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Digital Adoption and Loan-to-Deposit Ratio in Bank Performance: NIM Mediation and CAR Moderation in Indonesian KBMI 3 and KBMI 4 Banks

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Abstract

Digital transformation has become a central component of banking strategies; however, its contribution to profitability depends on how effectively technology adoption, financial intermediation, interest margins, and capital adequacy are managed. This study examined the effects of digital adoption and the Loan-to-Deposit Ratio (LDR) on Return on Assets (ROA), with Net Interest Margin (NIM) as a mediating variable and the Capital Adequacy Ratio (CAR) as a moderating variable. A quantitative panel data approach was applied to 16 Indonesian banks classified as KBMI 3 and KBMI 4 during 2020–2024, resulting in 80 bank-year observations. Model selection indicated the use of a Random Effects Model for the NIM model and a Fixed Effects Model for the ROA model. Mediation analysis was conducted using the Sobel test and a 95% Monte Carlo confidence interval as a robustness check. The results showed that digital adoption had a positive effect on ROA but did not significantly affect NIM. LDR did not have a direct effect on ROA but positively affected NIM, while NIM positively affected ROA. NIM did not mediate the relationship between digital adoption and ROA but significantly mediated the relationship between LDR and ROA. CAR weakened the effects of digital adoption on NIM and ROA, strengthened the relationship between NIM and ROA, and did not moderate the LDR-related relationships. These findings indicated that bank profitability depended on the ability to transform digital capabilities and credit intermediation into economic value while maintaining capital resilience and financial stability.

INTRODUCTION

The global banking industry is experiencing a structural transformation in which digital technology increasingly shapes customer interfaces, payment activities, internal processes, credit decisions, data utilization, and business models. The post-pandemic recovery improved profitability across many banking systems; however, the sustainability of these improvements remains uncertain as banks continue to face changes in funding costs, interest rates, asset quality, cybersecurity risks, operational complexity, and regulatory requirements. In this environment, financial performance is no longer determined solely by the ability to generate revenue. Instead, it increasingly depends on how effectively banks combine technological innovation, efficient

financial intermediation, prudent risk management, and adequate capital capacity to create sustainable value over time (Cardillo et al., 2021; Darboe, 2026; Park & Kim, 2020; Scardovi, 2016; Vikas et al., 2022).

This issue is particularly relevant to Indonesian banks classified as Kelompok Bank Berdasarkan Modal Inti (KBMI) 3 and KBMI 4. These institutions possess relatively large capital bases, asset portfolios, customer networks, and investment capacities, making them strategically important and operationally complex components of the Indonesian financial system. However, their profitability has not increased consistently. The average Return on Assets (ROA) increased from 1.45% in 2020 to 1.75% in 2021, 2.02% in 2022, and 2.10% in 2023 before declining to 1.95% in 2024. This pattern indicates that the post-pandemic recovery in profitability was followed by a moderation phase despite the strong scale and capitalization of the sampled banks.

At the same time, digital banking activities have expanded rapidly. Bank Indonesia payment system data used in this study indicate significant growth in proprietary digital channels, particularly mobile banking and internet banking, in terms of transaction volume and value. This development reflects a major shift in customer behavior from conventional banking channels toward digitally enabled services and demonstrates that technology has become a core component of banking strategy. The coexistence of accelerating digital adoption and a more moderate profitability trajectory creates the empirical problem underlying this study. If digital adoption automatically generated efficiency and financial value, the expansion of digital channels would be expected to correspond with a similarly strong and continuous improvement in ROA. However, the observed divergence suggests that the transformation of digital capability into financial performance is neither immediate nor automatic.

The IT Productivity Paradox provides a relevant perspective for understanding this phenomenon. Technology investment requires substantial expenditure on infrastructure, software, cybersecurity, data integration, employee capabilities, regulatory compliance, and organizational transformation before financial benefits can be fully realized. These benefits may initially appear through improved service speed, enhanced customer experience, increased transaction activity, or reduced processing costs rather than immediate increases in accounting profitability. The Resource-Based View (RBV) further explains that technology generates strategic value when combined with complementary resources and organizational capabilities. Therefore, digital platforms, analytics, and automated processes become valuable resources only when effectively integrated into lending, funding, service delivery, and decision-making processes. Previous empirical studies also indicate that digitalization can improve bank efficiency and performance, although its financial impact depends on implementation quality and organizational capabilities (Dadoukis et al., 2021; Fraihat et al., 2023; Yuniarti et al., 2024).

A central question is how digital adoption is converted into profitability. This study considers Net Interest Margin (NIM) as a potential transmission mechanism. NIM reflects banks' ability to generate net interest income from earning assets after considering funding costs. Digital adoption may improve credit processing, customer analytics, credit scoring, pricing strategies,

portfolio monitoring, and asset-liability management. When these improvements enhance the effectiveness of traditional financial intermediation, digital capability may increase NIM and subsequently improve ROA. Previous studies have identified NIM as an important determinant of bank profitability and demonstrated that margin formation is influenced by bank characteristics, funding structures, asset composition, and interest rate conditions (Hanzlík & Teplý, 2022; Hossain & Ahamed, 2021). Nevertheless, digital adoption may also influence ROA through operational efficiency, service scalability, customer retention, and fee-based income activities. Therefore, the mediating role of NIM requires empirical examination rather than assumption.

Financial intermediation represents another pathway influencing bank performance. The Loan-to-Deposit Ratio (LDR) indicates the extent to which third-party funds are converted into credit. A higher LDR may increase productive assets and interest income; however, it may also create greater funding pressure, liquidity exposure, provisioning requirements, and credit risk. Therefore, lending intensity does not necessarily represent lending quality. Previous findings remain inconsistent, with some studies associating stronger financial intermediation with improved bank performance, while others reporting that LDR does not consistently explain ROA (Begum et al., 2024; Liyana & Indrayani, 2020; Mufarodi & Meliza, 2023). These inconsistent findings provide a rationale for examining NIM as the mechanism through which LDR influences ROA. If lending expansion improves profitability only when generated returns exceed funding costs and associated risks, NIM should transmit the effect of LDR on ROA.

The relationship between resources, financial intermediation, and profitability is also influenced by capital strength. This study uses Capital Adequacy Ratio (CAR) to represent banks' capacity to absorb potential losses relative to risk-weighted assets. From the Risk-Adjusted Return on Capital (RAROC) perspective, performance evaluation should consider returns in relation to risk exposure and the capital required to support those risks. Strong capital adequacy can improve resilience, market confidence, and operational continuity; however, it may also influence asset allocation decisions, lending expansion, and the ability to maximize technology investments. Therefore, CAR is positioned as a moderating variable in the relationships between Digital Adoption and NIM, LDR and NIM, Digital Adoption and ROA, LDR and ROA, and NIM and ROA. This approach aligns with previous literature emphasizing that capital conditions and risk management influence the relationship between banking strategies and financial performance (Hassan et al., 2022; Sutanto et al., 2024; Oktaviana & Miranti, 2025).

This study is also associated with the sustainable development perspective adopted in the research framework. In this context, ROA represents the financial dimension of performance rather than a comprehensive measure of environmental and social sustainability. Long-term financial value depends on banks' ability to maintain profitability through innovation, efficient resource allocation, effective intermediation, and resilience to risk. Digital banking contributes to Sustainable Development Goal 9 by supporting innovative and resilient financial infrastructure. Therefore, the strategic issue is not merely whether banks have digital channels but whether digital

capability, financial intermediation, interest margins, and capital adequacy can be integrated to support sustainable bank performance.

Previous studies have frequently examined digitalization, LDR, NIM, capital adequacy, and profitability as separate relationships. Limited empirical evidence simultaneously explains whether Digital Adoption and LDR influence ROA through NIM and whether CAR alters the strength of these relationships, particularly among Indonesia's large KBMI 3 and KBMI 4 banks. This study addresses this gap by integrating Digital Adoption and LDR as performance determinants, NIM as a mediating mechanism, and CAR as a moderating condition within a unified empirical framework. Accordingly, this study tested five direct-effect hypotheses (H1–H5), five moderation hypotheses (H6–H10), and two mediation hypotheses (H11–H12). The objective was to determine whether Digital Adoption and LDR affected ROA directly or indirectly through NIM and to assess whether CAR strengthened or weakened these relationships during the 2020–2024 period.

METHOD

Research Design and Sample

This study employed a quantitative explanatory research design using secondary panel data. The unit of analysis was the bank-year observation. The observation period covered 2020–2024, representing the period of accelerated digital banking adoption and post-pandemic changes in bank profitability. Data were collected through documentation of annual reports, published financial statements, and official information from the Indonesia Stock Exchange, Otoritas Jasa Keuangan (OJK), Bank Indonesia, and the sampled banks. This research design enabled the study to examine both cross-sectional differences among banks and changes over time.

The sample was selected using purposive sampling. The selection criteria required banks to be classified as KBMI 3 or KBMI 4, listed on the Indonesia Stock Exchange, and provide complete data for all research variables during the observation period. The final sample consisted of 16 banks, including 12 KBMI 3 banks and four KBMI 4 banks, with five annual observations for each institution. The balanced panel dataset comprised 80 bank-year observations. The sampled banks included Bank Rakyat Indonesia, Bank Mandiri, Bank Central Asia, Bank Negara Indonesia, Bank CIMB Niaga, Bank Danamon Indonesia, Bank Syariah Indonesia, Bank Tabungan Negara, Bank Permata, Bank OCBC NISP, Bank Maybank Indonesia, Bank Mega, Bank Pan Indonesia, Bank SMBC Indonesia, Bank BJB, and Bank Jatim.

Variable Measurement

Digital Adoption (AT) is measured using the breadth of eight banking technologies and electronic services available at each bank: Automated Teller Machine (ATM), Electronic Data Capture (EDC), credit/debit cards, SMS banking, internet banking, mobile banking, phone banking, and video banking. The variable therefore captures the availability of service technologies rather than the intensity of customer use. LDR is measured as total credit to third parties divided by third-party funds and represents the intermediation function. NIM is measured

as net interest income relative to productive assets and serves as the mediator. CAR is measured as capital relative to risk-weighted assets and represents the capital-adequacy dimension used as the moderator. ROA is used as the dependent variable to represent financial performance. The regulatory context for LDR, NIM, CAR, and ROA follows the banking and bank-soundness framework referenced in the thesis (Bank Indonesia 2018; Otoritas Jasa Keuangan 2016, 2017).

Table 1. Operationalization of Research Variables

Variable	Role	Operationalization	Scale
Digital Adoption (AT)	Independent	Number of available banking technologies/services: ATM, EDC, credit/debit cards, SMS banking, internet banking, mobile banking, phone banking, and video banking	Score
LDR	Independent	Total credit to third parties / Third-party funds × 100%	%
NIM	Mediator	Net interest income / Productive assets × 100%	%
CAR	Moderator	Capital / Risk-weighted assets × 100%	%
ROA	Dependent	Profitability relative to total assets	%

Source: Developed by the authors based on banking regulations and previous literature.

Estimation, Moderation, and Mediation Procedures

The empirical analysis begins with descriptive statistics, followed by panel-model selection. Common Effects Model (CEM), Fixed Effects Model (FEM), and Random Effects Model (REM) specifications are compared. The Chow test determines whether FEM is preferred to CEM, the Hausman test compares FEM and REM, and the Lagrange Multiplier test compares REM and CEM. All statistical decisions use a 5% significance level. Model selection is conducted separately for the NIM and ROA equations because the error structure and unobserved heterogeneity can differ between the two dependent variables. The selected model for each equation is then used to estimate the principal paths needed for hypothesis testing.

The first equation explains NIM using Digital Adoption, LDR, and CAR. The second equation explains ROA using Digital Adoption, LDR, NIM, and CAR. Moderation is assessed by adding the relevant product term to the selected panel equation. For NIM, the interaction terms are AT×CAR and LDR×CAR. For ROA, the interaction terms are AT×CAR, LDR×CAR, and NIM×CAR. The final interaction specifications reported in the thesis use panel EGLS and covariance adjustments for clustering/cross-sectional dependence. A significant positive

interaction indicates that CAR strengthens a relationship, while a significant negative interaction indicates that CAR weakens the relationship within the estimated specification.

Mediation is evaluated for two indirect effects: AT→NIM→ROA and LDR→NIM→ROA. Coefficients and standard errors for AT→NIM and LDR→NIM are obtained from the selected REM for the NIM equation, whereas the NIM→ROA coefficient and standard error are taken from the selected FEM for the ROA equation. The Sobel test evaluates the statistical significance of the indirect effect at the 5% level. The final thesis also uses a 95% Monte Carlo Confidence Interval (MCCI) based on 1,000,000 simulations as a robustness check. An indirect effect is considered supported when the statistical test is significant and the confidence interval does not contain zero. This direct assessment of the indirect effect is used to classify the mediation pattern.

$$NIM\_it = \alpha + \beta 1\ AT\_it + \beta 2\ LDR\_it + \beta 3\ CAR\_it + \varepsilon\_it \quad (1)$$

$$ROA\_it = \alpha + \beta 1\ AT\_it + \beta 2\ LDR\_it + \beta 3\ NIM\_it + \beta 4\ CAR\_it + \varepsilon\_it \quad (2)$$

RESULT AND DISCUSSION

Descriptive Statistics and Model Selection

The descriptive statistics show meaningful variation across the sampled banks. ROA has a mean of 1.855%, a minimum of 0.45%, a maximum of 3.87%, and a standard deviation of 0.829. NIM averages 4.680%, with values between 3.00% and 7.85%. LDR has a mean of 84.678%, ranging from 64.50% to 98.50%, indicating that the sample contains banks with substantially different levels of intermediation intensity. CAR averages 23.968%, with a minimum of 16.78% and a maximum of 33.55%, suggesting generally strong capital positions. Digital Adoption has a mean of 6.95, a minimum of 6, a maximum of 8, and a relatively small standard deviation of 0.418. The narrow AT range indicates that most KBMI 3 and KBMI 4 banks already offer a broad set of electronic and digital banking services, while their financial outcomes remain much more heterogeneous.

Table 2. Descriptive Statistics

Statistic	ROA	NIM	LDR	CAR	AT
Mean	1.8550	4.6799	84.6775	23.9684	6.9500
Median	1.7450	4.4900	86.0000	24.0400	7.0000
Maximum	3.8700	7.8500	98.5000	33.5500	8.0000
Minimum	0.4500	3.0000	64.5000	16.7800	6.0000
Std. Dev.	0.8295	0.9901	8.1083	3.7448	0.4180

Source: Processed secondary data from annual reports and financial statements of sampled banks (2020–2024).

The model-selection tests support different estimators for the two equations. For the NIM equation, the Chow test yields p = 0.0000, indicating that fixed effects improve on the common-effects specification, while the Hausman test produces p = 0.2474, so the difference between FEM and REM is not statistically significant under the test criterion. The Lagrange Multiplier test produces p = 0.0000. Accordingly, REM is selected for Model 1. The REM equation is jointly significant with Prob(F) = 0.000014 and adjusted R-squared of 0.252889. For the ROA equation, the Chow test yields p = 0.0012 and the Hausman test p = 0.0000, supporting FEM. The selected

ROA equation is jointly significant with Prob(F) < 0.001 and adjusted R-squared of 0.944180. The high explanatory power of the FEM reflects both the observed regressors and bank-specific fixed effects; it should therefore be interpreted as within-sample model fit rather than as proof of causality.

Table 3. Panel Model Selection

Model	Chow p-value	Hausman p-value	LM p-value	Selected model
Model 1: NIM	0.0000	0.2474	0.0000	REM
Model 2: ROA	0.0012	0.0000	0.0000	FEM

Source: Processed secondary data using panel data regression analysis (Chow Test, Hausman Test, and Lagrange Multiplier Test).

Direct Effects and Digital Value Conversion

Digital Adoption has a positive and statistically significant effect on ROA, with β = 0.583932 and p = 0.0001, so H1 is supported. The result indicates that banks with broader technological adoption tend to achieve higher profitability after the other variables in the model are considered. The direction is consistent with the idea that digitalization can lower transaction and service costs, accelerate business processes, improve customer access, increase transaction activity, and generate economies of scale. The sampled KBMI 3 and KBMI 4 banks possess relatively large customer bases and technological capacity, so the migration of customers to mobile and internet channels can increase service productivity without requiring a proportional expansion of physical distribution. This finding is consistent with empirical work associating digital banking with efficiency and profitability improvements (Fraihat et al. 2023; Yuniarti et al. 2024; Putra et al. 2024).

The economic interpretation of H1 becomes more informative when it is combined with H3 and H11. Digital Adoption has a positive coefficient on NIM (β = 0.324261) but the effect is not significant at the 5% level (p = 0.0780), so H3 is not supported. The AT→NIM→ROA indirect effect equals 0.242999, with Sobel Z = 1.7438 and p = 0.0812. The 95% Monte Carlo interval is [−0.0232; 0.5288], which contains zero. H11 is therefore not supported. Because AT has a significant direct effect on ROA while the indirect path through NIM is not significant, the thesis classifies the pattern as direct-only non-mediation. Digitalization improves profitability, but the improvement is not statistically transmitted through the interest-margin mechanism in this sample.

This pattern suggests that the value created by digital banking may emerge through channels other than NIM. Digital services can reduce operating and transaction costs, improve service speed, raise customer retention, support fee-based activity, and increase the number of transactions handled by the same infrastructure. These benefits can improve ROA without widening the spread between interest income and interest expense. NIM is more directly affected by funding structure, interest-rate conditions, credit quality, loan pricing, productive-asset composition, and asset-liability management. Consequently, simply providing more digital services does not ensure that the bank's lending and funding spread will improve. From the RBV perspective, the finding indicates that technology creates value only when connected with complementary organizational capabilities, and different digital capabilities can influence different parts of the income statement.

Financial Intermediation and NIM Mediation

The LDR results reveal a contrasting pathway. LDR has a positive but non-significant direct effect on ROA (β = 0.011843; p = 0.3354), so H2 is not supported. This means that a higher proportion of deposits allocated to lending does not automatically increase profitability. Credit expansion may increase earning assets, but it can simultaneously raise funding costs, credit-risk exposure, provisioning needs, and liquidity pressure. The absence of a direct effect therefore supports the view that the quantity of intermediation alone is insufficient to explain financial performance. Earlier studies similarly show that LDR is not always a direct determinant of ROA and that the quality of credit and funding management remains important (Liyana and Indrayani 2020; Mufarodi and Meliza 2023; Nasution et al. 2024).

Unlike its direct relationship with ROA, LDR has a positive and significant effect on NIM (β = 0.030119; p = 0.0405), supporting H4. NIM in turn has a strong positive effect on ROA (β = 0.749392; p < 0.001), supporting H5. The indirect effect of LDR on ROA through NIM equals 0.022571, with Sobel Z = 2.0166 and p = 0.0437. The Monte Carlo interval [0.0013; 0.0456] is entirely above zero. Accordingly, H12 is supported and the final thesis classifies the relationship as indirect-only mediation because the indirect effect is significant while the direct LDR→ROA effect is not. The result provides a clear distinction between intermediation quantity and intermediation quality: credit deployment contributes to profitability when it produces a healthy net interest margin.

The mediation result has strong managerial meaning. A bank can increase LDR without improving ROA if loan yields do not adequately compensate for funding costs, credit risk, and other balance-sheet costs. By contrast, when credit growth is supported by appropriate loan pricing, efficient deposits, controlled non-performing loans, and effective asset-liability management, the resulting NIM can translate lending activity into profitability. The finding is consistent with the RAROC logic that return must compensate for risk and capital usage. It also explains why NIM is more informative than LDR alone for understanding the realized economics of intermediation. Management should therefore avoid treating a high LDR as an end in itself and should instead assess credit expansion together with spreads, funding efficiency, portfolio quality, and risk-adjusted returns.

CAR as a Moderating Condition

The moderation tests show that CAR operates asymmetrically. For the relationship between Digital Adoption and NIM, AT×CAR has a coefficient of −0.06263 and p = 0.0143, supporting H6. For Digital Adoption and ROA, AT×CAR is also negative and significant (β = −0.03716; p = 0.0029), supporting H8. These interaction effects indicate that higher CAR weakens the marginal positive association of Digital Adoption with NIM and ROA. The result does not mean that stronger capital is undesirable. Instead, it is consistent with a trade-off between resilience and the short-term monetization of digital expansion. Well-capitalized banks may maintain larger risk buffers, apply more conservative resource allocation, and incur additional expenditures on cybersecurity, regulatory compliance, technology controls, and operational resilience. These

investments strengthen safety and continuity but can reduce the immediate incremental return from further digital expansion.

The negative AT×CAR findings are particularly relevant to the RAROC perspective. Digital investment should not be evaluated only by its gross contribution to revenue or cost savings because technology also creates operational, cyber, implementation, and compliance risks that need to be supported by capital and control systems. A bank with higher capital adequacy may deliberately prioritize resilience over short-term asset utilization. The interaction results therefore suggest that the economic payoff from digital resources is conditional on the bank's capital position and risk-management stance. For management, the implication is not to reduce CAR, but to improve the productivity of digital investment so that technology contributes to operating efficiency, credit decisions, and revenue while the institution preserves adequate loss-absorption capacity.

CAR does not significantly moderate the LDR→NIM relationship ($\beta = -0.00244$; $p = 0.2361$), so H7 is not supported. It also does not moderate the LDR→ROA relationship ($\beta = -0.00021$; $p = 0.8576$), so H9 is not supported. The result suggests that capital strength alone does not determine whether lending intensity creates margins or profitability. Loan quality, risk-based pricing, funding costs, borrower characteristics, collection effectiveness, and asset-liability management are more immediate determinants of the economic result of credit intermediation. CAR provides a buffer against losses but does not automatically transform additional lending into a profitable spread. The generally strong capitalization of KBMI 3 and KBMI 4 banks may also limit cross-bank variation in the moderating effect.

In contrast, CAR strengthens the relationship between NIM and ROA. The NIM×CAR interaction is positive and significant ($\beta = 0.02308$; $p = 0.0204$), supporting H10. This result means that a healthy interest margin contributes more strongly to profitability when the bank is supported by stronger capital adequacy. Adequate capital enables banks to absorb unexpected losses, maintain business continuity, and sustain intermediation without allowing shocks to consume a disproportionate share of current earnings. Therefore, the combination of strong NIM and healthy CAR provides a more resilient profitability profile. This finding is consistent with RAROC because the conversion of return into value depends on whether sufficient capital is available to support the risk profile of the bank.

Table 4. Summary of Hypothesis Testing

Hypothesis	Relationship	Coefficient	p-value	Decision
H1	AT → ROA	0.583932	0.0001	Supported
H2	LDR → ROA	0.011843	0.3354	Not supported
H3	AT → NIM	0.324261	0.0780	Not supported
H4	LDR → NIM	0.030119	0.0405	Supported
H5	NIM → ROA	0.749392	0.0000	Supported
H6	AT × CAR → NIM	−0.06263	0.0143	Supported
H7	LDR × CAR → NIM	−0.00244	0.2361	Not supported
H8	AT × CAR → ROA	−0.03716	0.0029	Supported
H9	LDR × CAR → ROA	−0.00021	0.8576	Not supported

Hypothesis	Relationship	Coefficient	p-value	Decision
H10	NIM × CAR → ROA	0.02308	0.0204	Supported
H11	AT → NIM → ROA	0.242999	0.0812	Not supported
H12	LDR → NIM → ROA	0.022571	0.0437	Supported

Source: Processed secondary data using panel regression analysis and moderation testing.

Table 5. Mediation and Monte Carlo Robustness Results

Indirect path	Indirect effect	Sobel Z	p-value	95% Monte Carlo CI	Conclusion
AT → NIM → ROA	0.242999	1.7438	0.0812	[−0.0232; 0.5288]	No mediation
LDR → NIM → ROA	0.022571	2.0166	0.0437	[0.0013; 0.0456]	Mediation supported

Source: Processed secondary data using Sobel Test and Monte Carlo Confidence Interval analysis.

Theoretical and Practical Implications

Taken together, the results provide three theoretical contributions. First, they refine the RBV argument by showing that the value of digital resources is pathway-specific. Digital Adoption significantly improves ROA but does not increase NIM or generate a significant indirect effect through NIM. Technology therefore appears to create value through operating or non-interest channels rather than through margin expansion. Second, the LDR mediation result provides a process-based explanation of financial intermediation: lending intensity contributes to profitability when it is transformed into a positive NIM. Third, CAR is not a universally positive moderator. It weakens the digital-adoption effects, does not alter the LDR effects, and strengthens the NIM effect. This asymmetric role illustrates why risk and capital conditions should be integrated into performance analysis instead of being treated only as background controls.

The findings also extend the practical interpretation of Signaling Theory. ROA, NIM, LDR, and CAR convey different information to investors and other stakeholders. ROA provides a broad signal of profitability, NIM reflects the quality of core interest earnings, LDR signals the intensity of intermediation, and CAR indicates capital resilience. The results show that these indicators should not be evaluated in isolation. A high LDR without a healthy NIM does not necessarily signal stronger profitability, while a strong NIM supported by adequate CAR has a stronger positive relationship with ROA. Similarly, extensive digital adoption is financially meaningful when it is connected to productive processes and risk controls rather than merely representing the availability of many channels.

For bank management, the evidence supports a differentiated digital-investment strategy. Technologies aimed at customer service, payments, automation, and transaction processing should be evaluated using operating efficiency, transaction activity, service cost, fee income, and customer engagement. Technologies intended to improve interest margins should be integrated more directly with digital credit scoring, data-driven pricing, portfolio analytics, treasury, deposit management, and asset-liability management. Management should also evaluate lending expansion by its ability to produce risk-adjusted margins rather than by LDR growth alone. The

significant LDR→NIM→ROA pathway shows that credit intermediation creates financial value through the quality of the margin it produces.

For regulators, the results support an integrated approach to innovation and prudential resilience. OJK and Bank Indonesia can continue encouraging digital transformation and financial intermediation while ensuring that cyber-risk controls, data governance, operational resilience, capital adequacy, and credit quality evolve together. The strategic relevance and operational complexity of KBMI 3 and KBMI 4 banks make this balance particularly important. The objective of policy should not be the maximization of digital transactions or lending volume in isolation, but the development of a banking system in which innovation and intermediation are supported by strong risk management and capital buffers. This interpretation is consistent with the macroprudential intermediation and bank-soundness frameworks referenced in the thesis (Bank Indonesia 2018; Otoritas Jasa Keuangan 2016, 2017).

The sustainable-development implication is also important. The thesis links digital banking to SDG 9 because digital infrastructure can make financial services more innovative, efficient, and resilient. The empirical results show that sustainability in the economic sense requires more than technological expansion. Digital resources must generate productive value, credit must be converted into healthy margins, and capital must remain adequate to absorb risk. In this way, innovation and resilience are complementary rather than competing objectives. For investors, the same logic implies that assessment of bank quality should combine digital capability with NIM, LDR, CAR, asset quality, and funding efficiency instead of relying on a single profitability ratio.

Limitations and Future Research

Several limitations qualify the findings. First, the study covers only 16 KBMI 3 and KBMI 4 banks over five years, so the results cannot automatically be generalized to KBMI 1 and KBMI 2 banks, regional development banks, or other financial institutions. Second, Digital Adoption is measured from the availability of eight services and does not capture active users, digital transaction intensity, IT expenditure, digital revenue, or maturity of digital capabilities. Third, ROA captures only the financial-performance dimension, while CAR primarily captures capital adequacy rather than the full spectrum of bank risk. Fourth, variables such as non-performing loans, BOPO, bank size, governance, macroeconomic conditions, and digital-service quality are outside the model. Future research can use longer panels, broader bank groups, richer technology measures, alternative mediators such as operating efficiency or fee-based income, and more comprehensive measures of risk and sustainability.

CONCLUSION

This study examined the relationships among Digital Adoption, LDR, NIM, CAR, and ROA in 16 Indonesian KBMI 3 and KBMI 4 banks during the 2020–2024 period. Digital Adoption had a positive and significant effect on ROA but did not significantly affect NIM. LDR did not directly affect ROA; however, it positively affected NIM, while NIM significantly improved ROA. The mediation tests showed that NIM did not mediate the relationship between Digital Adoption and

ROA, whereas NIM significantly mediated the relationship between LDR and ROA. The Monte Carlo confidence intervals supported both mediation findings.

CAR demonstrated an asymmetric moderating effect. Higher CAR weakened the effects of Digital Adoption on NIM and ROA, did not significantly moderate the LDR-related relationships, and strengthened the positive effect of NIM on ROA. These findings indicate that bank performance is generated through different mechanisms: digital capabilities may enhance profitability beyond the interest margin channel, whereas lending activities contribute to profitability primarily when they generate a healthy NIM. Therefore, sustainable financial performance requires banks to integrate digital investment, intermediation quality, funding and pricing discipline, risk management, and capital resilience. For large Indonesian banks, balancing technological innovation with prudential strength is essential for creating long-term financial value.

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