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Determinants of ASEAN Banking System Stability: Panel Regression Analysis of Z-Score and NPL

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Abstract: This research examines the determinants of banking stability in six ASEAN countries (2019–2023) using a microprudential framework. Analyzing 438 commercial banks through Fixed Effect Models, we measure stability using the Z-Score (insolvency risk) and the NPL ratio (credit risk). The results identify ROA as the most influential determinant positively affecting the Z-Score while reducing NPL thereby confirming profitability's crucial role in strengthening banking stability. Moreover, bank size negatively affects both stability measures, suggesting that larger institutions may face systemic vulnerabilities despite their risk-absorption capacity. In addition, inflation increases the Z-Score, while GDP growth reduces NPL. CAR has a negative and significant effect on the Z-Score but is not significant for NPL, while LDR and BOPO do not show significant effects in either model. These findings emphasize that profitability management and strategic scaling are pivotal for enhancing financial resilience in ASEAN's banking sector.

Keywords: Banking Stability, Z-Score, NPL, Microprudential, ASEAN

Introduction

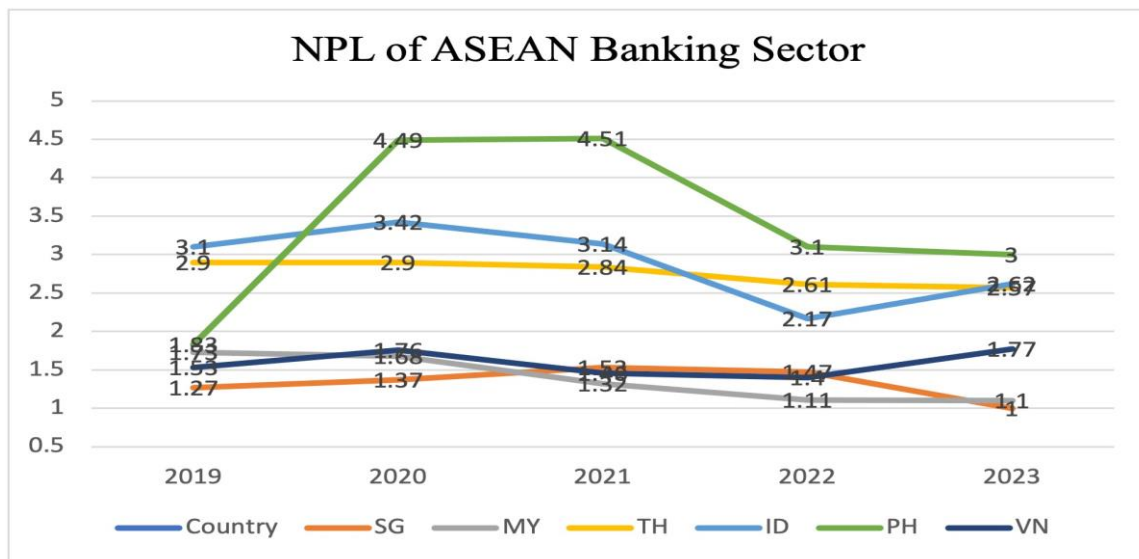
The stability of the banking system is a cornerstone of a nation's economic resilience, playing a critical role in the efficient allocation of capital, the mitigation of financial risks, and the absorption of external shocks (Pham & Doan, 2020). A stable banking sector promotes confidence, supports sustainable growth, and prevents contagion effects that can destabilize the broader financial system. This role is particularly vital in the Southeast Asian context, where banks function as the primary intermediaries in mobilizing savings and financing economic activity amid heightened global uncertainties, inflationary pressures, and the ongoing post-pandemic recovery. Unlike in more developed markets, ASEAN banking systems are predominantly bank-based, meaning that the banking sector serves as

the backbone of financial intermediation and economic continuity in the region (Pham & Doan, 2020). Ensuring the stability of this sector is therefore essential not only for maintaining public trust but also for sustaining financial inclusion and supporting long-term regional growth.

Assessing banking stability requires a multi-dimensional perspective that captures both solvency and asset quality risks. The Z-Score is widely used as an indicator of a bank's distance to default, representing its ability to absorb losses and remain solvent (Vuong et al., 2024). A higher Z-Score indicates stronger financial buffers and lower insolvency risk. In contrast, the Non-Performing Loan (NPL) ratio directly reflects the quality of a bank's loan portfolio and its exposure to credit risk. An increase in NPLs signals inefficiencies in credit assessment and risk management, potentially eroding profitability and capital adequacy. When used together, the Z-Score and NPL provide a more comprehensive and balanced understanding of banking stability, integrating both the solvency and credit risk dimensions (European Central Bank, 2019).

In addition to conceptual considerations, the empirical background of this study is supported by the observed development of Non-Performing Loan (NPL) ratios in ASEAN banking systems. Figure 1 illustrates the average NPL trends across six ASEAN countries (Indonesia, Malaysia, Thailand, Vietnam, Singapore, and the Philippines) during the 2019–2023 period. These data, processed from the World Bank and IMF databases, serve as the empirical foundation of this research.

Figure 1. Average ASEAN Banking NPL Ratios (2019–2023)



Source: World Bank and IMF, 2025

The figure demonstrates notable fluctuations in NPL ratios throughout the five-year period. Overall, countries such as the Philippines and Indonesia consistently reported the highest NPL levels, especially in 2020–2021, coinciding with the peak of the COVID-19 pandemic. The Philippines recorded NPL ratios approaching or exceeding 4%, with a peak around 4.49% in 2020, indicating elevated credit risk and weaker asset quality. In contrast, Singapore exhibited the lowest and most stable NPL ratios, remaining below 2%

throughout the observation period (e.g., 1.27% in 2019 and 1.63% in 2023), signaling theory strong financial stability and effective credit risk management.

Malaysia and Singapore displayed the most stable and efficient banking systems in terms of asset quality, while Indonesia and the Philippines showed persistently higher credit risk exposure, underscoring the need for improved credit supervision and recovery mechanisms. The cross-country comparison also reveals disparities in risk management practices among ASEAN banks, suggesting that institutional efficiency and macroeconomic conditions both play crucial roles in shaping NPL dynamics. Thus, the persistent variation in NPL performance across ASEAN economies justifies the need for a region-wide empirical investigation using a microprudential framework to identify internal bank-level factors driving stability and credit risk. This context underpins the rationale for the present study.

Despite the extensive body of literature addressing banking stability in the ASEAN region (Heliani et al., 2023; Marsuki et al., 2022), several research gaps remain. First, empirical studies that encompass multi-country comparative analyses during the post-pandemic period (2019–2023) remain limited, even though this era is marked by inflation surges, interest rate volatility, and digital transformation pressures. Second, most existing studies predominantly emphasize macroeconomic determinants (e.g., GDP, inflation, interest rates) while neglecting the microprudential dimensions internal bank-specific factors that more directly capture managerial decisions and operational resilience. Third, there is a lack of research integrating both solvency (Z-Score) and asset quality (NPL) indicators within a unified framework, despite their interdependence in reflecting systemic and institutional stability (Maudy et al., 2024b).

To address these gaps, this study adopts a microprudential perspective, focusing on five key internal determinants of stability: Capital Adequacy Ratio (CAR), Loan to Deposit Ratio (LDR), Return on Assets (ROA), Bank Size, and Operating Efficiency (BOPO). These indicators collectively capture capital strength, liquidity management, profitability performance, scale efficiency, and cost control five elements that shape a bank's resilience against financial distress. By simultaneously analyzing the effects of these variables on both Z-Score and NPL, the study aims to provide an integrated view of the mechanisms driving stability in the ASEAN banking sector.

This study contributes to the literature by providing a dual-measure assessment of banking stability through the simultaneous use of Z-Score and NPL, offering a more comprehensive evaluation of insolvency and credit-risk dimensions compared to prior ASEAN studies that rely on a single indicator. Furthermore, the use of a large multi-country bank-level panel (438 banks across six ASEAN economies) enhances cross-country comparability and microprudential insights. The study also integrates bank-specific and macroeconomic factors within a unified Fixed Effect estimation framework, enabling a more robust identification of internal drivers of stability. Although it does not incorporate moderator or mediator structures, this approach provides an empirical foundation for future studies employing advanced econometric techniques.

Consequently, this research aims to (1) examine the effect of CAR, LDR, ROA, Size, and BOPO on banking stability proxied by Z-Score, and (2) analyze the same microprudential variables' effects on credit risk proxied by NPL. Additionally, GDP Growth and Inflation

are incorporated as macroeconomic control variables to capture the broader economic environment influencing bank performance. From a practical standpoint, the study's findings are expected to provide insights for bank executives in optimizing capital and risk management strategies, and for regulators in designing more targeted microprudential supervision frameworks that enhance stability under dynamic market conditions.

From a theoretical standpoint, this study is grounded in Signaling Theory (Ross, 1997), which posits that managers communicate private information about a firm's quality and financial condition through observable financial indicators and strategic decisions. In the context of banking, these financial ratios serve as credible signals to external stakeholders investors, depositors, and regulators about the institution's underlying health. A high CAR signals strong capitalization and risk absorption capacity (Rizkia, 2023); a balanced LDR signals prudent liquidity and lending management (Kenzen & Afandy, 2023); and a strong ROA signals profitability and managerial competence (Heliani et al., 2023). Conversely, an increasing NPL ratio or high BOPO indicates potential inefficiency and rising credit risk (Dewantara, 2024). Thus, by empirically testing how these signals influence both solvency and credit risk, this study contributes to understanding how internal bank performance acts as a signaling mechanism for overall financial stability within the ASEAN context.

Literature Review

Signaling Theory

Signaling Theory, first introduced by (Ross, 1997), provides a theoretical foundation for understanding how financial decisions made by management act as signals to external stakeholders in conditions of asymmetric information. In this situation, managers possess more accurate and detailed information about the firm's actual condition compared to outside investors. Consequently, every financial policy such as capital structure, profitability, or liquidity management transmits information, or "signals," to the market regarding the true quality and stability of the institution.

In the banking context, these signals are primarily conveyed through key financial ratios that reflect internal soundness and managerial quality. A strong Capital Adequacy Ratio (CAR) signals that a bank maintains adequate capital buffers to absorb potential losses and sustain solvency (Rizkia, 2023). Similarly, a balanced Loan to Deposit Ratio (LDR) signals prudent liquidity management and the ability to channel funds efficiently into productive loans without overexposing the institution to liquidity risk (Kenzen & Afandy, 2023).

Furthermore, Return on Assets (ROA) acts as an important signal of profitability and management effectiveness. A high ROA indicates that a bank can generate earnings from its assets efficiently, suggesting sound decision-making and strong operational control (Heliani et al., 2023). Bank Size also plays a dual signaling role; larger banks often signal stability, diversified operations, and market confidence, but excessive size can indicate higher systemic exposure and potential operational rigidity (Dwitama, 2022). Lastly, BOPO (Operating Expenses to Operating Income) serves as a signal of managerial efficiency. A lower BOPO ratio indicates cost control and productivity, while a higher ratio suggests inefficiency and financial vulnerability (Dewantara, 2024).

Recent empirical studies strengthen the relevance of signaling theory in the banking sector. (Shahriar et al., 2023) and (Ullah et al., 2024) emphasize that profitability and capitalization serve as credible signals of financial soundness, particularly in post-crisis and post-pandemic contexts. Similarly, (Humanita et al., 2023) argue that efficiency ratios such as BOPO and ROA convey information about managerial quality that investors and regulators use to infer bank stability. These findings confirm that the signaling mechanism embedded in financial ratios remains an essential analytical lens in understanding banking resilience, especially in ASEAN economies.

In this study, Signaling Theory is employed to explain how these microprudential indicators (CAR, LDR, ROA, Size, and BOPO) communicate the internal financial strength and risk position of banks in ASEAN. Through these signals, stakeholders such as investors, regulators, and depositors assess the credibility, resilience, and performance of banks. Thus, understanding these signals provides insights into how financial institutions maintain stability amid external shocks and market uncertainties.

Beyond signaling mechanisms, this study is further supported by Financial Intermediation Theory, which emphasizes the role of banks as intermediaries that transform deposits into loans. Efficient intermediation, reflected through liquidity and cost-efficiency indicators such as LDR and BOPO, is crucial for maintaining bank stability and preventing credit deterioration (Fatmala et al., 2019; Fitrayansyah & Fadli, 2024).

Additionally, the 'Too-Big-To-Fail' (TBTF) Theory provides a framework for understanding the dual role of bank size. While large banks may benefit from diversification and economies of scale, they also carry higher systemic risks and may experience reduced risk-adjusted stability due to their complexity and market expectations (Hasannasab et al., 2025).

To complement these perspectives, Capital Buffer Theory posits that banks must maintain capital in excess of minimum regulatory thresholds to absorb unexpected losses and increase resilience during periods of macroeconomic stress. (Abbas et al., 2021) demonstrate that stronger capital buffers enhance banks' ability to withstand downturns, reduce insolvency risk, and stabilize credit supply, indicating that higher CAR levels contribute meaningfully to financial stability.

Together, these theories offer a comprehensive foundation for examining how microprudential indicators shape both insolvency risk (Z-Score) and credit risk (NPL) across ASEAN's banking landscape.

Z-Score and Non-Performing Loans (NPL)

The Z-Score, developed by Altman (1968) and later adapted for banking applications, combines profitability, capital adequacy, and earnings volatility to assess a bank's probability of default. The formula used in this study follows (Shahriar et al., 2023; Vuong et al., 2024):

$$Z\text{-Score} = \frac{(ROA + EQTA)}{\sigma(ROA)} \times 100$$

Where ROA denotes profitability, EQTA represents the equity-to-asset ratio, and $\sigma(\text{ROA})$ is the standard deviation of returns. A higher Z-Score implies a lower probability of insolvency, representing a more stable and resilient financial institution.

Meanwhile, the Non-Performing Loan (NPL) ratio, as defined by the (IMF, 2022) (OJK, 2023), measures the percentage of loans in default for more than 90 days relative to total loans. It reflects credit risk and asset quality the lower the NPL, the stronger the financial health of the bank. Persistent increases in NPL ratios can erode profitability, reduce capital adequacy, and destabilize the overall financial system (Estiasih, 2024; Nguyen, 2023).

Recent research (Aliffianti Safiria Ayu Ditta et al., 2024; Suljić Nikolaj et al., 2022) emphasizes that combining Z-Score and NPL provides a more comprehensive representation of banking stability because they jointly capture solvency and credit risk dimensions. This dual-indicator approach aligns with modern prudential frameworks advocated by the (European Central Bank, 2019), ensuring a balanced measurement of institutional resilience.

Banking Stability

Banking stability is a multidimensional concept that reflects the resilience of the financial system in maintaining its core functions intermediation, payment systems, and risk transformation while withstanding economic or financial disruptions. According to (Pham & Doan, 2020), a stable banking sector ensures efficient allocation of resources, supports sustainable economic growth, and mitigates contagion effects that could spread throughout the broader financial system.

In empirical research, the stability of a bank is often captured by two key indicators: the Z-Score and the Non-Performing Loan (NPL) ratio. The Z-Score measures a bank's distance to default, incorporating profitability, capital adequacy, and earnings volatility to indicate insolvency risk (Vuong et al., 2024). A higher Z-Score represents stronger solvency and financial resilience. On the other hand, the NPL ratio directly reflects credit quality and asset performance (Rohadi et al., 2024). A rising NPL ratio implies increasing credit risk, declining loan portfolio quality, and potential weakness in risk management.

Using both indicators in tandem allows researchers to assess stability from two complementary perspectives: solvency and credit risk (European Central Bank, 2019). Several studies (Shahriar et al., 2023) and (Ditta et al., 2024), emphasize that stability is not merely the absence of crisis but the sustained ability of banks to perform efficiently under macroeconomic uncertainty. Furthermore, (Suljić Nikolaj et al., 2022) highlight that both indicators jointly capture how internal governance and market conditions interact to shape risk absorption capacity. Moreover, stable banks play a vital role in preventing bank runs, preserving depositor confidence, and ensuring financial inclusion particularly in bank-based economies such as ASEAN.

Accordingly, this study adopts Z-Score as a measure of insolvency risk and the NPL ratio as a measure of credit risk, aligning with established empirical findings and ensuring theoretical consistency with prior research.

Insolvency risk represents the likelihood that a bank's capital and earnings become insufficient to absorb losses, leading to potential failure. According to (Mercadier & Strobel, 2024), insolvency risk can be measured through volatility-adjusted returns, capital adequacy indicators, and profitability stability, with the Z-Score considered the most widely validated composite metric of a bank's distance to default. Similarly, empirical evidence from the Turkish banking sector confirms that Z-Score and its variations reliably capture changes in solvency conditions and systemic vulnerability across banks of different sizes (Tarkocin & Donduran, 2023).

Credit risk, in contrast, reflects the probability that borrowers fail to meet their repayment obligations. Common measurements include the Non-Performing Loan (NPL) ratio, loan-loss provisions, and impaired loan exposure. (Atoi, 2019) show that increases in NPL ratios significantly weaken bank stability by reducing profitability, eroding capital buffers, and heightening vulnerability to shocks. Consistent findings are documented in emerging economies such as Vietnam, where NPL and credit-quality indicators remain critical determinants of overall banking stability (Nguyen et al., 2024)

Accordingly, this study adopts the Z-Score as a measure of insolvency risk and the NPL ratio as a measure of credit risk, in line with empirical validation from recent cross-country evidence.

Key Determinants of Banking Stability

Several microprudential indicators have been identified in the literature as critical determinants of banking stability. These factors, often used in empirical studies, capture internal aspects of financial management that influence a bank's ability to absorb shocks and maintain solvency.

a. Capital

Capital represents the bank's financial cushion used to absorb unexpected losses and ensure the continuity of its operations. In the literature, several measurements are commonly used to capture the capital position of a bank, including the Capital Adequacy Ratio (CAR), the Tier 1 capital ratio, and capital buffer indicators mandated under Basel regulations. The CAR measures the proportion of a bank's capital relative to its risk-weighted assets and reflects the institution's ability to absorb credit, market, and operational risks. Meanwhile, Tier 1 capital ratios emphasize core equity capital, and capital buffers capture the additional capital banks accumulate beyond minimum regulatory thresholds.

A higher level of capital generally signals stronger solvency, regulatory compliance, and a greater capacity to withstand financial shocks (Saputra et al., 2024). However, excessively high capital ratios may indicate underutilization of funds, reduced lending capacity, and lower profitability due to overly conservative balance-sheet management. Therefore, maintaining an optimal capital level is crucial for balancing risk absorption with income generation.

Recent empirical evidence demonstrates that capital plays an essential stabilizing function, especially in emerging financial systems. (Alnabulsi et al., 2023) find that capital buffers significantly strengthen bank stability when supported by prudent asset allocation and

effective risk-management practices. This aligns with the broader view that robust capitalization enhances resilience while preventing pro-cyclical weaknesses during periods of macroeconomic volatility.

b. Liquidity

Liquidity refers to a bank's capability to meet its short-term obligations and withdrawable funds without disrupting daily operations or requiring costly external financing. In the literature, liquidity is commonly measured using several indicators, including the Loan to Deposit Ratio (LDR), Liquidity Coverage Ratio (LCR), Quick Ratio, and Financing to Deposit Ratio (FDR) in Islamic banking contexts. These measurements collectively reflect the bank's ability to convert assets into cash, manage maturity mismatches, and maintain adequate liquid buffers, especially during periods of financial stress.

Among these indicators, the Loan to Deposit Ratio (LDR) is one of the most widely used proxies of liquidity and intermediation efficiency. LDR measures how far customer deposits are channeled into lending activities (OJK, 2023). A balanced LDR indicates effective liquidity management where banks utilize funds productively while maintaining sufficient cash reserves whereas excessively high LDR values suggest aggressive lending that may reduce liquidity buffers and elevate liquidity risk. Conversely, very low LDR ratios may indicate inefficient fund allocation, underutilized deposits, and reduced profitability.

Empirical evidence demonstrates that liquidity plays an important role in determining financial stability. (Shahriar et al., 2023; Vuong et al., 2024) show that moderate lending activity can enhance profitability and operational efficiency, supporting stability through stronger earnings performance. However, aggressive credit expansion that pushes LDR too high increases exposure to credit risk and raises the likelihood of higher NPLs, ultimately weakening bank stability. Additional evidence from emerging markets indicates that maintaining adequate liquidity buffers helps banks absorb funding shocks and sustain resilience during macroeconomic volatility.

c. Return on Assets (ROA)

ROA represents profitability and efficiency in utilizing assets. Higher ROA enhances capital accumulation, strengthens solvency, and increases a bank's Z-Score (Khamisah et al., 2020). Empirical findings (Widyaningsih & Sampurno, 2022) show that banks with higher profitability demonstrate greater resilience during economic downturns, highlighting ROA as a consistent predictor of stability across different financial systems. (Shahriar et al., 2023) and (Humanita et al., 2023) further argue that profitability serves as the primary determinant of both solvency and credit risk, confirming its central signaling role in microprudential stability frameworks.

d. Bank Size (SIZE)

Bank size reflects operational scale, market reach, and systemic significance. Large banks typically benefit from diversification and economies of scale, which enhance stability (W. Sari et al., 2023). However, excessive size can lead to "too-big-to-fail" risks and reduced managerial agility, increasing systemic vulnerability (Maudy et al., 2024). (Chowdhury et al., 2024) note that bank size should be interpreted cautiously while it provides advantages in risk distribution, it also implies higher exposure to macroeconomic shocks.

e. Operating Efficiency (BOPO)

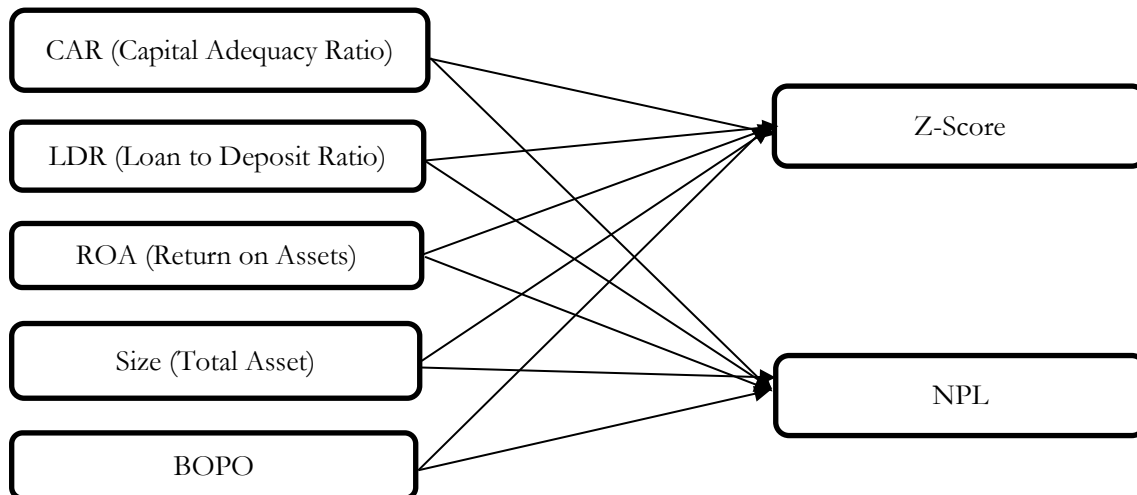
BOPO, or the ratio of Operating Expenses to Operating Income, measures managerial efficiency and cost control (Yakub & Murtanto, 2024). Lower BOPO ratios indicate higher operational efficiency and profitability, contributing positively to stability (Irawan et al., 2025). Conversely, high BOPO ratios imply operational inefficiency, reduced margins, and potential instability. Thus, BOPO serves as both a performance and risk indicator, linking operational management to overall financial soundness.

These microprudential factors have been widely examined in ASEAN studies, such as those by (Maudy et al., 2024) and (N. N. Sari & Sudarmawan, 2023), who found that profitability (ROA) and efficiency (BOPO) are among the strongest predictors of stability, while the influence of Size and CAR varies across contexts. The inclusion of GDP growth and inflation as macroeconomic controls provides further contextualization, as macroeconomic volatility can amplify or mitigate the effects of internal financial signals

Conceptual Framework

Based on the theoretical foundation and empirical evidence reviewed in the previous section, this study develops a conceptual framework linking microprudential bank characteristics to banking stability in ASEAN countries. This framework is grounded in Signaling Theory (Ross, 1997), which posits that financial indicators such as capital, liquidity, profitability, and efficiency act as credible signals of internal strength and risk exposure. In addition, the framework is supported by Financial Intermediation Theory and findings from recent studies (Humanita et al., 2023; Shahriar et al., 2023; Vuong et al., 2024), which confirm that bank-level fundamentals significantly shape solvency and credit risk outcomes.

Figure 2. Empirical Framework Illustrates the Hypothesized Relationships



The empirical framework depicts the causal relationship between microprudential determinants and banking stability, measured through two dimensions: Z-Score, representing solvency and default risk, and Non-Performing Loans (NPL), representing asset quality and credit risk. The independent variables Capital Adequacy Ratio (CAR), Loan-to-Deposit Ratio (LDR), Return on Assets (ROA), Bank Size (SIZE), and

Operational Efficiency (BOPO) are theorized to influence stability based on prior studies and established financial theories.

CAR reflects a bank's loss-absorbing capacity. Empirical evidence (Humanita et al., 2023; Maudy et al., 2024b) suggests that adequate capital contributes to higher solvency and lower credit losses. LDR measures intermediation efficiency; optimal lending supports stability, while excessive lending increases risk exposure (Saputri & Hasanuh, 2022). ROA captures profitability and managerial performance; higher profitability consistently reduces insolvency risk and NPLs (Shahriar et al., 2023). SIZE indicates economies of scale and diversification benefits, where larger banks tend to exhibit lower credit risk (Chowdhury et al., 2024). Meanwhile, BOPO reflects operational efficiency, with higher cost ratios signaling weaker performance and elevated risk (Kenzen & Afandy, 2023).

Macroeconomic controls GDP Growth and Inflation represent external conditions affecting bank resilience. Economic expansion strengthens repayment capacity and improves asset quality, while inflation may pressure margins and credit performance (Saputra et al., 2024; Vuong et al., 2024).

This empirical framework provides a comprehensive theoretical justification for the proposed relationships. The framework not only synthesizes prior theoretical and empirical findings but also serves as the basis for formulating the study's hypotheses, which propose that microprudential indicators significantly influence banking stability as measured by Z-Score and NPL.

Based on the empirical framework illustrated above, this study proposes that microprudential variables CAR, LDR, ROA, SIZE, and BOPO affect banking stability in ASEAN. Guided by Signaling Theory and supported by empirical evidence (Humanita et al., 2023; Shahriar et al., 2023; Vuong et al., 2024), these indicators are expected to influence solvency (Z-Score) and asset quality (NPL). Therefore, the following hypotheses are formulated:

- H1: CAR significantly affects Z-Score.
- H2: LDR significantly affects Z-Score.
- H3: ROA significantly affects Z-Score.
- H4: SIZE significantly affects Z-Score.
- H5: BOPO significantly affects Z-Score.
- H6: CAR significantly affects NPL.
- H7: LDR significantly affects NPL.
- H8: ROA significantly affects NPL.
- H9: SIZE significantly affects NPL.
- H10: BOPO significantly affects NPL.

Methods

Research Design

This study adopts a quantitative research design using an unbalanced panel data model to analyze the determinants of banking stability in ASEAN. The analysis is conducted through two separate regression models to capture different dimensions of stability:

Model I — Solvency Stability, proxied by the Z-Score, and

Model II — Credit Risk, proxied by the Non-Performing Loan (NPL) ratio.

This dual-model framework allows for a comprehensive examination of how microprudential indicators influence both solvency and asset quality dimensions of stability, consistent with methodologies applied by (Noman et al., 2017) and (Hadi et al., 2021).

Population and Sample

The population includes 438 commercial banks operating in six ASEAN countries. Indonesia, Malaysia, Singapore, Thailand, the Philippines, and Vietnam, during the period 2019–2023. A purposive sampling technique was applied using two selection criteria:

- (1) banks must have published complete financial statements for the entire period, and
- (2) all research variables must be available after screening, the final sample consists of 168 commercial banks, distributed as follows:

Table 1. Research Sample Composition

Country	Number of Banks	Percentage (%)
Indonesia	92	54.76
Vietnam	28	16.76
Malaysia	17	10.12
Thailand	17	10.12
Singapore	3	1.79
Philippines	11	6.55
Total	168	100

Source : Author's Calculation, 2025

Data Sources and Operational Definitions of Variables

This study relies on secondary quantitative data obtained through documentation. Bank-level financial data were retrieved from the BankFocus database and respective banks' annual reports, while macroeconomic data (GDP growth and inflation) were sourced from the World Bank.

The research involves two dependent variables, five independent (microprudential) variables, and two macroeconomic control variables. Detailed operational definitions are presented below.

Table 2. Operational Definitions of Variables

Concept	Variabel	Measurement and Formula	Reference
Insolvency Risk	Z-Score	Bank stability measure: $(ROA + Equity/Assets) / \sigma(ROA)$	(Shahriar et al., 2023; Vuong et al., 2024)
Credit Risk	NPL	Non-Performing Loan Ratio: $(Total\ Non-Performing\ Loans / Total\ Loans) \times 100\%$	(Rohadi et al., 2024)
Capital	CAR	Capital Adequacy Ratio: $(Capital / Risk-Weighted\ Assets) \times 100\%$	(Saputra et al., 2024)
Liquidity	LDR	Loan to Deposit Ratio:	(OJK, 2023; Saputri

Concept	Variabel	Measurement and Formula	Reference
		(Loans / Third-Party Funds) × 100%	& Hasanuh, 2022)
Profitability	ROA	Return on Assets: (Net Income / Total Assets) × 100%	(Heliani et al., 2023)
Bank Size	Size	Bank Size (natural logarithm of total assets): ln(Total Asset	(Dwitama, 2022)
Operational Efficiency	BOPO	Operational Efficiency Ratio: (Operating Expenses / Operating Income) × 100%	(Dewantara, 2024)
Economic Growth	GDP Growth	Annual Gross Domestic Product Growth (%)	(Sharma et al., 2024)
Inflation	Inflation	Annual inflation rate (%)	(IMF, 2022)

Data Analysis Technique

Data analysis was conducted using STATA version 16.0 through a series of systematic stages. First, descriptive statistics were employed to provide a general overview of the data characteristics. Second, classical assumption and diagnostic tests were performed, including a multicollinearity test using the Variance Inflation Factor (VIF), where values below 10 indicate the absence of serious multicollinearity. Heteroskedasticity was examined using the Modified Wald test, and autocorrelation was tested using the Wooldridge test; in response to both issues, robust standard errors were applied. Third, panel model selection was carried out to determine the most appropriate model among Pooled Least Squares (PLS), Fixed Effects (FE), and Random Effects (RE). This process involved the Chow test to compare PLS and FE, the Lagrange Multiplier (LM) test to compare PLS and RE, and the Hausman test to choose between FE and RE. The results consistently favored the Fixed Effect Model (FEM) for both Model I (Z-Score) and Model II (NPL), indicating the presence of individual heterogeneity across banks. Finally, panel regression estimation was conducted using the FEM with cluster-robust standard errors at the bank level to ensure unbiased and efficient results. The general model specifications are as follows:

Model I – Z-Score :

$$Z - Score_{it} = \alpha + \beta_1 CAR_{it} + \beta_2 LDR_{it} + \beta_3 ROA_{it} + \beta_4 Size_{it} + \beta_5 BOPO_{it} + \beta_6 GDP_{it} + \beta_7 Inflation_{it} + \varepsilon_{it}$$

Model II – NPL :

$$NPL_{it} = \alpha + \beta_1 CAR_{it} + \beta_2 LDR_{it} + \beta_3 ROA_{it} + \beta_4 Size_{it} + \beta_5 BOPO_{it} + \beta_6 GDP_{it} + \beta_7 Inflation_{it} + \varepsilon_{it}$$

This analytical approach enables the study to isolate the effects of internal bank performance and macroeconomic context on both solvency and credit stability, offering a dual-perspective understanding of ASEAN banking resilience.

Findings

Table 3 presents the descriptive statistics for the main variables used in this study. The total observations vary across variables due to data availability during the 2019–2023 period for 438 commercial banks in six ASEAN countries. The table reports the mean, standard deviation, minimum, and maximum values of both microprudential (bank-specific) and macroeconomic variables.

Table 3. **Descriptive Statistics of Variables**

Variable	Mean	Std. Dev	Min	Max
CAR	0.282	0.260	0.084	1.846
LDR	0.711	0.291	0.050	2.160
ROA	0.009	0.012	-0.0049	0.038
SIZE	15.102	1.691	11.862	18.734
BOPO	0.585	0.374	0.148	2.931
NPL	0.026	0.020	0.000	0.122
Z-Score	6.348	6.998	-2.165	36.325
GDP_Growth	0.034	0.038	-0.095	0.089
Inflation	0.027	0.014	-0.011	0.061

Source: Data processed, 2025

The descriptive results indicate substantial variation across ASEAN banks. The Capital Adequacy Ratio (CAR) averages 28.2%, reflecting relatively strong capitalization above regulatory minima. However, the wide standard deviation (0.26) and high maximum value (1.846) suggest heterogeneity, where some banks maintain excessive capital buffers possibly due to conservative risk management (Saputra et al., 2024).

The Loan-to-Deposit Ratio (LDR) averages 71.1%, implying a moderate intermediation level. The wide range (0.05–2.16) indicates differences in lending behavior, where some institutions adopt conservative credit policies, while others engage in aggressive expansion that could pressure liquidity (Kenzen & Afandy, 2023).

Return on Assets (ROA) averages 0.9%, indicating modest profitability during 2019–2023, consistent with pandemic-related disruptions (Heliani et al., 2023). The negative minimum (-0.049) demonstrates temporary losses in several banks, especially in 2020–2021.

For Non-Performing Loans (NPL), the mean value of 2.6% remains below the prudential threshold of 5%, consistent with stable asset quality across the region (Rohadi et al., 2024). However, the high maximum (12.2%) reflects persistent credit risk in weaker markets such as Indonesia and the Philippines.

Operating efficiency (BOPO) averages 58.5%, suggesting that most banks operate efficiently, though the maximum of 2.93 indicates that a few institutions face severe cost inefficiencies (Irawan et al., 2025). Bank Size (SIZE) averages 15.10 (log assets),

highlighting disparities between large international banks (e.g., in Singapore) and smaller domestic ones (e.g., in Vietnam). The Z-Score average of 6.35 reveals varying solvency levels, with some banks exhibiting high resilience while others are financially fragile.

At the macro level, the average GDP growth rate (3.4%) and inflation (2.7%) indicate steady macroeconomic recovery following the COVID-19 contraction in 2020 (Heliani et al., 2023; Vuong et al., 2024). Overall, the descriptive findings demonstrate that ASEAN banks remain sound but heterogeneous in risk exposure and performance justifying the need for regression analysis to identify key determinants of stability.

This study examines the determinants of ASEAN banking system stability using a microprudential approach through two panel regression models: Model I (Z-Score) and Model II (NPL). This study employs a Fixed Effect Model (FEM) to examine the determinants of banking stability across 438 commercial banks across six ASEAN countries (Indonesia, Malaysia, Singapore, Thailand, the Philippines, and Vietnam) from 2019 to 2023.

The regression results for Model I reveal that profitability (ROA) and inflation have a positive and significant effect on banking stability. High profitability strengthens solvency through retained earnings and capital accumulation (Heliani et al., 2023), aligning with Signaling Theory, which posits that profitability signals managerial efficiency and institutional soundness (Ross, 1997). Conversely, larger banks exhibit lower Z-Scores, consistent with the too-big-to-fail hypothesis (Maudy et al., 2024) where size increases systemic exposure.

The negative effect of CAR indicates potential inefficiency in capital utilization (Saputra et al., 2024), while inflation's positive coefficient supports findings by (Vuong et al., 2024) that moderate inflation may improve net interest margins and solvency buffers. BOPO, LDR, and GDP growth are statistically insignificant but theoretically relevant for explaining bank intermediation and cost efficiency (Irawan et al., 2025; Kenzen & Afandy, 2023).

Table 4. Regression Result – Model I (Z-Score)

Variable	Coefficient	Std.Error	t-Statistic	Prob
CAR	-2.454	0.384	-6.39	0.000
LDR	0.631	0.364	1.73	0.083
ROA	84.879	7.359	11.53	0.000
SIZE	-1.551	0.198	-7.85	0.000
BOPO	0.374	0.253	1.48	0.139
GDP_Growth	1.544	1.520	1.02	0.310
Inflation	10.997	4.270	2.58	0.010
Constant	29.505	3.085	9.56	0.000

R² (within): 0.311 | Prob > Chi² = 0.000 | N = 775

Source : Data Processed, 2025

Capital Adequacy Ratio (CAR) shows a negative and significant effect on the Z-Score ($\beta = -2.454$; $p < 0.01$). This indicates that during the study period, higher capitalization did not necessarily translate into greater solvency. In some ASEAN banks, excess capital may have reflected conservative or inefficient asset utilization, reducing return potential and signaling risk aversion rather than strength. Loan to Deposit Ratio (LDR) has a positive but insignificant relationship ($\beta = 0.631$; $p = 0.083$). This suggests that credit intermediation activities were moderately supportive of stability, but the variation across banks prevented a statistically strong conclusion.

Return on Assets (ROA) exerts a strong positive and significant influence ($\beta = 84.879$; $p < 0.01$), confirming that profitability is the most robust determinant of solvency. High ROA enhances retained earnings, thereby strengthening capital buffers and reducing insolvency risk. Bank Size (SIZE) has a negative and significant coefficient ($\beta = -1.551$; $p < 0.01$), implying that larger banks may face structural risks stemming from complex operations, diversification inefficiencies, or exposure to moral hazard — a phenomenon consistent with the “too big to fail” paradox.

Operating Efficiency (BOPO), although positive, is not significant ($\beta = 0.374$; $p = 0.139$), suggesting that operational costs did not materially affect solvency risk. GDP Growth is positive but insignificant ($\beta = 1.544$; $p = 0.310$), indicating that macroeconomic expansion alone did not guarantee higher stability during this post-pandemic period. Inflation, however, has a positive and significant impact ($\beta = 10.997$; $p < 0.05$), implying that moderate inflation may enhance bank stability through improved interest margins and stronger loan performance.

Variables LDR, BOPO, and GDP Growth are statistically insignificant but remain theoretically relevant in determining liquidity management and operational performance.

The results for Model II, The NPL model demonstrates that ROA, SIZE, and GDP Growth have significant negative effects on credit risk. Higher ROA indicates stronger profitability and more effective credit risk management, reducing loan defaults (Humanita et al., 2023). This aligns with Signaling Theory, where profitability sends a positive signal of sound management and asset quality (Ross, 1997).

Larger banks (SIZE) tend to have lower NPLs due to diversification benefits and superior risk monitoring (Chowdhury et al., 2024). Meanwhile, GDP Growth negatively affects NPLs, confirming that a favorable macroeconomic environment improves repayment capacity (Vuong et al., 2024).

CAR, LDR, BOPO, and Inflation are insignificant, indicating that capital strength, liquidity, and cost efficiency were not major predictors of credit risk during the post-pandemic period. This finding resonates with (Rohadi et al., 2024) and (Sari & Sudarmawan, 2023), who observed that profitability and macroeconomic resilience are more decisive factors for ASEAN banks' credit performance than regulatory ratios alone.

Table 5. Regression Result – Model II (NPL)

Variable	Coefficient	Std.Error	t-Statistic	Prob
CAR	0.001	0.003	0.28	0.779
LDR	-0.004	0.003	-1.23	0.219
ROA	-0.322	0.067	-4.77	0.000
SIZE	-0.003	0.001	-3.59	0.000
BOPO	0.000	0.001	0.09	0.929
GDP_Growth	-0.045	0.017	-2.56	0.010
Inflation	0.002	0.046	0.05	0.964
Constant	0.072	0.012	6.16	0.000

Source : Data Processed, 2025

Capital Adequacy Ratio (CAR) shows a positive but insignificant effect ($\beta = 0.001$; $p = 0.779$), indicating that higher capitalization did not significantly mitigate credit risk. This suggests that capital buffers in many ASEAN banks serve more as regulatory compliance rather than active credit-risk absorbers during the study period. Loan to Deposit Ratio (LDR) displays a negative but insignificant impact ($\beta = -0.004$; $p = 0.219$). Although theoretically, higher lending relative to deposits can increase credit exposure, the insignificant result implies that banks in ASEAN maintained prudent lending policies after the pandemic recovery phase.

Return on Assets (ROA) exhibits a strong negative and significant relationship with NPLs ($\beta = -0.322$; $p < 0.01$). This confirms that more profitable banks have better credit screening, monitoring, and recovery mechanisms—thereby lowering default probability. This finding aligns with Signaling Theory (Ross, 1997), suggesting that high profitability sends a positive signal of prudent management and asset quality. Bank Size (SIZE) has a negative and significant coefficient ($\beta = -0.003$; $p < 0.01$), indicating that larger banks tend to maintain stronger risk-management structures and diversified portfolios that reduce credit exposure. This also implies economies of scale in risk monitoring. Operating Efficiency

(BOPO) is insignificant ($\beta = 0.000$; $p = 0.929$), meaning that operational cost fluctuations did not directly influence loan quality. However, persistent inefficiencies could indirectly pressure future profitability and stability if unmanaged. GDP Growth has a significant negative relationship with NPLs ($\beta = -0.045$; $p < 0.05$). This confirms that macroeconomic expansion supports borrowers' repayment capacity and overall credit quality, consistent with the cyclical behavior of NPLs observed in developing economies. Inflation has a positive but insignificant coefficient ($\beta = 0.002$; $p = 0.964$), suggesting that inflationary pressures during the study period did not meaningfully alter credit performance, possibly due to central banks' effective monetary control within the ASEAN region.

CAR, LDR, BOPO, and Inflation are insignificant, implying that during the 2019–2023 period, profitability and macroeconomic resilience played a more prominent role than prudential ratios in explaining credit performance.

Table 6 consolidates the regression results of both Model I (Z-Score) and Model II (NPL) by removing the standard error and t-statistic columns, enabling a clearer comparison of solvency determinants and credit-risk determinants in a single framework. The merged table highlights that ROA is the most consistent and strongest predictor across both stability dimensions. In Model I, ROA shows a large positive coefficient ($\beta = 84.879$), confirming that profitability significantly strengthens solvency. In Model II, ROA displays a significant negative coefficient ($\beta = -0.322$), indicating that higher profitability effectively reduces credit risk. This dual impact reinforces the central role of profitability in enhancing overall banking resilience in the ASEAN region.

Bank Size (SIZE) exhibits an interesting two-sided effect. SIZE negatively influences solvency ($\beta = -1.551$), suggesting that larger banks tend to face higher insolvency risk due to structural complexity, consistent with the too-big-to-fail hypothesis. However, SIZE simultaneously reduces credit risk ($\beta = -0.003$), reflecting stronger risk management capabilities and diversification benefits in larger institutions. These contrasting results underscore the importance of distinguishing between solvency risk and credit risk when evaluating the stability of large banks.

Macroeconomic variables also demonstrate asymmetric effects. GDP Growth significantly lowers NPLs ($\beta = -0.045$), indicating that economic expansion improves borrowers' repayment capacity. Yet, GDP Growth is insignificant in influencing solvency stability. Conversely, inflation positively affects solvency ($\beta = 10.997$) but does not significantly influence credit quality. These results imply that macroeconomic conditions may strengthen one dimension of stability while leaving another unaffected.

On the other hand, prudential ratios such as CAR and LDR do not show consistent significance across the two models. CAR significantly reduces the Z-Score ($\beta = -2.454$) but has no meaningful effect on NPLs, suggesting inefficiency in capital utilization rather than risk absorption. LDR shows insignificant effects in both models, indicating that liquidity-driven intermediation did not substantially shape the stability profile of ASEAN banks during 2019–2023.

Overall, the merged results from Table 6 demonstrate that profitability and macroeconomic performance represent the most influential and consistent determinants of stability, while prudential ratios and operational efficiency variables played a more limited role throughout the study period.

Table 6. Regression Result for Model I (Z-Score) and Model II (NPL)

Variable	Coefficient (Model I – Z-Score)	Prob	Coefficient (Model II – NPL)	Prob
CAR	–2.454	0.000	0.001	0.779
LDR	0.631	0.083	–0.004	0.219
ROA	84.879	0.000	–0.322	0.000
SIZE	–1.551	0.000	–0.003	0.000
BOPO	0.374	0.139	0.000	0.929
GDP Growth	1.544	0.310	–0.045	0.010
Inflation	10.997	0.010	0.002	0.964
Constant	29.505	0.000	0.072	0.000
R ² Within	0.311		0.228	
Observations (N)	775		775	

Source : Data Processed, 2025

The results of the Fixed Effect panel regression analysis reveal that ROA, Size, and Inflation are significant determinants of banking stability (Z-Score), while ROA, Size, and GDP Growth significantly affect credit risk (NPL). Collectively, the model is statistically significant (Prob > Chi² = 0.000), indicating that the independent variables jointly influence banking stability across the ASEAN region.

More specifically, ROA has a positive and significant effect on Z-Score and a negative and significant effect on NPL, confirming that profitability is the primary determinant of banking resilience. This finding aligns with (Humanita et al., 2023) and (Ullah et al., 2024), who state that banks with higher profitability tend to maintain larger capital buffers to absorb risks, enhance managerial efficiency, and sustain depositor confidence. In the ASEAN context, ROA emerges as the most critical microprudential indicator reflecting a bank's capacity to preserve stability amid global post-pandemic uncertainties.

Furthermore, CAR shows a negative and significant effect on Z-Score, indicating that higher capitalization does not always enhance stability. This result is consistent with (Suljić Nikolaj et al., 2022), who explain the existence of a risk-taking channel where well-capitalized banks may engage in riskier activities. In ASEAN's bank-based financial systems, this behavior deserves close supervision as it may indicate potential moral hazard.

Bank Size (SIZE) exerts a negative and significant effect on Z-Score but a negative and significant effect on NPL, demonstrating the duality of bank size. This finding supports (Shahriar et al., 2023) and (Alnabulsi et al., 2023), who find that large banks may heighten systemic risk (the too-big-to-fail phenomenon), yet simultaneously exhibit superior risk diversification and asset management capabilities that reduce credit risk. Thus, bank size plays a dual role as both a strength and a source of vulnerability in sustaining regional financial stability.

Inflation has a positive and significant relationship with Z-Score, indicating that moderate inflation can enhance stability through improved interest margins and higher net interest income. This is consistent with (Ditta et al., 2024) and (Humanita et al., 2023), who find that controlled inflation strengthens interest spreads, improving profitability and capital buffers.

Meanwhile, GDP Growth shows a significant negative effect on NPL, implying that stronger economic growth enhances borrowers' repayment capacity and lowers non-performing loans. This result aligns with (Maudy et al., 2024) and (Heliani et al., 2023), emphasizing the vital role of macroeconomic conditions in shaping bank asset quality, particularly in emerging markets.

The variables LDR and BOPO show no significant influence on either stability indicator. This may be attributed to differences in intermediation strategies and operational efficiency across countries, where lending activities have not consistently reinforced systemic stability in ASEAN. This result echoes (Shahriar et al., 2023), who note that structural and macroprudential policy variations among nations may explain the insignificance of these relationships.

In summary, the findings confirm the microprudential and Signaling Theory (Ross, 1997) framework, suggesting that internal financial ratios such as ROA, CAR, and Size act as key signals for markets and regulators in evaluating the health and resilience of financial institutions. Strong profitability provides a positive signal of financial stability, whereas excessive capitalization and large bank size must be accompanied by robust governance to prevent systemic instability.

Conclusion

This study analyzes the determinants of banking stability in 438 commercial banks across six ASEAN countries during 2019–2023, using a microprudential approach and two stability indicators: Z-Score and Non-Performing Loan (NPL). The results indicate that profitability (ROA) and bank size (Size) are the primary factors influencing the stability of the ASEAN banking system.

ROA consistently enhances solvency and reduces credit risk, while bank size shows a dual effect, improving credit quality but potentially reducing systemic stability. Inflation is positively associated with stability, suggesting that moderate inflation strengthens banks' net interest income, whereas GDP growth significantly lowers NPLs, demonstrating the impact of macroeconomic performance on asset quality. Capital adequacy (CAR), liquidity (LDR), and operational efficiency (BOPO) are statistically insignificant, indicating that these factors were not dominant drivers of ASEAN banking stability during the study period.

From a policy perspective, several implications emerge, financial regulators should balance capital strengthening with prudent supervision of expansion risks, especially for large banks that may pose systemic threats. Bank management must focus on enhancing efficiency and profitability as the key pillars of resilience against macroeconomic volatility. Macroprudential policies should be harmonized with microprudential supervision to ensure sustainable banking system stability across ASEAN. Overall, this research reinforces the understanding of financial stability in emerging markets by highlighting the interaction between bank-specific factors and macroeconomic conditions. The findings provide empirical support for developing integrated monitoring models to ensure long-term banking system stability in the ASEAN region.

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