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The efficiency of Islamic Banks in the Southeast Asia (SEA) Region

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Abstract

The Islamic banking sector has become a crucial part of the global banking industry. Despite the Islamic banking industry's encouraging growth in the Southeast Asia (SEA) region, prior studies mostly focused on Islamic banks' efficiency in the individual country. To fill the literature gap, this study aims to measure the efficiency and productivity growth of Islamic banks in the SEA region. This study adopted the DEA technique and the Malmquist productivity index to evaluate 31 Islamic banks' performance in SEA from 2014 to 2019. The results evidenced an improvement in efficiency and progress in productivity for the banks in the region. The findings documented better efficiency and gradual progress in productivity for Islamic banks in Indonesia, consistent efficiency for Malaysia, a significant improvement for Brunei; hence, both Thailand and the Philippines Islamic bank depicted a drop-in efficiency for 2019. The findings trigger bank managers to acknowledge the inefficiencies and their sources. Investors and policymakers may find the findings useful in observing the banks' performance; thus, taking effective mechanism and policies to promote competent and sustainable SEA Islamic banks in the long run.

Keywords: Efficiency, Islamic banking efficiency, Total factor productivity (TFP), Islamic Banks' performance, DEA, The Malmquist productivity index, SEA Islamic banks

Introduction

The banking sector is one of the key players in the global financial sector; not leaving the Islamic banking behind which becomes a crucial part [76]. According to the Islamic Finance Development Report (2020), an increase of 14% in global Islamic finance assets was depicted, with a total amount of $2.88 trillion, while Southeast Asia (SEA) reached $685 billion in 2019 [35]. 69% of the total assets was constituted by Islamic banking ($2 trillion). Malaysia, Indonesia, and Brunei ranked 1st, 2nd, and 11th in the global Islamic finance, respectively, while the Philippines government has recently passed a new Islamic banking act in 2019 [35]. Islamic banking is a banking system based on *Shariah* principles [44, 59] and these principles include the prohibition of interest and the practice of profit and loss sharing (PLS) contracts [21, 43, 44, 59]. Nevertheless, the Islamic banks and conventional banks, being profit-oriented entities, share similar objectives to increase shareholders' wealth by maximising profit [56]. Hence, Islamic banks need to strive for efficiency to remain competitive in the market by efficiently utilising resources [40, 42].

Islamic banks evidenced the gradual growth globally after the 2008 financial crisis [35] and marked its presence in more than 75 countries [21, 40, 42]. With this rapid growth, Islamic banks have demonstrated their resilience over the years [40, 42]. Despite its impressive growth, IFSB [36] reported that global Islamic banks' performance was slightly weakened due to operational inefficiency caused by cash maintenance expenses, technology expenditures, and operating expenses (IFSB Report, 2019). Notwithstanding the slowdown in Islamic banking globally, the growth in Malaysia, Indonesia, and the GCC countries continues to keep its momentum (S&P, [65]). Based on the Global Financial Report, Islamic

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banking exhibited significant growth in 2019 compared to the earlier years [35].

Southeast Asia (SEA) acts as a central hub for Islamic banking and finance [49], especially Malaysia, Indonesia, and Brunei with a large Muslim population [40, 42]. In the last three decades, these countries' economic growth was greatly influenced by the role played by Islamic banks [40, 42]. The SEA region ranked third position in the total Islamic banking assets [35]. Besides, the ASEAN Economic Community formation initiated the unbendable competition in the financial sector, especially for the Islamic banking sector [4]. Certainly, efficient Islamic banks help in being competitive and resilient in the financial sector and can endure negative shocks [74]. Prior studies mostly focused on the efficiency of Islamic banks in the individual country of the SEA [40, 42, 68], while very few studies were done on the Islamic banks' efficiency in the region despite the significant growth of Islamic banking and finance in the region [40, 42]. This research gap motivates this current study to measure Islamic banks' efficiency and productivity growth in the SEA region. This study, therefore, aims to measure the efficiency and productivity growth of the SEA Islamic banks. This study contributes to the literature in two aspects; firstly, filling the research gaps on the efficiency of Islamic banks in the region; and second, enriching the literature on productivity change of SEA Islamic banks considering the limited studies in this aspect. Furthermore, it is imperative to have a clear understanding on Islamic banks' efficiency in SEA, considering the significant role of the banking system in the region. Thirdly, this study employed the Data Envelopment Analysis (DEA) techniques to distinguish the various levels of efficiency, for instance, technical, pure technical (operational) and scale efficiency, and Malmquist technique for productivity growth analysis. The variation in approaches is imperative to provide the detailed insight into the efficiency and productivity growth of Islamic banks.

Further, a systematic comparison of various types of efficiency for Islamic banks contributes to the banks' betterment in the future. The evaluation of Islamic banking efficiency will provide a better understanding to improve Islamic banks' performance in the SEA region [4]. More so, the underlying causes of inefficiency lead managers to improve banks' performances, thus encouraging best practices [18] and enabling them to align with a transition in the business environment. Accordingly, this study's findings will associate Islamic banks' strategic management decisions according to their efficiency level as well. Investors and stakeholders will better understand the current performance of Islamic banks in the region. Simultaneously, the policymakers may use the findings for their decisive planning to develop and enhance the SEA region's cooperation in the financial sector.

Literature review

Banking theories

Over the centuries, three common banking theories have been acknowledged [79], the credit creation theory, the financial reserve theory, and the intermediation theory. The credit creation theory explains the role of money creation during the accounting operations and loan disbursement; the financial reserve theory expounds that the creation of money can be done collectively by the banking system, where an individual bank functions as a financial intermediary by collecting deposits and loaning them out [80]. The financial intermediation theory treats banks as financial intermediaries both collectively and individually, interpreting them as indistinguishable from non-bank financial institutions in their nature, especially regarding the surplus and deficit businesses, in which the non-banks are incapable of forming money collectively or individually [63, 80, 63]. The theory stresses banks' role as a mediator between those who have savings and those who need credits. Accordingly, banks gather deposits and provide loans to investors. [63]. Among the three mentioned theories, the intermediation theory is the most popular one [63].

Banking efficiency

Banks' performance is commonly examined using the frontier efficiency that compares banks' efficiency, and the findings recognise the best practices among the banks based on the frontier efficiency analysis [18]. Henceforward, two main concepts; effectiveness and efficiency measure banks' productivity [67]. Effectiveness refers to the capability of setting, achieving goals and objectives by the bank, while efficiency is the ratio of output generated over input consumed [20]. Henceforth, efficiency denotes the dimension of relative performance for decision-making units (DMUs) [9]. According to the resource-based theory [19], proportionate profitability performance relates to efficiency variations [50]. Efficiency variances might ascend from changes in technology, practices, or the business model [39]. The concept of efficiency was first introduced by Farrell [28]. He proposed a few concepts, such as a single output from the two production factors, in complex cases, multiple outputs from multiple inputs. The bottom line is efficiency in utilising input to produce maximum output [75]. In general, the ratio of output to input outlines the efficiency; higher output per unit of input exhibits better efficiency, whereas optimum efficiency is reflected by maximum output per unit of input [67]. The measurement of efficiency leads to

maximising its output and profitability while minimising costs [52].

Extensive past studies have focused on measuring banking efficiency [39, 76]. Banking competition forces banks to operate efficiently, thus require effective strategies to survive in all situations [53, 75]. Regardless of the competition, efficiency can be altered due to technological innovation, institutional improvement, and financial inclusion [6, 78]. Moreover, banking inefficiency is not necessarily due to management's incapability, and it might also be caused by technical, socioeconomical, and managerial consequences [67]. Prior studies provide evidence on the significant and positive impact of banking efficiency on economic growth at the macro-level [2, 10, 16]. At the same time, bank managers and policymakers can utilise the benchmarking on efficiency to improve banks' performance at the micro-level [39, 76]. Accordingly, some past studies used the Malmquist Productivity Index (MPI) to quantify total factor productivity (TFP) changes in the banking sector. Berg et al. [15] studied deregulation of banks in Norway, Sathye [66] evaluated productivity changes for banks in Australia, Keskin Benli and Degirmen [14] measured the total productivity of Turkish banks. Hence, most previous studies evaluated the technical efficiency and TFP changes by applying DEA and MPI.

Efficiency and productivity of SEA Islamic banks

Islamic banks practice *shariah* principles in their banking operations, most commonly avoiding debt interest payment, short-selling, multifaceted derivative products, trading in alcohol and tobacco and gambling [39]. Islamic banks are significantly purported to be more profitable [32], share the same risk profile as conventional counterparts [3, 61], and depict higher technical efficiency [38]. However, Islamic banks are still subject to economics shocks, while the claim is more subdued [55].

Prior studies on banking efficiency devoted to comparing the efficiency of Islamic and conventional banks. Several studies exhibited no significant difference [33, 51], while some denoted higher efficiency for Islamic banks [54, 56] and others exhibited conventional banks having higher efficiency [1, 41]. Furthermore, limited studies are found in measuring SEA Islamic banks' efficiency (i.e., [4, 40, 42, 68]. Solihin et al. [68] exhibited lower efficiency for Indonesian Islamic banks, while Rodoni et al. [4] depicted stable efficiency and no significant differences among SEA Islamic banks. Also, Kamarudin et al. [40, 42] stated that the domestic Islamic banks depicted higher efficiency than foreign-owned Islamic banks in the SEA region. These inconsistent results are perhaps espoused from the studies' sample selection deficiencies [39]. More specifically, banks are assumed to face diverse economic situations in different countries over time.

Likewise, limited studies using the Malmquist Productivity Index (MPI) were found focusing on the SEA Islamic banks. Using MPI analysis, Kamarudin et al. [40, 42] evidenced the change of efficiency in total productivity during 2006–2014 in selected SEA Islamic banks. Meanwhile, Andriyani et al. [5] investigated the social funds' productivity of Indonesian Islamic banks. Based on the findings, Islamic banks' productivity of social funds elucidated progress from 2012 to 2018 was contributed by technological change and operational efficiency. Defung [24] applied the MPI to evaluate Indonesian banks' productivity growth between 1999 and 2011 and found the positive productivity changed at the end of the period. Hadad et al. [31] and Omar et al. [57] found that productivity growth was triggered by the technical change in Indonesian commercial banks.

Meanwhile, Basri et al. [12] explained the contribution of technological change on the increasing trend of total productivity change (2008–2015) of Malaysian Islamic banks. Despite this, the studies on the efficiency of Islamic banks in the SEA region and their productivity change are limited, and this creates the gap in the literature. Hence, this study intends to fill the gap by providing empirical evidence on Islamic banks' efficiency and productivity change in the SEA region.

Methods

Data

This study measures the technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) of SEA Islamic banks throughout 2014–2019. The Islamic banks' annual reports were the primary source of data collection. A total of 31 Islamic banks (14 Malaysian, 14 Indonesian, 1 Brunei, 1 Thailand, and 1 the Philippines) were included in the data analysis. The sample size was determined based on the availability of the Islamic banks' annual reports within the study period.

Data envelopment analysis (DEA)

Two types of techniques are used to measure efficiency, namely; the parametric and the nonparametric [7, 17]. The Efficiency frontier technique, namely DEA (nonparametric), is commonly used to evaluate banks' performance. In prior studies, DEA was documented to be popular for measuring banking efficiency [34, 40, 42, 68, 75]. Therefore, this study applied the DEA technique to measure TE, PTE, and SE for SEA Islamic banks. Technical efficiency (TE) refers to the extent of maximum output produced by a certain input level (Wan Ibrahim and Ismail 2020); thus providing overall technical efficiency. Pure technical efficiency (PTE) and scale efficiency (SE) both identify the technical

issues associated with the operational scale or the quantity and combination of input and output factors [46].

Wahyudi and Azizah [75] reported that Islamic banking in SEA is very competitive, thus examining the region's ranking is necessary. Followingly, the CCR output (CRS)-oriented model maximises output within specific inputs [62]. A set of *JDMUs*, and each *DMUj* generates n different outputs using m different inputs that are denoted as y_{rj} (outputs) and x_{ij} (inputs). The following linear programming of CCR output-oriented model computed the efficiency as exhibited in model A;

$$\begin{aligned}
&\text{Max} \sum_{r=1}^{n} u_{rj} y_{rj} \\
&\text{Such} \sum_{i=1}^{m} v_{ij} x_{ij} = 1; \\
&\sum_{r=1}^{n} u_{rj} y_{rj} - \sum_{i=1}^{m} v_{ij} x_{ij} \leq 0; \quad j = 1, 2, \ldots, J \\
&u_{rj} v_{ij} \geq 0; \quad r = 1, 2, \ldots, N; \quad i = 1, 2, \ldots, M \quad \text{(Model } A\text{)}
\end{aligned}$$

Weighted sum of output to weighted sum of inputs ratio is exhibited in Model A, with optimal values of the variables' weights u_r and v_i to be determined as a solution to the CCR model. In details, the linear programming algorithm finds the maximum ratio of the weighted sum of output to the weighted sum of input as the most efficient DMU by computing the efficiency of each DMU. It is applied as a scale against the other DMUs that leads to the best-practice DMUs to set on the efficient frontier line, which is reasonably efficient and 100% efficient (efficiency = 1) recognised by DEA. The above explanation is espoused among others by Cooper et al. [23], Galagedera and Silvapulle [29], Ji and Lee [37], Klimberg et al. [45], Ramanathan [62], Sherman and Zhu [67], and Yekta et al. [82]. Accordingly, the DEA measures bank efficiency for a set of DMUs by calculating each DMU's efficiency provided by indistinguishable inputs and outputs variables [58].

BCC (VRS) model was applied in this study to examine the PTE and SE to identify the elements that cause banking inefficiency [40, 42]. Banker, Charnes, and Cooper have extended the first CCR model in 1984 known as DEA-BCC [58]. BCC is quite similar to the CCR model, except it foils the equation to evaluate output shortfalls and input excesses [37]. Model B exhibits the BCC model:

$$\begin{aligned}
&\text{Max}_{u_r v_i} E_d = \frac{\sum_{r=1}^{n} u y_{dr} - u_0}{\sum_{i=1}^{m} v x_{di}} \\
&\text{Subject to,} \frac{\sum_{r=1}^{n} u_r y_{dr} - u_0}{\sum_{i=1}^{m} v x_{di}} \\
&\text{Is} < 1 \qquad \text{(Model } B\text{)}
\end{aligned}$$

where E_d = efficiency of $\overset{th}{d} DMU$; u_0 = scalar free sign or (positive or negative or 0).

Both DEA-CCR and DEA-BCC models were applied for this study to evaluate efficiency for SEA Islamic banks. DEAP 2.1 software was used to run the DEA analysis.

The Malmquist productivity index (MPI)

The MPI, introduced by Malmquist [48], evaluates total factor productivity (TFP) growth and is used in the current study to quantify the SEA Islamic banks' productivity growth. The MPI can be measured using several approaches, for example; DEA and translog index [25]. Besides, MPI is a technique which generally depends on DEA that evaluates the change in productivity over a fixed value either increase or decrease in between two periods [15]. Specifically, the DEA approach in evaluating TFP facilitates the correct explanation of productivity's [25]. TFP growth is a combination of technical efficiency and technical change [24, 25, 30]. Technical efficiency change explains the efficiency in determining the limitation of productivity and technological change shows the move of productivity limit [47]. The multiplication of technological change and technical efficiency change produces the total factor productivity index change [14]. Coelli [22] stated that an increase or decrease in productivity could be observed when the TFP exceeds one or less than one in TFP, respectively.

MPI is employed to achieve the current study's objective to determine the long-run sustainable efficiency growth of Islamic banks. So, the TFP change is measured for the banks and mean value is computed for banking groups from 2014 to 2019. Indeed, by analyzing the TFP growth, the banks' weaknesses and strengths can be identified, which are ultimately useful to propose the necessary actions and suggestions to improve productivity [25]. This study adopted an output-oriented approach which predicts maximum production of output with a specific amount of input. In contrast, input-oriented approach predicts the minimum amount of input used for the production given specific output [14].

An output-oriented Malmquist productivity change index designated as an approach of production detailed by Färe et al. [27], whereas input X_t produces output Y_t in the consecutive period t and $t+1$ as shown below:

$$P_t(X_t) = \langle Y_t : X_t \text{ may produce } Y_t \rangle$$

$$P_{t+1}(X_{t+1}) = \langle Y_{t+1} : X_{t+1} \text{ may produce } Y_{t+1} \rangle$$

The aloofness between outputs can be exhibited as:

$$\begin{aligned}
d_t(X_t, Y_t) &= \min \left\{ P\left(y_t \cdot^{\cdot} p\right) \in P_t(X_t) \right\} \\
&= [\max \{P : (PY_t) \in P_t(X_t)\}]^{-1}
\end{aligned}$$

The TFP displays the "changes and shifts" by decaying into technical efficiency and technical progress as follows:

$$\begin{aligned}\text{Total factor productivity change}\left(tfpch\right) &= M(X_t, Y_t, X_{t+1}, Y_{t+1}) \\ &= \left[\frac{d_t(X_{t+1}, Y_{t+1})}{d_t(X_t, Y_t)} * \frac{d_{t+1}(X_{t+1}, Y_{t+1})}{d_{t+1}(X_t, Y_t)}\right]^{1/2} \\ &= \frac{d_t + 1(X_{t+1}, Y_{t+1})}{d_t(X_t, Y_t)} * \left[\frac{d_t(X_{t+1}, Y_{t+1})}{d_{t+1}(X_{t+1}, Y_{t+1})} * \frac{d_t(X_t, Y_t)}{d_{t+1}(X_t, Y_t)}\right]^{\frac{1}{2}}\end{aligned} \tag{1}$$

$$\text{Technical efficiency change } \left(effch\right) = \frac{d_{t+1}(X_{t+1}, Y_{t+1})}{d_t(X_t, Y_t)} \tag{2}$$

$$\text{Technical change}(techch) = \left[\frac{d_t(X_{t+1}, Y_{t+1})}{d_{t+1}(X_{t+1}, Y_{t+1})} * \frac{d_t(X_t, Y_t)}{d_{t+1}(X_t, Y_t)}\right]^{1/2} \tag{3}$$

where TFP change (tfpch)=(effch)∗(techch); effch = pech (pure technical efficiency change) ∗ sech(scale efficiency change); X_t = input in the period t; X_{t+1} = input in the period $t+1$; Y_t = output in the period t; Y_{t+1} = output in the period $t+1$; d_t = output distance in the period t; d_{t+1} = output in the period $t+1$.

Selection of inputs and outputs

The most crucial part of the DEA method is identifying the appropriate approach to selecting the input and output variables [69, 70]. Prior studies widely applied the intermediation approach, where the type of banking activities is described as financial intermediaries [8, 40, 42]. Banks gather deposits and capital, which they transform into credits (finances) and other assets [8, 77]. The deposits with labor (salaries and wages) and capital included as inputs; simultaneously, the loan amount is used to calculate outputs [8]. Concerning the Islamic banks, financing with investment income and other income is measured as outputs [40, 42]. Figure 1 exhibits the flow of financial intermediation activities of Islamic banks.

It is important to include appropriate and more reliable variables for efficiency measurement. Based on the user-cost approach [11, 26], in banks; a negative user cost of money implies the increase in revenues, while a positive user cost of money advocates the asset or liability contributes to the operating cost [8]. Accordingly, this study chose inputs and outputs not only based on the literature review but also the availability and common variables for all banks in terms of productivity and business nature [73]. Further, a rule is required to be followed while selecting the number of inputs and outputs [23]. The rule represents the ɳ number of DMUs; ɱ inputs; and ʂ outputs; where $ɳ \geq \max\{ɱ \times ʂ, (ɱ + ʂ)\}$. Three inputs and three outputs; deposits ($X1$), collected from the surplus that moves to the economic unit to generate profit, labor (salaries and wages) ($X2$) expenses carried out by either assets or liability, total equity ($X3$); capital purchased from shareholders. On the other hand, output; total financing ($Y1$) converts deposits to

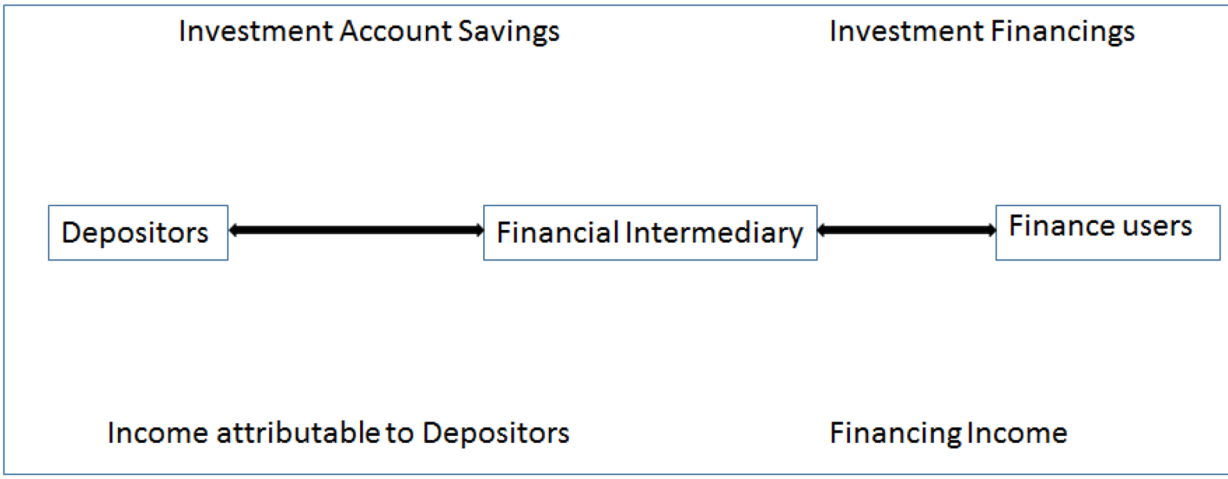

Figure 1 Financial intermediation for Islamic banks. Adopted from Batchelor [13]

financing to increase investment income (*Y*2) and other income (*Y*3). The summary statistics of input and output used for efficiency frontiers are provided in Table 1.

Results

Output-oriented DEA methodology is employed to measure bank efficiency. The score of technical efficiency, pure technical efficiency, and scale efficiency is yielded in DEA estimates. The average scores are exhibited in Table 2 ("Appendix 1" displays scores for individual banks) of the SEA countries. The table also displays scores for each year from 2014 to 2019. A value of 1 stipulates the bank is fully efficient; in other words, the bank had fully utilised the inputs to achieve desirable outputs. The results display a mixed result of technical efficiency (TE) for SEA Islamic banks throughout the study period. In other words, the average TE scores for SEA Islamic banks were volatile during 2014–2019. For instance, the TE score exhibited 0.79 in 2014, dropped to 0.656 in 2015, and again rose to 0.859 in 2016. Certainly, SEA Islamic banks depict better in scale efficiency than managerial efficiency (PTE) throughout the study period. Scale efficiency (SE) scores are higher than 90% during the study period, except for 2015 (0.829).

Table 1 Summary statistics of variables in local currency (in millions)

	*X*1	*X*2	*X*3	*Y*1	*Y*2	*Y*3
Country mean (2019)						
Malaysia	45,205	5047	131	43,786	2504	119
Indonesia	32,241,613	11,466,881	1,152,265	8,605,862	8,604,760	496,232
Brunei	8352	1163	37	3291	318	50
Thailand	79,265	18,951	1125	57,038	3205	683
Philippines	564,537	93,933	33,722	246,381	34,885	1689
2018						
Malaysia	41,376	4690	124	40,220	2710	75
Indonesia	31,630,065	10,923,202	1,061,955	7,308,973	4,602,659	418,424
Brunei	7512	1089	35	2974	305	46
Thailand	78,453	19,555	895	52,537	3260	81
Philippines	591,479	168,650	33,722	304,594	34,333	161
2017						
Malaysia	37,789	4337	81	38,877	2615	8
Indonesia	3,419,717	2,155,151	512,647	5,720,080	2,068,789	185,068
Brunei	7435	507	34	2639	253	114
Thailand	85,213	20,110	797	45,241	3107	60
Philippines	463,486	239,358	28,716	203,294	26,425	683
2016						
Malaysia	33,908	4010	74	35,653	2005	−7
Indonesia	2,478,514	1,830,221	388,969	5,273,280	1,197,639	272,861
Brunei	7115	725	32	2603	234	228
Thailand	93,498	17,198	811	91,901	3999	47
Philippines	304,622	298,727	25,288	182,618	13,710	2978
2015						
Malaysia	31,921	3076	76	32,641	1866	−3
Indonesia	3,075,538	1,605,985	384,754	5,204,679	1,260,353	235,569
Brunei	5243	725	30	2815	208	195
Thailand	99,530	13,772	805	94,013	4918	43
Philippines	402,290	350,233	23,942	189,158	13,474	31,070
2014						
Malaysia	30,233	2822	45	29,086	1532	4
Indonesia	2,745,560	1,350,816	368,174	4,645,990	1,190,926	199,572
Brunei	5405	725	29	2450	195	108
Thailand	111,772	8930	1118	112,017	5294	40
Philippines	294,071	373,772	23,666	185,503	18,657	29,475

*X*1 = deposits, *X*2 = equity, *X*3 = labor, *Y*1 = financing, *Y*2 = investment income, *Y*3 = other income

Among the SEA countries, Thailand Islamic bank shows the best performance throughout the period. The bank exhibits fully efficient in the year 2014, 2016, 2017, 2018, and 2019. Consistently, the Philippines Islamic bank depicts fully efficient throughout the period except 2017 and 2019 (0.400 and 0.273, respectively). Brunei's Islamic bank has shown the charismatic changes in efficiency in recent years (2018 and 2019), while it shows low scores at the beginning of the study period (i.e., 2014–2017). Indonesia, the biggest Muslim-populated country [81], presents unpredictable TE scores throughout the period. The inefficiency scores were higher than 20% from 2014 to 2018, while less than 20% in 2019. Finally, Malaysia, the country for successful inclusion of Islamic banking and finance, has displayed steady efficiency scores for Islamic banks during the study period with inefficiency scores close to 10% for most of the years.

VRS estimates indicate the sources of bank inefficiency. According to the empirical results, Malaysian banks exhibit larger scale efficiency (SE) scores than pure technical efficiency (PTE) throughout the study period. Indonesian banks depict mixed inefficiency during the period, for example, PTE is higher than SE in 2014, lower in 2015, higher in 2016 and 2017, lower in 2018 and then higher in 2019. Brunei Islamic bank shows significant improvement throughout the period where the SE is higher than PTE for almost the whole period except 2018. Thailand records lower SE in 2015 and 2019 while fully efficient during other years. Likewise, the Philippines' Islamic bank exhibits significantly lower SE than PTE score in 2019 (0.273), higher SE (0.912) in 2017, and fully efficient in the rest of the period. Finally, SEA Islamic banks exhibit better technical efficiency (TE = 0.787) and SE (0.897) overweighing PTE (0.856) for all years under study. Thailand Islamic bank captures the highest efficiency (0.941) while Brunei records the lowest (0.63) technical efficiency. Malaysian, Indonesian, and Brunei Islamic banks' SE outweigh PTE, while Thailand and Philippines record higher PTE.

The total factor productivity change (TFPCH) to the efficiency change (EFFCH) and the technological change (TECHCH) of SEA Islamic banks were calculated using MPI. The summary of changes in the TFPCH, EFFCH, TECHCH, PECH (Pure technical efficiency change), and SECH (Scale efficiency change) Islamic banks for the period 2013–2018 is represented in Table 3 (to see more refer to "Appendix 2"). Hence, the period 2014 is the reference period; therefore, 1 is the initial score for all components for 2014. As discussed earlier, any less than 1 is considered the decline in productivity, while a contrary is considered productivity growth.

Based on the MPI, SEA Islamic banks displayed a volatile total productivity change throughout the study period. The biggest change occurred during 2014–2015, while the lowest exhibited in 2015–2016. Hence, positive growth is

Table 2 Average efficiency (TE, PTE, SE) scores

Year	Score	SEA	Malaysia	Indonesia	Brunei	Thailand	Philippines
2014	TE	0.79	.848	.728	.403	1	1
	PTE	0.871	.879	.867	.545	1	1
	SE	0.894	.958	.827	.739	1	1
2015	TE	0.656	.752	.537	.383	.914	1
	PTE	0.748	.781	.688	.614	1	1
	SE	0.829	.936	.72	.624	.914	1
2016	TE	0.859	.924	.799	.517	1	1
	PTE	0.902	.926	.891	.522	1	1
	SE	0.929	.997	.847	.991	1	1
2017	TE	0.799	.885	.744	.562	1	.4
	PTE	0.878	.933	.866	.59	1	.439
	SE	0.887	.95	.81	.952	1	.912
2018	TE	0.799	.878	.683	.915	1	1
	PTE	0.848	.927	.737	1	1	1
	SE	0.913	.929	.885	.915	1	1
2019	TE	0.82	.839	.834	1	.729	.273
	PTE	0.89	.902	.855	1	.982	1
	SE	0.927	.933	.977	1	.743	.273
All years	TE	.787	.854	.721	.63	.941	.779
	PTE	.856	.891	.817	.712	.997	.907
	SE	.896	.95	.844	.87	.943	.864

posited among the SEA Islamic banks. Malaysian banks have exposed the highest TFPCH in 2014–2015 and 2018–2019 while performed poorly in other periods. Meanwhile, Indonesian banks posited a constant positive TFPCH throughout the study period with the highest change exhibited in 2014–2015. On the other hand, Brunei bank displayed positive TFPCH throughout the periods except 2015–2016 with a negative change. However, both Thailand and the Philippines exhibited a non-constant trend in TFPCH throughout the study periods.

The EFFCH and TECHCH influenced SEA banks' TFPCH in different periods. The TECHCH has shown higher than 1 for 2015 (128.37%) and 2017 (33.94%), while the EFFCH outperformed the TECHCH in 2016 (77.59%), 2018 (18.57%), and 2019 (40.34%). In a particular country, Malaysian banks dominated by technological change in 2015, 2016, and 2019 by 164.96%, 4.26%, and 38.24% consecutively, while led by efficiency change in 2018 (78.17%). However, a decline was reported in the year 2017 caused by TECHCH (52.17%).

Looking at Indonesian banks, except for 2015 (led by TECHCH with (114.16%), EFFCH dominated the TFPCH from 2016–2019. Hence, Brunei has shown the different trend; EFFCH dominated in 2016 (26.70%) and 2018 (62.17%), while EFFCH gained better in 2015, 2017, and 2019 by 39%, 33.8%, and 32.1%, respectively. Meanwhile, Thailand's positive productivity change was contributed by TECHCH in 2016, 2017, and 2019, while EFFCH caused the negative TFPCH in 2015 and TECHCH in 2018. Similarly, the mixed trend was predicted related to the Philippines. It shows TECHCH positively caused the TFFCH in 2015 and EFFCH in 2018. Hence, 2016, 2017, and 2019 exhibited the negative TFPCH caused by TECH, EFFCH, and EFFCH consecutively. Based on average TFPCH, the SEA Islamic banks evidenced an increase of 76.82% during the study period.

Table 3 Malmquist productivity index results for SEA Islamic banks

Bank	EFFCH	TECHCH	PECH	SECH	TFPCH
2014–2015					
SEA	1.4105	2.2837	1.1647	1.1527	3.4112
Malaysia	1.6314	2.6496	1.5614	0.9961	4.4454
Indonesia	1.2872	2.1416	0.7942	1.3592	2.8534
Brunei	0.9510	1.3900	1.1260	0.8450	1.3220
Thailand	0.9140	0.9970	1.0000	0.9140	0.9120
Philippines	1.0000	1.3300	1.0000	1.0000	1.3300
2015–2016					
SEA	1.7759	0.5964	1.2480	1.3589	1.0612
Malaysia	1.7817	0.4731	1.1611	1.4406	0.7876
Indonesia	1.9106	0.6764	1.3988	1.3124	1.3744
Brunei	1.2670	0.4660	0.8500	1.4900	0.5900
Thailand	1.0940	1.1770	1.0000	1.0940	1.2880
Philippines	1.0000	0.7510	1.0000	1.0000	0.7510
2016–2017					
SEA	1.2751	1.3394	1.0130	1.0852	1.7017
Malaysia	0.9997	1.0426	1.0398	0.9629	1.0698
Indonesia	1.6464	1.5804	1.0200	1.2348	2.4428
Brunei	1.0830	1.3380	1.1260	0.9620	1.4490
Thailand	1.0000	1.2400	1.0000	1.0000	1.2400
Philippines	0.4000	2.2210	0.4390	0.9120	0.8890
2017–2018					
SEA	1.1857	0.9564	1.0102	1.1479	1.1209
Malaysia	0.9916	0.8281	0.9918	0.9844	0.7826
Indonesia	1.2679	1.0972	0.8898	1.3391	1.3819
Brunei	1.6270	1.3110	1.6950	0.9600	2.1340
Thailand	1.0000	0.7630	1.0000	1.0000	0.7630
Philippines	2.4980	0.6190	2.2780	1.0960	1.5470
2018–2019					
SEA	1.4034	1.1457	1.1725	1.0907	1.5462
Malaysia	1.1501	1.3824	1.0204	1.0411	1.6731
Indonesia	1.8077	0.7991	1.3629	1.2234	1.5300
Brunei	1.0930	1.3210	1.0000	1.0930	1.4440
Thailand	0.7290	1.4220	0.9820	0.7430	1.0370
Philippines	0.2730	2.2330	1.0000	0.2730	0.6090

TFPCH = total factor productivity change, EFFCH = efficiency change, TECHCH = technological change, PECH = pure technical efficiency change, SECH = scale efficiency change

Discussion

The analysis of efficiency scores presents various positions of SEA Islamic banks in different countries. It is observed from the empirical results that SEA Islamic banks achieve moderate banking efficiency throughout the period except for a decline from 2014 to 2015. These findings are consistent with Kamarudin et al. [40, 42] who found the declining trend of efficiency at the end of their study period (2004–2014). However, the current study exhibits improvement in efficiency started from 2016 until the end of the period. These findings are also consistent with Rodoni et al. [4]. The findings from VRS suggest managerial incompetency, causing the inefficiency of SEA banks throughout the study period. Therefore, bank managers need to effectively focus on their operational activities by utilising resources to produce maximum output.

Among the SEA countries, Brunei shows a significant improvement in efficiency at the end of the study period. However, in the beginning, it shows lower than 50% efficiency scores which are in line with Kamarudin et al. [40, 42]. The findings suggest that Brunei Islamic bank had become stable in recent years, with significant technical efficiency improvement supported by managerial competency and optimal scale efficiency. On the other hand, Indonesian Islamic banks' average technical efficiency mostly exhibited lower efficiency than average SEA Islamic banks efficiency, in line with Solihin et al. [68]. However, they recorded higher than average SEA efficiency in the year 2019. Indeed, both

managerial competency and optimal usage of resources showed improvement. In other words, every different year exhibits improvement in management or optimal usage of resources. Hence, the banks showed the highest average optimal usage of resources in 2019. These findings acknowledge the improvement of Indonesian Islamic banks in both managerial and utilisation of resources.

Comparably, Malaysian Islamic banks depict better, stable, and higher-than-average SEA efficiency scores throughout the study period. These findings are consistent with the past studies of Hosen and Muhari [34], Rodoni et al. [64], and Syadullah [71]. Furthermore, the findings demonstrate better resource usage than managerial competency, although managerial competency has improved in recent years compared to the beginning of the study period. The Philippines Islamic bank records a significant drop in technical efficiency in 2017 and 2019, while it exhibits complete efficiency in all other years. Further, the dramatic drop in technical efficiency for 2017 is caused by managerial incompetency while inefficient scale efficiency led to the drop in 2019. These histrionic changes in bank efficiency are caused by lower economic growth, driven by a slow pace of investment growth in the global economy and public spending [72]. In these consequences, an Islamic bank is assumed to be weak in utilising its resources to produce the expected output. Thailand Islamic bank, the most efficient and consistent in performance, reports lower efficiency in 2015 and 2019. Even the inefficiency was not significant in 2015, like the Philippines Islamic bank, it has shown quite a huge drop in 2019 due to scale inefficiency. Panpiemras [60] reported that Thai banking performance is affected by the economic slowdown in 2019. Notwithstanding, both the Philippines and Thailand Islamic banking showed lower efficiency in 2019 than in the earlier years due to the respective countries' economic slowdown. The overall efficiency growth for the SEA Islamic banks exhibits improvement and higher efficiency during the study period.

Based on the MPI analysis, Indonesian Islamic banks are consistently showing productivity growth. This finding is in line with the recent Global Islamic Finance Report that showed the significant growth of Indonesian Islamic finance and ranked the top second overall (ICD-Refinitiv [35]. This finding is also consistent with Andriyani et al. [5], who expounded on Indonesian Islamic social funds' positive productivity change. However, they found the technological change as a contributing factor, while the current study found technical change contributes to the positive productivity change. Meanwhile, Malaysia has exhibited different total productivity change in different periods. Hence, the findings presented the positive productivity change influenced by technological change. In contrast, the decline in productivity change was caused by technical efficiency, supporting the previous study by Basri et al. [12].

Meanwhile, technological change contributed to Brunei's Islamic bank's productivity change almost the entire period, in which both progress and decline in productivity were caused by technological change. Regarding Thailand and the Philippines, efficiency change caused the total factor productivity change in most periods. On average, the SEA Islamic banks are moving forward with productivity progress that is constantly influenced by efficiency change throughout the period, supporting the earlier study conducted by Kamarudin et al. [40, 42]. According to their findings, the Southeast Asia Islamic banks exhibited productivity progress influenced by efficiency change. Further, the SEA Islamic banks showed a sharp increase in productivity progress influenced by efficiency change for the whole study period. Based on the efficiency and productivity change analysis, the SEA Islamic banks are experiencing a gradual improvement in efficiency; thus, productivity progresses.

Conclusions

This study contributes to the prevailing SEA Islamic banks literature with an inclusive measurement of efficiencies and total productivity change, employing the DEA method and the Malmquist productivity index. The results exhibited the SEA Islamic banks' efficiencies in several efficiency aspects (TE, PTE, SE) and total factor productivity (EFFCH, TECHCH, PECH, SECH). Despite the findings acknowledging the improvement of efficiencies and productivity index among Islamic banks in the SEA countries, various inefficiencies were still reported during the study period. In practice, these findings trigger the bank managers to acknowledge the inefficiencies and their sources. Also, investors and policymakers may find the findings useful in measuring the appropriate banks' performance; thus, taking effective mechanisms and policies to promote competent and sustainable SEA Islamic banks in the long run.

Finally, these findings may suggest banks improve their efficiency by utilising maximum inputs to produce better output levels. The banking sector should focus on management practices, product, and service innovations to improve efficiency and performance. The SEA policymakers may consider these findings as a benchmark for their efforts and success. They should enhance their monitoring and effort to keep Islamic banks' growth momentum in the upcoming periods.

However, this study has some limitations in terms of data availability, selection of variables, and the number of sample banks. Due to its limitations, this study could be extended in some ways. Further study on the SEA Islamic banks' progress and efficiency is recommended to include risk exposure determinants and be analyzed for overall performance and productivity. Future studies may also include the production and operating approach for efficiency and productivity change analysis and apply parametric and nonparametric methods for data analysis comparison.

Appendix 1: Efficiency Scores

Year	2014			2015			2016			2017			2018			2019		
Banks	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Alliance Islamic	0.635	1	0.635	0.209	0.21	0.998	1	1	1	1	1	1	0.225	0.468	0.482	1	1	1
AmBank Islamic	1	1	1	1	1	1	0.43	0.436	0.986	0.728	0.787	0.924	0.756	1	0.756	1	1	1
Bank Islam Malaysia	1	1	1	0.502	0.505	0.993	0.604	0.624	0.968	0.667	0.667	1	1	1	1	0.676	0.686	0.985
Bank Muamalat Malaysia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.979	1	0.979
CIMB Islamic Bank	0.99	1	0.99	0.57	0.601	0.948	1	1	1	0.929	0.929	1	1	1	1	1	1	1
HSBC Amanah Malaysia	0.152	0.154	0.991	0.952	1	0.952	1	1	1	0.823	1	0.823	0.968	1	0.968	0.302	0.99	0.305
Hong Leong Islamic	0.127	0.156	0.816	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kuwait Finance House (Malaysia)	1	1	1	0.152	0.333	0.455	1	1	1	1	1	1	0.593	0.617	0.961	0.852	0.857	0.994
MBSB Bank	0.974	1	0.974	1	1	1	0.901	0.903	0.998	0.762	0.769	0.991	0.749	0.886	0.845	0.613	0.758	0.809
Maybank Islamic	1	1	1	0.894	1	0.894	1	1	1	1	1	1	1	1	1	1	1	1
OCBC Al-Amin Bank	1	1	1	1	1	1	1	1	1	0.649	1	0.649	1	1	1	0.592	0.593	0.999
Public Islamic Bank	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RHB Islamic Bank	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.735	0.747	0.984
Standard Chartered Saadiq	1	1	1	0.25	0.291	0.859	1	1	1	0.827	0.91	0.909	1	1	1	1	1	1
PT. Bank Mega Syariah	0.981	1	0.981	0.174	0.415	0.419	0.552	0.697	0.792	0.65	1	0.65	1	1	1	0.062	0.062	0.999
PT. Bank Syariah Mandiri	1	1	1	0.829	1	0.829	1	1	1	1	1	1	1	1	1	1	1	1
PT. Bank BRISyariah	0.283	0.5	0.567	0.525	0.535	0.982	1	1	1	0.828	1	0.828	1	1	1	0.919	1	0.919
Btpn Syariah	0.68	1	0.68	0.69	1	0.69	1	1	1	0.214	0.693	0.308	0.187	0.573	0.327	1	1	1
PT. Bank Panin Dubai Syariah	1	1	1	1	1	1	1	1	1	0.787	1	0.787	0.409	0.447	0.916	0.632	0.636	0.994
PT. BCA Syariah	0.074	0.914	0.081	0.594	0.954	0.623	1	1	1	1	1	1	0.597	0.598	0.998	0.722	0.876	0.825
PT. Bank BNI Syariah	1	1	1	0.092	0.5	0.185	0.17	0.5	0.34	1	1	1	0.403	0.44	0.918	0.613	0.629	0.974

Year	2014			2015			2016			2017			2018			2019		
Banks	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
PT. Bank Syariah Bukopin	1	1	1	0.22	0.336	0.656	0.947	1	0.947	0.558	0.577	0.967	0.217	0.289	0.749	0.972	1	0.972
PT. Bank Muamalat Indonesia	0.292	0.36	0.811	0.284	0.304	0.934	1	1	1	0.334	0.489	0.683	1	1	1	1	1	1
PT. Bank Aceh Syariah	0.952	1	0.952	1	1	1	1	1	1	1	1	1	0.71	0.745	0.953	1	1	1
PT. BPD Nusa Tenggara Barat Syariah	0.869	1	0.869	0.234	0.558	0.42	0.12	0.582	0.206	1	1	1	0.827	0.857	0.965	1	1	1
PT. Bank Victoria Syariah	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PT. Bank Jabar Banten Syariah	0.447	0.482	0.928	0.071	0.186	0.385	0.393	0.694	0.566	0.044	0.367	0.119	0.205	0.365	0.56	0.761	0.765	0.995
pt Bank Net Indonesia Syariah	0.618	0.88	0.703	0.809	0.85	0.952	1	1	1	1	1	1	1	1	1	1	1	1
Bank Islam Brunei Daruusalam	0.403	0.545	0.739	0.383	0.614	0.624	0.517	0.522	0.991	0.562	0.59	0.952	0.915	1	0.915	1	1	1
Islamic Bank of Thailand	1	1	1	0.914	1	0.914	1	1	1	1	1	1	1	1	1	0.729	0.982	0.743
Al-Amanah Islamic Bank of Philippines	1	1	1	1	1	1	1	1	1	0.4	0.439	0.912	1	1	1	0.273	1	0.273

Appendix 2: Malmquist productivity index

Period	2014–2015					2015–2016					2016–2017					2017–2018					2018–2019				
Banks	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch
Alliance Islamic	0.33	6.84	0.21	1.57	2.26	1.00	0.98	1.00	1.00	0.98	1.00	0.00	1.00	1.00	0.00	0.24	0.86	0.47	0.51	0.21	4.36	1.59	2.10	2.08	6.91
AmBank Islamic	1.00	2.68	1.00	1.00	2.68	0.43	0.43	0.44	0.99	0.18	1.68	1.49	1.80	0.94	2.51	1.04	0.75	1.27	0.82	0.78	1.32	1.60	1.00	1.32	2.11
Bank Islam Malaysia	0.50	1.44	0.51	0.99	0.72	1.20	0.51	1.24	0.98	0.61	1.10	0.92	1.07	1.03	1.02	1.50	0.90	1.50	1.00	1.34	0.68	1.04	0.69	0.99	0.70
Bank Muamalat Malaysia	1.00	1.14	1.00	1.00	1.14	1.00	0.32	1.00	1.00	0.32	1.00	1.21	1.00	1.00	1.21	1.00	0.89	1.00	1.00	0.89	0.98	0.49	1.00	0.98	0.48
CIMB Islamic Bank	0.58	1.42	0.60	0.96	0.82	1.75	0.60	1.66	1.06	1.05	0.93	0.95	0.93	1.00	0.88	1.08	0.90	1.08	1.00	0.97	1.00	3.20	1.00	1.00	3.20
HSBC Amanah Malaysia	6.25	2.31	6.51	0.96	14.43	1.00	0.00	1.00	1.00	0.00	0.82	0.87	1.00	0.82	0.71	0.70	1.18	0.70	1.00	0.83	0.30	1.41	0.99	0.31	0.43
Hong Leong Islamic	7.86	3.99	6.41	1.23	31.36	1.00	0.33	1.00	1.00	0.33	1.00	1.28	1.00	1.00	1.28	1.00	0.94	1.00	1.00	0.94	1.00	0.95	1.00	1.00	0.95
Kuwait Finance House (Malaysia)	0.15	1.98	0.33	0.46	0.30	6.60	0.71	3.00	2.20	4.71	1.00	0.38	1.00	1.00	0.38	0.59	0.87	0.62	0.96	0.52	1.43	1.26	1.36	1.05	1.79
MBSB Bank	1.03	2.29	1.00	1.03	2.35	0.90	0.40	0.90	1.00	0.36	0.85	0.99	0.85	0.99	0.84	0.98	0.90	1.15	0.85	0.89	0.71	1.28	0.82	0.88	0.91
Maybank Islamic	0.89	0.89	1.00	0.89	0.80	1.12	1.13	1.00	1.12	1.26	1.00	1.57	1.00	1.00	1.57	1.00	0.58	1.00	1.00	0.58	1.00	2.53	1.00	1.00	2.53
OCBC Al-Amin Bank	1.00	0.00	1.00	1.00	0.00	5.94	0.00	1.02	5.84	0.00	0.79	1.05	1.00	0.79	0.82	1.54	0.00	1.00	1.54	0.00	0.59	0.80	0.59	1.00	0.47
Public Islamic Bank	1.00	1.64	1.00	1.00	1.64	1.00	0.59	1.00	1.00	0.59	1.00	1.68	1.00	1.00	1.68	1.00	0.87	1.00	1.00	0.87	1.00	0.82	1.00	1.00	0.82
RHB Islamic Bank	1.00	1.48	1.00	1.00	1.48	1.00	0.63	1.00	1.00	0.63	1.00	1.45	1.00	1.00	1.45	1.00	1.01	1.00	1.00	1.01	0.74	1.04	0.75	0.98	0.76
Standard Chartered Saadiq	0.25	9.00	0.29	0.86	2.25	1.00	0.00	1.00	1.00	0.00	0.83	0.77	0.91	0.91	0.64	1.21	0.95	1.10	1.10	1.14	1.00	1.36	1.00	1.00	1.36

Period	2014–2015					2015–2016					2016–2017					2017–2018					2018–2019				
Banks	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch	effch	techch	pech	sech	tfpch
PT. Bank Mega Syariah	0.18	2.52	0.42	0.43	0.45	2.82	0.41	1.54	1.83	1.16	1.18	1.70	1.44	0.82	2.00	1.54	0.68	1.00	1.54	1.04	0.06	1.07	0.06	1.00	0.07
PT. Bank Syariah Mandiri	0.83	1.28	1.00	0.83	1.06	1.21	0.70	1.00	1.21	0.85	1.00	1.11	1.00	1.00	1.11	1.00	3.51	1.00	1.00	3.51	1.00	0.17	1.00	1.00	0.17
PT. Bank BRISyariah	1.85	1.32	1.07	1.73	2.44	1.90	0.57	1.87	1.02	1.08	0.83	1.10	1.00	0.83	0.91	1.21	1.44	1.00	1.21	1.74	0.92	0.62	1.00	0.92	0.57
Btpn Syariah	1.02	2.24	1.00	1.02	2.27	1.45	1.02	1.00	1.45	1.48	0.21	0.79	0.69	0.31	0.17	0.88	1.04	0.83	1.06	0.91	5.34	0.96	1.75	3.06	5.10
PT. Bank Panin Dubai Syariah	1.00	3.86	1.00	1.00	3.86	1.00	0.19	1.00	1.00	0.19	0.79	1.08	1.00	0.79	0.85	0.52	0.92	0.45	1.17	0.48	1.52	1.15	1.39	1.10	1.75
PT. BCA Syariah	8.07	2.58	1.04	7.73	20.80	1.68	0.87	1.01	1.66	1.45	1.00	0.85	1.00	1.00	0.85	0.60	0.92	0.60	1.00	0.55	1.19	0.73	1.44	0.83	0.87
PT. Bank BNI Syariah	0.09	0.97	0.50	0.19	0.09	1.84	0.61	1.00	1.84	1.13	5.88	1.18	2.00	2.94	6.93	0.40	1.09	0.44	0.92	0.44	1.52	1.24	1.43	1.06	1.88
PT. Bank Syariah Bukopin	0.22	1.96	0.34	0.66	0.43	3.51	0.57	1.55	2.27	2.01	0.58	1.36	0.58	1.01	0.79	0.39	1.34	0.50	0.77	0.52	4.49	0.71	3.46	1.30	3.18
PT. Bank Muamalat Indonesia	0.97	1.32	0.85	1.15	1.28	3.52	0.60	3.29	1.07	2.10	0.33	1.22	0.49	0.68	0.41	2.99	1.09	2.04	1.46	3.27	1.00	0.60	1.00	1.00	0.60
PT. Bank Aceh Syariah	1.05	1.53	1.00	1.05	1.61	1.00	0.91	1.00	1.00	0.91	1.00	2.60	1.00	1.00	2.60	0.71	0.30	0.75	0.95	0.21	1.41	0.68	1.34	1.05	0.96
PT. BPD Nusa Tenggara Barat Syariah	0.27	4.72	0.56	0.48	1.27	0.15	1.00	0.58	0.25	0.15	8.20	1.39	1.72	4.77	11.40	0.83	0.61	0.86	0.97	0.50	1.21	1.65	1.17	1.04	1.99
PT. Bank Victoria Syariah	1.00	2.18	1.00	1.00	2.18	1.00	0.35	1.00	1.00	0.35	1.00	3.21	1.00	1.00	3.21	1.00	1.24	1.00	1.00	1.24	1.00	0.19	1.00	1.00	0.19
PT. Bank Jabar Banten Syariah	0.16	2.09	0.39	0.42	0.33	4.44	1.35	2.57	1.73	6.01	0.05	1.67	0.37	0.14	0.09	4.69	1.01	1.00	4.70	4.75	3.66	1.00	2.05	1.79	3.68
pt Bank Net Indonesia Syariah	1.31	1.44	0.97	1.35	1.88	1.24	0.30	1.18	1.05	0.37	1.00	2.88	1.00	1.00	2.88	1.00	0.18	1.00	1.00	0.18	1.00	0.43	1.00	1.00	0.43
Bank Islam Brunei Daruusalam	0.95	1.39	1.13	0.85	1.32	1.27	0.47	0.85	1.49	0.59	1.08	1.34	1.13	0.96	1.45	1.63	1.31	1.70	0.96	2.13	1.09	1.32	1.00	1.09	1.44
Islamic Bank of Thailand	1	1	1	0.914	1	1.09	1.18	1.00	1.09	1.29	1.00	1.24	1.00	1.00	1.24	1.00	0.76	1.00	1.00	0.76	0.73	1.42	0.98	0.74	1.04
Al-Amanah Islamic Bank of Philippines	1	1	1	1	1	1.00	0.75	1.00	1.00	0.75	0.40	2.22	0.44	0.91	0.89	2.50	0.62	2.28	1.10	1.55	0.27	2.23	1.00	0.27	0.61

Abbreviations
SEA: Southeast Asia; DEA: Data envelopment analysis; TFP: Total factor productivity; ICD: Islamic corporation for the development; PLS: Profit and loss sharing; IFSB: Islamic Financial Services Board; GCC: Gulf Cooperation Council; ASEAN: Association of Southeast Asian Nations; DMUs: Decision-Making Units; MPI: The Malmquist Productivity Index; TE: Technical efficiency; PTE: Pure technical efficiency; SE: Scale efficiency; CRS: Constant Return to Scale; VRS: Variable Return to Scale; TFPCH: Total factor productivity change; EFFCH: Technical efficiency change; TECHCH: Technical change; PECH: Pure technical efficiency change; SECH: Scale efficiency change.

Authors' contributions
HR conducted the data analysis and editing of the paper. CMAM prepared the manuscript by contributing literature, data collection, and discussion for this study. Both authors read and approved the final manuscript.

Availability of data and materials
The data collected from annual reports, which are saved on Microsoft excel, remain with authors. The data are available upon request.

Declarations

Competing interest
The authors declare that they have no conflict of interest.

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