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DEA WINDOW ANALYSIS OF INDONESIAN ISLAMIC BANK EFFICIENCY

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ABSTRACT

This study measures the efficiency of Islamic banks in Indonesia using data envelopment analysis (DEA) window methods on 14 Indonesian Islamic banks covering the period from 2011 to 2020. The results show that the efficiency of Islamic banks averages 80% and showed an increasing trend over the study period. Based on stability measures, namely standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP), and Long Distance per Year (LDY), we find that the efficiency of PT Bank BRI Syariah (BSI) and PT Bank Syariah Mandiri (BSI) is relatively stable.

Keywords: Efficiency, Window analysis, DEA, Islamic bank, Indonesia.
JEL classification: C14; G20; G21.

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I. INTRODUCTION

1.1. Background

The recent global financial crisis of 2017-2018 has stimulated much debate on alternative and more resilient financial systems. In this regard, the Islamic financial system has attracted much attention. It is argued that with shared welfare as its priority, Islamic finance can potentially be the best choice, especially in improving the banking system (Johnes, Izzeldin, Pappas, & Alexakis, 2018).

Islamic banking has been fast growing and has assumed a significant market share in many countries, e.g. Malaysia and several Middle Eastern countries, as well as penetrating many other countries (Rahim, Rahman, & Rosman, 2013). The development of the Islamic banking industry in Indonesia, as in many other countres, has exhibited a positive trend, albeit at a slow pace. As of April 2021, the Islamic banking sector in Indonesia comprised 12 Shariah Commercial Banks (BUS) with total assets of 399,886 billion rupiahs and a total of 2,037 offices, 20 Sharia Business Units (UUS) with total assets of 194,091 billion rupiahs and a total of 374 offices, as well as 163 Islamic Micro Financing Banks (BPRS) with 635 BPRS offices throughout Indonesia (Otoritas Jasa Keuangan, 2021).

According to the Global Islamic Finance Report 2020, Indonesia is recognized as on of the top countries in the Islamic Finance Country Index (IFCI). Indeed, in 2019, its IFCI climbed 5 places to take the first position, although in the following year it was overtaken by Malaysia. Despite achieving a fairly high score of 82.01 in 2020, Indonesia is still seen to have high potential in developing its Islamic finance industry. The market share of Islamic banking has increased over the years, reaching 6.51% by the end of 2020 and then 6.55% in early 2021. While this level of market share is an achievement in itself, Islamic banking still needs to strive for performance and efficiency improvements in face of various emerging challenges, such as competition and the conversion of sharia business units into sharia commercial banks.

Although the Islamic banking and finance system has improved rapidly in recent years, many studies have provided a mixed picture of the efficiency of Islamic banks compared to conventional ones. Therefore, a study of the efficiency level of the Islamic banking sector remains important (Rani, Sukmaningrum, & Salleh, 2020).

1.2. Objective

This research has two objectives. First, it aims to measure the efficiency level of Indonesia's Islamic Commercial Banks (BUS) over a 10-year period from 2011 to 2020. Second, it also conducts intertemporal efficiency analysis through the DEA window analysis approach, by observing the results per year (LDY), per window (LDW), and overall (LDP). This was done to verify the efficiency results in DEA, which are relative in nature and tend to fluctuate when the datasets are different. To this end, DEA window analysis was employed.

Data Envelopment Analysis (DEA) is a widely used approach to measuring the efficiency of business units, including banks. Some examples of studies that have adopted the method include those of Rani, Rusydiana, and Widiastuti (2017), Kamarudin, Sufian, and Nassir (2016), Hersugondo, Wahyudi, and Laksana (2021),

Octrina and Mariam (2021); Safiullah (2021), Trinugroho, Santoso, Irawanto, and Pamungkas (2021), Yusuf, Santi, and Rismaya (2021), Rusydiana and Sanrego (2018), Rusydiana (2018a, 2018b), and Rusydiana and Firmansyah (2017).

However, the efficiency of measurements using the DEA method depend crucially on the number of data points used to form efficiency frontiers. That is, when the data points or observations increase, the measurement results can become quite different. To overcome this shortcoming of the DEA approach, Charnes, Clark, Cooper, and Golany (1985) introduced the concept of DEA window analysis. Normally termed DEWA, it is an extension of DEA for measuring the performance of a DMU (Decision Making Unit) over time by treating it as a different entity in each period.

DEWA allows for the shifting of frontiers between different historical periods, and as a result can produce more consistent and dependable findings (Sueyoshi, Yuan, Li, & Wang, 2017). As a result, the efficiency scores achieved by this method become more reliable.

This paper is structured as follows. The second part reviews the related literature, while the third part describes the methodology, including the data and models. The fourth section presents and reports on the results, while providing an analysis of the most productive and the most efficient Islamic banks. The fifth part closes the paper and contains a summary of the main discussions and recommendations.

II. RELATED LITERATURE

A business unit is considered to be fully efficient if it achieves maximum output for given levels of inputs or employs minimum levels of inputs to produce a given level of output. Oscar (2008) divided efficiency into technical, cost, scale, and allocation efficiency. Technical efficiency is the process of converting inputs into outputs. This concept applies only to the internal technical relationship between inputs and outputs. A company is considered to be economically efficient if it can minimise production costs to produce a certain output within the general technological level and the market price level (Farrell, 1957).

Broadly speaking, there are two approaches normally used to measure firms' efficiency level: the parameteric approach based on Stochastic Frontier Analysis (SFA), and the nonparameteric approach based on Data Envelopment Analysis (DEA). Table 1 shows examples of these two approaches, as applied in various contexts and types of firms, including banking firms.

Table 1.
Approaches to Frontier Efficiency Measurements

MODEL	Y	AUTHORS	TYPE
Stochastic Frontier Approach als77	1977	Aigner, Lovell, and Schmidt	Parametric
SFA Model mvb77	1977	Meeusen and van den Broeck	Parametric
Data Envelopment Analysis CCR	1978	Charnes, Cooper, and Rhodes	Nonparametric
SFA Model stev80	1980	Stevenson	Parametric
SFA Model mlti	1981	Pitt and Lee	Parametric
Malmquist Productivity Index	1982	Caves, Christensen, and Diewert	Nonparametric
DEA Model BCC	1984	Banker, Charnes, and Cooper	Nonparametric
Free Disposal Hull [FDH]	1984	Deprins, Simar, and Tulkens	Nonparametric
SFA Model fe	1984	Schmidt and Sickles	Parametric
SFA Model regls	1984	Schmidt and Sickles	Parametric
DEA Window Analysis	1984	Charnes, Clarke, Cooper, and Golany	Nonparametric
DEA Additive Model	1985	Charnes,Cooper,Golany,Seiford,and Stutz	Nonparametric
DEA Assurance Region [DEA-AR]	1986	Thompson, Singleton, Thrall, and Smith	Nonparametric
DEA Cross Efficiency	1986	Sexton, Silkman, and Hogan	Nonparametric
DEA Facet Model	1988	Bessent, Bessent, Elam, and Clark	Nonparametric
SFA Model mlti	1988	Battese and Coelli	Parametric
SFA Model fecss	1990	Cornwell, Schmidt, and Sickles	Parametric
SFA Model kumb90	1990	Kumbhakar	Parametric
DEA Cone Ratio	1990	Charnes, Cooper, Huang, and Sun	Nonparametric
TFA [Thick Frontier Approach]	1991	Berger and Humphrey	Parametric
SFA Model bc92	1992	Battese and Coelli	Parametric
Fuzzy DEA	1992	Sengupta	Nonparametric
DFA [Distribution Free Approach]	1993	Berger	Parametric
SFA Model fels	1993	Lee and Schmidt	Parametric
DEA Super Efficiency	1993	Andersen and Peterson	Nonparametric
SFA Model bc95	1995	Battese and Coelli	Parametric
Network DEA	1996	Fare and Grosskopf	Nonparametric
Hierarchical/Nested Model DEA	1998	Cook, Chai, Doyle, and Green	Nonparametric
Bootstrapped DEA	1998	Simar and Wilson	Parametric
DEA Russell Measure [ERM]	1999	Pastor, Ruiz, and Sirvent	Nonparametric
Imprecise Data [IDEA]	1999	Cooper, Park, and Yu	Nonparametric
Parallel Model DEA	2000	Cook, Hababou, and Tuenter	Nonparametric
Dynamic DEA	2000	Fare and Grosskopf	Nonparametric
DEA Slack Based Measure [SBM]	2001	Tone	Nonparametric
Meta Frontier	2003	Rao, O'Donnel, and Battese	Nonparametric
Context-Dependent DEA	2003	Seiford and Zhu	Nonparametric
SFA Model gre03	2003	Greene	Parametric
SFA Model tfe	2005	Greene	Parametric
SFA Model tre	2005	Greene	Parametric
Game Cross Efficiency	2008	Liang, Wu, Cook, and Zhu	Nonparametric

Source: Rusydiana, 2018a

The levels of Islamic bank efficiency and stability have been a topic of discussion in several previous studies, with several techniques used to estimate these. Saaid, Rosly, Ibrahim, and Abdullah (2003) measured the efficiency of Sudanese Islamic banks using the Stochastic Frontier Approach (SFA). In the context of Indonesian Islamic banking, Octrina and Mariam (2021) also analysed efficiency using the SFA. Mokhtar, Abdullah and Alhabshi (2008) examined the efficiency level of Islamic banks in Malaysia and compared them with conventional banks using the DEA method. Shahid, ur Rehman, Niazi, & Raoof (2010) and Abbas, Azid, & Besar (2016) had similar objectives, but focused on Pakistani Islamic banks. Similar to Mokhtar et al. (2008), Ahmad and Abdul Rahman (2012) also examined the level of efficiency using the DEA method with a limited sample of Islamic and conventional commercial banks in Malaysia. Sufian and Noor (2009) analysed the efficiency of Islamic banks in MENA and Asia and identified several determinants that positively affected the level of efficiency, using a two-stage procedure (DEA and Tobit regression) as the methodology. In line with Sufian and Noor (2009), Mobarek and Kalonov (2014) and Alqahtani, Mayes, and Brown (2017) investigated whether OIC state Islamic or conventional banks had better efficiency and stability performance during the subprime crises. Asmild, Kronborg, Mahbub, and Matthews (2019) also examined the effect of the global financial crisis on the efficiency of Islamic banks in Bangladesh.

Furthermore, Bitar, Pukthuanthong, and Walker (2019) examined the role of capital and liquidity levels and their effect on the efficiency of Islamic banks during the 2008-2009 financial crisis using DEA and quantile regression. In the context of ASEAN Islamic banking, Nailah and Rusydiana (2020) recently investigated aspects of efficiency and stability using DEWA. Rusydiana and Marlina (2019) explored the financial and social efficiency of Indonesian Islamic banks using the DEA and Free Disposal Hull (FDH) methods. Previous studies have shown that topics related to efficiency, stability, and Islamic banking are still relevant. This was confirmed by Rusydiana, Rahmawati, and Shafitranata (2021), who examined the development map of Islamic bank DEA research using bibliometrics, showing that the publication of DEA Islamic bank research was witnessing an upward trend.

However, the number of studies that specifically discuss Islamic banks in Indonesia using the DEWA method, a window analysis approach proposed by Charnes et al. (1985), remain limited. One study that is relevant to this research is that conducted by Shawtari, Ariff, and Razak (2015), who used the DEWA approach. Shawtari et al. (2015) analysed the efficiency of the banking industry in Yemen over the period 1996 to 2011 using the DEWA method. Their findings show that in general the banking industry in Yemen had experienced a downward trend and unstable efficiency during the study period. The results of their study also indicate that the majority of Yemen's conventional banks are relatively more stable, even though they are not efficient.

Al-Delaimi and Al-Ani (2006) also used the data envelopment analysis and window DEA analysis methods to measure and analyse the relative cost efficiency of 24 Islamic bank institutions. In addition, research using the DEA window model for banking was also conducted by Asmild, Paradi, Aggarwall, and Schaffnit (2004), Bergendahl (1998), Kisielewska, Guzowska, Nellis, and Zarzecki (2005), Repkova (2014), Sufian and Majid (2007), Sufian (2007), and Zimkova (2014).

Based on the previous research, it has been found that studies that discuss the performance of banking efficiency have been widely conducted using the data envelopment analysis method. Some have also employed the Malmquist Productivity Index to measure the levels of productivity and efficiency. However, in its development, the DEA method has undergone revisions and modifications to provide better and more robust measurement of efficiency, one of which is the DEA window analysis method. This introduces measures such as LDY, LDW, LDP and Standard Deviation so that the issue of measurement consistency can be addressed (Sueyoshi et al., 2017). Various studies, as noted above, have recently adopted DEA window analysis, but its application to Indonesian banking data is limited. Therefore, this study seeks to fill this gap by conducting DEWA on 14 Islamic commercial banks in Indonesia covering the period 2011 to 2020.

III. METHODOLOGY

3.1. Data

The study uses secondary data derived from the financial statements of 14 Indonesian Islamic commercial banks during the period 2011-2020, and employs data envelopment analysis (DEA) with a window-based approach. Through the DEA window analysis (DEWA), the decision-making unit (DMU) is considered to be in each period (Sufian & Majid, 2007). Therefore, DEWA allows assessment of the level of efficiency for each DMU (Charnes et al., 1985) to evaluate performance over time (Asmild et al., 2004); to identify the best and the worst performing DMUs; and to examine efficiency stability (Halkos & Tzeremes, 2009). We used the BCC model, a modified DEA model that uses variable return to scale (VRS) (Banker, Charnes, & Cooper, 1984). Table 2 lists the 14 Islamic banks used in the study.

Table 2.
Examples of Islamic Commercial Banks in Indonesia

No	Islamic Bank
1.	PT Bank Aceh Syariah
2.	PT Bank BNI Syariah (BSI)
3.	PT Bank BRI Syariah (BSI)
4.	PT Bank Jabar Banten Syariah
5.	PT Bank Mega Syariah
6.	PT Bank Muamalat Syariah
7.	PT Bank Panin Dubai Syariah
8.	PT Bank Syariah Bukopin
9.	PT Bank Syariah Mandiri (BSI)
10.	PT Bank Tabungan Pensiunan Nasional Syariah
11.	PT Bank Victoria Syariah
12.	PT BCA Syariah
13.	PT BPD Nusa Tenggara Barat Syariah
14.	PT Maybank Syariah Indonesia (PT Bank Net Syariah)

In the study, fixed assets (X1), labour costs (X2), third party funds (X3) are used as inputs, and total financing (Y1) and operating income (Y2) as outputs. Table 3 presents the descriptive statistics of these variables.

Table 3.
Descriptive Statistics for Inputs and Outputs (In Million Rupiah)

Indicator	Fixed Assets	Labour Costs	Third Party Funds	Total Financing	Operational Income
Mean	397,920	416,937	13,338,402	13,853,153	1,447,431
Max	3,357,284	2,179,574	84,334,054	125,990,338	8,635,480
Min	1,080	2,700	1	54	17,995
SD	631,773.165	492,326.087	19337696.15	22,494,930.93	1,862,744.563

3.2. Method

MaxDEA 7.1 was employed to measure the efficiency level of all the DMUs of Islamic banks during the period 2011-2020. The analysis was performed in two stages. The first stage involved the measurement of standard efficiency using the CRS or CCR approach of Charnes et al (1978), while in the second stage the window analysis was performed.

In general, the mathematical equation commonly used for the DEA window is as follows, where M is the average efficiency level and K is the window length:

$$M_l = \frac{\sum_{t=1}^{M-K+1} \sum_{j=1}^{i+K-1} . E_{i,j}}{K \text{ x } (M-K+1)}, l = 1, L, N$$

As recommended by Cooper, Seiford, and Zhu (2011), the window analysis results can be used to check the relative efficiency through several summary statistics, such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) and Long Distance per Year (LDY). These four measurements can be used to analyse the efficiency stability achieved by each DMU.

Standard deviation measures the difference in the average level of DMU efficiency for each window. The smaller the standard deviation value, the more stable the efficiency value achieved by each DMU, in this case, Islamic banks. Long-Distance per Window (LDW) shows the largest difference in efficiency figures in one window. The smaller the LDW value of an Islamic bank ,the more stable its efficiency, and vice versa. Long-Distance per all periods (LDP) describes the largest difference in efficiency figures in all the observation periods. A smaller LDP value indicates higher efficiency stability, and vice versa. Finally, Long-Distance per Year (LDY) shows the largest difference in efficiency figures in one year. Similar to LDW and LDP, a smaller LDY value indicates more stablility in the efficiency value achieved by each DMU, and vice versa.

To monitor changes in the efficiency level of Islamic banks over time, Window DEA was conducted (Charnes et al, 1985). In this study, a five-year window analysis

is used. Hence, for each analysis, there were 70 DMUs (5 x 14), with the same DMUs for different periods treated as different DMUs. Therefore, benchmarking was not only performed on peer DMUs, but also on their performance. 14 Islamic commercial banks were considered, all classified as Islamic Commercial Banks (BUS) in Indonesia.

In general, two approaches are widely used in the application of DEA to banking firms, namely the intermediation approach and the production approach. In this study, the intermediation approach was employed. As a result, under this approach Indonesian Islamic commercial banks were assumed to function as intermediaries between lenders and borrowers. The approach uses accumulated deposits and borrowed funds as inputs and borrowing and securities as outputs (Freixas & Rochet, 2008; Sufian & Majid, 2007).

DEA window analysis has a specificity, in that the calculation of efficiency performance enables assessment of whether efficiency scores are consistent over time. This approach not only makes comparisons between data for each year from all periods, but also compares them using window groupings, with a total of five years in each window. The use of windows serves to split the research period into various groups of years to establish whether the efficiency scores achieved by each bank change significantly or remain roughly at the same level.

In addition to the performance of other units, the performance of a unit in a certain period of DEWA is compared to its own performance in other periods. This increases the number of data points included in the analysis, which might be beneficial when working with a limited sample size, as previously mentioned. In this case, varying the window width (the number of time periods included in the analysis) means covering the spectrum from contemporaneous analysis, which includes only observations from a single time period, to intertemporal analysis, which includes observations from the entire period under consideration (Zimkova, 2014).

Six windows were employed in this study, with the length of each being five years. Therefore, observations were evaluated solely in the context of previous observations made throughout the course of a four-year period. This was done in order to avoid the problem of unfair comparison over time by choosing a period that is as short as possible. It is claimed that despite the fact that significant technical advances took place during the study period, their effects on banks have been gradual, and the comparison of bank efficiency over a five-year period is still fair.

IV. RESULTS AND ANALYSIS

4.1. Results

Table 4 presents the average efficiency for each 14 Islamic commercial bank in Indonesia with a return to scale variable approach. Based on the results, the efficiency level varies from 74% to 89% over the period 2011 to 2020. In addition, the average efficiency for all banks reaches 80%. Among the 14 banks, we identified the most efficient (average efficiency value above 80%) during the study period. These were BRI Syariah Bank (95%), Muamalat Syariah Bank (81%), Panin Dubai Syariah Bank (87%), Bukopin Syariah Bank (84%), Mandiri Syariah Bank (93%),

West Nusa Tenggara Syariah BPD (92%), and Net Syariah Bank (88%). Note that other Islamic commercial banks in Indonesia have an average efficiency level below 80%.

Table 4.
Islamic Commercial Banks VRS Efficiency Level in Indonesia 2011-2020

DMU	Score										Mean
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Bank Aceh Syariah	0.66	0.91	1.00	1.00	1.00	0.53	0.67	0.70	0.65	0.58	0.77
Bank BNI Syariah (BSI)	0.75	0.65	0.74	0.72	0.90	0.80	0.88	0.77	0.70	0.59	0.75
Bank BRI Syariah (BSI)	0.80	1.00	0.79	0.98	0.98	1.00	0.96	1.00	1.00	1.00	0.95
Bank Jabar Banten Syariah	0.69	0.73	0.83	0.74	0.86	0.77	0.70	0.70	0.72	0.70	0.74
Bank Mega Syariah	0.72	0.74	1.00	0.84	0.68	0.76	0.77	0.71	0.78	0.80	0.78
Bank Muamalat Syariah	0.95	1.00	0.93	1.00	0.93	0.76	0.75	0.61	0.59	0.56	0.81
Bank Panin Dubai Syariah	0.67	0.83	0.84	1.00	1.00	0.85	0.77	0.71	0.99	1.00	0.87
Bank Syariah Bukopin	0.63	0.73	0.87	0.94	0.92	0.85	0.77	0.84	0.86	1.00	0.84
Bank Syariah Mandiri (BSI)	0.82	0.74	0.96	0.87	0.98	0.98	1.00	1.00	1.00	1.00	0.93
BTPN Syariah	0.09	0.34	1.00	0.72	0.91	0.89	0.57	0.64	1.00	0.94	0.71
Bank Victoria Syariah	1.00	0.94	0.54	0.70	0.74	0.59	0.66	0.71	0.74	0.78	0.74
BCA Syariah	0.59	0.71	0.43	0.52	0.56	0.54	0.56	0.60	0.63	0.58	0.57
BPD NTB Syariah	1.00	1.00	0.91	1.00	0.97	0.79	1.00	1.00	0.76	0.77	0.92
Maybank Syariah	1.00	0.66	0.88	0.92	1.00	0.99	0.81	1.00	1.00	0.56	0.88
Mean	0.74	0.78	0.84	0.85	0.89	0.79	0.78	0.79	0.82	0.78	0.80

Since the DEWA method can capture a general picture or general trend of efficiency, we report the average overall efficiency for each bank in each window in Table 5. Mean column represents the average of all scores for each bank. The standard deviation for each bank score is shown in the SD column. The LDY column shows the most significant difference between bank scores in different windows in the same year, while the LDP column refers to the biggest difference between bank scores over the entire period. These measures are used to capture the stability efficiency of each DMU. The lower the level of these four values , the more stable the efficiency obtained (Nailah & Rusydiana, 2020).

Table 5 shows the results of the DEA window analysis for Islamic commercial banks in Indonesia over the period 2011 to 2020. Each analysis is divided into six windows, with each year length per window being 5 years.

Table 5.
DEA Window Analysis of Indonesian Islamic Commercial Banks, 2011-2020

Islamic Bank	Window	Efficiency Score										Summary Measures				
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean/ Window	The Mean	SD	LDW	LDP
PT Bank Aceh Syariah	W1	0.84	0.91	1.00	1.00	1.00						0.95	0.82	0.11	0.42	0.42
	W2		0.91	1.00	1.00	1.00	0.58					0.90				
	W3			1.00	1.00	1.00	0.64	0.70				0.87				
	W4				1.00	1.00	0.64	0.72	0.75			0.82				
	W5					1.00	0.64	0.70	0.71	0.67		0.75				
	W6						0.59	0.71	0.71	0.65	0.60	0.65				
	LDY	x	0.00	0.00	0.00	0.00	0.06	0.02	0.04	0.02	x			0.15		
PT Bank BNI Syariah (BSI)	W1	0.76	0.66	0.75	0.75	1.00						0.78	0.81	0.05	0.34	0.40
	W2		0.66	0.75	0.75	0.60	0.83					0.77				
	W3			0.90	0.77	0.91	0.82	0.99				0.88				
	W4				0.77	0.90	0.81	0.99	0.85			0.86				
	W5					0.90	0.81	0.88	0.77	0.74		0.82				
	W6						0.81	0.88	0.77	0.70	0.60	0.75				
	LDY	x	0.00	0.15	0.02	0.10	0.02	0.11	0.07	0.03	x			0.15		
PT Bank BRI Syariah (BSI)	W1	0.80	1.00	0.86	1.00	1.00						0.93	0.98	0.03	0.20	0.20
	W2		1.00	0.86	0.99	1.00	1.00					0.97				
	W3			0.88	1.00	1.00	1.00	1.00				0.98				
	W4				1.00	1.00	1.00	0.99	1.00			1.00				
	W5					1.00	1.00	0.98	1.00	1.00		1.00				
	W6						1.00	0.99	1.00	1.00	1.00	1.00				
	LDY	x	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	x			0.02		

Table 5.
DEA Window Analysis of Indonesian Islamic Commercial Banks, 2011-2020 (Continued)

Islamic Bank	Window	Efficiency Score										Summary Measures				
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean/ Window	The Mean	SD	LDW	LDP
PT Bank Jabar Banten Syariah	W1	0.75	0.73	0.87	0.76	0.91						0.81	0.80	0.03	0.18	0.20
	W2		0.73	0.87	0.76	0.91	0.80					0.82				
	W3			0.89	0.76	0.91	0.83	0.76				0.83				
	W4				0.78	0.94	0.82	0.76	0.77			0.81				
	W5					0.86	0.81	0.74	0.74	0.77		0.78				
	W6						0.80	0.72	0.72	0.74	0.73	0.74				
	LDY	x	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.03	x			0.05		
PT Bank Mega Syariah	W1	0.80	0.78	1.00	0.98	0.83						0.88	0.85	0.04	0.23	0.27
	W2		0.77	1.00	0.97	0.80	0.80					0.87				
	W3			1.00	0.97	0.84	0.84	0.84				0.90				
	W4				1.00	0.84	0.85	0.84	0.78			0.86				
	W5					0.75	0.81	0.82	0.77	0.84		0.80				
	W6						0.78	0.80	0.73	0.80	0.88	0.80				
	LDY	x	0.01	0.00	0.03	0.04	0.06	0.04	0.04	0.04	x			0.06		
PT Bank Mualamat Syariah	W1	1.00	1.00	1.00	1.00	1.00						1.00	0.89	0.11	0.32	0.37
	W2		1.00	1.00	1.00	1.00	0.84					0.97				
	W3			1.00	1.00	1.00	0.84	0.88				0.94				
	W4				1.00	1.00	0.83	0.89	0.70			0.88				
	W5					1.00	0.84	0.91	0.72			0.83				
	W6						0.78	0.85	0.65	0.63	0.65	0.71				
	LDY	x	0.00	0.00	0.00	0.00	0.07	0.06	0.07	0.06	x			0.07		

Table 5.
DEA Window Analysis of Indonesian Islamic Commercial Banks, 2011-2020 (Continued)

Islamic Bank	Window	Efficiency Score										Summary Measures				
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean/ Window	The Mean	SD	LDW	LDP
PT Bank Panin Dubai Syariah	W1	0.76	0.93	0.88	1.00	1.00						0.91	0.91	0.02	0.25	0.25
	W2		0.93	0.88	1.00	1.00	0.85					0.93				
	W3			0.84	1.00	1.00	0.87	0.81				0.91				
	W4				1.00	1.00	0.87	0.81	0.75			0.89				
	W5					1.00	0.87	0.81	0.75	1.00		0.89				
	W6						1.00	0.83	0.76	1.00	1.00	0.92				
	LDY	x	0.00	0.04	0.00	0.00	0.15	0.03	0.01	0.00	x			0.15		
PT Bank Syariah Bukopin	W1	0.67	0.76	0.87	0.94	0.92						0.83	0.88	0.03	0.28	0.33
	W2		0.76	0.87	0.94	0.92	0.86					0.87				
	W3			0.87	0.94	0.92	0.89	0.81				0.89				
	W4				0.95	0.93	0.88	0.81	0.87			0.89				
	W5					0.92	0.88	0.81	0.87	0.90		0.88				
	W6						0.94	0.81	0.90	0.95	1.00	0.92				
	LDY	x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	x			0.08		
PT Bank Syariah Mandiri (BSI)	W1	0.82	0.76	1.00	1.00	1.00						0.92	0.97	0.03	0.24	0.24
	W2		0.76	1.00	1.00	1.00	1.00					0.95				
	W3			1.00	0.94	1.00	1.00	1.00				0.99				
	W4				0.94	1.00	1.00	1.00	1.00			0.99				
	W5					1.00	1.00	1.00	1.00	1.00		1.00				
	W6						1.00	1.00	1.00	1.00	1.00	1.00				
	LDY	x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	x			0.06		

Table 5.
DEA Window Analysis of Indonesian Islamic Commercial Banks, 2011-2020 (Continued)

Islamic Bank	Window	Efficiency Score										Summary Measures				
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean/ Window	The Mean	SD	LDW	LDP
PT Bank Tabungan Pensiunan Nasional Syariah	W1	0.52	0.41	1.00	0.92	1.00						0.77	0.88	0.06	0.59	0.59
	W2		0.56	1.00	0.88	1.00	1.00					0.89				
	W3			1.00	0.88	1.00	1.00	0.82				0.94				
	W4				0.92	1.00	1.00	0.81	0.89			0.92				
	W5					0.92	0.90	0.79	0.86	1.00		0.89				
	W6						0.90	0.70	0.77	1.00		0.87				
	LDY	x	0.16	0.00	0.04	0.08	0.10	0.12	0.12	0.00	x			0.16		
PT Bank Victoria Syariah	W1	1.00	0.96	0.60	0.71	0.75						0.81	0.73	0.06	0.40	0.45
	W2		1.00	0.60	0.72	0.77	0.80					0.78				
	W3			0.55	0.70	0.75	0.59	0.66				0.65				
	W4				0.70	0.75	0.59	0.67	0.73			0.69				
	W5					0.75	0.59	0.67	0.73	0.82		0.71				
	W6						0.6	0.7	0.77	0.84	0.89	0.76				
	LDY	x	0.04	0.06	0.01	0.02	0.22	0.05	0.04	0.02	x			0.22		
PT BCA Syariah	W1	0.59	0.80	0.49	0.59	0.59						0.61	0.63	0.03	0.31	0.33
	W2		0.80	0.49	0.59	0.59	0.57					0.61				
	W3			0.46	0.57	0.64	0.62	0.68				0.59				
	W4				0.57	0.64	0.62	0.68	0.74			0.65				
	W5					0.63	0.62	0.66	0.71	0.75		0.67				
	W6						0.61	0.64	0.69	0.72	0.64	0.66				
	LDY	x	0.00	0.03	0.02	0.05	0.05	0.03	0.05	0.03	x			0.05		

Table 5.
DEA Window Analysis of Indonesian Islamic Commercial Banks, 2011-2020 (Continued)

Islamic Bank	Window	Efficiency Score										Summary Measures				
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean/ Window	The Mean	SD	LDW	LDP
PT BPD Nusa Tenggara Barat Syariah	W1	1.00	1.00	0.91	1.00	1.00						0.98	0.96	0.02	0.22	0.22
	W2		1.00	1.00	1.00	1.00	0.92					0.98				
	W3			1.00	1.00	1.00	0.82	1.00				0.96				
	W4				1.00	1.00	0.82	1.00	1.00			0.96				
	W5					1.00	0.91	1.00	1.00	0.78		0.94				
	W6						1.00	1.00	1.00	0.82	0.81	0.93				
	LDY	x	0.00	0.09	0.00	0.00	0.18	0.00	0.00	0.04	x			0.18		
PT Maybank Syariah Indonesia (PT Bank Net Syariah)	W1	1.00	0.67	0.92	0.95	1.00						0.91	0.95	0.03	0.33	0.33
	W2		1.00	0.92	0.95	1.00	1.00					0.97				
	W3			0.90	0.93	1.00	1.00	1.00				0.97				
	W4				0.93	1.00	1.00	0.88	1.00			0.96				
	W5					1.00	1.00	0.85	1.00	1.00		0.97				
	W6						1.00	0.85	1.00	1.00	0.80	0.93				
	LDY	x	0.33	0.02	0.02	0.00	0.00	0.15	0.00	0.00	x			0.33		

The results of the calculation of the DEA window analysis for the 14 Islamic commercial banks (BUS) in Indonesia during the 2011-2020 period are shown in Table 5. In general, all the Islamic banks increasingly experience fluctuations in efficiency. The most significant increase occurred at PT Bank Tabungan Pensiunan Nasional Syariah, which saw changes in the first 2011-2015 window (with efficiency values of 52%, 41%, 100%, 92%, and 100%), in the 2012-2016 window (with efficiency values of 56 %, 100%, 88%, 100%, and 100%), and in the last 2016-2020 window (with efficiency values of 90%, 70%, 77%, 100%, and 96%).

PT Bank Syariah Mandiri (BSI) and PT Bank Syariah Mandiri (BSI) both demonstrated increasing efficiency and relative stability, achieving 100% efficiency values by the end of the period. In the first window, namely 2011-15, and the second window, namely 2012-2016, the two banks both achieved efficiency values of 70% to 80%, which continued to increase until reaching values of 100% in the third, fourth, fifth and sixth windows, namely from 2013 to 2020. The DMUs of these two banks also show the highest average efficiency values, at 95% for PT Bank BRI Syariah (BSI) and 93% for PT Bank Syariah Mandiri (BSI).

The opposite was experienced by PT Bank Muamalat Syariah, which saw a significant reduction in efficiency from the 2011-2015 window (with a total efficiency value of 100%) to the second, third, and fourth windows (with average efficiency values per window of 97%, 94% and 88%). These fell in the fifth window in 2015-2019, with efficiency values of 100%, 84%, 91%, 72%, and 68%. PT Bank Muamalat Syariah experienced a drastic fall in efficiency values in the sixth window of 2016-2020, with values of 78%, 85%, 65%, 63%, and 65%. The bank recorded an average efficiency of 89%.

Based on the DEA window analysis, the Islamic commercial bank with the highest average score during the 2011-2020 research period was PT Bank BRI Syariah (BSI), with an average efficiency value of 95%. This was followed by PT Bank Syariah Mandiri (BSI), at 93%. Third place was occupied by PT BPD Nusa Tenggara Barat Syariah, a regional bank, which had an average efficiency value of 92%. The bank with the lowest average efficiency value during the study period was PT BCA Syariah, with an average value of 57%.

From the perspective of efficiency stability analysis through several statistical summaries such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP), and Long Distance per Year (LDY), the Islamic banks whcih had relatively stable efficiency scores were PT Bank BRI Syariah (BSI) and PT Bank Syariah Mandiri (BSI). PT Bank BRI Syariah (BSI) had a statistical value of 0.03 for SD, 0.02 for LDY, 0.20 for LDW, and 0.20 for LDP, while PT Bank Syariah Mandiri (BSI) had values of 0.03 for SD, 0.06 for LDY, 0.24 for LDW, and 0.24 for LDP. In addition, PT Bank BRI Syariah (BSI) had an average efficiency value of 0.98 during the observation period and PT Bank Syariah Mandiri (BSI) average of 0.97, both higher than most other Islamic banks.

Based on the results in Table 5, it can be noted that there are fluctuating levels of efficiency. In windows 2 to 3, the banks experienced an upward trend, but then declined in windows 3 to 4. A further slight downward trend in windows 5-6 can be seen. During the period 2011-2020, 2015 is the year in which all banks had a constant level of efficiency for each window.

Among the 14 banks, Bank BRI Syariah was ranked the most efficient and stable, followed by Bank Mandiri Syariah. The results show that BRI Syariah bank had the best performance, with an overall efficiency level of 98%, LDY 0.02, and SD 0.03, followed by Bank Syariah Mandiri, with an overall efficiency level of 97%, LDY 0.06 and SD 0.03.

However, from the results obtained, the banks as a whole appear to have varying degrees of efficiency in each window. For example, in contrast to Bank BRI Syariah, which was stable, BCA Syariah experienced instability. Although it saw an increased level of efficiency, the results show that the upward trend in this was not significant (57%, 64%, 62%, 68%, and 74%).

To further evaluate the performance of the Indonesian Islamic commercial banks, we classified them based on their level of efficiency and stability into four quadrants. Quadrant 1 consists of Islamic commercial banks with a high level of efficiency and efficiency stability, which are the top performers. Quadrant 2 consists of banks with a high level of efficiency, but less stability, while Quadrant 3 consists of those with low levels of efficiency, but which are are more stable. Finally, Quadrant 4 consists of banks that have a low level of efficiency and are also less stable. The efficiency column is derived from the average efficiency level in the window analysis results, while the stability shown in the efficiency column is generated from the long-distance per year (LDY) from the window analysis results. Figure 1 shows the details of the quadrant categories.

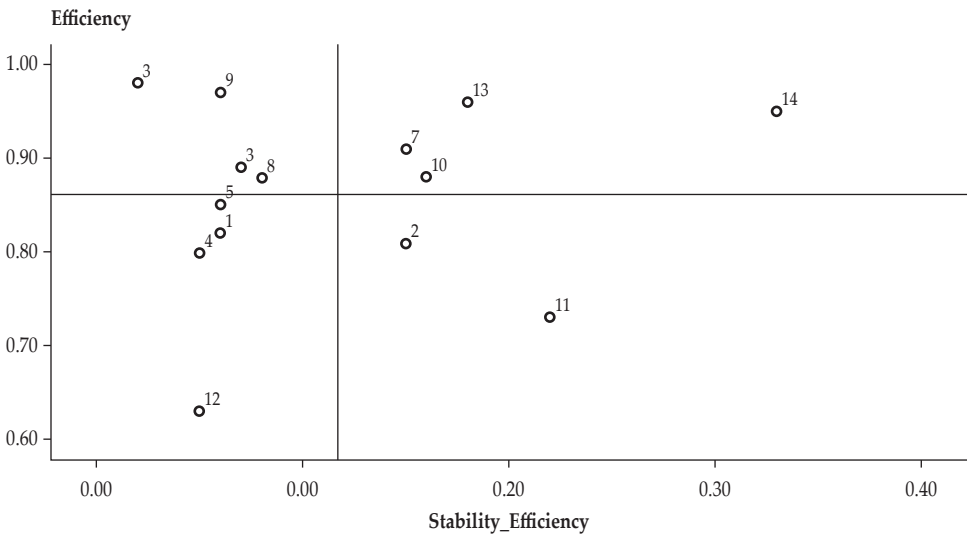

Figure 1.
Efficiency-Stability Efficiency Quadrant of Islamic Banks

As shown in Figure 1, out of the 14 Islamic commercial banks in Indonesia, only four had the highest levels of efficiency and stability, namely BRI Syariah Bank, Muamalat Syariah Bank, Bukopin Syariah Bank and Mandiri Syariah Bank. Interestingly, these results validate the Indonesian Islamic commercial bank

merger program of 2021 between Bank BRI Syariah, Bank Mandiri Syariah, and Bank BNI Syariah. The market perception of this merger program is trelatively positive and it is expected to become a sharia megabank in Indonesia. The findings suggest that the level of efficiency and stability of banks can be a tool to explain market perceptions of mergers (Kohers, Huang, & Kohers, 2000) and to consider mergers and acquisitions (M&A), as the merged banks are expected to function efficiently in a global context (Lin, Wang, & Shi, 2020).

Quadrant 2 consists of four sharia commercial banks: Panin Dubai Sharia Bank, Sharia National Pension Savings Bank, West Nusa Tenggara BPD Sharia Bank, and Clean Sharia Bank. In this quadrant, the banks tend to be efficient, but have unstable levels of efficiency. Quadrant 3 consists of two Islamic commercial banks: BNI Syariah Bank and Victoria Syariah Bank. This quadrant includes Islamic commercial banks that have low efficiency levels but were able to maintain their stability during the 2011-2020 period.

On the other hand, because Aceh Sharia Bank, West Java Sharia Banten Sharia Bank, Mega Sharia Bank, and BCA Sharia Bank are in quadrant 4, they are considered to be the worst performers in terms of efficiency and stability during the study period. Islamic commercial banks that fall into this category are unable to maintain their efficiency; that is, they make insignificant progress or struggle to take big steps to keep up with market conditions.

4.2. Analysis

The increase in the growth in efficiency of Islamic banks is largely due to technological changes (Abbas, Hammad, Elshahat, & Azid, 2015; Ajija, Yasin, & Albra, 2017; Jreisat, Al-Barghouthi, Qasim, & Nimer, 2017; Nugrohowati, Fakhrunnas, & Haron, 2020; Omar, Abd. Majid, & Rulindo, 2007; Rani et al., 2020). Internal bank variables are also stronger than macroeconomic conditions in their effect on the efficiency of Islamic banks (Andriyani, Usman, & Pambuko, 2020). Other studies have shown that higher lending activity increases bank profit efficiency, but harms cost efficiency (Srairi, 2010).

Cost efficiency is specifically positively related to liquidity risk, as are capital, bank specialisation, credit risk, profitability, size, inflation, market concentration, and crisis (Amin, Ali, & Nor, 2018). In many studies, Islamic banks have shown marginal efficiency gains compared to conventional banks for most of the year (Abdul-Majid, Saal, & Battisti, 2010; Jubilee et al., 2021). The factors that affect the efficiency of Islamic banks are bank size, credit risk, market power, management efficiency, and inflation (Kamarudin et al., 2020). Capitalisation, liquidity, and determinants of the world financial crisis also tend to have a significant effect on the efficiency level of Islamic banks (Kamarudin et al., 2017).

Another study that obtained different results shows that Islamic banks experience inefficiency, which is caused by external factors, and not by managerial ones (Rodoni et al., 2017). Regarding internal factors, the orientation of input and output does not make a significant difference, which shows the optimisation aspect in efficiency and output expansion. In terms of productivity, the growth trend continues to increase due to managerial factors rather than technological ones, which can increase efficiency in the banking industry.

A further study found that the main source of technical inefficiency that occurs in Islamic banks is the small scale of their operations (Rahim et al., 2013). In addition, several studies demonstrate that the operational costs of Islamic banks are not significant and have a positive effect on total financing; that total assets have a significant and positive effect on total financing; and that labour costs are not significant and have a negative effect on total financing (Hersugondo et al., 2021).

Table 6.
Indonesian Islamic Commercial Banks' Potential Improvement

Islamic Bank	X1	X2	X3	Y1	Y2
PT Bank Aceh Syariah	28%	0%	0%	0%	0%
PT Bank BNI Syariah (BSI)	0%	0%	0%	30%	0%
PT Bank BRI Syariah (BSI)	0%	0%	0%	0%	0%
PT Bank Jabar Banten Syariah	73%	0%	0%	0%	0%
PT Bank Mega Syariah	78%	0%	0%	26%	0%
PT Bank Muamalat Syariah	84%	0%	7%	0%	0%
PT Bank Panin Dubai Syariah	0%	0%	0%	0%	0%
PT Bank Syariah Bukopin	0%	0%	0%	0%	0%
PT Bank Syariah Mandiri (BSI)	0%	0%	0%	0%	0%
PT Bank Tabungan Pensiunan Nasional Syariah	34%	0%	0%	0%	0%
PT Bank Victoria Syariah	0%	0%	0%	39%	0%
PT BCA Syariah	59%	0%	0%	0%	0%
PT BPD Nusa Tenggara Barat Syariah	40%	0%	0%	0%	0%
PT Maybank Syariah Indonesia (PT Bank Net Syariah)	35%	0%	0%	9%	0%

At the bank level, DEA also provides information on potential improvements through sensitivity analysis. Table 6 shows the results of the sensitivity analysis for each bank in the 2020 dataset, indicating the amount of slack (the difference between the projected efficiency value and the original value of the data) in each controllable input and observation output for each bank. The slack variable is used to identify sources of inefficiency. If a variable tends to be low, it means the bank is not fully efficient because inputs can be reduced without reducing output. Slack is calculated by comparing the inputs and outputs of each bank with those of the efficient bank reference dataset. The efficient reference banks are those that operate under similar circumstances to the banks being compared, but have 100% efficiency and a gap of 0%.

For example, PT Bank Aceh Syariah can become efficient (increasing efficiency to 1.00) by increasing all inputs X1 by 28% total slack. The possible savings shown in the table 6 above reveal the usual level of inefficiency with respect to the variable that Islamic banks need to improve. In certain banks, there is considerable scope for reducing inputs or a need to increase output.

V. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study has calculated the efficiency scores of 14 Islamic Commercial Banks (BUS) in Indonesia in the 2011-2020 period. The scores fluctuate over the period and have an average value of 80%. At the beginning of the period, or in 2011, the average efficiency of all the banks was 74%. This then increased in 2013, 2014, and 2015 to 84%, 85%, and 89% respectively, but then gradually declined before stabilising at between 70% and 80%. This can be explained by several reasons, ranging from the relatively high level of competition and bank management performance, to economic fluctuations at home and abroad that affected the efficiency of Indonesian Islamic banks.

Based on the DEA window analysis, the Islamic commercial bank with the highest average score during the 2011-2020 research period was PT Bank BRI Syariah (BSI), with an average efficiency value of 95%. The results obtained are similar to those of measurements using the standard CRS method. The difference that does appear is that the average efficiency value of the DEA window analysis is relatively higher than the results of the standard CRS model. This is because the greater the number of observations employed, the lower the efficiency value. The advantage of the DEA window analysis model is that it can measure efficiency stability through several statistical measures.

The findings at the DEWA stage also show that 12 Islamic banks in Indonesia had consistent levels of efficiency, with an LDY (Long Distance per Year) score below 0.2. However, two of these, namely PT Bank Victoria Syariah and PT Maybank Syariah Indonesia, had high LDY levels in several years, with scores of 0.22 and 0.33. The Islamic bank with the highest efficiency level score consistency was PT Bank BRI Syariah, with a maximum LDY score of 0.02. The other banks achieved LDY scores between 0.05 and 0.18.

The study has also provided a classification of potential improvement for each input and output variable. The results of the analysis show that Islamic banks in Indonesia need to improve their fixed asset input and financing output. Meanwhile, other inputs and outputs are dominated by banks that have an efficient status with an improvement rate of 0% so that there is nothing that needs to be improved.

By using the DEWA research method in calculating the efficiency level of Islamic banking in Indonesia, the study has filled the gap in previous studies, most of which use the standard DEA approach. The results of this study can assist Islamic banking in evaluating efficiency scores in Indonesia. By referring to the input and output variables, banking practitioners can identify the variables that need to be improved in order to obtain the maximum level of efficiency.

5.2. Recommendations

Banks with both high and low efficiency scores need to pay attention to the level of consistency in order to face major challenges in the form of intense competition and major adverse shocks. They are advised to look for strategies to maintain their competitive advantage in order to achieve positive and consistent levels of efficiency. They should focus on improving the variables indicated by potential improvements, namely the input and output variables that can be improved to achieve the maximum efficiency level for each.

Other suggestions for Islamic banking include the need to pay further attention to improving technology in order to increase efficiency; for example, in the form of adding digital-based services, improving customer data security systems, and implementing branchless banking. Such technological improvements would strengthen the efficiency of Islamic banks, allowing them to operate better. Policymakers also need to strengthen supervision and guidance to improve efficiency. The management of Islamic banks must also evaluate existing regulations in order to continuously improve efficiency, maintain performance, and improve service quality and the quality of the information provided to the public to be able to compete in the domestic and international banking industry.

This research can be a reference and benchmark for Islamic banking in terms of efficiency scores and their stability based on the DEWA method. It could assist Islamic banks in identifying the variables that need to be improved to increase their efficiency scores. The results could also help Islamic banks to map their future strategies and develop the relevant variables.

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APPENDIX

Indonesian Islamic Commercial Bank Quadrant Category

Islamic Bank	Efficiency	Stability of efficiency	Quadrant
PT Bank Aceh Syariah	0.82	0.06	IV
PT Bank BNI Syariah (BSI)	0.81	0.15	III
PT Bank BRI Syariah (BSI)	0.98	0.02	I
PT Bank Jabar Banten Syariah	0.80	0.05	IV
PT Bank Mega Syariah	0.85	0.06	IV
PT Bank Muamalat Syariah	0.89	0.07	I
PT Bank Panin Dubai Syariah	0.91	0.15	II
PT Bank Syariah Bukopin	0.88	0.08	I
PT Bank Syariah Mandiri (BSI)	0.97	0.06	I
PT Bank Tabungan Pensiunan Nasional Syariah	0.88	0.16	II
PT Bank Victoria Syariah	0.73	0.22	III
PT BCA Syariah	0.63	0.05	IV
PT BPD Nusa Tenggara Barat Syariah	0.96	0.18	II
PT Maybank Syariah Indonesia (PT Bank Net Syariah)	0.95	0.33	II
Mean	0.86	0.12	

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