

## Interest Rate in the Relationship Between Fundamental Factors and Efficiency of Indonesian Regional Development Banks (2020–2024)

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### Abstract

*This study examines the effects of key financial ratios, namely Capital Adequacy Ratio, Return on Assets, and Non-Performing Loans, along with the moderating role of the interest rate on the operational efficiency of Regional Development Banks in Indonesia, measured by the Cost-to-Income Ratio (CIR). A quantitative approach is employed using panel data from 2020–2024, with model selection indicating the Random Effects Model as the most appropriate specification, complemented by Moderated Regression Analysis to capture interaction effects. The results show that Return on Assets has a negative and significant effect on CIR ( $\beta = -6.349$ ;  $p < 0.01$ ), confirming that profitability plays a central role in enhancing efficiency. In contrast, Capital Adequacy Ratio and Non-Performing Loans do not exhibit significant partial effects. The model explains 57.01% of the variation in efficiency ( $R^2 = 0.570$ ). Furthermore, the interest rate significantly moderates all relationships, with interaction effects on CAR ( $\beta = 2.293$ ;  $p < 0.05$ ), ROA ( $\beta = -109.548$ ;  $p < 0.01$ ), and NPL ( $\beta = 31.183$ ;  $p < 0.01$ ). Simultaneous testing confirms that internal financial factors jointly influence operational efficiency ( $F = 31.489$ ;  $p < 0.01$ ). These findings suggest that efficiency is shaped not only by internal performance but also by its interaction with monetary conditions, providing implications for improving capital allocation, profitability management, and adaptive risk strategies.*

**Keywords:** *Cost-to-Income Ratio (CIR), Capital Adequacy Ratio (CAR), Return on Assets (ROA), Non-Performing Loans (NPL), Interest Rate*

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## INTRODUCTION

Banks act as financial intermediaries, channeling funds from surplus to deficit units while supporting investment, consumption, and financial stability (Garr & Awadzie, 2021; Gurley & Shaw, 1956; Levine, 1997). Their effectiveness depends on risk management, profitability, and operational efficiency (Berger, 2007), making credit dynamics a reflection of intermediation quality and economic conditions. During 2020–2024, Indonesia's credit growth fluctuated from -2.41% (2020) to 12.36% (2024), indicating sensitivity to economic cycles and monetary policy (Bisnis Indonesia, 2024).

Credit distribution also shifted across bank groups. State-owned banks increased their share from 45.90% (2020) to 48.81% (2024), while private domestic banks declined from 43.10% to 40.52% and foreign banks from 3.10% to 2.56%. Regional Development Banks remained stable at 8.3–8.9%, peaking at 8.93% in 2022, reflecting consistent intermediation support. However, this stability was not matched by efficiency performance. The Cost-to-Income Ratio (CIR) remained high, moving from 86.58% (2020) to 83.55% (2021), 78.7% (2022), and 79.95% (2024), indicating persistent cost pressure (Bisnis Indonesia, 2024).

At the aggregate level, asset shares remained at 8.2–8.8%, third-party funds at 8.5–9.6%, and credit at 8.3–9.0% during 2021–2024 (Otoritas Jasa Keuangan, 2024b, 2024a). Despite this stability, net profit share declined from 9.5% (2021) to 5.1% (2024), implying that performance sustainability increasingly depends on efficiency rather than scale (Belke et al., 2016; Effendi et al., 2018; Karamoy & Tulung, 2020). Efficiency is theoretically driven by Capital Adequacy Ratio, Return on Assets, and Non-Performing Loans, which jointly influence CIR (Avrita & Pangestuti, 2016; Pinasti & Mustikawati, 2018), while interest rates affect funding costs, margins, and credit supply (Aviliani et al., 2015; Tripuspitorini & Setiawan, 2020).

Although banking performance has been widely studied, most research focuses on large banks and does not fully capture Regional Development Banks (Mandagie, 2021; Ningsih & Dewi, 2020). Prior studies highlight their role in regional economic development with distinct risk and efficiency structures (Belke et al., 2016; Ottemoesoe, 2019). Efficiency research has evolved using frontier approaches but remains limited in variable integration (Abidin et al., 2021; Effendi et al., 2018; Satyagraha et al., 2022), while digital transformation and fintech competition further intensify efficiency challenges (Iman, 2019).

Most existing studies on banking efficiency primarily focus on internal determinants, while the incorporation of macroeconomic variables remains limited and not yet fully integrated into empirical models (Akdeniz et al., 2024; Azzabi & Lahrichi, 2023). This limits understanding of how internal banking fundamentals interact with external economic conditions. Accordingly, this study examines the effects of Capital Adequacy Ratio (CAR), Return on Assets (ROA), and Non-Performing Loans (NPL) on operational efficiency, proxied by the Cost-to-Income Ratio (CIR), in Regional Development Banks, with interest rate (BI Rate) as a moderating variable using panel data regression (Baltagi, 2021; Basuki & Prawoto, 2021). This approach evaluates both partial and simultaneous relationships while offering a more integrated view of efficiency determinants.

Financial intermediation theory explains that banks bridge surplus and deficit agents in the saving–investment process (Gurley & Shaw, 1956), and now extends to liquidity creation, risk management, and information asymmetry reduction (Danthine et al., 2025; Greenbaum et al., 2019). Its effectiveness depends on optimal asset–liability management, as imbalances increase risk and operational costs. From a dynamic view, Anticipated Income Theory emphasizes that liquidity sustainability relies on stable lending income streams (Ho & Saunders, 1981; Prochnow, 1949), while income instability, particularly from rising non-performing loans, raises provisioning costs and weakens efficiency (Coccorese & Girardone, 2021; Ozili, 2019).

The Capital Adequacy Buffer Model states that banks hold capital above regulatory minimums to absorb shocks and support financial stability and intermediation (Allen et al., 2016; Corbae & D’Erasmus, 2021; Lindquist, 2004). However, excess capital creates opportunity costs, implying a trade-off between stability and efficiency (Bitar et al., 2018; Mankart et al., 2020). Banking efficiency is commonly measured using the Cost-to-Income Ratio (CIR), capturing the relationship between operating costs and income (Ahmad et al., 2020; Ikra et al., 2021) and is recognized under OJK regulation No. 6/POJK.03/2016. A lower CIR indicates higher efficiency, where CAR, ROA, and NPL jointly determine cost structure, income generation, and risk exposure (Ningsih & Dewi, 2020).

CAR reflects a bank’s ability to absorb risk. Theoretically, stronger capital improves stability and efficiency by reducing risk exposure and financial distress costs (Moyer, 1990). This aligns with capital buffer literature, which argues that banks maintain capital above regulatory requirements to absorb shocks and sustain stability (Allen et al., 2016; Corbae & D’Erasmus, 2021; Jokipii & Milne, 2011; Lindquist, 2004). Empirically, CAR is generally associated with better performance and efficiency. Alnajjar & Othman (2021) find a positive effect on performance, while Azhar & Yeniwati (2021) and Deanna (2018) report a negative relationship with CIR, indicating improved efficiency. Similar evidence is provided by Fathurrahman & Rahmadani (2024), who show that CAR significantly reduces CIR.

**H1:** Capital Adequacy Ratio (CAR) affects the Cost-to-Income Ratio (CIR)

ROA reflects a bank’s ability to generate profits from its assets and serves as a key indicator of asset utilization efficiency (Akbar, 2021). From a financial intermediation perspective, higher profitability indicates more effective asset management and better cost control relative to income. From an agency perspective, ROA also reflects managerial efficiency in resource allocation (Jensen & Meckling, 1979). Empirical evidence consistently shows that

ROA has a significant negative effect on CIR, indicating improved operational efficiency (Azhar & Yeniwati, 2021; Fathurrahman & Rahmadani, 2024).

**H2:** Return on Assets (ROA) affects the Cost-to-Income Ratio (CIR).

NPL reflect credit quality and bank risk exposure. Within anticipated income theory, rising NPL disrupts expected cash flows, increases provisioning costs, and reduces profitability, ultimately raising the Cost-to-Income Ratio (CIR) (Ozili, 2019). Empirical studies consistently confirm that NPL positively affects CIR, indicating lower efficiency (Azhar & Yeniwati, 2021; Deanna, 2018; Liviawati et al., 2020).

**H3:** Non-Performing Loans (NPL) affect the Cost-to-Income Ratio (CIR).

Beyond individual effects, banking efficiency is shaped by the joint interaction of capital adequacy, profitability, and credit quality. Within financial intermediation theory, these variables collectively determine cost structures and income generation, where capital supports stability, profitability reflects asset efficiency, and credit quality ensures income sustainability. Imbalances among these factors increase costs and reduce efficiency. Empirical evidence supports their simultaneous influence on banking efficiency (Azhar & Yeniwati, 2021; Fathurrahman & Rahmadani, 2024).

**H4:** Capital Adequacy Ratio (CAR), Return on Assets (ROA), and Non-Performing Loans (NPL) simultaneously affect the Cost-to-Income Ratio (CIR).

Banking efficiency is influenced by both internal conditions and external factors, particularly interest rates as a key monetary policy instrument affecting funding costs and intermediation margins (Mishkin, 2021). Changes in interest rates influence lending rates, cost of funds, and profit margins, thereby affecting profitability and efficiency. Empirical evidence shows that higher interest rates tend to increase operational costs and reduce efficiency, reflected in higher CIR (Aviliani et al., 2015; Ekananda, 2017; Liviawati et al., 2020; Viphindartin et al., 2021). Interest rates also shape the effectiveness of capital adequacy, where higher funding costs may weaken efficiency gains from strong capital, while lower rates support more efficient credit expansion.

**H5:** Interest rates moderate the relationship between Capital Adequacy Ratio (CAR) and the Cost-to-Income Ratio (CIR).

In the relationship between profitability and operational efficiency, interest rates play a strategic role by shaping lending margins, credit demand, and default risk. Although higher rates may widen margins, they can suppress credit demand and increase credit risk, ultimately constraining profitability. Empirical evidence shows that rising interest rates weaken profitability and increase operational pressure (Darmawan et al., 2020; Syah, 2018), indicating that the ability of ROA to improve efficiency is not constant. Under high-interest conditions, the effectiveness of ROA in reducing the Cost-to-Income Ratio (CIR) tends to decline due to higher funding costs and increased credit risk.

**H6:** Interest rates moderate the relationship between Return on Assets (ROA) and the Cost-to-Income Ratio (CIR).

Interest rates also play a critical moderating role in credit quality by influencing borrowers' repayment capacity. Rising rates increase borrowing costs, elevate default risk, and contribute to higher non-performing loans (NPL), which in turn raise provisioning costs and reduce income, ultimately increasing CIR and weakening efficiency. Empirical evidence confirms that interest rates are positively associated with NPL, while higher NPL reduces efficiency (Azizzah et al., 2021; Ozili, 2019). This mechanism is further supported by anticipated income theory, which emphasizes the role of expected cash flows in sustaining banking performance (Ho & Saunders, 1981; Prochnow, 1949), as well as financial intermediation theory highlighting the impact of credit risk on operational efficiency (Greenbaum et al., 2019). Thus, interest rates not only affect NPL directly but also amplify its adverse impact on efficiency under tighter monetary conditions.

**H7:** Interest rates moderate the relationship between Non-Performing Loans (NPL) and the Cost-to-Income Ratio (CIR).

Banking efficiency reflects the interaction of intermediation, income generation, and capital strength. Financial intermediation theory emphasizes efficient fund allocation (Greenbaum et al., 2019; Gurley & Shaw, 1956), Anticipated Income Theory highlights income stability (Ho & Saunders, 1981; Prochnow, 1949), and the Capital Adequacy Buffer Model underscores the role of capital adequacy in maintaining resilience (Allen et al., 2016; Lindquist, 2004). Taken together, these frameworks explain how CAR, ROA, and NPL shape CIR, indicating that bank performance depends not only on profitability but also on stability and sustainability (Ningsih & Dewi, 2020). This is evident in Regional Development Banks (BPD), which function as financial intermediaries and development agents under Law No. 10 of 1998 and Law No. 13 of 1962, and operate within regulatory frameworks such as POJK No. 12/POJK.03/2021, POJK No. 12/POJK.03/2020, and Law No. 4 of 2023, contributing to MSME financing, infrastructure development, and regional financial stability (Akilah, 2024; Goodfriend, 1999; Rosanti & Sulawesi, 2020).

Based on these theoretical foundations, the conceptual framework of this study is presented as follows.

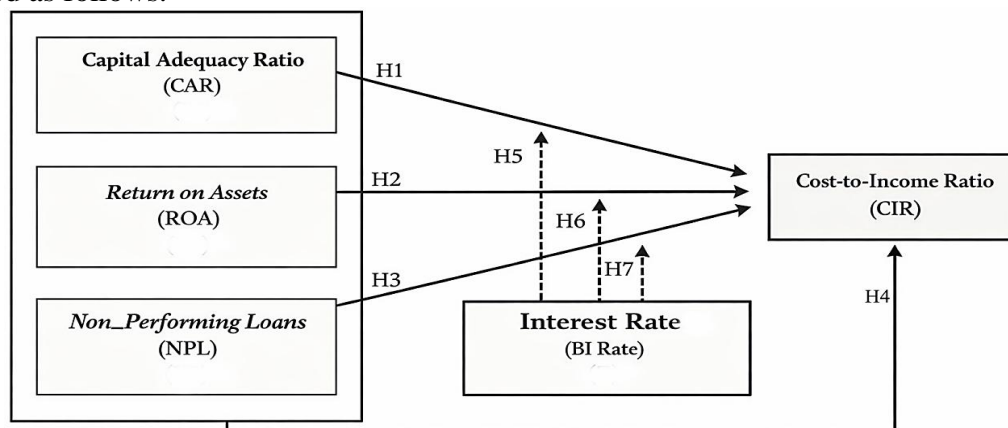


Figure 1. Conceptual Framework

Source: Author's elaboration:

## RESEARCH METHODS

This study uses a quantitative descriptive approach to analyze the operational efficiency of Regional Development Banks (RDBs) in Indonesia during 2020–2024, based on secondary data obtained from annual reports and official publications of the Financial Services Authority (OJK), Bank Indonesia (BI), and ASBANDA. From a population of 27 RDBs, 20 banks are selected through purposive sampling based on data completeness, reporting consistency, and the absence of mergers or capital constraints, yielding 100 observations. The study employs the Cost-to-Income Ratio (CIR) as the dependent variable, while Capital Adequacy Ratio (CAR), Return on Assets (ROA), and Non-Performing Loans (NPL) are used as independent variables, with the interest rate (BI Rate) as a moderating variable. Panel data analysis is applied to capture both cross-sectional and time-series variations, allowing a more comprehensive understanding of banking performance dynamics (Baltagi, 2021; Wooldridge, 2019).

Panel data regression is used to capture both cross-sectional and time-series variations, with model selection conducted through Chow, Hausman, and Lagrange Multiplier tests to identify the most appropriate specification among CEM, FEM, and REM (Baltagi, 2021; Basuki & Prawoto, 2021). The Random Effects Model (REM) is estimated using Generalized Least Squares (GLS), which accounts for unobserved heterogeneity and relaxes classical OLS

assumptions by incorporating the variance–covariance structure of residuals (Baltagi, 2021; Wooldridge, 2019), making diagnostic tests supportive rather than primary. Hypothesis testing is performed using t-test, F-test, and Adjusted R<sup>2</sup>, complemented by Moderated Regression Analysis (MRA) to examine the moderating effect of interest rates through interaction terms, with all estimations conducted using EViews 13 (Basuki & Prawoto, 2021).

## RESULTS AND DISCUSSION

### Results

Descriptive statistics in Table 1 provide an overview of the data prior to panel regression estimation. CAR shows an average of 25.37% with values ranging from 15.19% to 45.64%, indicating moderate variation in capital strength across RDBs. ROA averages 2.16%, ranging from 0.51% to 4.31%, reflecting relatively low but stable profitability. NPL average 2.36% with a range between 0.45% and 6.27%, indicating variation in credit quality across banks. CIR averages 77.01%, ranging from 60.58% to 90.20%, suggesting relatively high but dispersed operational costs. Interest rates average 4.9%, fluctuating between 3.5% and 6%. CAR and NPL exhibit relatively higher variability compared to ROA, while CIR remains persistently high, indicating efficiency constraints in the banking sector during the observation period.

Table 1. Descriptive Statistics of Research Variables

	CAR	ROA	NPL	Interest Rate	CIR
Mean	0.253726	0.021609	0.023631	0.049000	0.770122
Median	0.241550	0.020400	0.023650	0.052500	0.772500
Maximum	0.456400	0.043100	0.062700	0.060000	0.902000
Minimum	0.151900	0.005100	0.004500	0.035000	0.605800
Std. Dev.	0.057448	0.007081	0.010255	0.010848	0.065910
Skewness	1.399015	0.508077	0.596145	-0.248122	-0.217373
Kurtosis	5.113525	2.896784	4.030516	1.257538	2.626308
Jarque-Bera	51.23319	4.346765	10.34799	13.67680	1.369374
Probability	0.000000	0.113792	0.005662	0.001072	0.504248
Sum	25.37260	2.160900	2.363100	4.900000	77.01220
Sum Sq. Dev.	0.326728	0.004963	0.010411	0.011650	0.430065
Observations	100	100	100	100	100

Source: Processed data using EViews 13

Panel regression model selection is conducted to identify the most appropriate specification among the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM), as summarized in Table 2. The Chow test favors FEM over CEM, while the Hausman test supports REM over FEM by indicating no correlation between individual effects and the regressors. The Lagrange Multiplier test further confirms REM over CEM. These results establish REM as the most appropriate specification for the panel data..

Table 2. Summary of Panel Data Regression Model Selection

No.	Test	Model Comparison	Result	Selected Model
1	Chow Test	CEM vs FEM	0.0000 < 0.05	FEM
2	Hausman Test	FEM vs REM	0.0824 > 0.05	REM
3	LM Test	CEM vs REM	0.0000 < 0.05	REM

Source: Processed data using EViews 13

Estimation using the REM–EGLS approach (Table 3) shows that ROA has a negative and significant effect on CIR, while CAR, NPL, and interest rates are not significant. The rho value

of 0.3869 indicates moderate cross-sectional variation, supporting the use of REM. ROA emerges as the most consistent determinant of CIR, highlighting the central role of profitability in shaping operational efficiency across RDBs.

Table 3. Random Effect Model (REM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.946688	0.028064	33.73337	0.0000
CAR	-0.132866	0.074762	-1.777182	0.0787
ROA	-6.349309	0.691251	-9.185246	0.0000
NPL	0.401457	0.419176	0.957728	0.3406
Suku Bunga	-0.308954	0.300605	-1.027774	0.3067
Effects Specification				
			S.D.	Rho
Cross-section random			0.021506	0.3869
Idiosyncratic random			0.027073	0.6131

Source: Processed data using EViews 13

From Table 3, the panel regression yields the following equation: **CIR = 0.946688 – 0.132866 CAR – 6.349309 ROA + 0.401457 NPL – 0.308954 Interest Rate.**

The constant of 0.946688 indicates the baseline level of CIR when all explanatory variables are held constant. The results reinforce the earlier finding that profitability plays a dominant role in shaping efficiency. ROA exhibits a negative and highly significant effect on CIR with a coefficient of  $-6.349309$  ( $p = 0.0000$ ), while CAR shows a negative effect that is significant at the 10 percent level ( $-0.132866$ ;  $p = 0.0787$ ). In contrast, NPL and interest rates do not exert statistically significant effects, with coefficients of  $0.401457$  ( $p = 0.3406$ ) and  $-0.308954$  ( $p = 0.3067$ ), respectively. These patterns suggest that operational efficiency in Regional Development Banks is driven more by the ability to generate income than by capital strength, credit risk, or interest rate movements during the observation period.

Model reliability is further supported by diagnostic evaluation. The Jarque–Bera probability of 0.0000 indicates non-normal residuals, yet this does not undermine inference under the REM–GLS framework, particularly with a sample size of 100, where estimators remain asymptotically valid (Baltagi, 2021). Heteroskedasticity is not separately tested, as the GLS approach already accounts for the variance–covariance structure of residuals, making robustness more relevant than formal testing (Wooldridge, 2019). Multicollinearity is not a concern, with all VIF values well below 10 (CAR = 1.427; ROA = 1.241; NPL = 1.260; interest rate = 1.436), and the Durbin–Watson statistic of 1.686 indicates no evidence of positive autocorrelation, confirming that residuals are sufficiently independent.

To complete the analysis, partial and simultaneous significance tests are applied within the established Random Effects Model. The t-test evaluates the contribution of each variable by accounting for the panel error structure, while the F-test captures their joint influence on CIR (Baltagi, 2021). The results are presented in Table 4.

Table 4. Results of t-test (Partial) and F-test (Simultaneous) – Random Effects Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.946688	0.028064	33.73337	0.0000
CAR	-0.132866	0.074762	-1.777182	0.0787
ROA	-6.349309	0.691251	-9.185246	0.0000
NPL	0.401457	0.419176	0.957728	0.3406
Suku Bunga	-0.308954	0.300605	-1.027774	0.3067
Effects Specification				
			S.D.	Rho
Cross-section random			0.021506	0.3869
Idiosyncratic random			0.027073	0.6131

Weighted Statistics			
R-squared	0.570051	Mean dependent var	0.377811
Adjusted R-squared	0.551948	S.D. dependent var	0.041551
S.E. of regression	0.027813	Sum squared resid	0.073489
F-statistic	31.48908	Durbin-Watson stat	1.686087
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.713238	Mean dependent var	0.770122
Sum squared resid	0.123326	Durbin-Watson stat	1.004722

Source: Processed data using EViews 13

Table 4 reports the REM results. The t-test shows that ROA has a negative and significant effect on CIR (5%), confirming that higher profitability improves efficiency. CAR is insignificant at 5% but weakly significant at 10%, while NPL and interest rates are not significant. The F-statistic (31.48908;  $p = 0.0000$ ) indicates joint significance of all variables. The model explains 57.01% of CIR variation (weighted  $R^2 = 0.570051$ ), with no serious autocorrelation ( $DW = 1.686087$ ), and REM–EGLS estimates remain efficient (Baltagi, 2021). Hypothesis testing results are summarized in Table 5.

Table 5. Summary of Hypothesis Testing

Hypothesis	Variable	Test Result	Decision	Conclusion
H1	CAR → CIR	$p = 0.0787$	Rejected	Not significant
H2	ROA → CIR	$p = 0.0000$	Accepted	Significant (negative)
H3	NPL → CIR	$p = 0.3406$	Rejected	Not significant
H4	Simultan	$F = 5.347612 (0.000629)$	Accepted	Significant

Source: Processed data using EViews 13

Table 5 shows that only ROA significantly affects CIR, while CAR and NPL are individually insignificant but jointly significant. This highlights profitability as the main driver of operational efficiency in Regional Development Banks during 2020–2024. To extend the analysis, MRA is applied using interaction terms between interest rates and each variable under the REM–EGLS framework. Results are presented in Table 6.

Table 6. Interaction Results of Moderated Regression Analysis (MRA)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.821555	0.011644	70.55702	0.0000
Interest Rate × CAR	2.292786	0.873955	2.623461	0.0101
Interest Rate × ROA	-109.5478	10.84169	-10.10431	0.0000
Interest Rate × NPL	31.18323	7.810380	3.992537	0.0001

Source: Processed data using EViews 13

Table 6 shows that interest rates significantly moderate all relationships. The interaction with CAR is positive ( $\beta = 2.292786$ ;  $p = 0.0101$ ), indicating that higher rates strengthen the sensitivity of efficiency to capital. The interaction with ROA is negative and highly significant ( $\beta = -109.5478$ ;  $p = 0.0000$ ), suggesting that profitability becomes more effective under higher rates. Meanwhile, the interaction with NPL is positive ( $\beta = 31.18323$ ;  $p = 0.0001$ ), implying that higher rates amplify the adverse effect of credit risk on efficiency. These results confirm that interest rates shape how internal banking fundamentals translate into operational performance..

### Discussion

In this study, capital adequacy shows a negative but statistically weak effect on the Cost-to-Income Ratio (CIR), indicating that stronger capital tends to improve efficiency, although the effect is not consistent across all Regional Development Banks. This suggests that while capital supports stability, its contribution to operational efficiency is not always direct. Theoretically,

higher capital reduces risk exposure and financial distress costs (Moyer, 1990), consistent with capital buffer literature emphasizing the role of excess capital in absorbing shocks and maintaining discipline (Allen et al., 2016; Corbae & D’Erasmus, 2021; Jokipii & Milne, 2011; Lindquist, 2004). From an agency perspective, stronger capital may limit risk-taking and improve cost control (Haque, 2018), although holding excess capital can create opportunity costs that may offset efficiency gains (Mankart et al., 2020). Banking efficiency is proxied by the Cost-to-Income Ratio (CIR), recognized under OJK Regulation No. 6/POJK.03/2016, reflecting how effectively banks convert resources into operational performance, where capital adequacy, profitability, and credit quality jointly shape cost structure, income generation, and risk exposure (Ningsih & Dewi, 2020).

Consistent with buffer theory, banks maintain capital above regulatory requirements to manage risk over time (Allen et al., 2016; Corbae & D’Erasmus, 2021; Jokipii & Milne, 2011). Empirically, CAR has a negative but statistically insignificant effect on CIR ( $p > 0.05$ ), indicating that the direction aligns with theory but lacks statistical strength. This contrasts with prior studies (Alnajjar & Othman, 2021; Azhar & Yeniwati, 2021; Fathurrahman & Rahmadani, 2024), suggesting that capital efficiency is context-dependent, particularly regarding cost structure and post-pandemic adjustments.

Profitability, proxied by Return on Assets (ROA), has a stronger effect on efficiency. ROA shows a significant negative effect on CIR ( $p < 0.01$ ), indicating that higher profitability improves cost efficiency. From a financial intermediation perspective, ROA reflects the effectiveness of asset transformation into income, enabling better cost control relative to revenue. In line with agency theory (Jensen & Meckling, 1979), higher profitability also reflects reduced agency conflicts and improved managerial efficiency. This finding is consistent with prior studies (Azhar & Yeniwati, 2021; Fathurrahman & Rahmadani, 2024; Pinasti & Mustikawati, 2018), reinforcing ROA as the most robust determinant of banking efficiency.

Credit quality, proxied by NPL, is theoretically expected to weaken operational efficiency due to its effect on income stability and cost structure. Within the anticipated income framework, banks rely on expected cash flows from lending activities to maintain liquidity and operational performance (Ho & Saunders, 1981; Prochnow, 1949). An increase in NPL disrupts these cash flows, increases provisioning costs, and ultimately raises the Cost-to-Income Ratio (CIR) (Ozili, 2019). This mechanism is supported by financial intermediation theory, which emphasizes that poor credit management weakens intermediation efficiency.

Empirically, NPL has a positive but statistically insignificant effect on CIR ( $p > 0.05$ ), suggesting that although the direction aligns with theory, its impact is not statistically strong. This finding contrasts with prior studies (Azhar & Yeniwati, 2021; Deanna, 2018; Liviawati et al., 2020), which generally report a significant positive effect. This pattern may reflect adaptive credit management practices, including restructuring and risk mitigation strategies in the post-pandemic period.

Banking efficiency is not driven by individual variables alone but by their combined interaction. The results show that CAR, ROA, and NPL are jointly significant in explaining CIR, indicating that efficiency reflects a systemic outcome rather than isolated effects (Azhar & Yeniwati, 2021). Interest rates, as a key external factor, influence funding costs, lending behavior, and margins (Greenbaum et al., 2019; Gurley & Shaw, 1956; Mishkin, 2021), shaping how internal fundamentals translate into efficiency and reinforcing sensitivity to macroeconomic conditions.

Building on these results, the interaction between interest rates and CAR is positive and significant, indicating that capital effectiveness becomes more sensitive under changing monetary conditions. This is consistent with capital buffer literature, which suggests that banks maintain capital above regulatory minimums to absorb shocks and sustain stability (Allen et al., 2016; Corbae & D’Erasmus, 2021; Jokipii & Milne, 2011; Lindquist, 2004). Empirical evidence

further shows that higher interest rates increase funding costs and reduce efficiency through margin pressures (Aviliani et al., 2015; Ekananda, 2017; Liviawati et al., 2020; Viphindrartin et al., 2021), while also influencing managerial decisions in capital allocation.

In contrast, the interaction between ROA and interest rates is negative and highly significant, suggesting that profitability becomes more effective in improving efficiency under tighter monetary conditions. ROA reflects both asset utilization and managerial efficiency (Jensen & Meckling, 1979), and prior studies show that interest rates affect profitability through funding cost pressures and lending margin dynamics (Darmawan et al., 2020; Syah, 2018). Under such conditions, more profitable banks are better able to sustain efficiency despite rising costs.

Similarly, the interaction between NPL and interest rates is positive and significant, indicating that interest rates amplify the adverse effect of credit risk. Consistent with anticipated income theory (Ho & Saunders, 1981; Prochnow, 1949), higher rates increase repayment burdens, elevate default risk, and raise provisioning costs, ultimately worsening CIR (Azizzah et al., 2021; Ozili, 2019). This reflects weakened credit allocation efficiency under macroeconomic pressure (Greenbaum et al., 2019).

These findings imply that efficiency in Regional Development Banks is primarily driven by profitability, with ROA highlighting the importance of effective asset utilization over capital accumulation. Managerially, this shifts attention toward better asset allocation, more disciplined credit pricing, and income diversification. While CAR and NPL show limited direct effects, their interaction with interest rates indicates that efficiency remains sensitive to changing monetary conditions, requiring more adaptive risk management aligned with interest rate movements.

From a policy perspective, interest rates act as a key transmission channel shaping efficiency through their impact on costs, margins, and risk exposure. This underscores the need for stronger macroprudential coordination, particularly during tightening cycles, to prevent rising funding costs and credit risk from amplifying inefficiencies in banking performance.

## CONCLUSION

This study finds that operational efficiency in Regional Development Banks is primarily driven by internal performance, with ROA as the most consistent factor reducing CIR. CAR shows a negative but weak effect, while NPL is not significant individually. However, all variables are jointly significant, indicating that efficiency arises from their interaction rather than isolated effects. Interest rates further moderate this relationship, shaping how internal performance translates into efficiency.

These findings offer a more integrated view than prior studies focused on partial effects. Profitability emerges as the most stable determinant, while capital adequacy and credit risk are more conditional on monetary conditions. The moderating role of interest rates shows that efficiency evolves with changes in funding costs, margins, and risk exposure, reflecting an adjustment between internal capacity and external pressure.

Future research may extend this framework by incorporating additional determinants such as liquidity risk, bank size, cost structure, digitalization, and governance. The use of dynamic panel methods, particularly GMM, can better address endogeneity and lagged effects. Comparative analysis across bank groups and longer observation periods may further capture structural differences and evolving efficiency under changing monetary conditions.

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