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Internal and External Determinants of Profitability In 50 Banks In Indonesia (2012-2023)

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Abstract. This research aims to analyze the influence of internal and external factors on bank profitability in Indonesia, measured by return on assets (ROA) and return on equity (ROE). Bank profitability is a crucial pillar for the sustainability and growth of financial institutions, making it highly essential for operational continuity and the ability to provide financial services. Therefore, an in-depth analysis of the factors influencing it is indispensable. The analysis was conducted using data from banks listed on the Indonesia Stock Exchange during the period 2012–2023 and the panel data regression method. The approaches used include the common effect model (CEM), fixed effect model (FEM), and random effect model (REM), along with diagnostic tests such as the Chow test, Hausman test, and Lagrange multiplier test to determine the best model. The research results indicate that bank profitability is positively and significantly influenced by net interest margin but negatively and significantly influenced by total money supply and the BI rate (or interest rates).

Keywords: Internal, External, Profitability, Bank Indonesia

INTRODUCTION

The banking sector plays a very important role in economic stability and growth by providing financial intermediation between savers and borrowers. Banks contribute to economic development through their ability to allocate resources effectively, allowing companies to thrive and individuals to access financing (Rose & Hudgins, 2015; Wang et al., 2025; Wiwoho et al., 2021). In Indonesia, Regional Development Banks (BPDs) play an important role in supporting the regional economy, especially in providing financing for Small and Medium Enterprises (SMEs), which are very important for the national economy (Fitri Rohimah et al., 2024; Khassawneh, 2024; Li & Pang, 2023; Wang et al., 2025).

However, despite their significant role, many BPDs in Indonesia face challenges that hinder their competitiveness compared to other commercial banks. According to the Financial Services Authority (OJK), BPDs show relatively low growth in terms of total assets, third-party funds, and credit disbursement, which impacts their ability to contribute to regional development effectively. This situation underscores the importance of understanding the factors that affect the profitability of these banks, as profitability is a key factor in a bank's ability to maintain operations, develop services, and contribute to economic development. Research by Supriyono and Herdhayinta (2019) revealed that the profitability of regional development banks in Indonesia is influenced by internal factors such as total assets and loan-to-deposit ratio (LDR), as well as external factors such as Bank Indonesia's inflation rate and interest rate, all of which have a significant impact on banks' financial performance. In addition, OJK (2015) stated that the low competitiveness of BPDs compared to other commercial banks has the potential to hinder regional economic growth, especially in supporting funding for MSMEs that depend on BPDs as their main source of financing.

Bank profitability is one of the main indicators in assessing a bank's financial performance. The two ratios that are often used to measure a bank's profitability are Return on Assets (ROA) and Return on Equity (ROE). ROA measures how effectively a bank uses its

assets to generate profits, while ROE measures the extent to which the bank can utilize the capital provided by shareholders to generate profits. An increase in ROA and ROE shows that the bank is able to manage its resources well, which in turn strengthens the bank's competitive position in the market. As explained in research by Supriyono and Herdhayinta (2019), banks with good financial performance can distribute more credit to the business sector and contribute to faster economic growth. However, the low competitiveness of BPDs in Indonesia, as highlighted by OJK (2015), shows the importance of increasing profitability to support the role of BPDs in regional economic development.

Various factors affect a bank's financial performance, both internal factors such as asset management, capital, and operating costs, as well as external factors such as macroeconomic conditions. According to research by Supriyono and Herdhayinta (2019), factors such as total assets, loan-to-deposit ratio (LDR), and non-performing loans (NPL) have a significant influence on bank profitability, both in terms of ROA and ROE. External factors such as Bank Indonesia's inflation rate and interest rates also affect bank profitability, with impacts varying depending on economic conditions. This research shows that banks that can manage internal factors well, such as asset management and non-performing loans, will be better able to increase their ROA and ROE, thereby strengthening the bank's competitive position in the market.

In addition, a study by Martini (2022) revealed that the ratio of operating costs to operating income (BOPO) and NPLs has a significant positive effect on the financial performance of banks in Indonesia (Martini, 2022). This research shows that increasing BOPO and NPLs can increase a bank's ROA, which in turn will increase the bank's overall profitability. These findings are in line with Arifin and Shafira (2024), which states that BOPO and NPLs have a significant influence on the profitability of Islamic banks in Indonesia. The research emphasizes that effective management of operational costs and credit risk are essential to improve the financial performance and competitiveness of banks. With more efficient BOPO management and a decrease in NPLs, banks can increase their Return on Assets (ROA), which in turn strengthens their position in Indonesia's increasingly competitive banking market.

Based on a review of the literature and empirical phenomena, a significant research gap was identified. The first gap lies in the inconsistency of empirical findings in previous studies. Many existing studies tend to test variables partially, resulting in divergent conclusions regarding the significance and direction of influence of variables such as LDR or Capital Adequacy Ratio (CAR) on profitability. These inconsistencies indicate the urgency for the development of a more comprehensive and holistic model by integrating a series of internal and external factors simultaneously.

The second gap, which is temporal and contextual, stems from the selection of the analysis period (2012-2023). This time span recorded unique economic dynamics, including structural disruptions due to the COVID-19 pandemic and the era of monetary policy normalization. Most previous research has not fully analyzed the impact of this full cycle on the resilience and adaptation of banking business models. Thus, an analysis of this period has the potential to provide new empirical insights that have not been extensively documented.

Finally, this study aims to fill the gap in terms of generalizability of results by expanding the scope of the sample to 50 banks. This approach allows for a richer and more representative analysis of the various scales and business models of banking in Indonesia, going beyond the

focus on the elite bank group (KBMI 4) that dominates the literature. Therefore, this study was proposed to address these gaps through a comprehensive analysis of the internal and external determinants of profitability (ROA and ROE) across a broad spectrum of banking during periods characterized by less stable economic conditions.

Thus, to increase the profitability and competitiveness of BPDs in Indonesia, it is very important to manage internal and external factors that affect ROA and ROE more efficiently. In addition, bank management needs to closely monitor and adapt policies that support sustainable profitability growth, so that banks can continue to make optimal contributions to regional economic development.

Based on the research background, the formulation of the problem and the objectives of this research focus on the analysis of the influence of internal and external factors of banking, namely Total Assets (TA), Total Core Capital (TCORCAP), Capital Adequacy Ratio (CAR), Non-Performing Loan (NPL), Loan to Deposit Ratio (LDR), Operating Costs to Operating Income (BOPO), Net Interest Margin (NIM), and macroeconomic factors in the form of Total Money Supply (TMS), inflation (INF), and the BI Rate on the profitability of Regional Development Banks (BPDs) in Indonesia as measured through Return on Assets (ROA) and Return on Equity (ROE). This research aims to provide a comprehensive understanding of how each of these variables affects the bank's profitability performance, as well as producing theoretical and practical benefits for academics, banking practitioners, investors, and the general public, especially in understanding the impact of regulations, capital management, operational efficiency, asset quality, and monetary policy on the stability and performance of the banking sector in Indonesia. The results of this research are expected to provide strategic recommendations for bank management in optimizing profitability by focusing on key variables such as Net Interest Margin (NIM), as well as managing the negative impacts of macroeconomic factors such as the BI Rate and Total Money Supply. Furthermore, this study contributes to the literature by offering an updated empirical model that integrates panel data regression with machine learning approaches, enriching the methodology used in banking financial analysis. Practically, the findings can serve as a reference for regulators in formulating policies that support the growth of a resilient and profitable national banking sector.

MATERIALS AND METHOD

This study uses a quantitative approach with an explanatory panel data analysis method to investigate the influence of the capital adequacy ratio and bank-specific variables on bank profitability. Profitability is measured using Return on Assets (ROA) and Return on Equity (ROE), with independent variables including Total Assets (TA), Total Core Capital (TCORCAP), Capital Adequacy Ratio (CAR), Non-Performing Loan (NPL), Loan to Deposit Ratio (LDR), Operating Expenses to Operating Income (BOPO), Net Interest Margin (NIM), Money Supply (TMS), Inflation (INF), and Benchmark Interest Rate (BIRATE). The empirical model is formulated in two equations, namely the ROA model and the ROE model, which are analyzed using panel data to combine the cross-section and time-series dimensions. The use of panel data allows for the control of unobserved individual heterogeneity and improves the efficiency and accuracy of estimates, thus providing more comprehensive information in explaining the causal relationships between study variables compared to the use of cross-sectional or time-series data separately.

The population in this study is all public companies that have been listed on the Indonesia Stock Exchange (IDX) since 1973. The research sample consists of 50 banks listed on the Indonesia Stock Exchange with quarterly financial data covering the period of the first quarter of 2012 to the fourth quarter of 2023. The selection of the time period is intended to capture the dynamics of Indonesian banking in the long term and covers a variety of different economic conditions, including periods of economic stability and volatility.

The use of panel data with 50 banks over 48 quarters or 12 years resulted in a large enough total observations to conduct robust econometric analysis. The combination of the cross-sectional dimension that includes 50 banks and the time-series dimension that includes 48 quarterly periods allows the study to analyze not only interbank variations but also changes within each bank over time. This provides an advantage in understanding the dynamics of banking profitability both from the perspective of comparison between institutions and temporal developments in each banking institution.

The data used in this study is secondary data obtained from various reliable sources. Quarterly financial data of banks listed on the Indonesia Stock Exchange (IDX) is collected from Capital IQ and Capital IQ Pro, which includes information on total assets, core capital, capital adequacy ratio, non-performing loans, loan to deposit ratio, net interest margin, and operating expenses to operating income. Meanwhile, macroeconomic variables are obtained from official government sources, namely Total Money Supply (TMS) and inflation data from the Central Statistics Agency (bps.go.id) and BI Rate data from Bank Indonesia (bi.go.id), to ensure the validity and reliability of the data. To minimize the influence of outliers that have the potential to distort the results of the analysis, all data is analyzed at a rate of 1% by replacing the extreme values at a certain percentile without eliminating observations. Data processing and analysis is carried out using R Studio software that supports panel data analysis and advanced statistical techniques.

This study uses twelve variables that refer to previous studies, with Return on Assets (ROA) and Return on Equity (ROE) as bound variables that measure the bank's profitability, while the independent variables include Total Assets (TA), Total Core Capital (TCORCAP), Capital Adequacy Ratio (CAR), Non-Performing Loan (NPL), Loan to Deposit Ratio (LDR), Net Interest Margin (NIM), and Operating Costs to Operating Income (BOPO), as well as control variables in the form of Total Money Supply (TMS), inflation (INF), and BI Rate. The analysis was carried out using the panel data method through the Common Effect Model (CEM), Fixed Effects Model (FEM), and Random Effects Model (REM), with the selection of the best model determined through the Chow Test, Hausman Test, and Lagrange Multiplier Test. To ensure the validity of the estimation results, this study also conducted diagnostic tests including autocorrelation (Wooldridge), heteroscedasticity (Breusch-Pagan), and cross-sectional dependence (Pesaran). In addition to the conventional econometric approach, this study complements the analysis with the measurement of the importance of variables using machine learning techniques, namely Random Forests and XGBoost, to identify the variables that have the most influence on the bank's profitability in a more comprehensive and robust manner.

RESULTS AND DISCUSSION
Results and Interception

Before conducting the regression of the panel data, the densest violations of the diagnostic test results, such as autocorrelation, heteroscedasticity, and cross-sectional dependency tests. All violations of classical assumptions have been addressed using Driscoll-Kraay Standard Errors. According to Driscoll and Kraay (1998), this approach is designed to provide a robust error standard to the problems of autocorrelation, heteroscedasticity, and cross-sectional dependence, which is particularly useful in panel data models where these problems are frequent. The Driscoll-Kraay method adjusts the error standard to accommodate the problem without requiring special assumptions about the data structure. This correction ensures that the estimated coefficients resulting from regression are reliable and can be used for accurate inferences, even in the presence of these economicometric problems (Driscoll & Kraay, 1998). Table 4.7 below shows the regression results of various financial variables in the two panel data regression models. These models are categorized based on two dependent variables, namely ROA and ROE. This comparative approach allows us to understand how different measurement ratios affect key banking metrics.

Table 1. Panel Data Regression Results

Independent Variables	ROA		ROE	
	Coef	P	Coef	P
TA	-0,0011	0,0575	-0,0088	0,0026*
TCORCAP	0,0029	0,2784	0,0167	0,2035
CAR	0,0155	0,16550	0,0057	0,8344
NPL	-0,0233	0,0294*	0,0159	0,8334
LDR	-0,0029	0,2313	-0,0210	0,2227
BEFORE	0,1870	0,0014*	0,8149	0,0026*
BOPO	-0,0004	0,8526	-0,0747	0,1567
TMS	-0,0164	0,0000*	-0,1071	0,0000*
INF	-0,0149	0,1304	0,7586	0,0013*
BI RATE	-0,1473	0,0187*	-1,9535	0,0000*
Adj, R-Squared	0,0407		0,0512	
Prob>F	0,0000*		0,0000*	

*) significant

Source: Analysis of panel data regression (Fixed Effect Model) using quarterly financial data of 50 banks listed on the Indonesia Stock Exchange (IDX), 2012–2023

The Probability value of F for both models is below 0.05, indicating that all models are significant at a 95% confidence level. This indicates that all models are valid and supports evidence that at least one variable is significant for the dependent variable. A very small probability value of F means that the regression model is valid so that the model can be relied upon to understand the factors that affect the bank's profitability. The result of the probability value of F is the same as the results of the research conducted by Supriyono and Herdhayinta (2019) where the probability of regression for all models is 0.0000.

There is a slight difference in value between the model-adjusted Adjusted R-Squared results for ROA and ROE. The Adjusted R-Squared value of 0.0407 for the ROA model indicates that the independent variables in the ROA model can only explain about 4% of the ROA variation. Although this value is considered low, it suggests that although both models have a significant effect on ROA, there is still about 96% variation in ROA explained by other

factors not accounted for in the model. For the ROE model, and the Adjusted R-Squared value of 0.0512 for the ROE model, it shows that independent variables in the ROE model explain about 5% of the ROE variation while 95% of the ROE variation can be affected by other factors not calculated in the model. The adjusted Adjusted R-Squared value of this study was significantly lower than the Adjusted R-Squared value of the study managed by Supriyono and Herdhayinta (2019), which obtained 0.902 for the ROA model and 0.848 for the ROE model.

The results showed that the TA variable had a p-value of 0.0575 and a coefficient value of -0.0011 for ROA and had a p-value of 0.0026 and a coefficient value of -0.0088 for ROE. So the H1a hypothesis is rejected and H1b is supported. This means that total assets have no influence on the bank's profitability in the form of ROA but Total Assets have a negative and significant influence on ROE. This research is not in line with the research of Supriyono and Herdhayinta (2019) which shows that total assets have a significant influence on the profitability of banks both in increasing ROA and ROE. However, the results of this study are in line with the results of research conducted by Mukaromah and Krisnaningsih (2023) which show that total assets have no influence on the bank's profitability (Mukaromah & Krisnaningsih, 2023). Ara et al. (2021) explain that although total assets have a positive influence on profitability, the very size of banks can face challenges in terms of operational efficiency and greater risk (Ara et al., 2021). Banks with very large total assets often face complexities in managing larger resources, which can reduce operational efficiency. On the other hand, Mai (2021) notes that while total assets play an important role in increasing profitability, banks should consider other factors, such as risk management and the quality of asset management, to ensure that large assets can be managed efficiently and contribute to long-term profitability (Mai, 2021).

The TCORCAP variable has a coefficient value of 0.0029 and a p-value of 0.2784 for ROA and has a coefficient value of 0.0167 and a p-value of 0.2035 for ROE. So the H2a and H2b hypotheses are rejected. This means that the total core capital has no influence on the bank's profitability. The results of this study are not in line with the research of Supriyono and Herdhayinta (2019) which showed that the results of total core capital have a negative and significant effect on the profitability of banks both in reducing ROA and ROE. However, the results of this study are in line with the results of research conducted by Wardan et al. (2024), the results of the study show that Total Core Capital (TCORCAP) has no effect on profitability. An increase in Total Core Capital, although it increases economic resources, but if invested in unproductive assets, it will increase the burden, so that profitability will decrease (Wardan et al., 2024).

The CAR variable has a coefficient value of 0.0155 and a p-value of 0.16550 for ROA and has a coefficient value of 0.0057 and a p-value of 0.8344 for ROE. So that the H3a and H3b hypotheses were rejected. This means that CAR has no influence on ROA and ROE. The results of this study are not in line with the research of Supriyono and Herdhayinta (2019) where CAR has a significant negative influence on ROA and capital adequacy ratio has no effect on ROE. However, the results of this study are in line with the results of research conducted by Wardan et al. (2024), the results of the study show that CAR has no effect on profitability. Increasing CAR, although it adds economic resources, if invested in unproductive assets, will increase the burden, so profitability will decrease (Wardan et al., 2024).

The NPL (Non-Performing-Loan) variable has a coefficient value of -0.0233 and a p-

value of 0.0294 for ROA and has a coefficient value of 0.0159 and a p-value of 0.8334 for ROE. So the H4a hypothesis is supported and H4b is rejected. This means that NPLs (Non-Performing-Loans) have a negative and significant influence on ROA but have no influence on ROE. The results of the study are not in line with the research of Supriyono and Herdhayinta (2019) which shows that NPLs (Non-Performing-Loans) do not have an influence on bank profitability either in increasing ROA. A high NPL ratio reflects the high credit risk faced by banks, which can reduce investor and customer trust in banks. In addition, Al-Sharkas and Al-Sharkas (2022) add that while a high NPL ratio may indicate greater risk, it may also reflect more aggressive lending policies that can increase short-term profitability if managed well (Al-Sharkas & Al-Sharkas, 2022). However, Prawira & Wiryono (2020) emphasize that high NPL ratios can indicate that banks face greater credit risk, which requires banks to reserve more funds to cover possible losses due to non-performing loans, which can ultimately affect the bank's profitability (Prawira & Wiryono, 2020).

The LDR (Loan to Deposit Ratio) variable has a coefficient value of -0.0029 and a p-value of 0.2313 for ROA and has a coefficient value of -0.0210 and a p-value of 0.2227 for ROE. So the H5a and H5b hypotheses were rejected. This means that LDR (Loan to Deposit Ratio) has no influence on the bank's profitability. The results of the study are not in line with the research of Supriyono and Herdhayinta (2019) which shows that LDR (Loan to Deposit Ratio) has a significant positive influence on bank profitability both in increasing ROA and ROE. However, the results of Mai (2021) research on LDR (Loan to Deposit Ratio) have no effect on bank profitability, which banks with high LDRs must be careful about, because excessive dependence on loans can increase liquidity risk. A low LDR, although it can reduce potential profitability, indicates that banks are more cautious in managing risk by ensuring that there are enough deposits to meet existing obligations (Mai, 2021).

The NIM (Net Interest Margin) variable has a coefficient value of 0.1870 and a p-value of 0.0000 for ROA and has a coefficient value of 0.8149 and a p-value of 0.0026 for ROE. So that the H6a and H6b hypotheses are not rejected. This means that NIM (Net Interest Margin) has a significant positive influence on the bank's profitability. The results of the study are in line with the research of Supriyono and Herdhayinta (2019) which shows that NIM (Net Interest Margin) has a significant positive influence on bank profitability both in increasing ROA and ROE. The NIM is determined from the interest rate, the larger this ratio, the more income on productive assets managed by the bank will increase, so that the possibility of banks in a problematic condition is smaller. With good credit quality, it can increase net interest income which can affect the bank's profitability. So with the higher the NIM ratio, the higher the bank's profitability (ROA) on its productive assets in the management of credit. However, the results of this study are not in line with Ishak et al. (2022) who stated that Net Interest Margin (NIM) has an insignificant effect on profitability (Ishak et al., 2022).

The BOPO variable has a coefficient value of -0.004 and a p-value of 0.8526 for ROA and has a coefficient value of -0.0747 and a p-value of 0.1567 for ROE. So the H7a and H7b hypotheses are rejected. This means that BOPO has no influence on the bank's profitability. The results of the study are not in line with the research of Supriyono and Herdhayinta (2019) which shows that BOPO has a significant positive influence on bank profitability both in increasing ROA and ROE. However, further research, Maryadi and Susilowati (2020) also found that BOPO has a negative effect on the value of companies listed on the IDX, confirming

that banks with better operational efficiency have a higher corporate value, although these findings are limited to the period 2015-2017 and only apply to banks listed on the stock exchange (Maryadi & Susilowati, 2020).

The TMS (Total Money Supply) variable has a coefficient value of -0.0164 and a p-value of 0.0000 for ROA and has a coefficient value of -0.1071 and a p-value of 0.000 for ROE. So the H8a and H8b hypotheses are supported. This means that TMS has a significant negative influence on the bank's profitability. The results of the study are in line with the research of Supriyono and Herdhayinta (2019) which shows that TMS (Total Money Supply) has a significant negative influence on bank profitability both in increasing ROA and ROE. However, these results are not in line with the results of research conducted by Ambarwati et al. (2021) and on the influence of gross domestic product, inflation, money supply and foreign exchange rate on the profitability of PT. Bank BRI Syariah Tbk stated that the money supply has a positive effect but does not have a significant effect on profitability (Ambarwati et al., 2021).

The INF variable (Inflation) has a coefficient value of -0.0640 and a p-value of 0.1304 for ROA and has a coefficient value of 0.7586 and a p-value of 0.0013 for ROE. So the H9a hypothesis is rejected and H9b is supported. This means that INF (Inflation) does not have the effect of ROA but INF (Inflation) has a significant positive influence on ROE. The results of the study are not in line with the research of Supriyono and Herdhayinta (2019) which shows that INF (Inflation) has a significant negative influence on bank profitability in both increasing ROA and ROE. However, these results are in line with the results of research conducted by Dithania and Suci (2022) showing that Inflation has a positive influence on the profitability of commercial banks listed on the Indonesia Stock Exchange (Dithania & Suci, 2022). Nahar and Sarker (2016) revealed that an increasing inflation rate will cause the price of goods and services to increase, this will also make investment increase. If investment increases, then Islamic bank financing will also increase and will increase the profitability of Islamic banks (Nahar & Sarker, 2016).

The BI RATE variable has a coefficient value of -0.1473 and a p-value of 0.0187 for ROA and has a coefficient value of -1.9483 and a p-value of 0.0000 for ROE. So the H10a and H10b hypotheses are supported. This means that the BI RATE has a significant negative impact on the Bank's profitability. The results of the study are not in line with the research of Supriyono and Herdhayinta (2019) which shows that BI RATE has a significant positive influence on bank profitability both in increasing ROA and ROE. However, these results are in line with the results of research conducted by Stefanus & Robiyanto (2020) stating that the BI RATE has a significant negative influence on changes in the stock price of the manufacturing sector, where the increase in the BI RATE causes high borrowing costs which in turn reduces the company's profitability (Stefanus & Robiyanto, 2020).

Based on the results of the analysis of the ROA of 0.0407 and ROE of 0.0512, increasing the bank's economic profitability can be achieved through the strategy of increasing Net Interest Margin (NIM), which has proven to have a positive and significant effect on both indicators. This shows that the bank's ability to manage the difference in income and interest costs is the main key to creating productive asset efficiency. On the other hand, management needs to be aware of the negative impact of Total Money Supply (TMS) and BI Rate which have been proven to suppress profitability, because increased liquidity and benchmark interest rates that are not addressed with proper risk management can erode profit margins. In addition, the

growth of Total Assets (TA) that is not balanced with management efficiency actually lowers ROE, so banks need to balance expansion with the quality of asset management. These findings confirm that profitability is not solely determined by size or capital, but by management's ability to respond to macroeconomic conditions adaptively and devise business strategies oriented towards efficiency and sustainability.

Variable Importance Analysis

This section uses Random Forests and XGBoost as machine learning techniques to evaluate the influence of variables on Return on Assets (ROA) and Return on Equity (ROE) and identify which variables contribute the most to a bank's profitability.
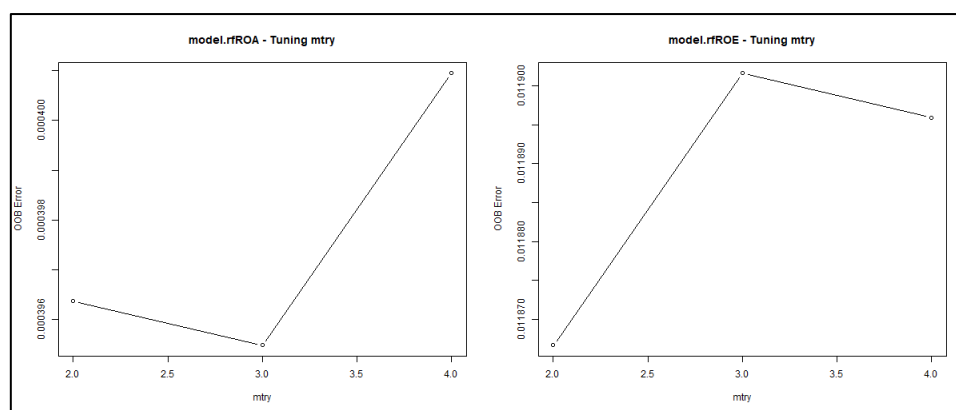
1. Random Forests

The first step in the application of Random Forests in this study is to impute the NA value on the data using the Random Forest method. The iteration parameter is set at 6, while the number of trees (ntree) is set at 500. Based on the graph below, the larger the number of trees used, the smaller the change in the Out-of-Bag error. After reaching about 500 trees, the increase in error rate becomes insignificant, so the ntree value is set at 500 to achieve a balance between model accuracy and computational efficiency.
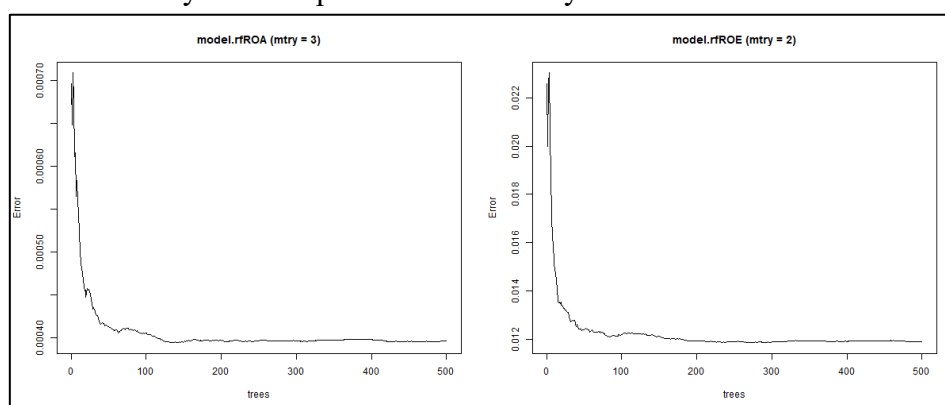
Figure 1. Out of Bag Error
Source: Output of Random Forest modeling using bank financial data (2012–2023), generated in R Studio

In the initial Random Forest model, an Out-of-Bag (OOB) Error evaluation was performed to assess the predictive performance of the ROA and ROE models. Based on Figure 1, it can be seen that as the number of trees increases to 500, the error rate shows a decrease before finally reaching stability. On the OOB Error chart for the ROA model, the error was initially around 0.0007, experienced a sharp decline to about 100 trees, and then stabilized at around 0.0004. Meanwhile, the OOB Error graph for the ROA model shows a similar pattern, where the error was initially at around 0.022, decreased sharply until the number of trees reached 100, and then sloped and stabilized at around 0.012. This pattern suggests that increasing the number of trees by more than 500 no longer provides a significant improvement in model accuracy, so the number of trees used is sufficient to produce an optimal model. The graph below visualizes the OOB Error for ROA and ROE models with different mtry values.

Figure 2. Tuned Random Forest Mtry models ROA and ROE
Source: Visualization of mtry parameter tuning results from Random Forest analysis on bank profitability data

Based on Figure 2, the tuning of the mtry parameters in the Random Forest model showed a significant influence on the accuracy of ROA and ROE predictions. In the ROA model, the optimal mtry value is 3 because it produces the lowest OOB Error. When mtry increases to 4, the OOB Error rises again due to excessive model complexity, thus reducing the prediction efficiency. For the ROE model, the optimal mtry is also at 2, where the model achieves the best performance. An increase or decrease in mtry beyond that number makes OOB Error increase, as the model loses balance in managing bias and variance. These results confirm that the selection of the right mtry value is essential to maintain prediction accuracy while maintaining the efficiency and generalization of the model.

Table 2. RMSE Model Random Forest

Random Forest	ROA	ROE
RMSE before tuning	0,0092	0,0499
RMSE after tuning	0,0090	0,0520

Source: Calculation of Root Mean Square Error (RMSE) based on Random Forest modeling using bank financial data (2012–2023)

Table 2 shows a comparison of the Root Mean Square Error (RMSE) values, or the rate of predictive error, of the Random Forest model in predicting ROA and ROE before and after model adjustment (tuning). The results showed that after tuning, the prediction error rate for ROA decreased slightly, suggesting that the accuracy of ROA predictions increased slightly, although not significantly. Meanwhile, ROE shows a slight increase in RMSE value. This shows that the tuning done does not have a significant effect on ROE or the ROE model is quite optimal. Although there was an increase in the RMSE value after tuning, the increase was only slightly around 0.0021 so it is not too worrying to worsen the ROE.

Table 3. Variable Importance Random Forest for ROA and ROE Models

ROA		ROE	
Variable	**Importance Level**	**Variable**	**Importance Level**
BEFORE	39,3700	BEFORE	30,6575
TCORCAP	18,6886	TCORCAP	22,9119
BOPO	15,1720	TA	21,4163
TA	14,5529	CAR	19,3996
CAR	12,7648	BOPO	18,0834
INF	9,9962	TMS	16,5234
TMS	9,7037	INF	11,4832
NPL	8,3916	NPL	7,1461
LDR	6,3615	YOU CHOOSE	6,8708
YOU CHOOSE	4,2055	LDR	6,4967

Source: Variable importance ranking derived from Random Forest analysis using financial and macroeconomic data of sampled banks

Table 3 shows that the Net Interest Margin (NIM) variable has the highest level of importance in influencing the prediction of the bank's financial performance, both for Return on Assets (ROA) and Return on Equity (ROE), with an interest level of 39.3700 in the ROA model and 30.6575 in the ROE model. TCORCAP is the second important factor in determining the bank's profitability so that capital is one of the foundations of the bank that has an influence on the bank's ability to generate profitability. Other variables such as BOPO and Total Assets (TA) also show significant influence on both models, reflecting the importance of operational efficiency and asset size in determining a bank's profitability.

Table 4.10 shows the level of importance or contribution of each variable to the Random Forest model in predicting ROA (Return on Assets) and ROE (Return on Equity). In the ROA model, the variable that has the greatest influence is Net Interest Margin (NIM), followed by Total Core Capital (TCORCAP), Operating Costs to Operating Income (BOPO), Total Assets (TA), Capital Adequacy Ratio (CAR), Inflation (INF), Total Money Supply (TMS) and Non-Performing Loans (NPL). The Loan-to-Deposit Ratio (LDR) and Interest Rate (BIRATE) variables have a smaller level of importance. In the ROE model, the Net Interest Margin (NIM) variable is also the most dominant, followed by Total Core Capital (TCORCAP), Total Assets (TA), Capital Adequacy Ratio (CAR), Operating Costs to Operating Income (BOPO), Total Money Supply (TMS), Inflation (INF) and Non-Performing Loans (NPL). Variable Interest Rates (BIRATE) and Loan-to-Deposit Ratio (LDR) have smaller levels of importance.
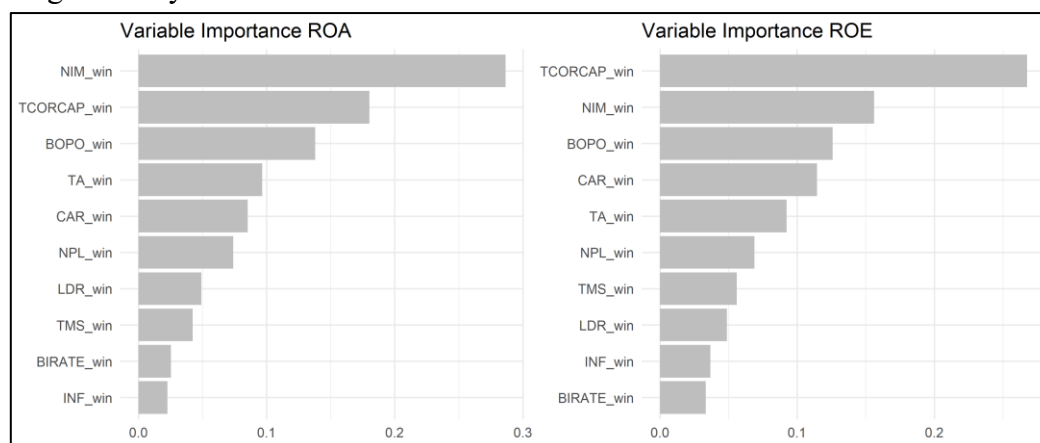
2. XGBoost

In this study, the XGBoost model was used to predict ROA (Return on Assets) and ROE (Return on Equity) by dividing the data into train data and test data using an 80:20 ratio. The initial model was run with max_depth parameters and a default number of 300 rounds, to calculate the Root Mean Square Error (RMSE) value on the training and test data in each boosting round. Next, a tuning process is carried out with a grid search on important parameters such as max_depth, eta, and nrounds to find the optimal combination of parameters. The following are the results of XGBoost RMSE, namely:

Table 4. XGBoost RMSE

XGBoost	ROA	ROE
RMSE before tuning	0,3454	0,3407
RMSE after tuning	0,0224	0,1303

Source: RMSE values from XGBoost model before and after hyperparameter tuning, based on bank dataset (2012–2023)

Based on Table 4, tuning on the XGBoost model successfully lowered the Root Mean Square Error (RMSE) value for ROA and ROE predictions. Prior to tuning, the model produces an RMSE of 0.3454 for ROA and 0.3407 for ROE. So that in the ROA the decrease is very large, namely 93.53% and for ROE of 61.90%. After tuning, the RMSE value decreased to 0.0224 for ROA and 0.1303 for ROE. This tuning process allows the model to reduce prediction errors by optimizing the balance between model complexity and the risk of overfitting, thereby improving accuracy.

Figure 3. Xgboost Variable Importance
Source: Variable importance plot from XGBoost model based on winsorized bank financial data (2012–2023)

Figure 3 shows the results of the variable importance of the XGBoost model on Return on Assets (ROA) and Return on Equity (ROE) after the winsorizing process on the data. For the ROA model, the variable that has the greatest influence is Net Interest Margin (NIM), followed by Total Core Capital (TCORCAP) and BOPO (operating costs to operating income). These variables show that operational efficiency and net interest income are key factors in determining the profitability of bank assets. Meanwhile, in the ROE model, the variable with the highest level of importance is TCORCAP, followed by NIM and BOPO, which indicates that capital strength as well as efficiency and interest margin are also the main determinants for equity returns. Other variables such as Total Assets (TA), Capital Adequacy Ratio (CAR), Non-Performing Loans (NPL), Loan to Deposit Ratio (LDR), Total Money Supply (TMS), Bank Indonesia interest rate (BIRATE), and inflation (INF) have a relatively smaller influence, but are still relevant. Overall, these results show that capital aspects, cost efficiency, and interest income structure remain the main determinants in measuring bank profitability, both in terms of assets and equity

Improving Model Performance

Based on the results of panel regression analysis with fixed effects models and evaluation using a machine learning approach, model optimization is carried out to improve the efficiency of predicting bank profitability. Based on Random Forest, the LDR and BI RATE variables were removed because they contributed low to the variance of asset efficiency in both the ROA and ROE models. Meanwhile, based on XGboost, the INF and BI RATE variables are removed because they contribute low to asset efficiency variance, while in the ROA and ROE models. The elimination of these variables aims to simplify the model without losing important information, thereby improving the model's ability to provide more accurate predictions.

Tabel 5. ROA Model Improvement Scenarios

No	Scenarios	Independent Variables	WO R-Squared
1	ROA Original Model	TA+TCORCAP+CAR+NPL+LDR+NIM+ BOPO+TMS+INF+BI RATE	0,0407
2	RF 3 variable	NIM+TCORCAP+BOPO	0,0023
3	RF 4 variable	NIM+TCORCAP+BOPO+TA	0,0019
4	RF 5 variable	NIM+TCORCAP+BOPO+TA+CAR	0,0081
5	RF without BIRATE	NIM+TCORCAP+BOPO+TA+CAR+INF+ TMS+NPL+LDR	0,0391
6	RF without LDR and BI RATE	NIM+TCORCAP+BOPO+TA+CAR+INF+TMS +NPL	0,0391
7	XGBoost without INF	NIM+TCORCAP+BOPO+TA+CAR+NPL+ LDR+TMS+BIRATE	0,0409
8	XGBoost without BIRATE dan INF	NIM+TCORCAP+BOPO+TA+CAR+NPL+ LDR+TMS	0,0390

Source: Comparison of Adjusted R-squared values across different variable selection scenarios based on Random Forest and XGBoost outputs

Tabel 6. ROE Model Improvement Scenarios

No	Scenarios	Independent Variables	WO R-Squared
1	Original Model ROE	TA+TCORCAP+CAR+NPL+LDR+NIM+ BOPO+TMS+INF+BI RATE	0,0512
2	RF 3 variable	NIM+TCORCAP+TA	0,0075
3	RF 4 variable	NIM+TCORCAP+TA+CAR	0,0071
4	RF 5 variable	NIM+TCORCAP+TA+CAR+BOPO	0,0060
5	RF without LDR	NIM+TCORCAP+TA+CAR+BOPO+TMS+ INF+NPL+BIRATE	0,0523
6	RF without BI RATE and LDR	NIM+TCORCAP+TA+CAR+BOPO+TMS+ INF+NPL	0,0389
7	XGBoost without BIRATE	TCORCAP+NIM+BOPO+CAR+TA+NPL+ TMS+LDR+INF	0,0389
8	XGBoost without INF dan BIRATE	TCORCAP+NIM+BOPO+CAR+TA+NPL+ TMS+LDR+INF	0,0381

Source: Comparison of Adjusted R-squared values across different variable selection scenarios based on Random Forest and XGBoost outputs

Based on Tables 5 and 6, improvements to the Return on Assets (ROA) and Return on Equity (ROE) models were carried out through various scenarios by eliminating several

independent variables. In Table 5, which focuses on the ROA model, the original model with all independent variables has an Adjusted R-Squared of 0.0407. The reduction of the variables to three (NIM, TCORCAP and BOPO) lowered the Adjusted R- Squared to 0.0023, indicating a significant influence of other variables on the model. The other scenario, the removal of the INF variable, slightly increased the Adjusted R-Squared, with a high value of 0.0409.

On the other hand, Table 6 shows similar results for the ROE model. The original model had an Adjusted R-Squared of 0.0512. The reduction of the variable to three (NIM, TCORCAP and BOPO) resulted in a significant decrease to 0.0075. Models with LDR variable elimination, slightly improved the Adjusted R-Squared, with the highest value of 0.0523.

CONCLUSION

This study analyzes the influence of internal and external factors on the profitability of banks in Indonesia using quarterly financial data of 50 banks listed on the IDX for the period 2012–2023, with ROA and ROE as indicators of profitability. The results showed that Total Assets had no effect on ROA but had a significant negative effect on ROE, while TCORCAP, CAR, LDR, and BOPO had no significant effect on profitability. NPLs have a significant negative effect on ROA but not on ROE, while NIM has a significant positive effect on ROA and ROE. Macroeconomic factors show that Total Money Supply (TMS) and BI Rate have a significant negative effect on ROA and ROE, while inflation does not affect ROA but has a significant positive effect on ROE. Theoretically, these findings support Credit Risk Theory and Liquidity Preference Theory, and show that credit risk management, asset efficiency, and interest margin determine profitability more than capital adequacy. From a managerial perspective, banks need to optimize asset utilization, reduce NPLs, and increase NIM, while further research is recommended to expand the sample, add variables, extend the analysis period, and combine quantitative and qualitative approaches.

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