International Journal of Business and Society, Vol. 26 No. 1, 2025, 135-150

DIGITAL TRANSFORMATION AND EFFICIENCY: EVIDENCE FROM INDONESIAN BANKS

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ABSTRACT

Recent studies suggest that digitalization does not uniformly enhance bank efficiency. A critical factor influencing this outcome is the size of the institution undergoing digital transformation (DT). Small and medium-sized commercial banks often encounter challenges such as limited financial resources and difficulty in adapting digital solutions that align with market conditions, thereby leading to DT failures. This study investigates the impact of DT on bank efficiency. Our analysis focuses on a sample of conventional Indonesian banks from 2015 to 2023. We also explore how digitalization affects the efficiency of both large and small banks. Regression analysis reveals nuanced findings. In large banks, the coefficient of DT^2 does not significantly affect performance, whereas in small and medium-sized banks, it exhibits a statistically significant negative relationship. This suggests that digitalization influences bank performance non-linearly, posing different implications for banks of varying sizes. This study contributes to understanding the heterogeneous impacts of DT on bank efficiency, offering insights relevant not only to the Indonesian banking sector, but also to other emerging markets undertaking similar DT strategies.

Keyword: Digital Transformation, Efficiency, Firm Size, Indonesian Banking, Non-Linear Relationship

Received: 23rd October 2024
Accepted: 10th February 2025
https://doi.org/10.33736/ijbs.9555.2025

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1. INTRODUCTION

The digital revolution has profoundly transformed the banking and financial sectors globally, introducing new efficiencies and reshaping traditional operational models (Dermine, 2016). In recent years, digitalization has brought significant changes to the banking industry, including in Indonesia. This process has transformed how financial institutions operate and serve customers with more modern and technology-driven approaches (Kitsios et al., 2021). Digital transformation promises substantial improvements in the efficiency of financial management and services (Chen et al., 2016). In Indonesia, this transformation is particularly critical due to the central role banks play in the national financial system. Banks dominate the financial landscape, holding the majority of financial assets. Therefore, any improvement in banking efficiency has far-reaching implications for economic growth, financial inclusion, and customer satisfaction.

Digital technologies promise to drive innovation, improve service delivery, and create efficiencies. In banking, efficiency—commonly measured by the cost-to-income ratio (CIR)—is a key performance metric linked to profitability, customer service, and financial stability (Lee et al., 2021; Safitri et al., 2019). Digitalization enables banks to optimize operations, as evidenced by the adoption of self-service technologies like mobile and internet banking. These innovations reduce dependency on physical branches and enhance accessibility for customers across various geographic regions (Lestari et al., 2023; Nguyen et al., 2023).

However, the journey toward full digitalization is not without challenges, especially in developing countries like Indonesia. The early stages of digitalization require significant financial resource allocation (Cheng et al., 2024). Banks must invest substantial capital to build modern technological infrastructure and strengthen security systems to protect increasingly complex customer data (Jameaba, 2024). The development of digital banking applications also becomes a priority, including services like mobile banking apps to facilitate customer transactions. Artificial intelligence (AI) adoption in customer services also demands significant resources (Berman, 2012). Furthermore, integrating new technologies often brings unexpected technical challenges, such as operational disruptions or system downtimes. Customers often feel overwhelmed by new technological changes, requiring time to adapt. Employee training also demands additional budgets.

At this early stage, operational efficiency tends to decline while costs increase. However, this is a necessary long-term investment (Nasiri et al., 2022). With proper management, these inefficiencies can be managed until banks achieve stability. Over time, banks begin to find a turning point in this U-shaped pattern (Ayadi et al., 2025; Xiang & Jiang, 2023a). They start optimizing processes by leveraging the full potential of digital technology. Advanced data analytics enable a better understanding of customer needs. For example, service preferences can be predicted based on transaction patterns. Artificial intelligence also helps detect risks in real-time, enhancing data security and preventing fraud. Process automation, such as Robotic Process Automation (RPA), accelerates repetitive tasks, letting staff to focus on higher-value tasks.

Cloud computing plays an important role in supporting service scalability. Cloud-based solutions enable more efficient data management and service expansion at lower costs. This combination of

technologies creates a foundation for better operational efficiency. Banks are beginning to realize tangible benefits from their investments, including reduced operational costs and increased productivity.

Banks in Indonesia are largely dominated by smaller-asset banks, such as BUKU 1 and BUKU 2 banks. Limited assets often restrict their ability to invest in advanced technologies or large-scale digital transformation. Consequently, smaller banks face unique challenges in competing with larger institutions that have greater financial and technological resources (Do et al., 2022a; Hoque et al., 2024). The dominance of smaller banks also means that the digitalization progress of the banking system is uneven. Nonetheless, the role of smaller banks remains crucial in serving niche markets, local communities, and underserved populations across the archipelago. Their presence is essential for promoting financial inclusion.

Understanding the impact of digitalization on banking efficiency in Indonesia is critical. With a large population spread across various islands, digital banking solutions offer significant opportunities to expand financial services to underserved areas. Moreover, the competitive banking landscape in Indonesia and globalization pressures demand banks prioritize cost reduction and process optimization. Digital transformation, therefore, becomes a crucial strategy for maintaining profitability and enhancing service quality. However, the unique challenges faced by Indonesian banks—from regulatory compliance to infrastructure disparities—necessitate a localized approach to assessing the impact of digitalization.

The novelty in measuring banking digitalization can be addressed by adopting the stages of digital transformation introduced by Cisco Consulting (Bradley et al., 2014). This approach categorizes banking digitalization into four evolutionary stages, reflecting the maturity of an institution's digital capabilities. The remaining of this paper is structured as follows: Section 2 provides the theoretical background and hypotheses development. Section 3 outlines the research method. Section 4 discusses the empirical results. In Section 5, we summarize the paper and admit limitations. Moreover, topics for further research are provided in this section.

2. THEORETICAL BACKGROUND AND RESEARCH HYPOTHESES

Schumpeter postulates a theory of creative destruction emphasizing that dynamic imbalances are common in a rapidly growing economy (de La Grandville, 2007). According to this theory, economic growth comes from an evolutionary process of the economic structure. The old equilibrium is disrupted to create a new, more productive equilibrium. This process involves replacing the old with the new and reallocating resources to drive growth. Innovations and technological changes made by companies will eliminate old methods and products, and create new opportunities and value (Wen et al., 2022). Innovation drives economic development by creating new value and optimizing efficiency.

In the context of DT, this theory suggests that the implementation of digital technologies by commercial banks can lead to significant changes in their operations and services. This can result

in improved efficiency, innovative products, and ultimately, higher profitability. DT facilitates the transition from obsolete to more adaptable business models that better meet market and customer needs. This transformation includes the adoption of new technologies, such as mobile banking, digital payment platforms, big data analytics, and AI, to improve banking services and operations. These technologies can help banks reduce costs, improve service speed and accuracy, and provide more personalized and relevant products and services to their customers.

DT has become a crucial factor in driving profitability across various sectors, particularly in the banking industry. Ren et al. (2024a) confirm that adopting digital technologies not only increases revenue but also improves cost efficiency through better risk management, resulting in higher Z-scores, reduced non-performing loans (NPLs), and enhanced cost-to-income ratios (CIRs). These advancements highlight the dual benefits of DT, which provides both increased revenue and reduced costs for financial institutions.

Technology like automation, big data, artificial intelligence (AI), and digital banking services can simplify operational processes, accelerate service time, and reduce costs. However, despite these significant benefits, the link between digitalization and efficiency is not always linear. Studies show that this relationship can form a U-shaped pattern, where efficiency initially declines in the early stages of digital adoption, then improves during the growth phase as technology integration matures (Brynjolfsson & McAfee, 2014; Ayadi et al., 2025; Xiang & Jiang, 2023a). Over time, banks begin to adopt new technologies and leverage their potential. The non-linear curve plays a significant role in this phase, where efficiency gradually recovers after initial challenges are overcome. The automation of manual processes, such as transaction settlement, risk management, and customer data processing, starts to yield positive impacts. Technologies like artificial intelligence (AI) also enhance efficiency by facilitating more accurate and faster data analysis, thereby supporting strategic decision-making. At this stage, technology also drives innovation in banking business models. For example, digital banking services via mobile applications or chatbot services provide better and more efficient customer experiences. These features reduce operational burdens in physical branches and allow banks to serve more customers with the same resources (Chui et al., 2016; Davenport & Ronanki, 2018).

As the level of digitalization increases, banks begin to achieve maximum efficiency. Mature technology integration enables fully automated systems, such as instant payments, digital portfolio management, and risk management algorithms. At this stage, banks can leverage big data to offer more personalized solutions to customers, enhance customer loyalty, and reduce churn rates. Moreover, efficiency at this stage is driven by lower operational costs, as processes that previously required human interaction are replaced by automated technology. For instance, in loan processing, creditworthiness analysis that previously took days can now be completed in minutes using machine learning algorithms (Gill et al., 2017).

Thus, it can be hypothesized that digitalization has a U-shaped relationship with efficiency. In the early stages, efficiency tends to decline due to initial implementation challenges. As technology adoption progresses, efficiency increases due to process optimization and better technology integration (Zhou & Liu, 2023).

H1: There is a non-linear impact of Digitalization on the efficiency of commercial banks.

3. RESEARCH AND METHODOLOGY

Data

We use data from 54 conventional banks in Indonesia for the years 2015–2023. This period is selected to capture the advancement of digital technology in Indonesia's banking system, marked by the increasing value of mobile banking and Internet banking transactions. The sample comprises banks with varying degrees of investment in Industry 4.0 technologies, such as IoT, AI, and blockchain. Some banks are actively involved in these technologies, while others are at different stages of digital evolution. We use data from conventional commercial bank financial reports available on the website of OJK[1], digital banking regulations issued by OJK, annual reports from each commercial bank, and other reliable official websites. The final sample comprises 531 bank-years. DT data is obtained through a textual analysis of each firm's annual reports, providing insights into their digital transformation activities.

Variable Construction

In this study, we focus on bank digitalization as the explanatory variable to explain bank efficiency. This variable is measured using a banking digital index constructed based on four stages of bank digitalization, as outlined by Cisco Consulting (Bradley et al., 2014). These stages include:

1. E-banking as a representation of Digital Banking 1.0,
2. Multichannel Integration as a representation of Digital Banking 2.0,
3. Omnichannel Analytics as a representation of Digital Banking 3.0, and
4. Internet of Everything as a representation of Digital Banking 4.0.

The index comprises 21 points: dial-up experience, email contact center, online brochureware, databases, customer relationship management (CRM), web-based account origination, online calculators and bill payments, click-to-chat and call, data warehouse, know your customer (KYC), seamless experience, full-function smartphone application, internal and hybrid cloud, click-to-video, big data and analytics, 360° customer view, digital bank and branches, rich cross-channel collaboration and advice, omnichannel analytics, market one customer-centricity, and intercloud.

The digital banking index is measured based on interval levels. Each bank is assigned a weighted score, with the lowest score given to banks that have implemented the lowest level on the index, and the score increases as the bank implements higher levels on the index. These scores are then summed and divided by the 21 points to calculate the final digital banking implementation score. The interval values for each bank are as follows:

a. Scale 0 – 1.75 : E-banking stage (Digitalization 1.0)
b. Scale 1.76 – 2.5 : Multichannel Integration stage (Digitalization 2.0)
c. Scale 2.51 – 3.25 : Omnichannel stage (Digitalization 3.0)
d. Scale 3.26 – 4.00 : Internet of Everything stage (Digitalization 4.0).

[1] OJK is the Indonesia Financial Services Authority (IFSA)

Research Model

In this study, bank efficiency is the explained variable and the level of digitization of commercial banks is the main explanatory variable. Accordingly, we construct the following model:

$$EB_{i,t=}\,\alpha_{i,t}+\beta 1 DT_{it}+\beta 2 DT_{it}^{2}+\beta 3 \Sigma Control_{it}+\varepsilon_{i,t} \qquad \text{Eq (1)}$$

EBit is the efficiency of commercial banks; this study uses CIR as a proxy variable for *EBit*. *DTit* represents the level of bank digitalization; this study uses the Indonesian Commercial Bank Digitalization Index (DT), constructed by Cisco Consulting, as a proxy variable for *DTit*. This study employs some control variables such as size, net interest margin (NIM), NPL, loan to deposit ratio (LDR), and return on assets (ROA). The specific calculations for each variable are listed in Table 1.

Table 1: Definitions of Operational Variables

	Variable	Definition	Reference	Expected Sign
Dependent	**Efficiency**	The CIR is a financial metric used to assess the efficiency of a company's operations by comparing its operating expenses to its operating income.	(Do et al., 2022b; Kriebel & Debener, 2020)	n/a
Independent	**Digital Transformation**	The index consists of 21 points.	(Hoque et al., 2024; Kriebel & Debener, 2020)	Negative
Control	**SIZE**	Log of total asset, proxy by size	(Do et al., 2022b)	Negative
	LDR	A ratio of total loans to total deposits	(N. T. H. Nguyen et al., 2022)	Negative
	NIM	A ratio of net interest income to average earning assets	(Lee et al., 2021)	Negative
	ROA	A ratio of net income to average total assets	(Kriebel & Debener, 2020)	Negative
	NPL	This is a financial term used to describe loans in which the borrower is not making the required payments, either principal or interest, for a specified period, usually 90 days or more.	(Chao et al., 2024)	Positive

We employ fixed effects model (FEM) to estimate the model because it assumes that there are unobserved fixed effects among entities, and that these effects are correlated with the explanatory variables at each time period.

4. RESULTS AND DISCUSSION

Descriptive Statistics

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std	Min	Max
CIR	531	82.82616	17.62936	34.13	287.86
SIZE	531	1.280008	3.01008	494606	2.17009
DT	531	0.5057571	0.1503433	0.143	0.9
ROA	531	1.993559	2.014492	-14.75	8.38
NIM	531	5.835235	2.179953	-3.52	19.3
NPL	531	1.917156	1.531239	-0.23	8.8
LDR	531	91.99484	44.74256	29.67	761.45

Table 2 explains the descriptive statistics. The average efficiency of banks is 82.55%. The lowest CIR of a bank is 34.13%, and the maximum value is 287.86%. According to Bank Indonesia Regulation No. 15/12/PBI/2013, the ideal CIR value as per Bank Indonesia's standards is a maximum of 85%. Based on the descriptive statistics, it can be inferred that banks in Indonesia generally have a relatively good CIR, indicating that the overall banking conditions in Indonesia are sound. The decreasing CIR value indicates improved efficiency in managing operational costs.

Furthermore, the DT variable has an average value of 0.50, indicating that banks in Indonesia are still in the multichannel integration stage (digitalization 2.0) based on the digital interval value. The minimum value is 0.143, indicating that some banks are still in the e-banking stage (digitalization 1.0). The maximum value for the digitalization variable is 0.9, indicating that there are also banks in Indonesia that have reached the Internet of Everything stage (digitalization 4.0).

Table 3: Correlation

	CIR	SIZE	DIG	ROA	NIM	NPL	LDR
CIR	1						
SIZE	-0.2419	1					
DT	-0.1588	0.5187	1				
ROA	-0.08	0.1357	0.0808	1			
NIM	-0.3123	-0.0251	-0.1342	0.4292	1		
NPL	0.3968	0.0503	0.0198	-0.4682	-0.1593	1	
LDR	0.0235	-0.0547	-0.1286	-0.0255	0.2147	0.0418	1

Table 3 presents the correlation metrics among explanatory variables. The values are relatively low and less than 0.5, implying that there is no multicollinearity issue in our regression model.

Baseline Regression

Table 4: Baseline Regression

		BELOW 50%	ABOVE 50%
	CIR	**CIR**	**CIR**
DT	36.61*	-2.347	-4.565**
	-2.33	(-1.87)	(-2.87)
DT²	-39.16**		
	(-2.88)		
ROA	-6.258***	-6.300***	-6.247***
	(-21.84)	(-21.73)	(-21.78)
NIM	1.280**	1.457***	1.243**
	-3.21	-3.61	-3.14
NPL	-1.033*	-0.851	-1.000*

	(-2.29)	(-1.89)	(-2.22)
LDR	-0.00689	-0.0075	-0.00733
	(-0.62)	(-0.67)	(-0.65)
SIZE	2.418*	1.827*	2.767**
	-2.39	-1.97	-3.18
_CONS	41.30*	58.68***	43.56**
	-2.52	-3.53	-2.79
N	531	531	531

Notes: *t* statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 presents the results of the regression analysis, where in Column (2), the DT2 coefficient of -39.16 is statistically significant at the 5% level. This finding indicates a U-shaped relationship between digitalization and efficiency, as measured by the CIR variable. This means that in the early stages, digitalization investments tend to be inefficient; however, over time, digitalization can provide benefits to banking efficiency. Additionally, the quantile regression conducted on the full sample confirms that the impact of digitalization on CIR is non-linear.

In the initial stage of digitalization (DT below 50%), banks tend to experience increased costs due to technology investments, organizational structure changes, and ongoing system adaptations. This condition can reduce profitability in the short term. However, when the level of digitalization exceeds 50%, banks begin to realize the benefits of operational efficiency and improved services, which contribute to enhanced performance. This indicates that the impact of digitalization on the CIR of commercial banks is non-linear, initially inhibiting and then advancing efficiency. This aligns with the findings of Xiang and Jiang (2023b), which reveal that digitalization has a non-linear effect on bank performance. This may be because, in the beginning of digitization, banks have to allocate considerable resources and capital. In the same time, they must adapt their organizational structure and culture. This could lead to short-term cost increases and a decrease in operational efficiency. However, as digitalization progresses and matures, it could ultimately improve bank performance.

Digitalization has brought significant changes across various sectors, including banking; however, its impact on bank performance is not always linear. During the initial stages of digitalization, banks typically need to make substantial investments to adopt new technologies (Aggreh et al., 2020). This includes purchasing hardware and software, training employees, and restructuring

operational systems. These large expenditures often lead to temporary declines in bank profitability, compounded by the learning curve for employees and management adapting to new technologies, which can disrupt day-to-day operations. As banks progress beyond these initial stages, they begin to adapt to new digital systems, thereby seeing improvements in operational efficiency. Many manual processes that are time-consuming and prone to errors can be automated, reducing operational costs and speeding up service time. The use of data analytics also helps banks better understand customer behavior, enabling them to deliver more targeted services and enhance customer satisfaction.

In the optimization phase, banks optimize the use of digital technology and begin reaping the full benefits of digitalization. They can develop innovative products and services that are more relevant to customer needs, such as mobile banking applications, chatbots, and digital payment services. Digital technology also allows banks to reach a larger market and serve customers who previously had no access to banking, including those in non-urban areas. Despite reaching the optimization stage, banks still face challenges and risks that may cause performance fluctuations. The risk of cyber-attacks increases with the use of digital technology, could potentially lead to financial losses and reputational damage.

Banks should also continue to innovate to be competitive, which means that investment in technology continues, and changes in technology and data privacy regulations can suddenly affect bank operations. Therefore, the impact of digitalization on bank performance is non-linear because of the various factors that influence each stage of implementation. First, digitalization has no effect on efficiency because of the high cost of investment and system adaptation. However, banks can achieve significant efficiency over time.

Table 5: Regression by Size

	SMALL BANK		**LARGE BANK**	
	CIR	**CIR**	**CIR**	**CIR**
DT	-5.197	113.3*	-7.728	36.42
	(-0.92)	-1.61	(-1.09)	-1.53
DT²		-86.02*		-48.82
		(-1.68)		(-1.93)
ROA	-3.734*	-3.628*	-6.690***	-6.687***
	(-2.26)	(-2.27)	(-3.54)	(-3.55)
NIM	1.031*	0.802*	1.315	1.442
	-0.5	-0.43	-1.19	-1.35

NPL	0.513*	0.305*	-0.99	-1.075
	-0.37	-0.22	(-0.85)	(-0.94)
LDR	0.045	0.0304	-0.00472	-0.00403
	-0.9	-0.79	(-0.27)	(-0.23)
SIZE	-2.032	-2.085	5.949	5.702
	(-1.07)	(-1.13)	-1.98	-1.9
_CONS	117.8*	82.72*	-3.192	-9.039
	-2.81	-2.19	(-0.06)	(-0.18)
N	426	426	105	105

Notes: *t* statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We also analyze the impact of digitalization on large and small banks in terms of banking efficiency. The regression results in Table 5, show that the coefficient of DT^2 is insignificant in for large banks and negatively significant for small banks. Digitalization can be a strategic tool for small banks to improve efficiency and competitiveness because they have a more flexible structure compared to large banks, which tend to be more bureaucratic in adopting new technology. However, the findings indicate that small and medium-sized banks only begin to experience the benefits of digitalization after reaching a higher level of digitalization, while in the early stages, they face various challenges that can reduce their performance.

Large banks already have well-established technology systems; therefore, adding more digital features does not make a significant difference to them (Xiang & Jiang, 2023c). Conversely, small and medium-sized banks can benefit more from digitalization because it significantly improves their efficiency and accessibility. These smaller banks have not yet fully adopted digital technology; thus, digitalization can have a larger positive impact when they start using it (Giotopoulos et al., 2017). Large banks have more resources to invest in advanced technology; therefore, the impact of digitalization is not as noticeable as that of smaller banks, which may be more sensitive to technological changes. Small and medium-sized banks may feel more pressure to adapt and compete, making digitalization a key factor in boosting their competitiveness.

One of the reasons why small banks do not immediately benefit from digitalization is resource constraints. Unlike large banks that already have a well-developed technological infrastructure, small and medium-sized banks should make significant investments in software, human resource training, and operational restructuring to adapt to new digital systems. In the initial stages, these

investment costs may outweigh the benefits gained, leading to a temporary decline in bank performance. Additionally, the adaptation process to digital technology can also disrupt bank operations, especially if the bank does not have a sufficiently skilled workforce to manage digital systems.

However, once small and medium-sized banks reach a higher level of digitalization, they begin to experience benefits such as improved operational efficiency, automated processes that reduce transaction costs, and enhanced service quality for customers. With more advanced technology adoption, banks can offer faster services, personalized financial products based on data, and improved accessibility for customers. Therefore, although digitalization may initially be a burden for small and medium-sized banks, in the long run, it can become a key factor in improving their efficiency and competitiveness in the banking industry.

Thus, the impact of digitalization on small and medium-sized banks is non-linear, where the initial adoption phase may reduce efficiency due to high investment costs and adaptation challenges, but as digital capacity increases, banks start to gain greater benefits. Therefore, for small and medium-sized banks, a digitalization strategy must be accompanied by well-planned investments, competent human resource support, and efficient technology integration to ensure that the benefits of digitalization are optimally realized.

Robustness Test

Table 6: Robustness Test

	Replacing the Dependent Variable		**Systematic GMM Regression**
	(1)	**(2)**	**(3)**
	NIM	**NIM**	**CIR**
L.CIR			0.0474
			(0.0551)
DT	-1.628***	-5.246***	67.68*
	(0.475)	(1.744)	(37.21)
DT²		3.211*	-49.70*
		(1.643)	(28.50)
ROA		0.252***	-7.486***
		(0.0297)	(1.756)
NPL		-0.0196	-0.535
		(0.0521)	(0.866)
LDR		0.00273**	0.00728
		(0.00128)	(0.0158)
SIZE		-9.81e-10**	-1.554**
		(4.99e-10)	(0.661)

NIM			0.959*
			(0.541)
_cons	6.658***	7.005***	94.21***
	(0.245)	(0.517)	(11.24)
N	531	531	472
R^2	0.024	0.179	
Arellano-Bond test for AR(1) in first differences: 0.474			
Arellano-Bond test for AR(2) in first differences: 0.321			
Hansen test of overid. restrictions: chi2(23) = 0.061			

Notes: Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In the robustness testing, we extend our analysis of the impact of digitization on commercial bank performance by employing NIM as an additional proxy variable. Bank margin (NIM) could be considered as a measure of bank performance because the higher the margin, the more profit bank can obtain. The regression outcomes are detailed in Table 6; specifically, Column (2) reveals that the coefficient of DT^2 is statistically significant at the 10% level. This finding aligns with the results of our initial regression analysis, thereby reinforcing the conclusions of this study.

In addition, we employ the two-stage generalized method of moments to form a dynamic panel model. GMM analysis was conducted for robustness to control for potential endogeneity. In the model test, $p = 0.474$ for AR(1) indicates no first-order autocorrelation, $p = 0.3021$ for AR(2) indicates no second-order autocorrelation, and $p = 0.061$ in Hansen's test confirms the null hypothesis of instrumental variable validity, thereby confirming that the overall model is adequate and the instrumental variables are valid. Moreover, the coefficient of DT^2 passes the 10% significance test, which is inline with the baseline results.

5. CONCLUSION

We investigate the effect of DT on the efficiency of commercial banks in Indonesia, particularly focusing on the non-linear relationship between digitalization and bank performance. The findings contribute to understanding how DT affects efficiency metrics such as CIR across banks of different sizes. First, the study confirms a U-shaped relationship between digitalization and bank efficiency, as indicated by the significant coefficient of DT^2 in the regression analysis. Initially, banks face challenges and costs associated with adopting new digital technologies, leading to a temporary decline in efficiency. However, as digitalization progresses, banks begin to reap the benefits through improved operational processes, cost efficiency, and enhanced customer service. This evolution suggests that, while digitalization may initially strain resources and disrupt operations, its long-term benefits outweigh these early challenges. Second, the impact of digitalization varies significantly between small and large banks. Small and medium-sized banks exhibit a pronounced non-linear effect of digitalization on efficiency, whereas large banks do not exhibit significant improvements. This disparity underscores the critical role of size in determining

how banks leverage digital technologies; smaller banks, constrained by financial resources, must strategically invest in DT to achieve efficiencies comparable to those of larger institutions. Furthermore, this study underscores the context-specific challenges faced by Indonesian banks, such as varying levels of digital maturity and regulatory frameworks. Despite Indonesia's proactive stance on digitalization, smaller banks continue to struggle with high investment costs and technical challenges, hindering their ability to fully capitalize on digital opportunities.

In conclusion, although DT offers substantial potential to enhance banking efficiency, its impact is nuanced and context-dependent. Successful implementation requires not only technological investments but also strategic alignment with organizational goals and market conditions. Future research should explore more additional factors affecting digitalization outcomes and refine strategies to maximize the benefits of DT in diverse banking environments.

ACKNOWLEDGMENTS

The earlier draft was presented at the Finance, Economics and Business Sustainability (FEBS) Conference 2024 organized by Universiti Malaysia Sarawak. This research was funded by the Indonesia Ministry of Education, Culture, Research, and Technology under the PMDSU Research Grant scheme 2024 with the contract number 0667/E5/AL.04/2024.

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