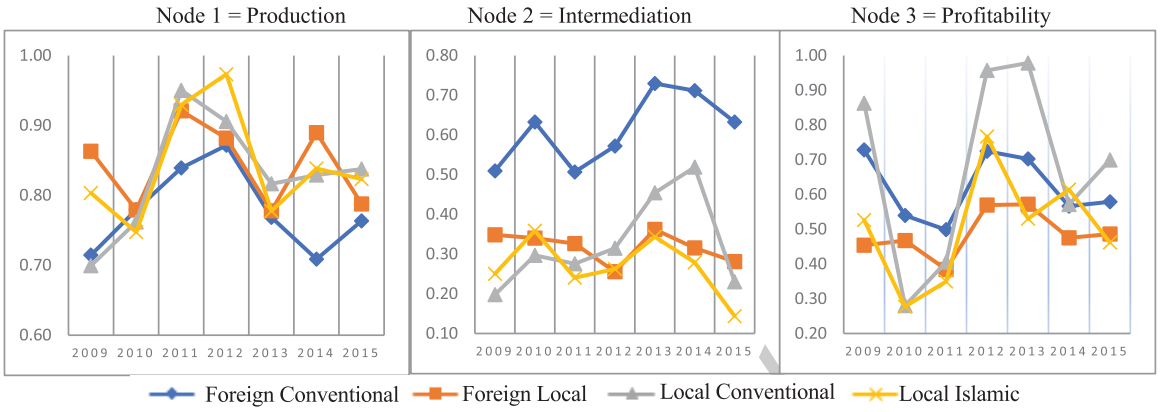

Fig. 3. Comparative node performance.

Amin Bank Berhad (FI5) with 99.6% and Standard Chartered Saadiq Berhad (FI6) with 96.3%. Of the six banks within this group, at least two banks were consistently found to be unit efficient in every year. This is a clear indication that it is possible for bank competition to exist in this group of banks. Also, there is an indication that Islamic foreign banks are more efficient than foreign conventional banks in the Malaysian context. Among the eighteen local banks (eight local conventional banks and ten local Islamic banks), only seven (three local conventional and four local Islamic) had high efficiency scores. No bank was found unit efficient throughout the study years. In both groups, the poorest performers recorded only 57% efficiency.

Table 3 also presents the efficiency scores from Node 2 of the proposed model. In this proposed model, banks are specifically assumed to create loans out of their earning assets (intermediate input) from Node 1. In addition, interest expenses are also included as input. Liquidity requirement is excluded from this node as expected output. Thus, examining Node 2 explains a fundamental job of a bank: how efficiently it can create loans from its earning assets with special attachment of interest expenses for financing the liability. Among the nineteen foreign conventional banks, two of them, Bank of China (Malaysia) Berhad (FC3) and Mizuho Bank (Malaysia) Berhad (FC12), were rated unit efficient during the period of analysis. On average, the best-performing (more than 90% efficiency) banks were Bank of America Malaysia Berhad (FC2), National Bank of Abu Dhabi Malaysia Berhad (FC13), and the Royal Bank of Scotland Berhad (FC18). Interestingly, seven banks out of the total nineteen banks scored below 50% efficiency during the period. The lowest efficiency score is recorded for J.P. Morgan Chase Bank Berhad (FC11) at only 12%. This means that banks are highly inefficient in Node 2 in converting the earning assets into loans and that foreign conventional banks have been keeping lots of liquid assets in their banks. Many variables can explain this loss of efficiency. It could be regulatory issues, management incapacity, lack of home-ground facilities, economic turmoil in the bank's home country, or other variables. In the case of foreign Islamic banks, out of six banks, only Asian Finance Bank Berhad (FI2) was found to be unit efficient throughout the years under study. Surprisingly, the remaining five banks' efficiency scores were lower than 20%. Among the foreign Islamic banks, OCBC Al-Amin Bank Berhad (FI5) is the least efficient bank (11%) in converting earning assets into loans compared to the unit-efficient bank (FI2). Overall, average efficiency of foreign Islamic banks is lower than that of foreign conventional banks.

The efficiency levels of eighteen local commercial banks for 2009 to 2015 in Node 2 are presented in Table 3. Most of the banks show a low efficiency (less than 40%). Among these banks, only two have scored more than 50%—namely Malayan Banking Berhad (LC6) and Affin Islamic Bank Berhad (LI1). The worst performers among the local banks are Asian Finance Bank Berhad (LI2) and Alliance Bank Malaysia Berhad (LC2) with only 6.9% and 9.4% efficiency scores, respectively. These low efficiencies among all type of banks confirm that banks are falling behind in converting earning assets into loans. The production capacity among the banks is somewhat low. This also signifies that compared to the most efficient banks (FC2, FC13, FC18, and FI2),

the remaining thirty-nine banks in Malaysia have less capacity to convert earning assets into loans and liquidity. This could also be because interest expense and liquidity of these banks are high.

Finally, Node 3 measures the bank loans to create profits. Findings show that among the eighteen local banks, only one bank is found to be unit efficient during the study period, namely Public Bank Berhad (LC7). The majority of the banks had efficiency scores between 40% and 80%. The least efficient performers among these banks are Affin Islamic Bank Berhad (LI1), with only 26.5% efficiency, and Bank Muamalat Malaysia Berhad (LI5), with an efficiency score of only 32.2%. These results also signify that only a few banks in Malaysia have been performing well in converting loans into profits and minimizing loan loss provisions.

Several issues can be highlighted in the comparison from Fig. 3. Average results are seen to be higher in Node 1 compared to Node 2 and Node 3 in all aspects of bank efficiency. Node 1 shows that on average, local conventional banks have performed better than foreign conventional banks. Similarly, local Islamic banks have higher performance on average compared to foreign Islamic banks. Initially, during 2009–10, all banks' average efficiency increased. When examining the average performance of selected groups of banks in the Malaysian context for Node 2, we see that the lowest average efficiency is recorded for foreign Islamic banks. Again, the highest average efficiency index is recorded for foreign conventional banks. Like the pattern in Node 1, all types of banks were least efficient in 2015, a year characterized by an economic slowdown in Malaysia [34, 42]. On average, only foreign conventional banks scored an efficiency level of 70% during 2013. Other than foreign conventional group, all groups' average efficiency is only observed between 20% and 40%. Nevertheless, this poor performance by all groups signifies that Malaysian banks, irrespective of their type, are less efficient in converting earning assets into loans.

Node 3 depicts many important issues. The ups and downs in the efficiency scores for local banks are extreme while the growth or decline of foreign banks' efficiency is a little smoother. This may reflect the direct effect of the master plan of the Malaysian government to force mergers and financial restructuring on local banks. In contrast, foreign banks' efficiency was moving upward or downward because of their operative performances and not because of external shocks. Another significant issue of Node 3 is the average scores among the groups. In 2013 the average efficiency of local conventional banks was found to be almost at 100%. This provides a clear indication of success in the financial master plan (financial restructuring and forced mergers and acquisitions) in the local Malaysian banking sector.

6. Conclusion

This study examines bank efficiency in Malaysia using a dynamic network DEA along with an analysis of undesired outputs. Major findings of this study reveal that the traditional application of DEA methods could not demonstrate the internal structure of calculation and reasonable impact of selection of variables. We used all the available bank-efficiency approaches (production, profitability, and intermediation) in one system to achieve the holistic result of bank efficiency based not only on each of the approaches but also on the total. Theoretically, this three-stage network DEA model gave us total efficiency scores and efficiency for each approach. Thus, a bank might have been efficient in its total score but its efficiency scores for the three different nodes might have differed. This will help managers and policy makers in developing strategies and targets to achieve efficiency in the future.

From the findings, we can derive direct policy implications. First, despite the significant improvements of financial markets in Malaysia with large processes of deregulation and participation of both local and foreign banks and intermediaries, we still observe large inefficiencies in the banking industry. This implies that a less efficient financial system hurts the economic development of the entire country by preventing economic agents from using credit expeditiously, for example. Regulation aiming to facilitate bank-level development and the enhancement of efficiency is clearly needed in Malaysia.

Additionally, lower levels of efficiency in financial intermediation mean necessarily higher prices for financial services. Consequently, firms and households are more likely to reject profitable investment projects because of greater financial costs, which burden their future economic growth. Resources, capabilities, and managerial know-how are bank-specific variables. Consequently, banks are called to adapt resources, structures, and processes to increase their efficiency.

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Appendix

Bank name	Short Name	Bank name	Short Name
Bangkok Bank Berhad	FC1	Al Rajhi Banking & Investment Corporation (Malaysia) Berhad	FI1
Bank of America Malaysia Berhad	FC2	Asian Finance Bank Berhad	FI2
Bank of China (Malaysia) Berhad	FC3	HSBC Amanah Malaysia Berhad	FI3
Bank of Tokyo-Mitsubishi UFJ (Malaysia) Berhad	FC4	Kuwait Finance House (Malaysia) Berhad	FI4
BNP Paribas Malaysia Berhad	FC5	OCBC Al-Amin Bank Berhad	FI5
Citibank Berhad	FC6	Standard Chartered Saadiq Berhad	FI6
Deutsche Bank (Malaysia) Berhad	FC7	Affin Bank Berhad	LC1
HSBC Bank Malaysia Berhad	FC8	Alliance Bank Malaysia Berhad	LC2
India International Bank (Malaysia) Berhad	FC9	AmBank (M) Berhad	LC3
Industrial and Commercial Bank of China (Malaysia) Berhad	FC10	CIMB Bank Berhad	LC4
J.P. Morgan Chase Bank Berhad	FC11	Hong Leong Bank Berhad	LC5
Mizuho Bank (Malaysia) Berhad	FC12	Malayan Banking Berhad	LC6
National Bank of Abu Dhabi Malaysia Berhad	FC13	Public Bank Berhad	LC7
OCBC Bank (Malaysia) Berhad	FC14	RHB Bank Berhad	LC8
Standard Chartered Bank Malaysia Berhad	FC15	Affin Islamic Bank Berhad	LI1
Sumitomo Mitsui Banking Corporation Malaysia Berhad	FC16	Alliance Islamic Bank Berhad	LI2
The Bank of Nova Scotia Berhad	FC17	AmIslamic Bank Berhad	LI3
The Royal Bank of Scotland Berhad	FC18	Bank Islam Malaysia Berhad	LI4
United Overseas Bank (Malaysia) Bhd.	FC19	Bank Muamalat Malaysia Berhad	LI5
		Public Islamic Bank Berhad	LI6
		CIMB Islamic Bank Berhad	LI7
		RHB Islamic Bank Berhad	LI8
		Hong Leong Islamic Bank Berhad	LI9
		Maybank Islamic Berhad	LI10