DIJEFA:
Dinasti International Journal of Economics, Finance & Accounting
E-ISSN: 2721-303X
P-ISSN: 2721-3021
https://dinastipub.org/DIJEFA dinasti.info@gmail.com +62 811 7404 455

DOI: https://doi.org/10.38035/dijefa.v6i6.5870
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Received: 09 November 2025 | **Revised:** 06 December 2025 | **Accepted:** 19 December 2025

Technical Efficiency of Digital and Non-Digital Banks in Indonesia: A Data Envelopment Analysis (DEA) Approach for the 2024–2025 Period

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Abstract: This study aims to analyze the efficiency of digital and conventional banks in Indonesia using the Data Envelopment Analysis (DEA) method and examine the effects of bank size, digitalization, and credit risk on efficiency. The data covers eight digital banks and eight conventional banks during the 2024–2025 period, with input variables: labor costs, total assets, and operational costs; and output variables: interest income, third-party funds (TPF), and total disbursed credit. The analysis results show that digital banks have a higher average efficiency level (0.91) than conventional banks (0.83). Bank size has a significant positive effect on efficiency, while digitalization and credit risk (NPL) have a negative effect. These findings emphasize the importance of business scale and risk management in maintaining banking efficiency in the digital era.

Keywords: Bank Efficiency, DEA, Digitalization, Bank Size, Credit Risk.

INTRODUCTION

The development of digital technology has driven a major transformation in the global banking sector, including in Indonesia. Banks are now competing to digitize their services to improve operational efficiency, expand customer reach, and increase competitiveness. Digital banking is not only transforming the way banks interact with customers but also impacting their cost structure, revenue, and productivity.

In this context, the need for objective measurement of banking performance efficiency arises. One widely used approach is Data Envelopment Analysis (DEA), a non-parametric, mathematically based method used to measure the relative efficiency of decision-making units (DMUs), such as bank branches or the banking institution as a whole. DEA is able to capture the relationship between inputs and outputs in a production system, making it suitable for assessing the technical efficiency of both digital and non-digital banks (Charnes, Cooper and Rhodes, 1978).

The use of DEA in analyzing the efficiency of digital and non-digital banks has become increasingly relevant due to significant differences in their operational models, cost structures, and service strategies. Digital banks tend to utilize information technology as their primary operational base, while non-digital banks still rely on physical interactions and branch networks. Therefore, DEA can help illustrate how these different business models impact the efficiency of each bank.

Several previous studies have shown that digital banks have the potential for higher efficiency due to greater economies of scale and lower operational costs (Ozili, 2018; Anderloni, L., & Bongini, 2009). However, not all studies have specifically compared the efficiency performance of digital and non-digital banks within a single DEA analysis framework. Therefore, a more in-depth study is essential to identify the input and output factors that most influence the efficiency of each type of bank.

The digital transformation in the banking industry has given rise to new models of bank operations, such as digital banks (neo-banks) that operate without physical offices, as well as traditional banks that have begun to gradually implement digital services. Although the adoption of digital technology is believed to reduce operational costs and expand service access, empirical findings on the efficiency of digital banks in Indonesia still show mixed results. Studies by Prayudya et all (2023) and Prayudya et all (2025) found that the DEA efficiency scores of digital banks like Bank Jago were below those of traditional banks with large assets like BRI and BTN, while research by Rivai, 2022 actually reported increased efficiency as the proportion of IT spending increased. This inconsistency raises questions about whether digital banks have truly achieved full efficiency or are still hampered by factors of scale, cost structure, and poorly managed operational risks.

METHODS

This research falls into the comparative quantitative research category with a descriptive and inferential approach. The primary objective of this study is to analyze and compare the efficiency levels between digital and non-digital banks in Indonesia using a three-stage Data Envelopment Analysis (DEA) method. The quantitative approach was used because this research focuses on processing numerical data (secondary data) and statistical hypothesis testing.

The population in this study includes all commercial banks in Indonesia that actively operated during the 2024–2025 period. The research sample was drawn using purposive sampling, namely banks that met the following criteria:

1. Registered as a conventional commercial bank or a fully digital bank (neo-bank).
2. Have complete and accessible monthly financial reports throughout the observation period.
3. Consistently implement their business model (digital or non-digital) throughout the study period.

Table 1. Sample

Bank Konvensional		Bank Digital	
1.	Bank Sinarmas	1.	Seabank
2.	Bank Jtrust Indonesia	2.	Bank Raya Indonesia
3.	Bank Victoria International	3.	Bank Jago
4.	Bank Mestika Dharma	4.	Bank KEB Hana Indonesia
5.	Bank Mayapada International	5.	Super Bank
6.	Bank OCBC NISP	6.	Bank Jasa Jakarta

Source: Primary data, 2025

This research does not use variables in the conventional sense as in experiments, but uses inputs and outputs which are components of the DEA model.

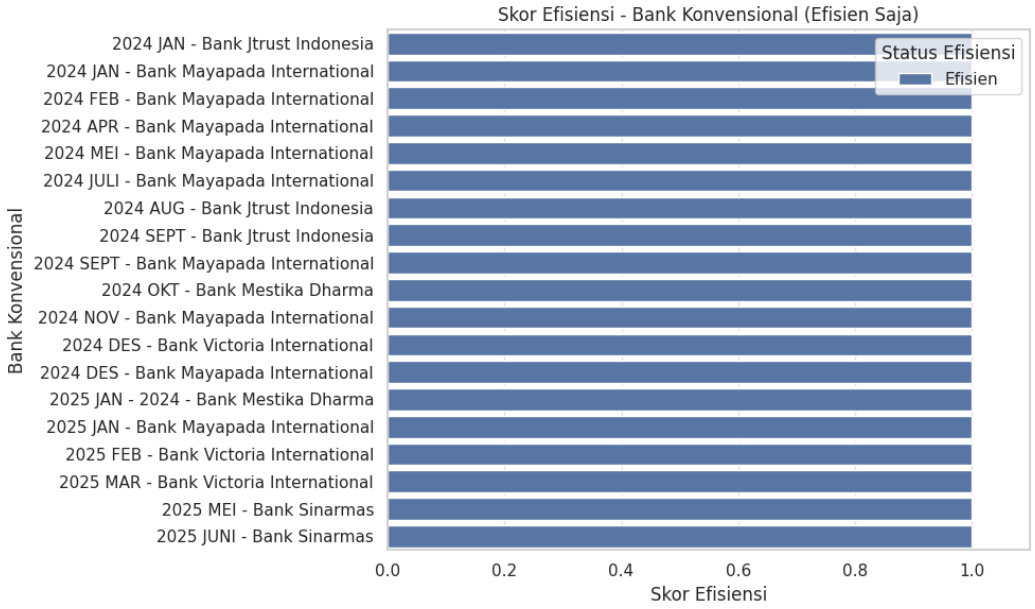
Table 2. Research Variables

Input Variables	Definition	Data Source
1. Labor Costs	Costs incurred by the Company's operations, within the scope of HR.	Financial statements
2. Total Assets	All of the company's economic resources.	Financial statements
3. Operational costs	All activity costs incurred by banking companies.	Financial statements
Output Variables	**Definition**	**Data Source**
1. Interest Income	The main income of the bank comes from the activity of distributing funds to other parties.	Financial statements
2. Dana Pihak Ketiga (DPK)	Funds collected from other parties used for credit distribution.	Financial statements
3. Total Credit Distributed	The total amount of loans disbursed to debtors and recorded as debtor liabilities.	Financial statements

Source: Primary data, 2025

RESULTS AND DISCUSSION

An organization is said to be efficient if its value reaches 100% or is equal to 1. The further the company's value is from perfect (100%) or closer to 0, the less efficient the company is (Akbar, 2009). (Kusumastuti et al., 2008) said that the indicator that is often and commonly used in measuring bank performance is by using economic indicators or references.

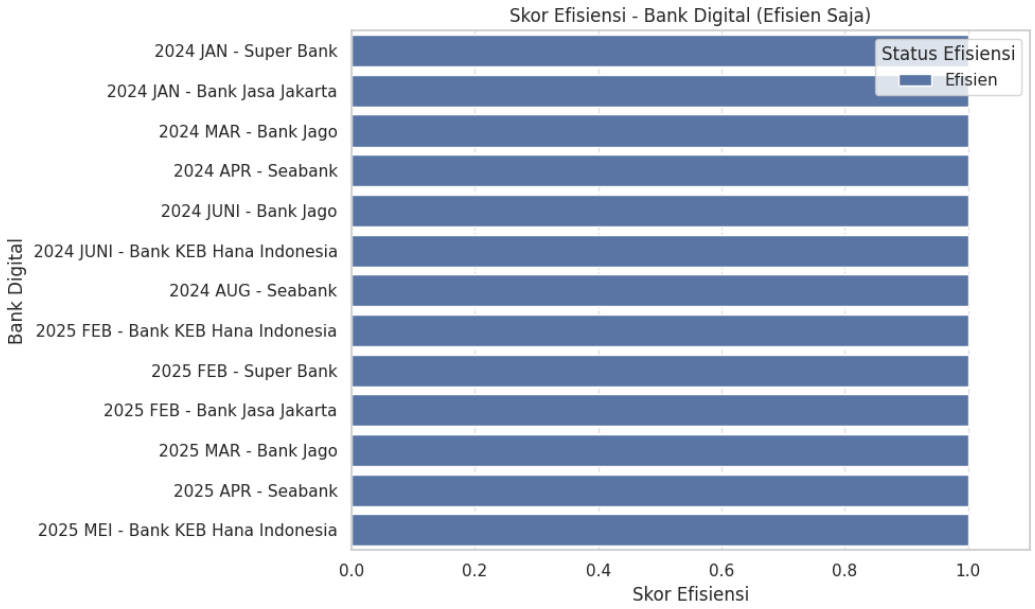


Source: Research Results

Figure 1. Conventional Bank Efficiency Score

Based on data processing using MaxDEA software, each bank's efficiency score was obtained. Efficiency scores range from 0 to 1, with a value of 1 indicating the bank is on the efficiency frontier (efficient), while a value below 1 indicates relative inefficiency.

From the graph above, it can be concluded that the efficient bank throughout 2024 is Bank Mayapada Internasional and in 2025 it is Bank Sinarmas and Bank Victoria.



Source: Research Results

Figure 2. Conventional Bank Efficiency Score

From the graph above, it can be concluded that the efficient banks throughout 2024 are Bank Sea Bank and Bank Jago, and in 2025 it is Hana Bank.

Table 3. Descriptive Statistics

Tahun	Jenis Bank	N	Rata-rata	Std. Dev	Min	Max
2024	Bank Digital	72	0,4625	0,3289	0,0022	1,0000
2024	Bank Konvensional	72	0,8543	0,1680	0,3848	1,0000
2025	Bank Digital	35	0,5356	0,3235	0,0099	1,0000
2025	Bank Konvensional	36	0,8606	0,1988	0,3155	1,0000

Source: Processed data, 2025

Based on the table above, it can be seen that the average efficiency value of conventional banks is higher than that of digital banks, both in 2024 and 2025. The larger standard deviation value of digital banks indicates a higher variation in efficiency among digital banks.

Hypothesis Testing

Hypothesis testing was conducted to determine whether there is a difference in efficiency between digital banks and conventional banks. The hypotheses tested were:

H_0: There is no difference in efficiency, or the efficiency of digital banks is less than that of conventional banks.

H_1: The efficiency of digital banks is greater than that of conventional banks.

Table 4. Levene's Test Table for Both Types of Banks

Tahun	N Digital	Mean Digital	N Konv	Mean Konv	Levene Stat	Levene p	t-stat	p (one-tailed)	Keputusan
2024	144	0,4625	72	0,8543	21,0754	0,000010	-9,0035	1,000000	Terima H_0
2025	71	0,5356	36	0,8606	19,6111	0,000035	-5,0834	0,999998	Terima H_0

Source: Processed data, 2025

Based on the Levene test results, a significance value of $p < 0.05$ was obtained, indicating that the variances of the two groups were not homogeneous. Therefore, a t-test was used with

the assumption of unequal variances (Welch's t-test). A negative t-value indicates that the average efficiency of digital banks is lower than that of conventional banks. A one-tailed p-value ≈ 1 indicates that there is no evidence to reject H_0.

H_0: Bank size (total assets) has no significant effect on bank efficiency.

H_2: Bank size (total assets) has a significant effect on bank efficiency.

Table 5. Correlation between Total Assets and Efficiency Score

Tahun	N	Pearson r	p (one-tailed)	p (two-tailed)	Spearman rho
Gabungan	216	0,190867	0,002491	0,004982	0,184820
2024	144	0,256012	0,000977	0,001953	0,251676
2025	71	0,024335	0,420179	0,840358	0,013059

Source: Processed data, 2025

Table 6. Simple Linear Regression of Total Assets with Efficiency Score

Tahun	N	β (SIZE ln)	SE	t	p (one-tailed)	p (two-tailed)
Gabungan	216	0,050061	0,017641	2,837782	0,002491	0,004982
2024	144	0,064191	0,020340	3,155904	0,000977	0,001953
2025	71	0,006991	0,034574	0,202198	0,420179	0,840358

Source: Processed data, 2025

Based on the results of the Pearson and Spearman correlation tests in Table 5, it was found that the relationship between bank size (ln total assets) and efficiency was positive throughout the observation period. The combined correlation value of 0.1909 with p(one-tailed) = 0.0025 indicates that the relationship is statistically significant at the 95% confidence level. This means that the larger a bank's asset size, the higher its efficiency.

The regression results in Table 6 show that for the combined data for 2024–2025, the regression coefficient β = 0.0501 (SE = 0.0176; t = 2.838; p = 0.0025). This positive and significant coefficient value indicates that increasing bank size (total assets) is positively related to the DEA efficiency score. Thus, H_0 is rejected and H_2 is accepted, meaning bank size has a positive and significant effect on efficiency.

H_0: The intensity of digitalization (as proxied by operational costs) has no significant effect on bank efficiency.

H_3: The intensity of digitalization (as proxied by operational costs) has a significant effect on bank efficiency.

Table 7. Correlation Test between ln(Operating Cost) and Efficiency Score

Tahun	N	Pearson r	t	p (two-tailed)	Spearman ρ
Gabungan	216	0,112696	1,659	0,098545	0,008645
2024	144	0,151027	1,821	0,070776	0,060037
2025	71	0,048199	0,401	0,689777	-0,041835

Source: Processed data, 2025

Table 8. Simple Linear Regression Test: Efficiency Score ln(Operating Cost)

Tahun	N	β (ln OPEX)	SE	t	p (two-tailed)	R^2
Gabungan	216	**0,012091**	0,00729	1,659	**0,098545**	0,0127
2024	144	**0,013350**	0,007333	1,821	**0,070776**	0,0228
2025	71	**0,008641**	0,021557	0,401	**0,689777**	0,0023

Source: Processed data, 2025

The results in Table 7 indicate that the relationship between ln(Operating Costs) and the Efficiency Score is positive but weak. In the combined data for all banks, the Pearson correlation coefficient is 0.1127 with a significance level of p = 0.0985, indicating insignificant at the 5% level. The Spearman correlation value is also very small (ρ = 0.0086), indicating there is no strong monotonic relationship between the two variables. In 2024, the correlation increased slightly to r = 0.1510, but remained insignificant (p = 0.0708), while in 2025, the correlation weakened (r = 0.0482, p = 0.6898). This means that during the 2024–2025 study period, there was no evidence that increasing operating costs had a significant negative relationship with bank efficiency.

Furthermore, the simple linear regression results in Table 8 show that the coefficient β (ln OPEX) is positive in all models (combined β = 0.0121; β 2024 = 0.0134; β 2025 = 0.0086) and is not statistically significant (p > 0.05). Since the direction of the hypothesis H_3 assumes a negative relationship (β < 0), these results indicate that H_0 cannot be rejected, or in other words, there is no significant negative influence between digitalization intensity (operational costs) and bank efficiency.

H_0: Credit risk (NPL) does not significantly affect bank efficiency.
H_4: Credit risk (NPL) significantly affects bank efficiency.

Table 9. Correlation Test between NPL and Efficiency Score

Tahun	N	Pearson r	t	p (two-tailed)	Spearman ρ
Gabungan	216	−0,319161	−4,926586	0,000002	−0,285273
2024	144	−0,346340	−4,399406	0,000021	−0,337372
2025	71	−0,242608	−2,077310	0,041497	−0,160192

Source: Processed data, 2025

Table 10. Regression Test between NPL and Efficiency Score

Tahun	N	β (NPL)	SE	t	p (two-tailed)	R^2
Gabungan	216	−0,092163	0,018707	−4,926586	0,000002	0,101864
2024	144	−0,093494	0,021251	−4,399406	0,000021	0,119952
2025	71	−0,084634	0,040742	−2,077310	0,041497	0,058858

Source: Processed data, 2025

The H_4 test indicates that credit risk (NPL) has a significant negative relationship with bank efficiency (DEA score). In the aggregated data for all banks, a Pearson correlation of −0.319 ($p<0.001$) and a regression coefficient of β(NPL) = −0.092 ($t=-4.927$; $p<0.001$) indicate that increasing NPLs are correlated with decreasing efficiency. Consistent evidence is seen in the year-by-year analysis: 2024 ($\beta=-0.093$; $p<0.001$) and 2025 ($\beta=-0.085$; $p=0.041$), both significantly negative. The R^2 values range from 0.06–0.12, meaning NPLs explain approximately 6–12% of the variation in efficiency scores—a moderate effect size for an industry study.

Economically, the β coefficient reflects the sensitivity of efficiency to changes in NPL: each 1-point increase in NPL (e.g., from 2% to 3%) is associated with a decrease in efficiency of ≈0.085–0.093 points (depending on the year). This result is consistent with the theory that non-performing loans increase cost burdens (provisions, collections, restructuring) and reduce asset productivity, resulting in a relative decline in frontier efficiency.

CONCLUSION

The level of efficiency between digital banks and non-digital banks in Indonesia

Conventional banks remain more efficient than digital banks in the 2024–2025 period. On average, conventional banks' efficiency is around 0.85, while digital banks' efficiency is

below 0.55. This can be explained by operational aspects and business structure. Conventional banks already have larger economies of scale, established infrastructure, and experience in asset and cost management. In contrast, digital banks are still in the expansion phase and undergoing significant technology investment, resulting in higher operational costs.

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H_0: There is no difference in efficiency or the efficiency of digital banks ≤ conventional banks.

Bank size (total assets) on bank efficiency

Theoretically, these results align with the theory of economies of scale, which states that the larger a company, the more efficient it is in utilizing its resources. In the banking context, large banks possess competitive advantages in the form of investment in information technology, extensive distribution networks, and diversified product and credit portfolios. This enables large banks to reduce operating costs per unit of asset and increase workforce productivity.

Empirically, these findings have important implications for bank management and regulators. For management, the results demonstrate that asset expansion strategies and financial structure optimization must be accompanied by improvements in operational quality to achieve sustainable efficiency. For regulators, these results emphasize the need for proportional oversight of large banks to prevent scale dominance from creating a competitive imbalance with smaller and digital banks.

H_2: Bank size (total assets) has a significant effect on bank efficiency.

The Intensity of Digitalization on Bank Efficiency

Theoretically, increasing operational costs are expected to reduce efficiency if they are not offset by increased productive output. However, the results of this study indicate a positive (albeit weak) relationship, indicating that increasing operational costs do not necessarily reduce bank efficiency. This can be explained because the majority of operational expenditures in the observation period (2024–2025) were strategic expenditures for digitalization, such as the development of technology infrastructure, cybersecurity, and digital service channels. These expenditures tend to increase long-term efficiency by lowering transaction costs and accelerating service processes, although in the short term they increase total operational costs.

H_0: The intensity of digitalization (proxied by operational costs) does not have a significant effect on bank efficiency.

Credit risk (NPL) on bank efficiency

In a simple linear regression test, the regression coefficient value $\beta = -0.092$ ($p<0.001$) was obtained for the combined data. This negative value confirms that the higher the NPL level, the lower the bank's efficiency score tends to be. Economically, this illustrates that every 1% increase in NPL has the potential to reduce the efficiency score by approximately 0.09 points. In other words, an increase in non-performing loans directly worsens the bank's operational performance in utilizing input resources to produce optimal output.

Theoretically, this finding aligns with Berger & Deyoung, 1997, view that an increase in the NPL ratio will increase provision and collection costs and reduce net interest income, thereby reducing a bank's technical efficiency. In the context of digital banks, low NPL levels reflect the effectiveness of data-driven credit analysis and automated risk assessment, while in

conventional banks, higher NPLs may indicate weak credit portfolio oversight and lower operational efficiency.

H_4: Credit risk (NPL) has a significant effect on bank efficiency.

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