

Evaluating Islamic Bank Efficiency and Productivity in ASEAN: Does Technological Advancement Play a Role?

Ririn Riani¹, Ihsanul Ikhwan², Aam Slamet Rusydiana³

¹Faculty of Islamic Economics and Business Management, Tazkia Institute, Jl. Ir. H. Djuanda No. 78 Sentul, Bogor, Indonesia, ririnriani@tazkia.ac.id*

²Kulliyah of Economics and Management Science, International Islamic University Malaysia (IIUM), Jl. Gombak, 53100 Kuala Lumpur, Selangor, Malaysia, ihsanulikhwan1997@gmail.com

³Department of Islamic Economics and Finance, Sakarya University, Üniversite Cd., 54050 Serdivan/Sakarya, Serdivan, Türkiye, aamrusydiana@sakarya.edu.tr

*) Corresponding author email

Abstract. Amid the economic crises triggered by the COVID-19 pandemic, sustainable financial systems have become essential for resilience and recovery, particularly in ASEAN countries where Islamic banks play a crucial role in economic stability. The purpose of this study is to evaluate the performances of the Islamic Bank in the ASEAN countries in terms of both efficiency and productivity. This study provides insights into 33 Islamic banks in Indonesia, Malaysia, Brunei Darussalam, Thailand, and the Philippines from 2015 to 2022. This study employs the Data Envelopment Analysis (DEA) technique and the Malmquist Productivity Index (MPI) to simultaneously attain elevated levels of efficiency and productivity. The result shows that Maybank Islamic Berhad was considered the most efficient and productive Islamic Bank within ASEAN countries. In terms of significant elements, it was discovered that shifts in technology capabilities have a greater magnitude of effect on Islamic banking productivity in ASEAN than shifts in innovation strategies and operational efficiencies. The findings also show that Islamic banks in ASEAN region experienced a growth in banking performance during the research period. This implies that the Islamic banking sector demonstrated enhanced performance despite the adverse effects of the COVID-19 pandemic. This study suggests that all ASEAN Islamic banks must continue to enhance the quality of their technology in order to raise their efficiency and generate more productivity in the future.

Key words: ASEAN, efficiency, Islamic bank, productivity, technological advancement.

Abstrak. Di tengah krisis ekonomi yang dipicu oleh pandemi COVID-19, sistem keuangan yang berkelanjutan menjadi sangat penting untuk ketahanan dan pemulihan, terutama di negara-negara ASEAN di mana bank-bank syariah memainkan peran penting dalam stabilitas ekonomi. Tujuan dari penelitian ini adalah untuk mengevaluasi kinerja bank syariah di negara-negara ASEAN dalam hal efisiensi dan produktivitas. Studi ini memberikan wawasan tentang 33 bank syariah di Indonesia, Malaysia, Brunei Darussalam, Thailand, dan Filipina dari tahun 2015 hingga 2022. Studi ini menggunakan teknik Data Envelopment Analysis (DEA) dan Malmquist Productivity Index (MPI) untuk secara simultan mencapai tingkat efisiensi dan produktivitas yang lebih tinggi. Hasilnya menunjukkan bahwa Maybank Islamic Berhad dianggap sebagai bank syariah yang paling efisien dan produktif di negara-negara ASEAN. Dalam hal elemen-elemen yang signifikan, ditemukan bahwa pergeseran dalam kemampuan teknologi memiliki pengaruh yang lebih besar terhadap produktivitas perbankan syariah di ASEAN dibandingkan dengan pergeseran dalam strategi inovasi dan efisiensi operasional. Temuan ini juga menunjukkan bahwa bank-bank syariah di kawasan ASEAN mengalami pertumbuhan kinerja perbankan selama periode penelitian. Hal ini mengimplikasikan bahwa sektor perbankan syariah menunjukkan peningkatan kinerja meskipun di tengah dampak buruk pandemi COVID-19. Studi ini menunjukkan bahwa semua bank syariah di ASEAN harus terus meningkatkan kualitas teknologi mereka untuk meningkatkan efisiensi dan menghasilkan lebih banyak produktivitas di masa depan.

Kata Kunci: ASEAN, bank syariah, efisiensi, kemajuan teknologi, produktivitas.

INTRODUCTION

Banks have a significant role in facilitating the circulation of funds to various economic sectors, particularly the real sector, through capital and productive financing (Mai et al., 2023). Banking is an invaluable instrument for integrating development and promoting economic prosperity; including Islamic banking with their shari'a instrument. According to the Refinitiv (2022), global Islamic finance assets increased by 14% to \$2.88 trillion, with Southeast Asia (SEA) reaching \$685 in 2021. Islamic banking accounted for 69% of total assets (\$2 trillion). Malaysia, Indonesia and Brunei were placed first, third and eleventh in the global Islamic finance rankings, respectively.

Southeast Asia (SEA) serves as a central hub for Islamic banking and finance, particularly in countries such as Malaysia, Indonesia and Brunei, which have a significant Muslim population (Kamarudin et al., 2017). The economic prosperity of these countries in the past thirty years was significantly affected by the critical part performed by Islamic banks (Alexakis et al., 2021). The Southeast Asia (SEA) region secured the third place in terms of the overall value of Islamic banking assets. In addition, the establishment of the ASEAN Economic Community has sparked intense competition in the financial sector, particularly in the realm of Islamic banking. Undoubtedly, the presence of efficient Islamic banks contributes to competitiveness and resilience in the financial system, enabling them to withstand adverse shocks.

The COVID-19 outbreak has exacerbated difficulties for numerous nations, including ASEAN nations. In times of economic uncertainty, competitive banks will aid developing nations and hasten economic recovery (Abdulahi et al., 2023). Therefore, bank efficiency and productivity will determine how sustainable its growth will be (Buchory and Java, 2017). The aspect of productivity evaluates the efficiency and capabilities of banks to make efficient use of a variety of resources, including inputs and outputs. An increase in productivity may result in an increase in profitability, or vice versa (Narwal and Pathneja, 2016). This is critical, especially for ASEAN countries that still rely on the performance of their banks to effectively route funds during the recent pandemic.

Extensive studies have been conducted over the past two years to investigate the efficiency of Islamic banks during the pandemic. These studies include the works of Grassa et al. (2022), Mirzaei et al. (2022), El-Chaarani et al. (2022), Sunarsih et al. (2022), Mansour et al. (2021), Lantara (2022), Ghouse et al. (2022), El-Chaarani (2023), Abdo (2023), and Yudaruddin (2023). Similarly, there exists a body of literature that examines the impact of the COVID-19 pandemic on the efficiency of Islamic banks. This literature includes studies conducted by Boubaker et al. (2022), Mateev et al. (2022), Mai et al. (2023), Ikhwan and Riani (2023) and Ünlü et al. (2022).

Research on productivity in the Islamic banking sector remains limited, particularly in exploring how technical change impacts overall productivity. Technological advancements, like automation and digital banking solutions, drive productivity by optimizing resource use, streamlining operations, and improving transaction speed. These shifts enable banks to manage costs more effectively, enhance service quality, and ultimately adapt to evolving economic demands, marking a crucial area for further study on efficiency improvements within the sector.

Productivity plays a crucial role in economic progress and competitive advantage, often driven by technological advancements. Solow (1957) argued that productivity growth stems from technical change, reflecting a country's degree of technological progress. In alignment, Otaviya and Rani (2020) emphasized that a company's success depends on the effective use of accessible resources, potentially integrating a broader range of subsystems. As such, productivity becomes essential for economic progress and gaining a competitive edge (Rani et al., 2017).

The objective of this study is to provide insights into the efficiency and productivity of Islamic banking throughout the ASEAN region. Additionally, we emphasize their differences and analyze the potential origins of inefficiency. Furthermore, the second stage involves identifying key factors that

may impact the level of efficiency. In this study, a set of prospective characteristics are selected to examine the determinants of efficiency of Islamic banks in ASEAN using Tobit regression analysis.

The remaining sections are organized as follows. Section 2 examines the relevant literature and prior research. The section 3 explains the pertinent methodologies. The section 4 presents the reports and discusses the empirical results. Section 5 concludes the investigation and suggests future research directions.

LITERATURE REVIEW

The efficiency and productivity of financial institutions have garnered much attention, and Islamic banking is certainly no exception. As a result of its resiliency during the global financial crisis, Islamic banks have gained prominence (Otaviya and Rani, 2020). Islamic banking is distinct from conventional banking in that it prohibits usury (interest) and gharar (uncertainty) and emphasizes justice and transparency (Guizaini and Ajmi, 2021).

In addition to intermediation services, Islamic banking offers fee-based services and Shariah-compliant products, such as profit-sharing finance, and aims to promote economic growth and stability (Rusydiana and Assalafiyah, 2021). The financial sector makes important contributions to the expansion of the economy in a number of different ways, including the effective distribution of capital, the regulation of financial institutions and the activity of good corporate governance, the diversification of risks, the maximization of savings, the facilitation of the trade of goods and services, and the dissemination of advanced technologies (Achi, 2021).

There are currently around 526 Islamic banks in various countries. These banks are projected to expand further in their operating areas to meet present and future Muslim demands (Basri et al., 2018). Islamic banking has advanced significantly in several Muslim-majority nations, notably Indonesia, Malaysia and Brunei Darussalam (Rani and Kassim, 2020). It is anticipated that the Islamic financial industry in Asia, particularly in ASEAN, will experience substantial expansion in the near future (Rani and Kassim, 2020). Concurrently, it is estimated that there will be a growth in the competitiveness of the banking industry. This indicates that Islamic banks need to improve their efficiency to compete in a market that is becoming increasingly competitive.

Each ASEAN member country has developed Islamic banking in its own distinctive way, but the industry has exploded in recent years, propelling Southeast Asia to the forefront of global Islamic finance. The Islamic banking sector in Malaysia is expanding at a greater pace than any other ASEAN country (Refinitiv, 2022). Although it is progressing more gradually than Malaysia, Islamic banking is being aggressively promoted in Indonesia (Usman et al., 2019). In addition to these two countries, Brunei Darussalam is quickly developing its own Islamic financial system. Both Thailand and the Philippines are keen on developing the region.

The scenario involving the COVID-19 outbreak has had a major impact on all aspects of the sector, which has led to a fall in sales and concerns with cash flow (Alabbad and Schertler, 2022). In conclusion, COVID-19 has altered the banking behavior preferences of financial institutions, which will result in a lower demand for bank loans. This is because financial institutions will be more wary of defaults or substandard loans, both of which can make an already difficult situation even worse. The rapid rise of Islamic banks even during the most recent global financial crisis has attracted the attention of a large number of academics, who apply a wide range of bank performance metrics in their research (Farandy et al., 2017; Isik and Uygur, 2021; Loong et al., 2017).

The importance of Islamic banks in the global banking sector is becoming increasingly apparent, especially in the context of the global economic recovery post-COVID-19, due to the expansion of the Islamic banking industry (Boubaker et al., 2022). According to Miah et al. (2021), the primary focus

of Islamic banks in Bangladesh during the year 2020 was the provision of financing for commerce and trade investment, both of which were significantly impacted by the COVID-19 pandemic.

Hassan et al. (2021) found a comparable condition in the MENA region, which includes the Middle East and parts of North Africa. They claim that COVID-19 has made things even worse for Islamic financial institutions in the region, who were already struggling due to low oil prices. It has been found by other researchers, like Beck et al. (2013) and Farooq and Zaheer (2015), they found that Islamic banks are better able to weather economic downturns like the AFC and GFC than LS. It may also be stated that investment banks are expected to rebound sooner than commercial banks.

According to Elnahass et al. (2021), Rehman et al. (2021), and Demirgüç-Kunt et al. (2021), they have all asserted that Islamic banks are less susceptible to the pandemic and as a result are in a better position to respond to the COVID-19 situation than conventional banks. Boubaker et al. (2022) suggest that the performance of Islamic banking has shown improvement despite the adverse effects of the COVID-19 pandemic.

Several studies have been conducted, the majority of which concentrate on just one nation, to assess the efficiency and productivity of Islamic banking (Abdul-Majid et al., 2011; Aisyah and Hosen, 2018; Otaviya and Rani, 2020; Omar et al., 2007; Usman et al., 2019), while others look at the subject from a larger perspective and across countries (Rodoni et al., 2017). Furthermore, previous study attempts to compare Islamic banking to conventional banking (Alexakis et al., 2018). Meanwhile, research related to the efficiency of Islamic banking in several countries has been carried out with various conclusions, especially when comparing the performance of the two types of banks (Al-Khasawneh et al., 2012; Johnes et al., 2014; Li et al., 2021; Loong et al., 2017; Nailah and Rusydiana, 2020; Rani and Kassim, 2020; Rodoni et al., 2017).

Over the last two decades, there has been an increasing interest among academics in the research of productivity change and its origins in financial intermediaries, which has led to the production of a large body of work that covers a wide range of topics related to the topic. The growth in productivity over the course of the time is measured in this article. Productivity growth is defined as the change in production that is primarily caused by changes in technical efficiency and technical change (Farrell, 1957). It does so by employing the Malmquist index approach, which is DEA-based (Grifell-Tatjé and Lovell, 1997) in order to quantify changes in both technological change and changes in efficiency.

Since Islamic banking has its role in society, the study of Islamic banking ought to be incorporated into banking studies. In this study, we try to analyze the productivity and efficiency of banks during both the time before and during the COVID-19. The analysis that was employed in this research was innovative in the sense that it focused its empirical investigation on nations in the ASEAN region that use dual banking systems. We make the assumption that there is a level of competition within the Islamic banking sector, and then we use the Malmquist Productivity Index (MPI) to calculate and directly compare the levels of productivity and efficiency of 33 Islamic banks across the countries of Indonesia, Malaysia, Brunei Darussalam, Thailand, and the Philippines during the period of 2015-2022.

METHOD

This study evaluates the performance of Islamic banks operating in five ASEAN countries—Indonesia, Malaysia, Brunei Darussalam, Thailand, and the Philippines—between 2015 and 2022. The selection of these countries in this study is based on their unique Islamic finance landscapes and data availability. Indonesia and Malaysia are key players in global Islamic finance with well-established systems, Brunei has a Sharia-based banking framework as part of its national vision, while Thailand and the Philippines are emerging markets with significant Muslim populations, expanding access to Islamic financial services.

Other ASEAN countries were excluded due to limited data access and less developed Islamic finance sectors. Bank annual reports, gathered from their respective websites, were aggregated and converted into US dollars for consistency. A total of 33 Islamic financial institutions were selected, ensuring complete data over the eight-year period. The period from 2020 to 2022 served as a benchmark to assess the impact of COVID-19 on banking efficiency.

In this analysis, total financing and operating revenues were employed as the output variable, while fixed asset value, labor cost, and external funding were the input variables. The input-output variables selection were referring to Sufian and Kamarudin (2015), Rusydia and Marlina (2019), and Ikhwan and Riani (2023). Intermediation approach efficiency and productivity used in this study considering Islamic bank as the intermediary institutions. According to Ascarya et al. (2008), the intermediation model is more appropriate for Islamic banking than the production and modern approaches since it considers banks as intermediary entities. This concept describes banking's activity as a mediator in converting money from a third party into money lent to borrowers (Ascarya et al., 2008).

The kind of research employed in the study was referred to as a quantitative approach, which is a methodology undertaking research that employs many sorts of statistical analysis in measuring data. DEA was utilized initially in order to determine how efficient Islamic financial institutions were. Following the estimates findings from DEA, MPI was developed to estimate TFPCH or productivity changes in the case study of Islamic banks in ASEAN, these dates range from 2015 to 2022. In the second stage, Tobit Regression is applied to identify the factors influencing efficiency. This step allows for investigating the potential impact of external shocks, such as the COVID-19 pandemic, along with other relevant determinants on the efficiency of the ASEAN Islamic banking industry. This two-stage approach provides both a foundational efficiency measurement and an in-depth exploration of factors affecting efficiency in response to external and internal influences.

Data Envelopment Analysis (DEA)

The Data Envelopment Analysis (DEA) was first introduced by Charnes et al. (1978) and subsequently extended by Banker, Charnes and Cooper (1984) to assess the efficiency of Decision-Making Units (DMUs). The measurement of efficiency is a common topic in the academic literature, with Data Envelopment Analysis (DEA) being a widely utilized tool for assessing both the allocative and technical efficiency of diverse institutions, including financial institutions (Sharma et al., 2013).

The Data Envelopment Analysis (DEA) methodology can be utilized to provide insights into the performance of DMUs, specifically ASEAN Islamic Banks in the context of this study. It enables the identification of DMUs that do not effectively utilize inputs and facilitates the examination of factors that contribute to inefficiencies, including both input and output variables. In summary, this methodology has the capacity to furnish data pertaining to the requisite adjustments in input and output quantities for attaining the utmost relative efficiency measure. Wu et al. (2006) assert that the use of Data Envelopment Analysis (DEA) is a common practice among researchers in their scholarly endeavors. This method allows for the generation of efficiency scores that consider both input and output factors (Yildirim, 2015).

The Data Envelopment Analysis (DEA) is a statistical technique that is both nonparametric and stochastic in nature. It is used to assess the performance of Decision Making Units (DMUs) in terms of their efficiency, in comparison to other DMUs that are similar. In this analysis, all the DMUs are positioned either on or below the efficiency frontier. The absence of assumptions regarding the production function is a result of the nonparametric nature of DEA. Furthermore, DEA formulates the production function by utilizing the observed data and employing techniques to minimize potential misspecification. The potential improvement analysis can be employed to assess how an inefficient DMU can enhance its performance and transition towards efficiency. Mathematically, the DEA model can be represented as:

$$Efficiency\ of\ DMU_0 = \frac{\sum_{k=1}^p v_k y_{k0}}{\sum_{j=1}^m u_j x_{j0}} \tag{1}$$

Whereby, p = different outputs, m = different inputs, y_{k0} = amount of output k produced by DMU_0 and x_{j0} = amount of output j consumed by DMU_0 .

$$L(y) = \{x \mid (x, y) \in \Omega\} \text{ or } L(y) = \{x \mid y \in P(x)\} \tag{2}$$

$$P(x) = \{y \mid (x, y) \in \Omega\} \text{ or } P(x) = \{y \mid x \in P(y)\} \tag{3}$$

Suppose that n firm producing s outputs $(Y_i, i = 1, 2, \dots, s)$ with m inputs $(X_i, i = 1, 2, \dots, m)$. The shadow output and input prices are $(\mu_r, r = 1, 2, \dots, s)$ and $(v_i, i = 1, 2, \dots, m)$. So for the unit K , they use the input bundle $Xk = (Xk_1, Xk_2, \dots, Xk_m)$ to produce $Yk = (Yk_1, Yk_2, \dots, Yk_s)$. The linear “fractional” programming problems are set up as:

$$\max AP_k = \frac{\mu Y_k}{v Y_k} = \frac{\sum_{i=1}^s \mu_{rk} Y_{rk}}{\sum_{i=1}^m v_{ik} X_{ik}} \tag{4}$$

However, the maximum value is achieved under the condition of two constraints. One important requirement is that the shadow pricing must be greater than or equal to zero. Furthermore, it is important to note that no unit possesses an input or output bundle that results in an overall average productivity exceeding 1. In mathematical terms, it can be represented as:

$$AP_j = \frac{\sum_{i=1}^s \mu_{rk} Y_{rk}}{\sum_{i=1}^m v_{ik} X_{ik}} \leq 1, \text{ where } \mu_{rk} \geq 0 \tag{5}$$

There exist multiple sets of shadow prices that fulfill these conditions; however, the software MaxDEA 8 can be employed to identify the specific set that maximizes AP_k . In order to guarantee a solution, the software typically simplifies this problem by applying a scaling factor, denoted as λ , to each shadow price. This approach facilitates the search for solutions.

Malmquist Productivity Index

The Malmquist Index has become the method of choice for estimating production levels, particularly when working with nonparametric specifications on microdata. This index was initially presented by Caves et al. (1982). In addition to the model of the first generation, which was established by Caves et al. (1982), there are two models of the Malmquist Productivity Index (Bjurek, 1996). "Malmquist input quantity index" and "Malmquist output quantity index" are the names of the first and second indices, respectively.

In their original work, Bjurek (1996) introduced a novel conceptualization of the Malmquist Productivity Index for production units operating within the time period from t to $t + 1$. This index is formulated by considering the technological level at two distinct time points, specifically $k = t$ and $k = t + 1$. The revised formulation of the Malmquist Productivity Index incorporates the technological advancements observed at two distinct time points, specifically $k = t$ and $k = t + 1$. According to the Tornqvist Productivity Index, the index that was formulated represents the ratio between an output index and an input index, where:

$$MTFP_K = \frac{MOK(y_t, y_{t+1}, x_k)}{MIK(y_t, y_{t+1}, x_k)} = \frac{E_k^0 \frac{y_{t+1} x_k}{E_k^0 (y_t x_k)}}{E_k^1 \frac{y_t x_k}{E_k^1 (y_{t+1} x_k)}}, k = t, t + 1 \tag{6}$$

The equation that can be found above expresses the connection that exists between the output index and the Malmquist input index. Productivity is considered to have increased if the value of the

productivity index is greater than one. If the index value is less than one, this indicates that there has been a decline in the overall level of production. If it is equal to one, then the level of productivity will remain the same.

The examination of the productivity change factor can be approached by considering the values of the efficiency change (EFFCH) and the technical change (TECH) index. This analysis allows for a comprehensive understanding of the elements that influence variations in productivity. Furthermore, the utilization of the pure efficiency change (PECH) and the scale efficiency change (SECH) index was employed to determine the components that contributed to the alteration in the efficiency change (EFFCH). The change in the index can be seen reflected in the total factor productivity change (TFPCH) number. If M is greater than 1, then productivity has increased; if M is equal to 1, then productivity has not increased; and if M is less than 1, then productivity has decreased. We also use Slack-Based Measurement (SBM) DEA model developed by Tone (2001) to check the robustness of the efficiency result, as follow:

$$SBM = \text{Min} \left\{ \left(\frac{1}{m} \sum_{i=1}^m \frac{x_{io} - S_{io}}{x_{io}} \right) \times \left(\frac{1}{s} \sum_{r=1}^s \frac{y_{ro} - S_{ro}}{y_{ro}} \right)^{-1} \mid (x_{io} - S_{io}, y_{ro} - S_{ro}) \in T \right\} \quad (7)$$

Tobit Regression

The second stage of the study utilizes Tobit regression. Hoff (2007) argued that the Tobit method as the second stage of DEA suffices in the majority of circumstances. James Tobin established the approach in 1958 to analyze the relationship between a small number of dependent variables and independent factors (Gujarati, 2008). Initially, he expected to assess the car-buying expenditures of American households. However, this complicates the OLS estimation because some households may not purchase a car (zero expenditure). The estimation is likely to be close to zero and insignificant. If it is considerable, the value will be unreliable and biased Tobin (1958).

The estimation of the Tobit regression model is based on the Maximum Likelihood result (ML). In comparison to OLS, parameter estimation yields more accurate results. The Tobit regression is often referred to as a censored regression (Gujarati, 2008). Tobit is used in this study to examine the determinants of efficiency value (the dependent variable), as the score ranges from 0 to 1. Several variables that may affect a bank's financial ratio, including Capital Adequacy Ratio (CAR), Non-Performing Financing (NPF), Financial Performance (ROA), Financing to Deposit Ratio (FDR) have been identified as independent variables together with the macroeconomics variable.

Despite the industry trend toward greater geographic diversification and wider use of financial engineering techniques to manage risk associated with business cycle forecasting, bank efficiency is sensitive to macroeconomic conditions. Higher economic growth typically encourages banks to lend more, enables them to charge higher margins, and improves the quality of their assets. As the development of the gross domestic product (GDP) slows, particularly during recessions, credit quality tends to deteriorate and the default rate rises, reducing the efficiency of banks.

GDP growth variable used to control for cyclical effects on output, which expected to have a positive impact on bank efficiency. The rate of inflation (INF) was adjusted to account for macroeconomic risk. The amount to which inflation affects bank efficiency is determined by whether future inflation movements are completely expected, which is determined by banks' capacity to effectively estimate future inflation movements. A fully predicted inflation rate improves profits because banks can adjust interest rates to increase revenues, whereas an unforeseen change may raise costs due to imperfect interest rate adjustment (Perry, 1992). Furthermore, dummy variables are included to measure the extent to which bank efficiency before and after the COVID-19 period. Tobit regression utilizes panel data, with the following Tobit model for the study:

$$Y_t = \beta_0 + \beta_1 CAR + \beta_2 NPF + \beta_3 ROA + \beta_4 FDR + \beta_5 GDP + \beta_6 INF + \beta_7 Covid + \mu \quad (8)$$

Table 1 Tobit variable's definition in the research of evaluating Islamic bank efficiency and productivity in ASEAN

Tobit Variable	Definition	References	Source
CAR	The ratio of risky capital to the risk-weighted asset	(Abdulahi et al., 2023; Banna et al., 2019; Batir et al., 2017; Wasiaturrahma et al., 2020)	Bank Financial Statement
NPF	Non-performing financing/total loan in percentage	(Abdulahi et al., 2023; Batir et al., 2017; Goswami et al., 2019; Lema, 2017)	Bank Financial Statement
ROA	The ratio of annualized earnings before taxes to the asset's average	(Abdulahi et al., 2023; Banna et al., 2019; Batir et al., 2017; Lema, 2017)	Bank Financial Statement
FDR	Financing-to-deposit ratio	(Abdulahi et al., 2023; Banna et al., 2019; Batir et al., 2017; Lema, 2017)	Bank Financial Statement
GDP	GDP growth (%)	(Abdulahi et al., 2023; Banna et al., 2019; Mai et al., 2023; Goswami et al., 2019)	World Bank
Inflation	Yearly increase of consumer price index (%)	(Abdulahi et al., 2023; Mai et al., 2023; Garza-García, 2012)	World Bank
Dummy Variable (COVID Period)	1: COVID-Period; 0: others	(Saâdaoui and Khalfi, 2022; Shabir et al., 2023; Mateev et al., 2022; Mai et al., 2023)	

RESULTS AND DISCUSSION

DEA Result

The results of a Data Envelopment Analysis (DEA) are presented in the following table, which illustrates the level of efficiency of 33 Islamic banks in ASEAN from 2015 to 2020. An efficiency score ranging from 0 to 1 will be used to indicate the outcomes of the analysis. A score of 1 indicates that the bank is capable of managing both its input and output variables in the most effective manner. In the meantime, if the efficiency ratings are lower than 1, it suggests that the bank is inefficient or is not managing its input and output variables in the most effective way possible. The table that follows presents the results of the data processing done with MAXDea.8 in terms of the efficiency scores.

Table 2 Summary of efficiency scores of ASEAN Islamic banks in 2015-2022

BANK	2015	2016	2017	2018	2019	2020	2021	2022	Mean
Malaysia									
Affin Islamic Bank Berhad	0.55	0.68	0.68	0.62	0.69	0.68	0.68	0.63	0.65
Al Rahji Banking and Investment Corporation	0.50	0.52	0.46	0.46	0.49	0.49	0.99	1.00	0.61
Alliance Islamic Bank Berhad	0.47	0.47	0.50	0.51	0.58	0.55	0.63	0.76	0.56
AmBank Islamic Berhad	1.00	1.00	0.76	0.78	0.69	0.67	0.66	0.81	0.80
Bank Islam Malaysia Berhad	0.57	0.62	0.67	0.66	0.73	0.71	0.80	0.87	0.71
Bank Muamalat Malaysia Berhad	0.46	0.50	0.51	0.51	0.55	0.57	0.67	0.71	0.56
CIMB Islamic Bank Berhad	0.65	0.66	0.65	0.70	0.73	1.00	1.00	1.00	0.80
Heong Long Islamic Bank Berhad	0.58	0.56	0.57	0.60	0.61	0.62	0.64	0.65	0.60
HSBC Amanah Malaysia Berhad	0.76	0.78	0.80	0.79	0.69	0.67	0.69	0.88	0.76
Kuwait Finance House Berhad	0.43	0.47	0.49	0.50	0.52	0.48	1.00	1.00	0.61
Maybank Islamic Berhad	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MSBS Bank Berhad	0.52	0.61	0.33	0.88	0.91	0.91	1.00	0.97	0.77
OCBC Al-Amin Bank Berhad	0.49	0.47	0.49	0.46	0.49	0.45	0.68	0.74	0.53
Public Islam Bank Berhad	0.76	0.66	0.65	0.63	0.64	0.68	0.80	0.80	0.70

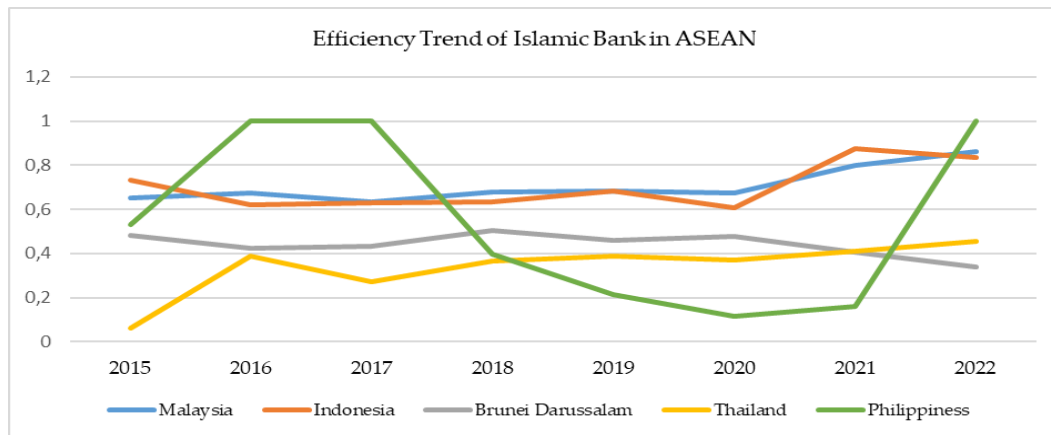
Table 2 Summary of efficiency scores of ASEAN Islamic banks in 2015-2022 (continue)

BANK	2015	2016	2017	2018	2019	2020	2021	2022	Mean
RHB Islamic Bank Berhad	0.75	0.78	0.78	0.79	0.78	0.78	0.94	0.99	0.82
Standard Chartered Saadiq Berhad	0.94	1.00	0.79	1.00	0.84	0.51	0.59	1.00	0.83
Indonesia									
Bank Aceh Syariah	1.00	0.20	0.58	0.61	0.59	0.54	0.87	0.64	0.63
Bank BNI Syariah (BSI)	0.72	0.67	0.70	0.65	0.65	0.59	1.00	1.00	0.75
Bank BPD Nusa Tenggara Barat Syariah	1.00	0.85	1.00	1.00	0.60	0.59	1.00	0.92	0.87
Bank BRI Syariah (BSI)	0.81	0.84	0.90	0.86	0.94	0.60	1.00	1.00	0.87
Bank Jabar Banten Syariah	0.55	0.50	0.47	0.49	0.48	0.49	0.39	0.35	0.46
Bank Mega Syariah	0.48	0.50	0.50	0.46	0.52	0.60	1.00	0.73	0.60
Bank Muamalat Syariah	0.82	0.73	0.69	0.59	0.57	0.53	1.00	1.00	0.74
Bank Panin Dubai Syariah	0.99	0.74	0.68	0.59	0.64	0.59	1.00	1.00	0.78
Bank Syariah Bukopin	0.67	0.57	0.50	0.56	0.58	0.51	0.58	0.55	0.57
Bank Syariah Mandiri (BSI)	0.93	0.90	0.90	0.97	0.97	1.00	1.00	1.00	0.96
Bank Tabungan Pensiunan Nasional Syariah	0.53	0.64	0.44	0.51	0.92	0.86	0.92	1.00	0.73
Bank Victoria Syariah	0.64	0.60	0.68	0.72	0.75	0.79	1.00	1.00	0.77
BCA Syariah	0.30	0.31	0.28	0.29	0.34	0.35	0.48	0.49	0.35
Maybank Syariah Indonesia (PT Bank Net Syariah)	0.82	0.61	0.50	0.55	1.00	0.44	1.00	1.00	0.74
Thailand									
Islamic Bank of Thailand	0.06	0.39	0.27	0.37	0.39	0.37	0.41	0.46	0.34
Brunei Darussalam									
BIBD	0.48	0.43	0.43	0.50	0.46	0.48	0.40	0.34	0.44
Philippines									
Al-Amanah Islamic Investment Bank	0.53	1.00	1.00	0.40	0.21	0.12	0.16	1.00	0.55
Average	0.66	0.64	0.63	0.64	0.65	0.61	0.79	0.83	0.68

Source: Authors, 2024 (processed data).

According to the data shown in Table 2, it is evident that Maybank Islamic Berhad is the sole DMU that achieves the highest level of efficiency. During an 8-year observation period, Maybank Islamic Bank Berhad consistently maintained a score of 1. Bank Syariah Mandiri (BSI) achieves the second-highest score in terms of efficiency, with an average of 0.96. Subsequently, Bank BPD Nusa Tenggara Barat Syariah and Bank BRI Syariah (BSI) follow closely with scores of 0.87 each. The Islamic Bank of Thailand received the lowest average score of 0.34, while BCA Syariah followed precisely with a score of 0.35.

The study period revealed fluctuations in the efficiency scores of ASEAN Islamic Banks. The average efficiency score across all observations is 0.68. Nevertheless, when assessed on a yearly basis, the average's trend reveals a compelling result. The efficiency value of the ASEAN Islamic Banking industry score ranges within the 0.6s, with the lowest efficiency observed in 2020, along with the onset of the COVID-19 pandemic across these countries. Nevertheless, there was a substantial increase in the average efficiency score between the years 2021 and 2022, reaching 0.79 and 0.83, respectively. This observation indicates that banks have effectively implemented strategies to enhance the efficiency of their management practices.



Source: Authors, 2024 (processed data).

Figure 1 Average efficiency trend of Islamic bank in ASEAN (2015-2022)

The efficiency trends of each country across the study period are depicted in Figure 1. Variations in efficiency scores are seen among countries of various sizes. Malaysia exhibits the highest level of efficiency, as indicated by its efficiency score, with the efficiency of Islamic banks in Indonesia following closely behind. To ensure the validity of our findings, we utilized different estimating methodologies, specifically the Slacks Based Measure (SBM).

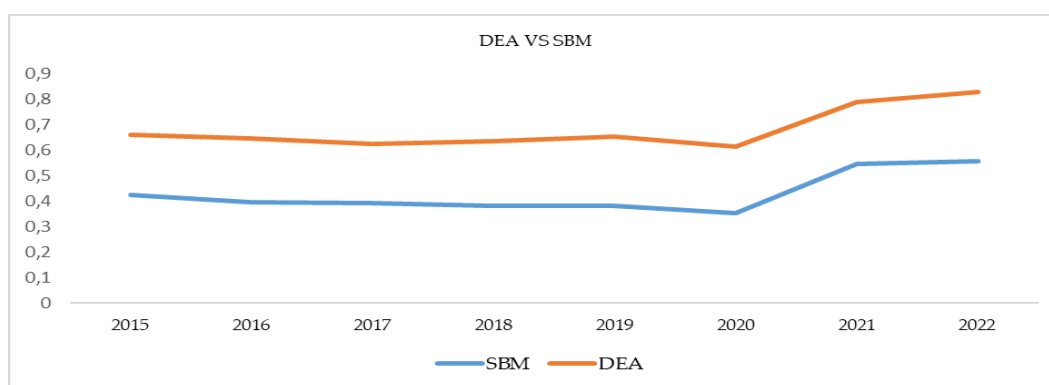
Table 3 Comparison of Data Envelopmenty Analysis (DEA) and Slacks Based Measure (SBM) model in the research of evaluating Islamic bank efficiency and productivity in ASEAN

Bank	DEA	SBM
Malaysia		
Affin Islamic Bank Berhad	0.649	0.256
Al Rahji Banking and Investment Corporation	0.613	0.240
Alliance Islamic Bank Berhad	0.561	0.286
AmBank Islamic Berhad	0.796	0.470
Bank Islam Malaysia Berhad	0.705	0.283
Bank Muamalat Malaysia Berhad	0.559	0.232
CIMB Islamic Bank Berhad	0.798	0.578
Heong Long Islamic Bank Berhad	0.603	0.276
HSBC Amanah Malaysia Berhad	0.758	0.342
Kuwait Finance House Berhad	0.612	0.388
Maybank Islamic Berhad	1.000	0.985
MSBS Bank Berhad	0.766	0.303
OCBC Al-Amin Bank Berhad	0.533	0.235
Public Islam Bank Berhad	0.702	0.455
RHB Islamic Bank Berhad	0.822	0.462
Standard Chartered Saadiq Berhad	0.833	0.653
Indonesia		
Bank Aceh Syariah	0.627	0.505
Bank BNI Syariah (BSI)	0.749	0.443
Bank BPD Nusa Tenggara Barat Syariah	0.871	0.714
Bank BRI Syariah (BSI)	0.868	0.559
Bank Jabar Banten Syariah	0.465	0.341
Bank Mega Syariah	0.599	0.471
Bank Muamalat Syariah	0.740	0.463
Bank Panin Dubai Syariah	0.779	0.659
Bank Syariah Bukopin	0.566	0.434
Bank Syariah Mandiri (BSI)	0.959	0.428
Bank Tabungan Pensiunan Nasional Syariah	0.727	0.575
Bank Victoria Syariah	0.771	0.677

Table 3 Comparison of Data Envelopment Analysis (DEA) and Slacks Based Measure (SBM) model in the research of evaluating Islamic bank efficiency and productivity in ASEAN (continue)

Bank	DEA	SBM
BCA Syariah	0.354	0.300
Maybank Syariah Indonesia (PT Bank Net Syariah)	0.739	0.580
Thailand		
Islamic Bank of Thailand	0.339	0.169
Brunei Darussalam		
BIBD	0.440	0.234
Philippines		
Al-Amanah Islamic Investment Bank	0.552	0.128

Source: Authors, 2024 (processed data).



Source: Authors, 2024 (processed data).

Figure 2 The result of robustness test using Slacks Based Measure (SBM) model in the research of evaluating Islamic bank efficiency and productivity in ASEAN (2015-2022)

Based on the robustness test using Slacks Based Measure (SBM) developed by Tone (2001), the annual average of each bank in ASEAN is relatively lower, but has the same pattern as in Figure 2. This shows that the main results of this study are valid and can be used as an evaluation of the efficiency of bank performance in ASEAN and a consideration in decision making.

Potential Improvement

The DEA method can also identify potential improvements or the level of improvement required to achieve optimal efficiency values. As a consequence, the variables should be optimized can be determined. To characterize the genuine value that must be achieved, potential improvement was examined separately from previous years, using the most recent year of observation. The anticipated value is compared to the real value or current data in this study. The difference between predicted and actual values reveals the degree of inefficiency in variables that Islamic banks must adjust. The Table 4 shows the results of the measurement of potential improvement:

Table 4 Potential improvement of Islamic banks in Indonesia, Malaysia, Philippines and Thailand

Islamic Banks	Operating Revenue	Total Financing	Fixed Asset	Labor Cost	Third-Party Funds
Islamic Bank in Indonesia	21.48%	49.77%	12.68%	8.61%	7.47%
Islamic Bank in Malaysia	21.32%	18.32%	22.78%	25.15%	12.43%
Islamic Bank in Philippines	24.93%	68.88%	2.34%	2.31%	1.54%
Islamic Bank in Brunei	25.16%	25.86%	25.40%	11.79%	11.79%
Islamic Bank in Thailand	36.77%	36.77%	9.04%	9.38%	8.03%
Average	25.93%	39.92%	14.45%	11.45%	8.25%

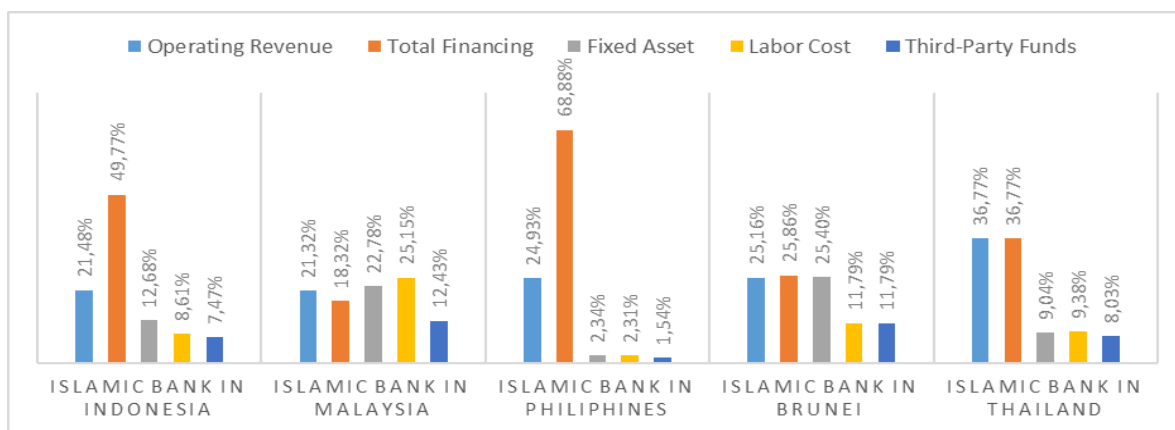
Source: Authors, 2024 (processed data).

On average of overall Islamic banking in ASEAN, the output variables, namely total financing (39.92%) and operating revenue (25.93%) are the main causes of inefficiency. This can be seen from the high percentage contribution of these two variables compared to other variables. This indicates that the achievement of Islamic bank’s financing and revenue are still not optimal and need to be improved in the future to achieve efficient performance. Referring to the results of the potential improvement analysis by country in Figure 3, the total financing variable is also the main contributor to inefficiency in sharia banking in ASEAN, except Malaysia. In the case of Malaysia, the main source of inefficiency actually comes from input variables, namely labor costs (25.1%) and fixed assets (22.78%). This shows that the output achievements of sharia banking in Malaysia are quite good, but they need to find various strategies to minimize the use of input variables.

The DEA analysis highlights that, unlike other ASEAN countries, Malaysia does not identify total financing as a primary source of inefficiency. Instead, input variables such as labor costs and fixed assets contribute most significantly to inefficiency. This difference may stem from Malaysia's relatively mature Islamic banking sector, which has undergone significant regulatory development and has leveraged technology and human resource investment to improve operational efficiency (Laldin and Furqani, 2018).

Malaysia’s Islamic banking industry has benefited from policies that support human capital development and asset management strategies. According to the Central Bank of Malaysia (BNM), their strategic focus on upskilling employees and optimizing asset use has reduced output inefficiencies and positioned Malaysia’s Islamic banking sector as a regional leader (BNM Annual Report, 2021). Thus, Malaysia's experience suggests that minimizing reliance on input-heavy operations, especially labor and fixed assets, can improve overall efficiency.

For other ASEAN Islamic banks, particularly in Indonesia, adopting similar strategies could enhance efficiency. This might include investing in employee training programs focused on productivity and optimizing asset usage to reduce operating costs without compromising service quality. As suggested by Bank Indonesia, Indonesian Islamic banks could benefit from Malaysia's example by focusing on capacity building and technology adoption to manage input variables better, thereby narrowing the efficiency gap (Bank Indonesia, 2022).



Source: Authors, 2024 (processed data).

Figure 3 Potential improvement result of Islamic banks in Indonesia, Malaysia, Philippines and Thailand

The calculation was then followed by an MPI or Malmquist Productivity Index evaluation of productivity. Table 5 displays the expected MPI results for Islamic banking in the five ASEAN nations.

Malmquist Index Summary of Annual Averages

Table 5 Malmquist index summary of Islamic banks in ASEAN based on annual averages

Year	EFFCH	TECH	PECH	SECH	TFPCH
2015-2016	0.919	1.457	0.951	0.967	1.339
2016-2017	1.001	1.235	0.961	1.043	1.236
2017-2018	1.053	0.913	1.108	0.951	0.961
2018-2019	0.736	2.138	1.021	0.721	1.575
2019-2020	1.044	0.699	0.955	1.093	0.731
2020-2021	0.248	5.768	0.413	0.611	1.431
2021-2022	1.472	1.041	1.151	1.279	1.531
Mean	0.831	1.469	0.897	0.926	1.219

Source: Authors, 2024 (processed data).

The effects of various levels of productivity are outlined in Table 5, which is based on annual averages. According to Table 5, the most significant increase in productivity growth happened in 2018-2019, as shown by a TFPCH value of 1.575. This information is demonstrated by the fact that this period was covered. The fast rate of growth in the value of TECH was the primary factor that contributed to the increase in productivity that occurred during that time period (2.138).

In the meantime, there was a significant drop in productivity in the 2019-2020 fiscal year, with a TFPCH value of 0.731. The main source that influenced the decline in productivity during that period was the low change in the TECH (0.699). The impact of COVID-19 on the financial performance of the Islamic banking sector in ASEAN is widely recognized. In these particular conditions, the banking industry must enhance its performance through various indicators, encompassing the adoption of information technology, technical progress, and enhanced customer experience. According to Ünlü et al. (2022), the advancements in the banking industry, which have been accelerated by the impact of COVID-19, have created a competitive advantage within the sector through the implementation of more streamlined procedures and the emergence of new products and services.

It can be seen that during the 2015-2022 period, Islamic Banks in ASEAN experienced an increase in productivity with the acquisition of a TFPCH value of 1.219, which means that on average, Islamic banks in ASEAN increased its performance in the field of banks productivity. This indicates that the rise in productivity of ASEAN Islamic banks has been contributed to by the high level of innovation or technology (TECH), which is 1.469, while the value of EFFCH (0.831) is lower than that of TECH. This is because the value of EFFCH is lower than that of TECH.

This result indicates that technical aspect such as technology and digitalization playing an important role through the Islamic bank's performance. In order to minimize the usage of physical branches and increase reliance on digital technologies, Islamic banks are advised by the World Health Organisation (WHO) to adopt contactless payment methods during the pandemic period (KNEKS, 2020). In addition, digitalization becomes something that cannot be ignored after the pandemic, because there has been a shift in customer behavior from conventional to digital.

Malmquist Index Summary Based on Country

Table 6 Malmquist index summary of Islamic banks in ASEAN based on country

Bank	EFFCH	TECH	PECH	SECH	TFPCH
Malaysia					
Affin Islamic Bank Berhad	0.837	1.325	0.831	1.007	1.109
Al Rahji Banking and Investment Corporation	0.366	1.049	1.000	0.366	0.384
Standard Chartered Saadiq Berhad	0.993	1.151	1.021	0.973	1.142
Alliance Islamic Bank Berhad	1.010	1.376	1.000	1.010	1.390
AmBank Islamic Berhad	1.000	1.736	1.000	1.000	1.736
Bank Islam Malaysia Berhad	1.105	1.086	1.000	1.105	1.200
Bank Muamalat Malaysia Berhad	1.106	1.061	1.063	1.040	1.173

Table 6 Malmquist index summary of Islamic banks in ASEAN based on country (continue)

Bank	EFFCH	TECH	PECH	SECH	TFPCH
CIMB Islamic Bank Berhad	1.000	1.778	1.000	1.000	1.778
Heong Long Islamic Bank Berhad	0.913	1.254	0.950	0.998	1.145
HSBC Amanah Malaysia Berhad	1.000	1.811	1.000	1.000	1.811
Kuwait Finance House Berhad	0.955	1.145	1.072	0.890	1.093
Maybank Islamic Berhad	1.000	4.792	1.000	1.000	4.792
MSBS Bank Berhad	1.055	1.573	1.000	1.055	1.659
OCBC Al-Amin Bank Berhad	0.958	1.107	0.955	1.003	1.061
Public Islam Bank Berhad	1.000	1.387	1.000	1.000	1.387
RHB Islamic Bank Berhad	1.000	1.388	1.000	1.000	1.388
Averages	0.956	1.564	0.993	0.965	1.516
Indonesia					
Bank Aceh Syariah	0.650	1.555	0.736	0.882	1.010
Bank BNI Syariah (BSI)	0.913	2.888	0.918	0.995	2.638
Bank BPD Nusa Tenggara Barat Syariah	1.067	2.136	1.000	1.067	2.278
Bank BRI Syariah (BSI)	0.913	2.610	0.918	0.995	2.384
Bank Jabar Banten Syariah	0.614	1.581	0.610	1.007	0.971
Bank Mega Syariah	0.677	1.438	0.676	1.002	0.973
Bank Muamalat Syariah	1.000	1.339	1.000	1.000	1.339
Bank Panin Dubai Syariah	0.693	1.401	0.726	0.955	0.971
Bank Syariah Bukopin	0.508	1.517	0.439	1.156	0.770
Bank Syariah Mandiri (BSI)	0.993	0.904	0.918	1.081	0.897
Bank Tabungan Pensiunan Nasional Syariah	0.708	0.369	0.835	0.848	0.261
Bank Victoria Syariah	0.590	1.510	1.005	0.587	0.890
BCA Syariah	0.554	1.719	0.605	0.915	0.953
Maybank Syariah Indonesia (PT Bank Net Syariah)	1.010	3.565	1.000	1.000	3.600
Averages	0.778	1.752	0.813	0.964	1.424
Brunei Darussalam					
BIBD	0.557	1.193	0.751	0.742	0.665
Averages	0.557	1.193	0.751	0.742	0.665
Thailand					
Islamic Bank of Thailand	1.243	0.957	1.162	1.070	1.190
Averages	1.243	0.957	1.162	1.070	1.190
Philippines					
Al-Amanah Islamic Investment Bank	0.478	1.726	1.000	0.478	0.826
Averages	0.478	1.726	1.000	0.478	0.826
Average	0.830	1.469	0.897	0.925	1.219

Source: Authors, 2024 (processed data).

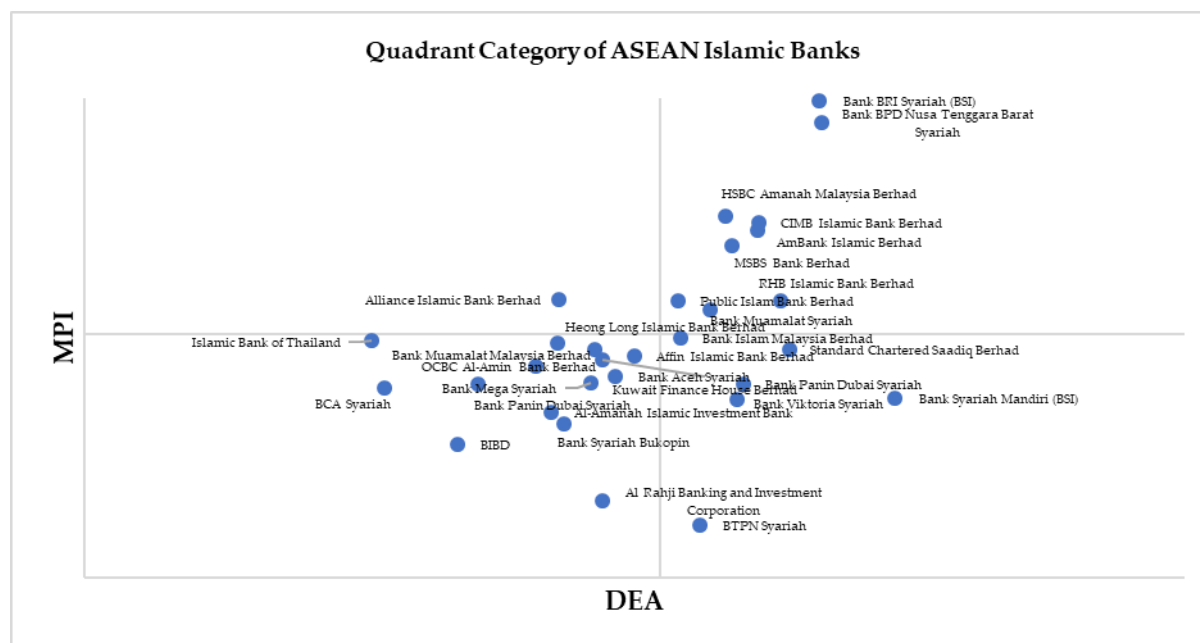
As can be shown in Table 6, the groups of Islamic banks operating in ASEAN countries have been experiencing an increase in their overall productivity development. With a TFPCH of 1.516, Islamic banks in Malaysia experienced the most growth in TFPCH over the course of the year. This indicates that the total factor productivity of Islamic banks in Malaysia has increased during the past period of time. The high level of technology change (TECH) that was obtained was one of the factors that contributed to the high level of productivity that the bank had attained, which was 1.564.

Indonesia and Thailand both showed an increase in Islamic bank productivity, with TFPCH values of 1.424 and 1.190, respectively. The high degree of technological innovation (TECH), which is 1.752, is a factor contributing to the high productivity of Islamic banks in Indonesia. While, the high level of productivity in Islamic banking in Thailand is driven by the high degree of efficiency change (EFFCH), which is 1.243.

During this time, Islamic banking in Brunei Darussalam and the Philippines suffered a decrease in productivity, with TFPCH values of 0.665 and 0.826, respectively. This decline is due to the decrease in the efficiency change rate (EFFCH), which is 0.557 and, thus, 0.478.

This study also divides all Islamic banking in ASEAN into four different quadrants based on their respective MPI productivity and DEA efficiency scores. This particular quadrant analysis was proposed by Kumar and Gulati (2008). The value of 1.219 is decided to be the average productivity value, and the value of 0.68 is determined to be the average efficiency value after all of the productivity and efficiency statistics have been averaged.

The calculation of Islamic banking, which is the primary concern of this investigation, is then performed using these two averages. If a bank's score is higher than the industry average, we consider that bank to be among the most productive and efficient in the industry. In addition, the two findings serve to define the quadrant, with the bank being placed in quadrant I if it belongs to the category of high production and efficiency. The situation falls into quadrant II when the productivity is great but the efficiency is low. The situation falls into quadrant III if the productivity is low but the efficiency is great. In conclusion, it is said to be in quadrant IV if production and efficiency are both low.



Source: Authors, 2024 (processed data).

Figure 4 The quadrant category of ASEAN Islamic banks based on Malmquist Productivity Index (MPI) and Data Envelopment Analysis (DEA)

In the top right quadrant, the most productive and efficient banks as measured by the MPI and DEA. There are a total of 12 financial institutions that fall under this category: AmBank Islamic Berhad, CIMB Islamic Bank Berhad, HSBC Amanah Malaysia Berhad, Maybank Islamic Berhad, MSBS Bank Berhad, Public Islam Bank Berhad, RHB Islamic Bank Berhad, Bank BNI Syariah (BSI), Bank BPD Nusa Tenggara Barat Syariah, Bank BRI Syariah (BSI), Bank Muamalat Syariah, and Maybank Syariah Indonesia (PT Bank Net Syariah).

Despite being highly productive on the MPI, banks in Quadrant II exhibit low efficiency as measured by the DEA. These financial institutions are generally slow to "catch up." An increasing number of financial institutions are located in the "less efficient" quadrant, indicating that banks' performance in this area is subpar. Alliance Islamic Bank Berhad, is the only financial institution located in this region.

There is a group of financial institutions located in Quadrant III that have a relatively low MPI productivity score but a high DEA efficiency score. It is possible to think of the groups of banks that fall into quadrant 3 as having low productivity but relatively strong growth in the efficiency performance of their operations. This sector contains six banks, including Bank Islam Malaysia Berhad, Standard Chartered Saadiq Berhad, Bank Panin Dubai Syariah, Bank Syariah Mandiri (BSI), Bank Victoria Syariah, HSBC Amanah Malaysia Berhad, Maybank Islamic Berhad, and BTPN Syariah.

Banks scoring low on both the MPI productivity and the DEA efficiency measures can be found in Quadrant IV. In this sense, we might characterize these financial institutions as those whose performance has remained mostly unchanged, leading to a low value of productivity and efficiency. There are 14 financial institutions located in this section: Affin Islamic Bank Berhad, Al Rahji Banking and Investment Corporation, Bank Aceh Syariah, Bank Jabar Banten Syariah, Bank Mega Syariah, Bank Syariah Bukopin, BCA Syariah, Bank Muamalat Malaysia Berhad, BIBD, Heong Long Islamic Bank Berhad, Islamic Bank of Thailand, Kuwait Finance House Berhad, and OCBC Al-Amin Bank Berhad.

Upon examining the categorization presented in the above table, it becomes evident that a significant proportion of banks within the ASEAN countries are concentrated in quadrants 1 and 4. The ASEAN Islamic banks, on average, are making improvements in terms of productivity, which is consistently influenced by technological developments throughout the years. This finding aligns with the previous research conducted by Chowdhury and Haron (2021). Based on their finding, the ASEAN Islamic banks demonstrated advancements in productivity that were affected by technological advancements. Moreover, it is evident that the ASEAN Islamic banks are undergoing a steady enhancement in productivity, leading to a corresponding progress in efficiency.

Because of the presence of the COVID-19 pandemic, Islamic banks have been compelled to continue their pursuit of technological advancement and innovation. During the pandemic, technological advancement in the banking industry can help clients overcome barriers to banking services caused by their inability to mobilize (Subanidja et al., 2022). Vergara and Aguado (2021) investigated the most important components of sustainable finance and fintech. According to their findings, fintech promotes the growth of financial enterprises by fostering sustainable finance. According to the findings of Subanidja et al. (2022), the performance of banks can be affected by both fintech and competitive advantage. In addition, Legowo et al. (2020) proposed that the existence of fintech is to enhance the long-term performance of banks. According to Banna et al. (2023), there is a strong suspicion that fintech supports both long-term financial performance and financial development.

As a consequence of this, the challenge for Islamic banks in ASEAN is to continue to improve the quality of their technology in an effort to reach higher levels of productivity in the future. It's possible that improved digital-based services, improved methods for protecting customer data, and branchless banking could all contribute to such a technical improvement. This will serve as an incentive for Islamic banks to optimize their output and will make it possible for them to perform more efficiently.

Tobit Regression

The analysis then extended to identify which factors that may influence the efficiency level using the Tobit regression model. The result depicts that the only FDR is significantly influencing the efficiency scores, The results illustrate that only the FDR variable significantly affects the efficiency score in terms of financial ratios. It was found that CAR and ROA have a positive effect, while NPF has a negative effect but has no significant relationship with the efficiency of Islamic banks in ASEAN. There's also found that GDP and dummy variable have a significant affected on bank efficiency, while the inflation variable failed to explain the efficiency achievement. Table 7 represents the overall findings of the Tobit estimation in this study:

Table 7 Tobit regression result in the research of evaluating Islamic bank efficiency and productivity in ASEAN

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.476817	0.037782	12.62011	0.0000
CAR	0.000134	0.000345	0.389689	0.6968
NPF	-0.008187	0.008038	-1.018484	0.3084
ROA	0.005025	0.004094	1.227226	0.2197
FDR	0.000730	0.000228	3.209473	0.0013
INF	-0.002658	0.008718	-0.304905	0.7604
GDP	0.021922	0.004914	4.461140	0.0000
COVID	0.166558	0.028505	5.843203	0.0000

Source: Authors, 2024 (processed data).

FDR is a ratio to assess the quality of a bank's liquidity and its intermediation performance. The higher FDR represents the better bank's performance in terms of its intermediation function. The regulator has promptly addressed the necessities of the banking industry. Central banks in ASEAN countries have implemented strategies such as decreasing banks' capital buffers to provide funds for rescheduling financings and allowing customers affected by the economic consequences of COVID-19 to defer financing repayments temporarily.

Several Islamic banking institutions have committed to offering assistance packages to their consumers during the COVID-19 outbreak to uphold the quality of financing. The positive result aligns with the perspective that Islamic banks possess a relative advantage in the face of an external shock. The existing body of literature pertaining to the Global Financial Crisis (GFC) indicates that Islamic banks have been observed to persist in providing financing during times of crisis. This can be attributed to the asset-based and risk-sharing systems that are inherent to Islamic banking (Boubakri et al., 2023).

Furthermore, it is observed that the GDP has a significant positive relationship with bank efficiency. As economies and societies gain wealth, the demand for financial services increases. It is argued that the maintenance of robust economic development has dual benefits. First, it enables countries to better endure crises and pandemics, as highlighted by Mai et al. (2023). Second, it enhances the efficiency and performance of the Islamic banking system. According to recent studies conducted by Elnahass et al. (2021), it is suggested that this could potentially facilitate the acceleration of the global economic recovery.

By using dummy variables, we are able to further examine the impact of COVID-19 on ASEAN banking sector efficiency. The result suggests that Islamic banks in ASEAN region experienced a growth in banking performance during the COVID-19 period. This implies that the Islamic banking sector demonstrated enhanced performance despite the adverse effects of the COVID-19 pandemic. As indicated by the considerably positive coefficient of the COVID period dummy in our model. This discovery, however, is not unexpected but reinforces the assertion that Islamic banks exhibit greater resilience in dealing with periods of volatility (Beck et al., 2013; Bourkhis and Nabi, 2013; Farooq and Zaheer, 2015; Miah and Uddin, 2017).

Despite immediately dealing with a decline during the onset of the COVID pandemic, sharia banking eventually remained stable due to the regulator's implementation of various policies. These policies enabled banks to effectively respond to the changing circumstances, resulting in their relative stability during the subsequent pandemic period. The findings of Boubaker et al. (2022) support the hypothesis that Islamic banks have exhibited steady efficient performance throughout the challenges posed by the COVID-19 pandemic. According to Rehman et al. (2021), Islamic banks had a more favorable response to the COVID-19 crisis in comparison to conventional banks.

CONCLUSION

Conclusion

This study reveals significant changes in the average efficiency levels of Islamic banks in ASEAN between 2015 and 2022. The ASEAN Islamic banking industry's efficiency scores ranged from a low of 0.6, with the lowest efficiency occurring in 2020, coinciding with the COVID-19 pandemic. However, a marked improvement in mean efficiency scores was noted from 2021 to 2022, reaching values of 0.79 and 0.83, respectively. Across ASEAN's Islamic banking sector, output variables—specifically total financing (39.92%) and operating revenue (25.93%)—are major contributors to inefficiency. The high percentage contributions of these variables indicate that Islamic banks' financing and revenue achievements are still suboptimal, underscoring a need for future improvements to attain efficient performance.

The Malmquist Index scores (TFPCH) show that the overall productivity of all 33 Islamic banks in the sample has improved, with a TFPCH score of 1.219. Notably, the TFPCH value for technological changes (1.469) exceeds that for efficiency changes (0.830), suggesting that technological innovation has had the greatest influence on Islamic bank productivity in ASEAN. This study extends the application of the Data Envelopment Analysis (DEA) methodology within a two-stage framework to evaluate efficiency factors determining ASEAN Islamic banks, particularly in light of the COVID-19 pandemic's impact. Empirical results indicate that GDP growth plays a crucial role in bolstering resilience during crises, such as the pandemic, potentially aiding in swift economic recovery. The resilience shown by the Islamic banking sector highlights its potential for contributing significantly to post-pandemic economic recovery.

Recommendations

The findings suggest that technological change is a primary contributor to productivity in ASEAN Islamic banks, highlighting the importance of investing in new financial services to further technological growth in the sector. This includes infrastructure for fintech solutions, which could drive productivity growth. Currently, management performance has been the primary productivity driver in ASEAN banking, underscoring the need for Islamic banks to adopt more technological innovations.

In the post-pandemic era, Islamic banks face the challenge of balancing investments in digitalization to adapt to changing consumer behavior against the risk of falling behind competitors, especially conventional banks. Islamic banks are therefore advised to develop a phased digitalization strategy to maintain stability and meet consumer needs effectively. This could involve creating a grand design for digitalization that supports customer engagement and preserves income ratios.

For Islamic banking practitioners, it's essential to strengthen human resource quality and embrace technology in banking products to expand customer options. Policymakers should consider reducing operational costs for Islamic banks and their clients, which may also help mitigate default risks. For academic researchers, updating information on Islamic banking productivity and expanding research to additional banks or countries beyond ASEAN could address study limitations. Islamic banks should aim for low overhead and high productivity to compete effectively with other financial institutions. Authorities should prioritize Islamic banks in their policies, promoting a stable financial ecosystem by incorporating fintech and the digital economy into regulatory frameworks.

REFERENCES

- Abdo, K. K. (2023). The effect of external economic variables on the conventional banks and Islamic banks financial performance in Jordan: A comparative study. *Journal of Sustainable Finance & Investment*, 13(1), 229-247. <https://doi.org/10.1080/20430795.2021.1891785>.
- Abdulahi, S. M., Yitayaw, M. K., Feyisa, H. L., & Mamo, W. B. (2023). Factor affecting technical

- efficiency of the banking sector: Evidence from Ethiopia. *Cogent Economics & Finance*, 11(1), 2186039.
- Abdul-Majid, M., Saal, D. S., & Battisti, G. (2011). The impact of Islamic banking on the cost efficiency and productivity change of Malaysian commercial banks. *Applied Economics*, 43(16), 2033-2054.
- Achi, A. (2021). Efficiency and its determinants in the Algerian banks: network data envelopment analysis and partial least squares regression. *International Journal of Productivity and Performance Management*. <https://doi.org/10.1108/IJPPM-07-2021-0407>.
- Aisyah, S. & Hosen, M. N. (2018). Total factor productivity and efficiency analysis on Islamic banks in Indonesia. *Jurnal Keuangan dan Perbankan*, 22(1), 137-147.
- Alabbad, A. & Schertler, A. (2022). COVID-19 and bank performance in dual-banking countries: An empirical analysis. *Journal of Business Economics*, 92(9), 1511-1557.
- Alexakis, C., Izzeldin, M., Johnes, J., & Pappas, V. (2019). Performance and productivity in Islamic and conventional banks: Evidence from the global financial crisis. *Economic Modelling*, 79, 1-14. <https://doi.org/10.1016/j.econmod.2018.09.030>.
- Al-Khasawneh, J. A., Bassadat, K., Aktan, B., & Thapa, P. D. P. (2012). Efficiency of Islamic banks: case of North African Arab countries. *Qualitative Research in Financial Markets*, 4(2-3), 228-239. <https://doi.org/10.1108/17554171211252547>.
- Ascarya, Yumanita, D., Achsani, N. A., & Rokhimah, G. S. (2008, October). Measuring the efficiency of Islamic banks in Indonesia and Malaysia using parametric and nonparametric approaches. In *3rd International Conference on Islamic Banking and Finance, SBP-IRTI, Karachi, Pakistan*.
- Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, 30(9), 1078-1092.
- Banna, H., Shah, S. K. B., Noman, A. H. M., Ahmad, R., & Masud, M. M. (2019). Determinants of sino-ASEAN banking efficiency: How do countries differ?. *Economies*, 7(1), 13.
- Banna, H., Hassan, M. K. & Bataineh, H. (2023). Bank efficiency and fintech-based inclusive finance: evidence from dual banking system. *Journal of Islamic Monetary Economics and Finance*, 9(1), 1-16. <https://doi.org/10.21098/jimf.v9i1.1621>.
- Basri, M. F., Muhamat, A. A., & Jaafar, M. N. (2018). The efficiency of Islamic banks in Malaysia: Based on DEA and Malmquist productivity index. *Journal of Emerging Economies & Islamic Research*, 6(3), 1-14.
- Batir, T. E., Volkman, D. A., & Gungor, B. (2017). Determinants of bank efficiency in Turkey: Participation banks versus conventional banks. *Borsa Istanbul Review*, 17(2), 86-96. <https://doi.org/10.1016/j.bir.2017.02.003>.
- Beck, T., Demirgüç-Kunt, A. & Merrouche, O. (2013). Islamic vs. conventional banking: Business model, efficiency and stability. *Journal of Banking and Finance*, 37(2), 433-447. <https://doi.org/10.1016/j.jbankfin.2012.09.016>.
- [BI] Bank Indonesia. (2022). *Annual Economic Report on Islamic Banking in Indonesia* [online]. [accessed 2024 Oct 10]. Retrieved from: <https://www.bi.go.id>.
- [BNM] Bank Negara Malaysia (BNM). (2021). *Annual Report 2021* [online]. [accessed 2024 Oct 10]. Retrieved from: <https://www.bnm.gov.my/annual-report-2021>.
- Boubaker, S., Le, T. D. Q. & Ngo, T. (2022). Managing bank performance under COVID-19: A novel inverse DEA efficiency approach. *International Transactions in Operational Research*. <https://doi.org/10.1111/ITOR.13132>.
- Boubakri, N., Mirzaei, A. & Saad, M. (2023). Bank lending during the COVID-19 pandemic: A comparison of Islamic and conventional banks. *Journal of International Financial Markets, Institutions and Money*, 84, 101743.
- Bourkhis, K. & Nabi, M. S. (2013). Islamic and conventional banks' soundness during the 2007-2008 financial crisis. *Review of Financial Economics*, 22(2), 68-77.
- Bjurek, H. (1996). The Malmquist total factor productivity index. *The Scandinavian Journal of Economics*, 98(2), 303-313.
- Buchory, H. A. & Java, W. (2017). Financial intermediation efficiency and its impact on profitability (study in state saving bank in Indonesia). *ICIBMAH*, 15(1), 1-13.

- Charnes, A., Cooper, W. W. & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444. [https://doi.org/10.1016/0377-2217\(78\)90138-8](https://doi.org/10.1016/0377-2217(78)90138-8).
- Chowdhury, M. A. M. & Haron, R. (2021). The efficiency of Islamic banks in the Southeast Asia (SEA) region. *Future Business Journal*, 7, 1-16.
- Caves, D. W., Christensen, L. R. & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica: Journal of the Econometric Society*, 50(6), 1393-1414.
- Demirgüç-Kunt, A., Pedraza, A., & Ruiz-Ortega, C. (2021). Banking sector performance during the COVID-19 crisis. *Journal of Banking and Finance*, 133. <https://doi.org/10.1016/j.jbankfin.2021.106305>.
- El-Chaarani, H. (2023). The Impact of COVID-19 on the performance of Islamic banks in the MENA region. *ISRA International Journal of Islamic Finance*, 15(1), 109-129. <https://doi.org/10.55188/ijif.v15i1.488>.
- El-Chaarani, H., Ismail, T. H., El-Abiad, Z., & El-Deeb, M. S. (2022). The impact of COVID-19 on financial structure and performance of Islamic banks: a comparative study with conventional banks in the GCC countries. *Journal of Economic and Administrative Sciences*. <https://doi.org/10.1108/JEAS-07-2021-0138>.
- Elnahass, M., Trinh, V. Q., & Li, T. (2021). Global banking stability in the shadow of Covid-19 outbreak. *Journal of International Financial Markets, Institutions and Money*, 72, 101322. <https://doi.org/10.1016/j.intfin.2021.101322>.
- Farandy, A. R., Suwito, D. A., & Dabutar, L. K. (2017). Efficiency of Islamic banks in Indonesia: Data envelopment analysis. *International Journal of Economics, Management and Accounting*, 25(2), 337-354.
- Farooq, M. & Zaheer, S. (2015). Are Islamic banks more resilient during financial panics?. *Pacific Economic Review*, 20(1), 101–124. <https://doi.org/10.1111/1468-0106.12096>.
- Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society Series A: Statistics in Society*, 120(3), 253-281.
- Garza-García, J. G. (2012). Determinants of bank efficiency in Mexico: A two-stage analysis. *Applied Economics Letters*, 19(17), 1679-1682. <https://doi.org/10.1080/13504851.2012.665589>.
- Ghouse, G., Ejaz, N., Bhatti, M. I., & Aslam, A. (2022). Performance of Islamic vs conventional banks in OIC countries: Resilience and recovery during Covid-19. *Borsa Istanbul Review*, 22, S60–S78. <https://doi.org/10.1016/j.bir.2022.11.020>.
- Goswami, R., Hussain, F., & Kumar, M. (2019). Banking efficiency determinants in India: a two-stage analysis. *Margin: The Journal of Applied Economic Research*, 13(4), 361-380. <https://doi.org/10.1177/0301574219868373>.
- Grassa, R., Sarea, A., El-Halaby, S., & Damak, A. N. (2022). Between two crises: Do Islamic banks suffer?. *Journal of Islamic Monetary Economics and Finance*, 8(2), 251 – 274.
- Grifell-Tatjé, E. & Lovell, C. K. (1997). The sources of productivity change in Spanish banking. *European Journal of Operational Research*, 98(2), 364-380. [https://doi.org/10.1016/S0377-2217\(96\)00353-0](https://doi.org/10.1016/S0377-2217(96)00353-0).
- Guizani, M. & Ajmi, A. N. (2021). Islamic banking and corporate investment efficiency: Empirical evidence from Malaysia. *International Journal of Productivity and Performance Management*, 71(5), 1854-1871. <https://doi.org/10.1108/IJPPM-06-2020-0331>.
- Gujarati, D. N. (2008). *Basic Econometrics* (5th ed.). New York (US), McGraw-Hill.
- Hassan, M. K., Rabbani, M. R., & Abdulla, Y. (2021). Socioeconomic impact of COVID-19 in MENA region and the role of Islamic finance. *International Journal of Islamic Economics and Finance (IJIEF)*, 4(1), 51–78.
- Hoff, A. (2007). Second stage DEA: Comparison of approaches for modelling the DEA score. *European journal of operational research*, 181(1), 425-435.
- Ikhwan, I. & Riani, R. (2023). Stability of Islamic bank efficiency in Indonesia and Malaysia: Has Covid-19 made any difference?. *Journal of Islamic Monetary Economics and Finance*, 9(3), 491-510. <https://doi.org/10.21098/jimf.v9i3.1526>.
- Isik, I. & Uygur, O. (2021). Financial crises, bank efficiency and survival: Theory, literature and

- emerging market evidence. *International Review of Economics & Finance*, 76, 952-987.
- Johnes, J., Izzeldin, M. & Pappas, V. (2014). A comparison of performance of Islamic and conventional banks 2004–2009. *Journal of Economic Behavior & Organization*, 103, S93-S107.
- Kamarudin, F., Sufian, F., Loong, F. W., & Anwar, N. A. M. (2017). Assessing the domestic and foreign Islamic banks efficiency: Insights from selected Southeast Asian countries. *Future Business Journal*, 3(1), 33–46. <https://doi.org/10.1016/j.fbj.2017.01.005>.
- [KNEKS] Komite Nasional Ekonomi dan Keuangan Syariah (KNEKS). (2020). *Bank Syariah Kala Pandemi di Semester II* [online]. [accessed 2023 Nov 25]. Retrieved from: <https://kneks.go.id/berita/324/bank-syariah-kala-pandemi-di-semester-ii?category=1>.
- Kumar, S. & Gulati, R. (2008). An examination of technical, pure technical, and scale efficiencies in Indian public sector banks using data envelopment analysis. *Eurasian Journal of Business and Economics*, 1(2), 33-69.
- Laldin, M. A. & Furqani, H. (2013). Developing Islamic finance in the framework of maqasid al-shari'ah: Understanding the ends (maqasid) and the means (wasail). *International Journal of Islamic and Middle Eastern Finance and Management*, 6(4), 278-289.
- Lantara, D. (2022). Indonesian Islamic banks: A review of the financial state before and after the COVID-19 pandemic. *Business Perspectives*, 17(4), 12-24.
- Legowo, M. B., Subanidja, S., & Sorongan, F. A. (2020, September). Model of sustainable development based on FinTech in financial and banking industry: A mixed-method research. In *2020 3rd International conference on computer and informatics engineering (IC2IE)* (pp. 194-199). IEEE.
- Lema, T. Z. (2017). Determinants of bank technical efficiency: Evidence from commercial banks in Ethiopia. *Cogent Business & Management*, 4(1).
- Li, X., Xie, Y. & Lin, J. H. (2021). COVID-19 outbreak, government capital injections, and shadow banking efficiency. *Applied Economics*, 53(4), 495–505. <https://doi.org/10.1080/00036846.2020.1808183>.
- Loong, F., Kamarudin, F., Sufian, F., & Naseem, N. A. M. (2017). Estimating efficiency in domestic and foreign Islamic banking and its determinants among three neighboring countries - Malaysia, Indonesia and Brunei. *International Journal of Economics and Management*, 11(1), 237–258.
- Mai, X. T. T., Nguyen, H. T. N., Ngo, T., Le, T. D., & Nguyen, L. P. (2023). Efficiency of the Islamic banking sector: Evidence from two-stage DEA double frontiers analysis. *International Journal of Financial Studies*, 11(1), 32.
- Mansour, W., Ajmi, H. & Saci, K. (2021). Regulatory policies in the global Islamic banking sector in the outbreak of COVID-19 pandemic. *Journal of Banking Regulation*, 1-23.
- Mateev, M., Sahyouni, A., & Al Masaeid, T. (2022). Bank performance before and during the COVID-19 crisis: Does efficiency play a role?. *Review of Managerial Science*, 18(1), 29-82.
- Miah, M. D. & Uddin, H. (2017). Efficiency and stability: A comparative study between Islamic and conventional banks in GCC countries. *Future Business Journal*, 3(2), 172-185.
- Miah, M. D., Suzuki, Y. & Uddin, S. M. S. (2021). The impact of COVID-19 on Islamic banks in Bangladesh: A perspective of Marxian “circuit of merchant’s capital.” *Journal of Islamic Accounting and Business Research*, 12(7), 1036–1054. <https://doi.org/10.1108/JIABR-11-2020-0345>.
- Mirzaei, A., Saad, M. & Emrouznejad, A. (2022). Bank stock performance during the COVID-19 crisis: Does efficiency explain why Islamic banks fared relatively better?. *Annals of Operations Research*, 334(1), 317-355. <https://doi.org/10.1007/s10479-022-04600-y>.
- Nailah, N. & Rusydiana, A. S. (2020). Efficiency and stability of Islamic banking in ASEAN: DEA window analysis. *Tazkia Islamic Finance and Business Review*, 14(1), 1–19. <https://doi.org/10.30993/tifbr.v14i1.211>.
- Narwal, K. P. & Pathneja, S. (2016). Effect of bank-specific and governance-specific variables on the productivity and profitability of banks. *International Journal of Productivity and Performance Management*, 65(8), 1057-1074. <https://doi.org/10.1108/IJPPM-09-2015-0130>.
- Omar, M. A., Majid, M. S. A., & Rulindo, R. (2007). Efficiency and productivity performance of the

- private national banks in Indonesia. *Gadjah Mada International Journal of Business*, 9(1), 1-18. <https://doi.org/10.22146/gamaijb.5603>.
- Otaviya, S. A. & Rani, L. N. (2020). Productivity and its determinants in Islamic banks: Evidence from Indonesia. *Journal of Islamic Monetary Economics and Finance*, 6(1), 189-212. <https://doi.org/10.21098/jimf.v6i1.1146>.
- Perry, P. (1992). Do banks gain or lose from inflation?. *Journal of Retail Banking*, 14(2), 25-31.
- Rani, L. N. & Kassim, S. (2020). Comparing the intertemporal efficiency of Islamic Banks in Indonesia and Malaysia. *Journal of Islamic Monetary Economics and Finance*, 6(4), 861–894. <https://doi.org/10.21098/jimf.v6i4.1147>.
- Rani, L., Rusydiana, A., & Widiastuti, T. (2017, November). Comparative analysis of Islamic bank's productivity and conventional bank's in Indonesia period 2008-2016. In *1st International Conference on Islamic Economics, Business and Philanthropy (ICIEBP 2017)* (pp. 118-123).
- Refinitiv. (2022). *Islamic Finance Development Report 2022: Embracing Change* [online]. [accessed 2023 Nov 25]. Retrieved from: <https://www.mifc.com/-/islamic-finance-development-report-2022-embracing-change>.
- Rehman, S. U. (2021). Impact of the Covid-19 pandemic on Islamic bank indices of the GCC countries. *International Journal of Islamic Banking and Finance Research*, 7(1), 1–17. <https://doi.org/10.46281/ijibfr.v7i1.1381>.
- Rodoni, A., Salim, M. A., Amalia, E. & Rakhmadi, R. S. (2017). Comparing efficiency and productivity in Islamic banking: Case study Indonesia, Malaysia and Pakistan. *Al-Iqtishad: Journal of Islamic Economics*, 9(2), 227–242. <https://doi.org/10.15408/aiq.v9i2.5153>.
- Rusydiana, A. S. & Assalafiyah, A. (2021). Advancement and setback in Islamic banking productivity in ASEAN: Do technological changes matter?. *Journal of Islamic Monetary Economics and Finance*, 7(3), 583-604. <https://doi.org/10.21098/jimf.v7i3.1322>.
- Rusydiana, A. S. & Marlina, L. (2019). Financial and social efficiency on Indonesian Islamic banks. *Journal of Islamic Monetary Economics and Finance*, 5(3), 579–602. <https://doi.org/10.21098/jimf.v5i3.1154>.
- Saâdaoui, F. & Khalfi, M. (2022). Revisiting Islamic banking efficiency using multivariate adaptive regression splines. *Annals of Operations Research*, 1-29. <https://doi.org/10.1007/s10479-022-04545-2>.
- Shabir, M., Jiang, P., Wang, W., & Işık, Ö. (2023). COVID-19 pandemic impact on banking sector: A cross-country analysis. *Journal of Multinational Financial Management*, 67, 100784.
- Sharma, D., Sharma, A. K. & Barua, M. K. (2013). Efficiency and productivity of banking sector: A critical analysis of literature and design of conceptual model. *Qualitative Research in Financial Markets*, 5(2), 195-224.
- Solow, R. M. (1957). Technical change and the aggregate production function. *The review of Economics and Statistics*, 39(3), 312-320.
- Subanidja, S., Sorongan, F. A., & Legowo, M. B. (2022). Sustainable bank performance antecedents in the covid-19 pandemic era: A conceptual model. *Emerging Science Journal*, 6(4), 786-797.
- Sufian, F. & Kamarudin, F. (2015). Determinants of revenue efficiency of Islamic banks. *International Journal of Islamic and Middle Eastern Finance and Management*, 8(1), 36–63. <https://doi.org/10.1108/imefm-12-2012-0114>.
- Sunarsih, S., Al Hashfi, R. U., Munawaroh, U. & Suhari, E. (2022). Nexus of risk and stability in Islamic banks during the pandemic evidence from Indonesia. *Journal of Islamic Monetary Economics and Finance*, 8(4), 599-614.
- Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica: Journal of the Econometric Society*, 24-36.
- Tone, K. (2001). A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research*, 130(3), 498-509.
- Ünlü, U., Yalçın, N., & Avşarlıgil, N. (2022). Analysis of efficiency and productivity of commercial banks in Turkey pre-and during COVID-19 with an integrated MCDM approach. *Mathematics*, 10(13). <https://doi.org/10.3390/math10132300>.
- Usman, N., Andriyani, L. & Pambuko, Z. B. (2019). Productivity of Islamic banks in Indonesia: Social funds versus financial funds. *The Journal of Asian Finance, Economics and*

- Business*, 6(3), 115-122. <https://doi.org/10.13106/jafeb.2019.vol6.no3.115>.
- Vergara, C. C. & Agudo, L. F. (2021). Fintech and sustainability: Do they affect each other? *Sustainability*, 13(13). <https://doi.org/10.3390/su13137012>.
- Wasiaturrahma, Sukmana, R., Ajija, S. R., Salama, S. C. U., & Hudaifah, A. (2020). Financial performance of rural banks in Indonesia: A two-stage DEA approach. *Heliyon*, 6(7).
- Wu, D., Yang, Z. & Liang, L. (2006). Using DEA-neural network approach to evaluate branch efficiency of a large Canadian bank. *Expert Systems with Applications*, 31(1), 108–115. <https://doi.org/10.1016/j.eswa.2005.09.034>.
- Yildirim, I. (2015). Financial efficiency analysis in Islamic banks: Turkey and Malaysia models. *Journal of Economics Finance and Accounting*, 2(3).
- Yudaruddin, R. (2023). Government policy response to COVID-19 and bank performance: a comparison between Islamic and conventional banks. *Journal of Islamic Accounting and Business Research*, 14(6), 952-972. <https://doi.org/10.1108/JIABR-09-2022-0248>.