International Journal of Innovative Research and Scientific Studies, 8(5) 2025, pages: 1802-1813

ISSN: 2617-6548

URL: www.ijirss.com

A panel vector autoregressive analysis of Cambodian commercial banks' loans

Bunthe Hor[1*], Siphat Lim[2]

[1,2]*CamEd Business School, Phnom Penh, Cambodia.*

Corresponding author: Bunthe Hor (*Email: bunthet@cam-ed.com*)

Abstract

This study investigates the dynamic relationship between the components of the CAMELS framework and the loan growth of commercial banks in Cambodia using a Panel Vector Autoregressive (PVAR) model. Regression results reveal that asset quality, management quality, efficiency, and liquidity significantly influence loan growth. Specifically, non-performing loans (NPLs) and return on assets (ROA) have a negative effect, suggesting that poor asset quality and high profitability are associated with more conservative lending behavior. In contrast, management quality and liquidity positively impact loan growth, indicating that operational investment and strong liquidity support credit expansion. Forecast Error Variance Decomposition (FEVD) shows that the influence of internal bank factors increases over time, with capital adequacy and earnings emerging as dominant long-run drivers of loan dynamics, followed by management quality and liquidity. Impulse Response Functions (IRFs) further confirm the negative impact of capital adequacy and ROA, and the positive but weaker responses to management quality and liquidity. Macroeconomic analysis highlights that real GDP growth significantly stimulates loan growth, while inflation has no meaningful effect. Overall, the findings underscore the importance of both internal bank performance and macroeconomic conditions in shaping lending behavior, offering valuable insights for regulators and financial institutions aiming to foster sustainable credit growth.

Keywords: CAMELS, FEVD, IRFs, Loan growth, PVAR model.

DOI: 10.53894/ijirss.v8i5.9276
Funding: This study received no specific financial support.
History: Received: 18 June 2025 / **Revised:** 18 July 2025 / **Accepted:** 21 July 2025 / **Published:** 13 August 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

To operate effectively, businesses require financial resources, which are typically accessed through two main channels: financial intermediaries, such as banks, and financial markets, including the money and capital markets. While both avenues provide funding for investment, the banking sector plays a particularly dominant role in Cambodia's financial system. In practice, most firms and investors in Cambodia rely heavily on commercial banks as their primary source of external finance, given the underdevelopment of the domestic capital market [1]. As a result, banks serve as the key intermediaries facilitating business growth and investment in the country.

Over the past three decades, the banking sector in Cambodia has played a pivotal role in bridging the gap between savers and borrowers. Banks serve as key financial intermediaries by mobilizing funds from individuals and institutions with excess liquidity and channeling them to those in need of financing. Specifically, banks accept deposits from surplus units, which may include households, firms, and government agencies, and then extend loans to deficit units also comprising households, businesses, and public sector entities. This intermediation process facilitates the efficient allocation of financial resources within the economy, promotes investment, and supports economic development. In Cambodia, where capital markets remain underdeveloped, the role of banks in the financial system is especially critical. They are the primary means through which savings are transformed into productive investments. By performing this intermediary function, banks not only contribute to financial inclusion but also ensure the circulation of funds across different sectors of the economy. This dynamic enhances liquidity, encourages entrepreneurship, and supports both public and private investment. Given this context, the development and stability of the banking sector are essential for sustaining Cambodia's economic growth [2].

In Cambodia, the mobilization of financial resources remains predominantly concentrated within the banking sector, despite the establishment of the Cambodia Securities Exchange over a decade ago. Given the limited development of capital markets, banks continue to serve as the primary conduit for funding to households and businesses. To ensure the banking sector operates efficiently in its lending function, maintaining sound financial health is essential. A widely accepted method for evaluating the financial condition of banks is the CAMELS framework, an analytical tool developed under the guidance of the Basel Committee on Banking Supervision at the Bank for International Settlements (BIS). This framework assesses six key dimensions: capital adequacy, asset quality, management quality, earnings, liquidity, and sensitivity to market risk [3]. Applying the CAMELS approach allows regulators and stakeholders to identify potential vulnerabilities and strengthen the resilience of the banking system in Cambodia.

Research on the impact of the six components of the CAMELS framework on commercial banks' loan growth remains limited in the Cambodian context. Although a study was conducted in 2023 to examine the influence of five CAMEL components on loan growth, it excluded the sensitivity to market risk (S) component. Moreover, the study relied solely on static panel data models, namely, pooled Ordinary Least Squares (OLS), Random Effects (RE), and Fixed Effects (FE), which are not well-suited to capturing the dynamic interrelationships among variables within the system [4]. In contrast, the current study seeks to address this gap by investigating the influence of all six CAMELS components on loan growth in Cambodian commercial banks using a Panel Vector Autoregressive (PVAR) model. This dynamic framework enables the simultaneous examination of feedback effects among variables over time. Additionally, the model incorporates two key macroeconomic indicators, real GDP growth and inflation rate, as exogenous control variables, providing a more comprehensive understanding of the factors influencing bank lending behavior in Cambodia.

This study is structured into five main sections. The first section introduces the research background, objectives, and significance. The second section provides a review of relevant literature, highlighting existing findings and research gaps. The third section outlines the research methodology, including data sources, variables, and model specification. The fourth section presents the empirical results, including regression analysis, variance decomposition, and impulse response functions. Finally, the fifth section offers the conclusion and discusses key policy implications derived from the findings, aiming to inform future banking regulation and credit policy in the context of Cambodia's financial sector.

2. Literature Reviews

Capital adequacy is vital for maintaining the financial soundness of banks and their capacity to support sustainable lending. Numerous empirical studies have examined the relationship between capital strength and bank lending behavior, with broadly consistent findings underscoring its importance in credit provision and financial stability. Athanasoglou et al. [5] investigated the determinants of bank profitability among Southeast European banks and found that capital adequacy positively influences lending behavior by enhancing financial resilience. Banks with stronger capital buffers were better positioned to absorb losses, enabling them to continue lending even under adverse economic conditions. Similarly, Berger and Bouwman [6] analyzed U.S. banks during financial crises and concluded that those with higher capital ratios were more capable of maintaining or expanding their loan portfolios during periods of stress. Their findings suggest that capital not only serves as a protective buffer against risk but also acts as a signal of stability that fosters borrower and investor confidence.

Lee and Hsieh [7] in a study of Asian commercial banks, reported a non-linear relationship between capital adequacy and loan growth. While moderate increases in capital levels tend to promote lending, excessively high capital ratios may reduce banks' willingness to take on credit risk, leading to more conservative lending practices. This indicates the presence of a threshold beyond which additional capitalization may hinder credit expansion. Applying the CAMELS framework to Bangladeshi banks, Rahman and Hamid [8] found a significant and positive association between capital adequacy and both loan performance and volume. Their results suggest that well-capitalized banks not only extend more credit but also maintain superior asset quality, highlighting the dual benefits of capital strength in supporting and protecting loan portfolios. Extending the analysis to emerging markets, Vu and Nahm [9] provided robust evidence that capital adequacy enhances banks' lending capacity. Their findings show that higher CAR levels are associated with faster loan portfolio growth, especially in jurisdictions with strong regulatory environments. According to the authors, well-capitalized banks are perceived as more stable, which enhances market confidence and facilitates credit expansion. Collectively, these studies affirm that capital adequacy is a key determinant of lending behavior in commercial banks. Adequate capitalization enhances a bank's ability to absorb shocks, maintain asset quality, and inspire confidence among stakeholders. However, some evidence suggests that overly conservative capital holdings may result in diminished lending activity, reflecting a potential trade-off between risk management and credit supply.

Recent studies consistently show that elevated non-performing loan (NPL) ratios hinder the lending capacity of commercial banks by increasing provisioning requirements, reducing capital buffers, and lowering risk appetite. These effects are particularly pronounced during periods of economic distress or within weak regulatory frameworks. Ozili [10] conducted a comprehensive thematic and bibliometric review of post-2020 global NPL research and highlighted loan growth as both a determinant and a consequence of NPL dynamics. The study emphasized that high levels of NPLs weaken banks' balance sheets, thereby impairing their ability to extend credit. Similarly, Muniru et al. [11] reviewed several decades of research and concluded that elevated NPL ratios directly reduce interest income while increasing provisioning costs, which in turn constrain bank liquidity and inhibit loan origination. This effect was found to be especially severe in emerging markets characterized by limited regulatory oversight. Apan et al. [12] also underscored that high NPL volumes erode investor confidence and contribute to financial instability, indirectly limiting credit creation across banking systems.

In a panel-VAR analysis of Zimbabwean banks from 2009 to 2017, Katuka et al. [13] found that shocks to NPL ratios led to significant short-term declines in loan growth. They also observed a feedback loop in which reduced lending further deteriorated bank stability. Consistently, Ozili [10] reinforced the view that loan growth is both a cause and an effect of NPL dynamics, concluding that deteriorating asset quality constrains banks' lending ability through capital depletion and increased risk aversion.

Management efficiency, commonly measured by the ratio of operating expenses to total assets, plays a critical role in determining a bank's operational strength and lending capacity. Excessive operating expenses can erode profitability, diminish capital reserves, and ultimately constrain the supply of credit. Doumpos et al. [14], using a multi-country sample of commercial banks, it was found that higher operating expense ratios significantly reduce loan growth. Elevated cost burdens were shown to lower profitability margins, particularly during periods of sluggish economic activity, thereby limiting the bank's ability to expand credit. In a data envelopment analysis (DEA)-based study of 42 listed Chinese banks, Liao [15] reported that high operating expense-to-asset ratios were associated with reduced lending capacity and lower efficiency scores. Conversely, banks with more efficient cost structures demonstrated stronger loan growth and greater stock market valuation. Similarly, Makri et al. [16] highlighted through cross-national analysis that banks with lower non-interest expense ratios used as a proxy for sound management achieved significantly higher loan-to-asset ratios and broader credit distribution, reinforcing the importance of cost control in supporting credit supply.

Further evidence from Mamonov et al. [17] revealed that, in the context of emerging markets and exchange-rate volatility, excessive operating costs, including revaluation losses, were negatively associated with credit growth. Banks that maintained tighter cost control during foreign exchange fluctuations were able to preserve more stable lending volumes. In a study of the U.S. commercial banks, Basu et al. [18] found that lower operating expense ratios not only predicted improved future performance but were also linked to higher loan growth, suggesting that management discipline and cost efficiency are key enablers of sustained credit expansion.

Return on Assets (ROA) is a fundamental indicator of bank profitability and overall efficiency, influencing lending behavior through its impact on capital accumulation, risk tolerance, and regulatory compliance. In a panel study of 26 Vietnamese banks covering the period from 2006 to 2016, Nguyen [19] found a positive association between ROA and future loan growth. The study suggests that higher profitability enables banks to build internal capital, thereby alleviating lending constraints, especially during periods of economic expansion. In the context of U.S. commercial banks, Basu et al. [18] demonstrated that banks with higher ROA tend to experience sustained credit growth over time. This positive relationship remained robust even after controlling for factors such as size, capitalization, and macroeconomic conditions, underscoring profitability as a primary driver of lending activity. Similarly, the Federal Reserve Bank of San Francisco [20] reported that tightening lending standards, often triggered by lower ROA, led to slower commercial and industrial lending, with broader macroeconomic consequences. The report reinforces the role of profitability in determining banks' willingness to lend.

In a DEA of Chinese banks, Liao [15] found that profitability, as measured by ROA, significantly enhanced both market efficiency and lending capacity. More profitable banks were also associated with stronger stock market valuations, indicating a favorable outlook for future lending. Supporting these findings, the Federal Deposit Insurance Corporation (FDIC) [21] observed that higher aggregate ROA among U.S. commercial banks in 2024 was accompanied by moderate loan growth, even amid a challenging interest rate environment. This suggests that profitability cushions helped sustain lending activity.

Liquidity management, typically measured by the ratio of liquid assets to total assets, plays a crucial role in shaping commercial banks' lending strategies. Recent empirical studies highlight a trade-off: while adequate liquidity supports loan origination, excessive liquidity holdings may constrain credit supply. Stulz [22] using data from 2010 to 2020, it was found that banks with fewer profitable lending opportunities tend to maintain higher liquid asset ratios. Moreover, when deposit inflows occur without corresponding lending prospects, banks are more likely to allocate resources toward liquid assets, thereby reducing credit extension. This behavior aligns with the portfolio theory perspective, where liquidity serves as a substitute for lending capacity. In the Netherlands, the implementation of a regulatory Liquidity Balance Rule led banks to increase their holdings of liquid assets. Dijkstra et al. [23] reported that institutions subject to stricter liquidity mandates reduced their lending activities in favor of holding high-quality liquid assets, resulting in a decline in new loan issuance. Similarly, the Basel III Liquidity Coverage Ratio (LCR), which requires banks to maintain sufficient liquid assets to withstand short-term shocks, has been shown to constrain asset composition during times of financial stress, limiting banks' capacity to extend credit [24].

In the United States, data from the Federal Deposit Insurance Corporation revealed a decline in the median liquid assets-to-assets ratio from 30.3% in 2021 to 21.4% in early 2023. This decline was attributed to rapid loan growth, suggesting an inverse relationship wherein expanding lending activities lead to reduced liquidity buffers, reflecting increased fund allocation toward credit extension [25]. Additionally, Vuong et al. [26] found that banks engaging in higher liquidity creation tend to take fewer risks and issue fewer loans, particularly in higher-risk segments. Their findings support the notion that excess liquidity often corresponds with a more conservative lending approach.

A study investigating the determinants of commercial bank loans in Cambodia employed the CAMEL framework and utilized panel data techniques, including pooled Ordinary Least Squares (OLS), Random Effects (RE), and Fixed Effects (FE) models. The findings indicated that asset quality, measured by the non-performing loan (NPL) ratio, played a statistically significant role in determining loan growth. Specifically, the slope coefficient for asset quality was significant at the 5% level across all three models. Additionally, the study found that both management capability and earnings quality had a significant positive impact on loan growth. The real GDP growth rate was also shown to have a statistically significant influence on loan expansion [4].

While the study effectively applied the CAMEL framework to analyze commercial bank lending, it excluded one key component: sensitivity to market risk (S). Furthermore, by relying solely on static panel data models (pooled OLS, RE, and FE), the study was limited in its ability to explore dynamic interrelationships among the variables. To address these limitations, the current research proposes the use of a panel vector autoregressive (PVAR) model. This dynamic modeling approach will allow for a more comprehensive analysis of the causal interactions among the CAMELS components and their impact on commercial bank loan growth in Cambodia.

3. Methodology

To examine the impact of CAMELS components on the loan activity of Cambodian commercial banks, this study employs a system of equations using panel vector autoregressive (PVAR) modeling. The CAMELS framework comprises six key components: capital adequacy, asset quality, management quality, earnings quality, liquidity, and sensitivity to market risk. In the PVAR model, seven endogenous variables are included: commercial bank loans and the six CAMELS indicators, all of which reflect internal bank performance metrics. Additionally, two macroeconomic variables, real GDP growth rate and inflation rate, are incorporated into the model as control variables (exogenous), allowing for the analysis of external economic influences on the banking system.

$$\boldsymbol{y_{it}} = \boldsymbol{\delta_0} + \boldsymbol{\delta_j} \sum_{j=1}^{l} \boldsymbol{y_{it-j}} + \boldsymbol{\beta x_{it}} + \boldsymbol{f_i} + \boldsymbol{d_{c,t}} + \boldsymbol{\epsilon_{it}} \tag{1}$$

$i \in \{1,2,\dots,N\}$, $j \in \{1,2,\dots,l\}$, and $t \in \{1,2,\dots,T_i\}$

In this model, $\boldsymbol{y_{it}}$ denotes a $1 \times k$ vector of endogenous variables, which includes loans, capital adequacy, asset quality, management quality, earnings quality, liquidity, and sensitivity to market risk of commercial banks. The term $\boldsymbol{y_{it-i}}$ represents the $n \times k$ matrix of lagged endogenous variables. The matrix $\boldsymbol{x_{it}}$ corresponds to a set of exogenous (control) variables, specifically real GDP growth and inflation, structured as a $2 \times k$ matrix. The parameter $\boldsymbol{\delta_0}$ refers to a vector of intercept terms, while $\boldsymbol{\delta_j}$ represents a matrix of coefficients capturing the effects of the lagged endogenous variables. The idiosyncratic errors are denoted by the $1 \times k$ vector $\boldsymbol{\epsilon_{it}}$, which is assumed to satisfy the following conditions: $\boldsymbol{E(\epsilon_{it})} = 0, \boldsymbol{E(\epsilon'_{it}\epsilon_{it})} = \boldsymbol{\Omega}$, and $\boldsymbol{E(\epsilon'_{it}\epsilon_{is})} = \boldsymbol{0}$ for all $t > s$, indicating that the error terms are mean zero, have a constant variance-covariance structure, and are serially uncorrelated.

Let N represent the number of commercial banks and t denote the time period; the combination of these cross-sectional and time-series dimensions constitutes a panel data structure. The model accounts for individual heterogeneity through $\boldsymbol{f_i}$, which captures unobserved, time-invariant characteristics specific to each bank. To address the potential correlation between $\boldsymbol{f_i}$ and the regressors, particularly those arising from the lagged dependent variables, use the Helmert transformation, also known as the forward mean-differencing method. This approach effectively removes individual effects while preserving the orthogonality between transformed variables and lagged regressors. This study employs the Generalized Method of Moments (GMM) as the primary estimation technique, which is numerically comparable to the equation-by-equation two-stage least squares (2SLS) approach, as outlined by Arellano and Bover [27]. To control for country-specific and time-related heterogeneity, the model incorporates time dummy variables, denoted as $\boldsymbol{d_{c,t}}$, capturing unobserved temporal effects across countries.

The research covers the period from 2012 to 2022 and includes 22 commercial banks with complete datasets, resulting in a total of 242 observations. This total is derived from the panel structure, where N represents the number of banks (22) and T represents the number of time periods (11 years). Accordingly, the number of observations is calculated as $N \times T$ = 22 × 11 = 242. The study incorporates a comprehensive set of variables grounded in the CAMELS framework to examine their impact on commercial banks' loan growth in Cambodia. The endogenous variables include seven key indicators: loan growth (LOAN), capital adequacy (EA), asset quality (NPL), management quality (OEA), efficiency (ROA), liquidity (LIQ), and sensitivity to market risk (SEN). Each of these indicators is measured as a percentage, representing internal bank performance dimensions such as equity-to-asset ratio, non-performing loan ratio, operating expense ratio, return on assets, and liquidity coverage. In addition to the bank-specific factors, two macroeconomic indicators are introduced as exogenous control variables: real gross domestic product growth (GDP) and inflation rate (INF). These variables are also expressed in percentage terms and are included to account for broader economic influences on bank lending behavior. A detailed summary of all variables, their definitions, abbreviations, and measurement scales is presented in Table 1. The banking-related data used in this study are obtained from the National Bank of Cambodia's database, while the macroeconomic indicators, real GDP growth rate and inflation rate are sourced from the Asian Development Bank (ADB) database.

Table 1.
Endogenous and exogenous variables.

Variable	Name	Abbreviation		Description	Scale
Endogenous Variables	Loan	LOAN		Loan growth rate	%
	Capital adequacy	C	EA	Equity/Asset	%
	Asset quality	A	NPL	Non-Performing Loan	%
	Management quality	M	OEA	Operating Expense/Asset	%
	Efficiency	E	ROA	Return on Asset	%
	Liquidity	L	LIQ	Liquidity Asset/Asset	%
	Sensitivity to market risk	S	SEN	Individual Bank Asset/Asset	%
Exogenous Variables	Gross Domestic Product	GDP		Real GDP growth rate	%
	Inflation rate	INF		Inflation rate	%

The optimal lag order for the PVAR model and the specification of moment conditions are determined using Hansen [28] *J*-statistic, which tests the validity of overidentifying restrictions in the GMM framework. Upon estimating the VAR model, a stability test is conducted to ensure the robustness of the system. Additionally, the Forecast Error Variance Decomposition (FEVD) and Impulse Response Functions (IRFs) are derived from the estimated GMM coefficients. To construct confidence intervals around the IRFs, a Monte Carlo simulation approach is employed, allowing for more reliable inference of the dynamic responses.

4. Empirical Results

The data analysis in this study is organized into two main sections. The first section presents descriptive statistics of the endogenous and exogenous variables. The second section provides a step-by-step explanation of the PVAR model estimation and analysis. This includes the determination of the optimal lag length, stability testing, regression results, as well as the generation and interpretation of FEVD and IRF.

Table 2 presents the descriptive statistics for the variables used in this study, all of which are expressed as percentages. These variables include commercial banks' internal indicators as well as two macroeconomic factors. The statistics include the mean, standard deviation, minimum, and maximum values, which together provide insights into the central tendency, dispersion, and range of each variable over the observed period. The average loan growth rate across commercial banks is 24.93%, with a notably high standard deviation of 53.60%. This substantial variability suggests considerable heterogeneity in lending behavior across banks or over time. The minimum loan growth rate of -49.21% implies that some banks experienced significant contractions in their loan portfolios, while the maximum of 756.05% may reflect extraordinary or one-time events, such as mergers, recapitalization, or aggressive credit expansion strategies.

Capital adequacy (EA), measured by the equity-to-asset ratio, has a mean value of 24.59% with a standard deviation of 14.85%. These figures indicate that, on average, banks maintained a healthy level of capitalization, although the wide range from 9.22% to 91.20% reveals significant differences in capital strength among institutions. The non-performing loan ratio (NPL), an indicator of asset quality, averages 2.92%, with a relatively moderate standard deviation of 3.33%. The minimum of 0.00% reflects banks with no recorded impaired loans, while the maximum of 19.20% indicates that some banks faced substantial asset quality challenges. Management quality (OEA), proxied by the operating expense-to-asset ratio, has a mean of 2.05%, suggesting a generally efficient cost structure among banks. The low standard deviation (1.11%) and narrow range (0.34% to 6.15%) imply that operational efficiency is relatively consistent across banks.

The average Return on Assets (ROA) is 1.39%, with a standard deviation of 1.26%. Although this indicates modest profitability, the minimum value of -7.92% shows that some banks incurred significant losses, while the maximum of 4.08% highlights better-performing institutions. Liquidity (LIQ), measured as the ratio of liquid assets to total assets, has a high average of 40.83% and a standard deviation of 13.59%, indicating variability in liquidity management practices. The values range from 13.94% to 85.61%, demonstrating that some banks prioritize liquidity to a much greater extent than others. The sensitivity to market risk (SEN), which reflects banks' exposure to market fluctuations, averages 3.56%, with a relatively high standard deviation of 4.47%. The range from 0.22% to 19.70% implies that while some banks operate with minimal exposure to market risks, others face substantial vulnerabilities.

Table 2.
Descriptive statistics.

Variable	Observation	Mean	Std. dev.	Minimum	Maximum
Loan	242	24.93	53.60	-49.21	756.05
EA	242	24.59	14.85	9.22	91.20
NPL	242	2.92	3.33	0.00	19.20
OEA	242	2.05	1.11	0.34	6.15
ROA	242	1.39	1.26	-7.92	4.08
LIQ	242	40.83	13.59	13.94	85.61
SEN	242	3.56	4.47	0.22	19.70
GDP	242	5.67	3.06	-3.14	7.50
INF	242	3.01	1.01	1.21	5.34

Turning to macroeconomic indicators, real GDP growth (GDP) averages 5.67%, reflecting strong economic performance over the study period. However, the standard deviation of 3.06% and the minimum value of -3.14% indicate periods of economic contraction, likely influenced by global shocks such as the COVID-19 pandemic. Finally, inflation (INF) maintains a relatively stable average of 3.01%, with low variability (standard deviation of 1.01%) and a range from 1.21% to 5.34%. This suggests a relatively controlled inflation environment during the sample period, which likely contributed to macroeconomic stability. Overall, the descriptive statistics reveal a banking sector characterized by varied financial performance and operational strategies. The wide dispersion in loan growth, capital adequacy, and risk-related indicators highlights the importance of bank-specific factors in determining lending behavior and financial resilience.

Table 3.
Lags order selection

lag	CD	J	J p-value	MBIC	MAIC	MQIC
1	0.9861	96.2749	0.4442	-394.9211	-93.7251	-215.8887
2	0.9988	59.1301	0.0066	-121.8368	-10.8699	-55.8776

Table 3 presents results derived from the lag selection procedure employed in estimating the Panel Vector Autoregressive (PVAR) model. The table encompasses essential model selection diagnostics, including the cross-sectional dependence (CD) statistic, Hansen's J-statistic with its corresponding p-value, and three model selection criteria: Modified Bayesian Information Criterion (MBIC), Modified Akaike Information Criterion (MAIC), and Modified Hannan-Quinn Information Criterion (MQIC) for lags 1 and 2. Hansen's J-statistic tests the validity of overidentifying restrictions in the GMM estimation. At lag 1, the J-statistic is 96.2749 with a p-value of 0.4442, indicating that the null hypothesis that the instruments are valid cannot be rejected. Conversely, at lag 2, the J-statistic decreases to 59.1301, but the p-value drops sharply to 0.0066, suggesting potential invalidity of the instruments at this lag length. Consequently, from the perspective of instrument validity, lag 1 is the preferred choice.

In terms of model fit, three information criteria, MBIC, MAIC, and MQIC, are examined. These criteria penalize model complexity differently, but in all three cases, lower values indicate a better-fitting model. For lag 1, the MBIC, MAIC, and MQIC are -394.9211, -93.7251, and -215.8887, respectively. For lag 2, the values are considerably higher: -121.8368, -10.8699, and -55.8776, respectively. The consistently more negative values at lag 1 across all three criteria provide strong evidence that the PVAR model with one lag offers a better overall fit. Additionally, the cross-sectional dependence (CD) statistics for both lag structures are very close to 1 (0.9861 for lag 1 and 0.9988 for lag 2), indicating that both specifications adequately account for cross-sectional dependence in the panel data. However, since CD is not the primary criterion for lag selection, it supports but does not outweigh the conclusions drawn from the J-test and information criteria.

In conclusion, based on the combination of statistical evidence from the J-test p-value and the information criteria, it is clear that the PVAR model with one lag is the optimal specification. This lag structure ensures instrument validity, maintains model parsimony, and offers the best fit to the data, thereby providing a reliable foundation for the dynamic analysis of the CAMELS components and their influence on commercial bank lending behavior.

Table 4.
Regression results of Loan's equation.

Dependent variable	Independent variable	Coefficient	Standard error	z	P>z	95% Confidence Interval	
Loan							
	Loan						
	L1.	0.0313	0.0574	0.55	0.585	-0.0811	0.1437
	EA						
	L1.	-0.0343	0.2854	-0.12	0.904	-0.5937	0.5251
	NPL						
	L1.	-2.7927	1.1246	-2.48	0.013	-4.9968	-0.5886
	OEA						
	L1.	20.5074	6.8309	3.00	0.003	7.1192	33.8956
	ROA						
	L1.	-9.0163	2.3461	-3.84	0.000	-13.6146	-4.4180
	LIQ						
	L1.	1.2001	0.3817	3.14	0.002	0.4521	1.9481
	SEN						
	L1.	-2.8291	2.0369	-1.39	0.165	-6.8213	1.1631
	GDP	1.4071	0.4159	3.38	0.001	0.5920	2.2221
	INF	-0.7133	1.4991	-0.48	0.634	-3.6515	2.2248
Instruments: L(1/3).(loan, EANPL, OEA, ROA, LIQ, SEN) GDP, INF)							

Although the PVAR model comprises a system of six equations corresponding to the six components of the CAMELS framework: capital adequacy (EA), asset quality (NPL), management quality (OEA), earnings (ROA), liquidity (LIQ), and sensitivity to market risk (SEN) the interpretation of the empirical results focuses exclusively on the loan equation. Specifically, the analysis of regression estimates, forecast error variance decomposition (FEVD), and impulse response functions (IRFs) is centered on understanding the factors that influence commercial banks' loan growth.

Table 4 presents the estimation results from the PVAR model, where the commercial banks' loan growth rate is specified as the dependent variable. The table includes endogenous variables at lag one (L1) and exogenous variables, estimated coefficients, standard errors, z-statistics, p-values, and 95% confidence intervals. The focus of this analysis is to examine how the components of the CAMELS framework and key macroeconomic indicators influence loan growth.

The coefficient for lagged loan growth is 0.0313 and is statistically insignificant ($p = 0.585$). This suggests that previous loan growth does not significantly predict current loan growth, indicating weak loan growth persistence in the sample. Capital adequacy has a negative but statistically insignificant coefficient of -0.0343 ($p = 0.904$), implying that changes in the equity-to-asset ratio do not have a meaningful impact on loan growth in the short term. Similarly, sensitivity to market risk shows a negative but insignificant coefficient of -2.8291 ($p = 0.165$), suggesting that market risk exposure does not significantly influence lending behavior.

In contrast, several variables demonstrate statistically significant effects on loan growth. Asset quality has a negative and significant impact (coefficient = -2.7927, $p = 0.013$), indicating that an increase in non-performing loans reduces the bank's ability or willingness to extend credit. This aligns with the theoretical expectation that poor asset quality impairs loan supply. Management quality, proxied by the operating expense-to-asset ratio, has a strong positive and statistically significant effect on loan growth (coefficient = 20.5074, $p = 0.003$). This result is somewhat counterintuitive, as higher operating expenses typically reflect inefficiencies. However, in this context, it may reflect increased investment in lending operations or business expansion efforts. Efficiency, measured by return on assets, has a significant negative effect on loan growth (coefficient = -9.0163, $p < 0.001$). This finding suggests that highly profitable banks may adopt more conservative lending strategies, possibly prioritizing financial stability over credit expansion. Liquidity has a positive and statistically significant effect (coefficient = 1.2001, $p = 0.002$), indicating that higher liquid asset holdings support greater lending capacity. This result supports the argument that liquidity-rich banks are better positioned to respond to loan demand.

Turning to the exogenous macroeconomic variables, real GDP growth exerts a strong and positive influence on loan growth (coefficient = 1.4071, $p = 0.001$). This result is consistent with expectations, as economic expansion tends to increase credit demand and improve borrowers' repayment capacity. Conversely, inflation has a negative but statistically insignificant effect on loan growth (coefficient = -0.7133, $p = 0.634$), suggesting that moderate inflation rates do not significantly alter lending behavior during the observed period.

Overall, the results highlight that several CAMELS indicators, specifically asset quality, management quality, efficiency, and liquidity, play a significant role in determining commercial bank loan growth in Cambodia. Among macroeconomic controls, GDP growth emerges as a key driver of credit expansion. These findings underscore the importance of both internal bank performance and external economic conditions in shaping lending dynamics.

The Hansen's J test is used to assess the validity of overidentifying restrictions in models estimated using the GMM, such as the PVAR model in this study. It tests whether the instruments used in the estimation are uncorrelated with the error term and are therefore valid. In this case, the Hansen's J statistic is 82.426, with 91 degrees of freedom, and the corresponding p-value is 0.728. Since the p-value is substantially higher than the conventional significance levels (e.g., 0.01, 0.05, or 0.10), we fail to reject the null hypothesis that the instruments are valid. This result indicates that the overidentifying restrictions are satisfied, and there is no evidence of misspecification in the instrument set. Therefore, the GMM estimates used in the PVAR model can be considered reliable and consistent within the context of this analysis.

Figure 1 presents the root plot of the companion matrix derived from the PVAR model, which is a crucial diagnostic tool for assessing the model's dynamic stability. The graph plots the eigenvalues (roots) of the companion matrix in the complex plane, where the horizontal and vertical axes represent the real and imaginary components of each root, respectively. The outermost circle represents the unit circle, a theoretical boundary with a radius of one, centered at the origin. For the PVAR model to be considered stable, a necessary condition for valid impulse response functions (IRFs) and forecast error variance decomposition (FEVD) all roots must lie strictly within the unit circle. Stability implies that the effects of shocks to the system dissipate over time, rather than persistently amplifying or diverging.

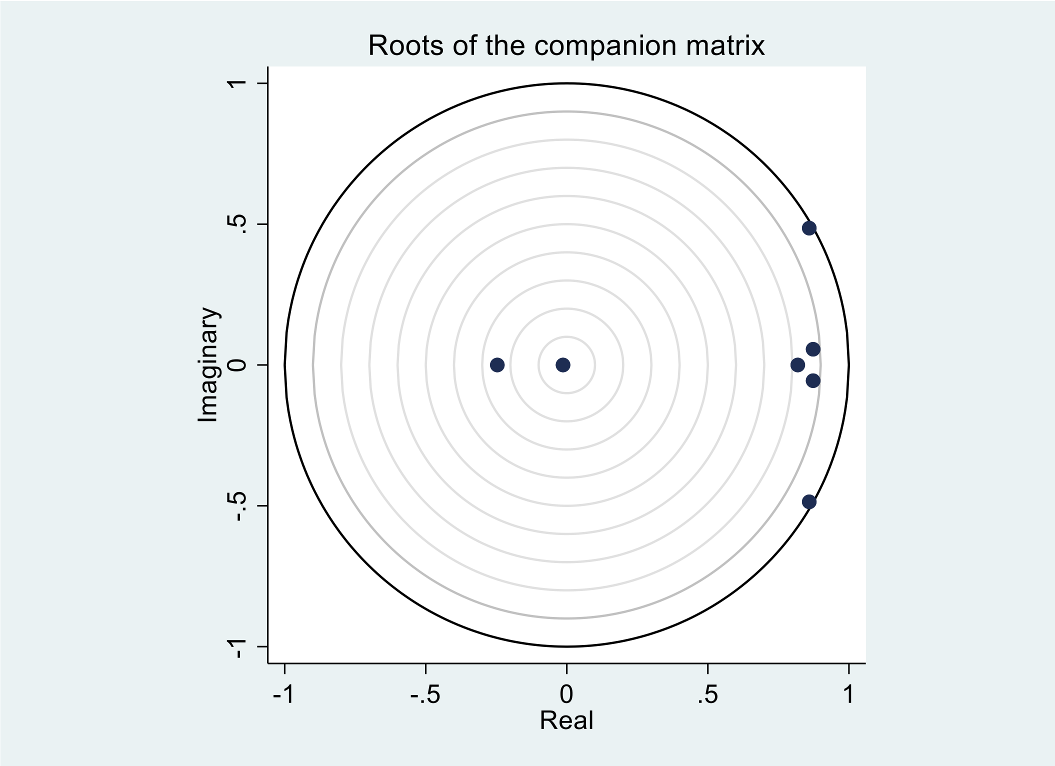

Figure 1.
Roots of the companion matrix.

As shown in the graph, all plotted roots lie well inside the unit circle, with none touching or crossing its boundary. This finding confirms that the estimated PVAR model is dynamically stable. The result indicates that the model's equations exhibit stationarity and that the endogenous variables in the system revert to equilibrium following a disturbance. In practical terms, this stability ensures that the estimated relationships among variables such as the influence of CAMELS indicators and macroeconomic variables on commercial bank loan growth are statistically reliable and economically interpretable over time. Without such stability, the dynamic responses would be prone to explosive behavior, rendering policy or managerial conclusions drawn from the model invalid. The companion matrix root plot validates the stability of the PVAR model, affirming that the model meets the key requirement for dynamic consistency. This result provides confidence in proceeding with further analyses, such as IRF and FEVD, to explore the dynamic interrelationships among bank performance indicators and macroeconomic variables.

Table 5.
Forecast error variance decomposition of Loan.

Response variable	Forecast horizon	Impulse variable						
		Loan	**EA**	**NPL**	**OEA**	**ROA**	**LIQ**	**SEN**
Loan								
	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.9075	0.0095	0.0000	0.0359	0.0252	0.0215	0.0005
	3	0.8218	0.0718	0.0024	0.0533	0.0260	0.0241	0.0006
	4	0.7024	0.1648	0.0025	0.0522	0.0567	0.0207	0.0006
	5	0.5799	0.2540	0.0022	0.0430	0.1023	0.0180	0.0006
	6	0.4849	0.3041	0.0039	0.0405	0.1507	0.0152	0.0006
	7	0.4268	0.3164	0.0074	0.0482	0.1864	0.0140	0.0007
	8	0.3976	0.3075	0.0108	0.0612	0.2043	0.0177	0.0008
	9	0.3840	0.2969	0.0126	0.0719	0.2059	0.0278	0.0009
	10	0.3723	0.2986	0.0125	0.0749	0.1996	0.0413	0.0010

Table 5 presents the FEVD results derived from the PVAR model, with loan growth as the response variable. The FEVD analysis measures the proportion of the forecast error variance in loan growth attributable to shocks in itself (Loan) and in the other CAMELS components: capital adequacy, asset quality, management quality, earnings, liquidity, and sensitivity to market risk, over a 10-period forecast horizon. At the initial horizon (period 0), all forecast error variance is naturally attributed to the variable itself, resulting in zero contribution from all other variables. At horizon 1, 100% of the variation in loan growth is still explained by its own shocks. However, starting from horizon 2, the influence of other variables begins to emerge and grows steadily over time, indicating increasing dynamic interaction. By horizon 2, approximately 90.75% of the variation in loan growth is still explained by its own past shocks, but the contribution of capital adequacy and earnings begins to materialize, with 0.95% and 2.52% respectively. Notably, management quality contributes 3.59% and liquidity 2.15%, while asset quality and sensitivity to market risk remain negligible at this stage. As the forecast horizon extends, the contribution of loans' own shocks decreases, reaching 37.23% by period 10, indicating that a significant portion of loan growth variation over the long run is explained by other factors. Among these, capital adequacy accounts for 29.86%, emerging as a major driver of loan dynamics. Earnings contribute 19.96%, reinforcing the role of profitability in influencing banks' lending behavior. Management quality steadily rises to 7.49%, suggesting its growing relevance over time. Liquidity also gains importance, accounting for 4.13% of the forecast error variance at horizon 10. Meanwhile, asset quality and sensitivity to market risk have only minor long-term influence, contributing 1.25% and 0.10% respectively by horizon 10. This implies that while non-performing loans and market sensitivity are relevant to risk management, their impact on loan growth variation appears limited in this context.

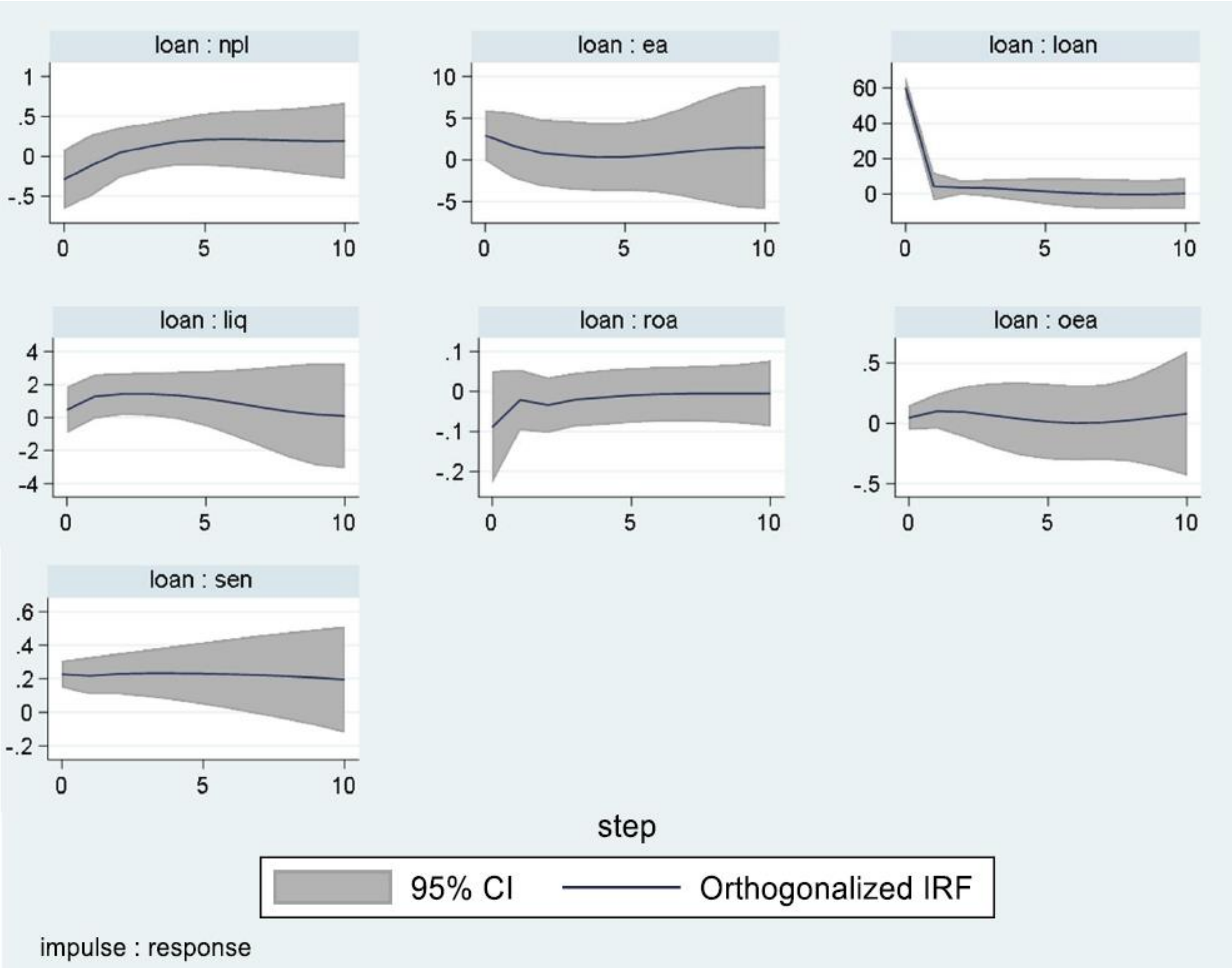

Figure 2.
Impulse response function of the Loan.

Figure 2 displays the orthogonalized impulse response functions (IRFs) that illustrate the dynamic effects of one-standard-deviation shocks to various components of the CAMELS framework on the loan growth of commercial banks. The shocks pertain to capital adequacy (EA), asset quality (NPL), management quality (OEA), earnings (ROA), liquidity (LIQ), and sensitivity to market risk (SEN). Each response is accompanied by a 95% confidence interval (CI), allowing for the assessment of the statistical significance of the estimated effects over a 10-period horizon.

The IRF for loan growth's own shock (Loan: Loan) reveals an immediate and substantial positive response in the first period, peaking sharply before rapidly declining. This behavior aligns with expectations, given the autocorrelated nature of loan growth. The effect, however, fades over time and stabilizes near zero, indicating that past loan performance has only a short-lived impact on future lending activity. A shock to capital adequacy induces a negative and statistically significant response in loan growth, with the IRF consistently remaining below zero and within the bounds of the confidence interval. This suggests that an increase in the equity-to-asset ratio may prompt banks to adopt a more cautious lending approach, possibly driven by tighter regulatory requirements or an internal preference for reduced risk exposure. In contrast, a shock to asset quality results in a moderate and persistent positive response in loan growth. Although this effect may appear counterintuitive since deteriorating asset quality is typically expected to constrain lending, the response remains statistically insignificant as the confidence intervals include zero throughout the forecast horizon. This may indicate that the direct impact of non-performing loans on short-term lending behavior is limited or influenced by other mitigating factors.

Loan growth also shows a positive and gradually increasing response to management quality, measured by the operating expense-to-asset ratio. Although the response is initially modest, it gains strength over time, suggesting that enhanced operational management and strategic allocation of resources may support sustained credit expansion. The response to earnings is consistently negative and statistically significant, particularly in the early periods. This result implies that higher profitability is associated with reduced loan growth. While this may seem counterintuitive, it could reflect a strategic shift among more profitable banks toward strengthening their balance sheets or minimizing credit risk rather than aggressively expanding their loan portfolios. With respect to liquidity, the IRF reveals a short-term positive impact on loan growth, which diminishes over time. This finding suggests that greater liquidity facilitates immediate lending capacity but has limited long-term influence on credit expansion. Finally, the response of loan growth to market risk sensitivity is negative but statistically insignificant. The IRF remains within the confidence band across all periods, indicating that variations in market risk exposure have little meaningful impact on lending activity in the observed sample.

In sum, the IRF results demonstrate that commercial bank loan growth is influenced by a subset of CAMELS indicators, with capital adequacy and earnings (ROA) exerting significant negative effects, reflecting more conservative lending practices in the face of financial strength and profitability. Conversely, management quality and liquidity contribute positively to loan growth, though with less statistical strength. These results emphasize the relevance of internal financial performance and strategic management in shaping credit allocation behavior over time.

5. Conclusion and Policy Implication

This study investigated the impact of the CAMELS components and macroeconomic variables on the loan growth of commercial banks in Cambodia using a Panel Vector Autoregressive (PVAR) model. The analysis incorporated regression estimates, forecast error variance decomposition (FEVD), and impulse response functions (IRFs) to uncover the dynamic relationships among internal bank performance indicators and loan growth.

The regression results revealed that several CAMELS components significantly influence loan growth. In particular, asset quality (NPL) and earnings (ROA) were found to have strong and statistically significant negative effects, indicating that increases in non-performing loans and profitability are associated with more cautious lending behavior. Conversely, management quality (OEA) and liquidity (LIQ) exerted positive and significant effects, suggesting that efficient resource allocation and strong liquidity positions support loan expansion. Interestingly, capital adequacy (EA) and sensitivity to market risk (SEN) showed statistically insignificant effects, implying that in the short term, these variables may not be primary drivers of lending behavior. The FEVD analysis further confirmed the evolving influence of different CAMELS indicators over time. While loan growth is initially self-driven, its explanatory power declines from 100% at horizon 1 to approximately 37% by horizon 10. Over time, capital adequacy (29.86%) and earnings (19.96%) emerged as the most influential drivers of loan growth variance. Management quality (7.49%) and liquidity (4.13%) also contributed meaningfully, albeit to a lesser extent. In contrast, the contributions of asset quality (1.25%) and market risk sensitivity (0.10%) remained minimal throughout the forecast horizon.

The IRF analysis provided additional insights into the dynamic effects of CAMELS components on loan growth. Shocks to capital adequacy and earnings consistently led to statistically significant declines in loan growth, reinforcing the view that stronger capitalization and profitability may lead banks to adopt more conservative lending practices. Conversely, shocks to management quality and liquidity produced positive responses in loan growth, though the magnitude and statistical significance varied over time. The effects of asset quality and market sensitivity, while present, were not statistically significant, suggesting limited or indirect influence on short-run credit dynamics. Overall, the findings underscore the critical role of internal bank performance, particularly capital adequacy, asset quality, management quality, earnings, and liquidity in shaping the lending behavior of commercial banks.

Among the macroeconomic controls, real GDP growth was a robust and positive determinant of loan growth, while inflation did not exhibit a statistically significant impact. These results highlight the importance of both prudential internal management and a stable macroeconomic environment in supporting credit expansion in the Cambodian banking sector. The study’s implications are particularly relevant for policymakers and bank managers. Regulatory focus should be maintained on improving asset quality and liquidity management while ensuring that capital buffers and profitability do not lead to excessive credit tightening. At the same time, macroeconomic stability, especially sustained economic growth, remains essential to support a healthy credit environment.

To promote sustainable loan growth in Cambodia’s banking sector, regulators and bank managers should prioritize the enhancement of credit risk management frameworks. This includes strengthening early warning systems and implementing stricter loan classification and provisioning standards to reduce non-performing loans and preserve asset quality. Given the observed negative relationship between return on assets (ROA) and loan growth, it is advisable for policymakers to encourage banks to adopt a more balanced strategy, reinvesting a portion of their earnings into productive lending activities, particularly in underserved segments such as small and medium-sized enterprises (SMEs).

The positive association between management quality and loan growth highlights the value of targeted operational investment. Accordingly, banks should be incentivized to allocate resources toward technology upgrades, employee training, and service innovation that enhance credit evaluation and customer engagement. Additionally, liquidity has been shown to play a vital role in supporting credit expansion. Regulators should therefore ensure that prudential liquidity ratios are upheld and that banks conduct regular stress testing to remain resilient under varying economic conditions.

On a macroeconomic level, the strong influence of GDP growth on lending activity suggests the importance of maintaining economic stability and fostering growth. Policies aimed at encouraging investment, expanding infrastructure, and promoting financial inclusion can stimulate both credit demand and supply. Lastly, the finding that higher capital adequacy ratios may dampen loan growth signals the need for a calibrated approach to capital regulation. Authorities could explore the implementation of countercyclical capital buffers or tailor capital requirements based on bank size and risk exposure to avoid unnecessarily restricting credit supply while still ensuring financial system stability. In conclusion, these recommendations emphasize the importance of improving internal bank performance and maintaining supportive macroeconomic conditions. A coordinated approach that balances prudential oversight with growth-oriented policies will be essential for fostering a robust and inclusive lending environment in Cambodia.

References

[1] Asian Development Bank, "Cambodia: Financial sector development strategy," 2022. https://www.adb.org
[2] National Bank of Cambodia, "Annual report 2022," 2022. https://www.nbc.gov.kh/english/
[3] International Monetary Fund, " Financial sector assessment: Cambodia," 2023. https://www.imf.org

[4] S. Lim, "The determination of commercial banks' loan growth in Cambodia," *Journal of Accounting, Finance, Economics, and Social Sciences*, vol. 8, no. 2, pp. 51–29, 2023. https://doi.org/10.62458/jafess.160224.8(2)51-59

[5] P. P. Athanasoglou, S. N. Brissimis, and M. D. Delis, "Bank-specific, industry-specific and macroeconomic determinants of bank profitability," *Journal of International Financial Markets, Institutions and Money*, vol. 18, no. 2, pp. 121-136, 2008. https://doi.org/10.1016/j.intfin.2006.07.001

[6] A. N. Berger and C. H. S. Bouwman, "How does capital affect bank performance during financial crises?," *Journal of Financial Economics*, vol. 109, no. 1, pp. 146-176, 2013. https://doi.org/10.1016/j.jfineco.2013.02.008

[7] C.-C. Lee and M.-F. Hsieh, "The impact of bank capital on profitability and risk in Asian banking," *Journal of International Money and Finance*, vol. 32, pp. 251-281, 2013. https://doi.org/10.1016/j.jimonfin.2012.04.013

[8] M. M. Rahman and M. A. Hamid, "Impact of CAMELS rating on the performance of commercial banks: Empirical evidence from Bangladesh," *Journal of Asian Finance, Economics and Business*, vol. 7, no. 1, pp. 41–51, 2020.

[9] T. H. Vu and D. Nahm, "Does capital adequacy influence bank lending? New evidence from emerging markets," *Research in International Business and Finance*, vol. 58, p. 101472, 2021.

[10] P. K. Ozili, "Bank non-performing loans research around the world," *Asian Journal of Economics and Banking*, vol. 9, no. 1, pp. 1–20, 2025.

[11] S. Muniru, N. David, O. Tom, and M. Michael, "Non-performing loans of commercial banks: A review," *Newport International Journal of Current Research in Humanities and Social Sciences*, vol. 5, no. 1, pp. 82-85, 2025. https://doi.org/10.59298/NIJCRHSS/2025/5.1.828500

[12] R. Apan, S. G. Othman, and W. Gabbori, "The impact of NPLs on financial market stability and credit supply: A global review," *F1000Research*, vol. 14, no. 486, pp. 1–12, 2025.

[13] B. Katuka, C. Mudzingiri, and E. Vengesai, "The effects of non-performing loans on bank stability and economic performance in Zimbabwe," *Asian Economic and Financial Review*, vol. 13, no. 8, pp. 393–405, 2023.

[14] M. Doumpos, V. Makri, and A. Tsagkanos, "The effect of capital structure, operating efficiency and non interest income on bank performance," *Asian Journal of Economics and Banking*, vol. 14, no. 3, pp. 256–279, 2022.

[15] Y. Liao, "Super efficiency and stock market valuation: Evidence from listed banks in China (2006–2023)," *arXiv*, 2024. https://doi.org/10.48550/arXiv.2407.14734

[16] V. Makri, A. Tsagkanos, and A. Bellas, "Bank stability, performance and efficiency," *International Review of Business and Social Science*, vol. 10, no. 2, pp. 45–62, 2022.

[17] M. Mamonov, C. F. Parmeter, and A. Prokhorov, "Bank cost efficiency and credit market structure under a volatile exchange rate," *arXiv*, 2024. https://doi.org/10.48550/arXiv.2408.05688

[18] S. Basu, E. Gomez, and B. Su, "Banks' efficiency ratio disclosure (December 22, 2023). Fox school of business research paper," 2023. https://ssrn.com/abstract=4958255 or http://dx.doi.org/10.2139/ssrn.4958255

[19] H. Nguyen, "Credit risk and financial performance of commercial banks: Evidence from Vietnam," *arXiv*, 2023. https://doi.org/10.48550/arXiv.2304.08217

[20] Federal Reserve Bank of San Francisco, *Economic effects of tighter lending by banks*. San Francisco, CA: SF Fed Economic Letter, 2024.

[21] Federal Deposit Insurance Corporation (FDIC), *Quarterly banking profile: Fourth quarter 2024*. Washington, DC: FDIC, 2025.

[22] R. M. Stulz, "Why are banks' holdings of liquid assets so high?," NBER Working Paper No. 30340, 2023.

[23] R. Dijkstra, J. Veldman, and F. de Jong, "Liquidity regulation and bank lending: Evidence from the Netherlands," *Journal of Banking & Finance*, vol. 125, p. 106035, 2021.

[24] Bank for International Settlements, *FSI Brief: Rethinking banks' liquidity requirements*. Basel, Switzerland: BIS, 2024.

[25] Federal Deposit Insurance Corporation (FDIC), *FDIC quarterly banking profile: Banking sector liquidity trends*. Washington, DC: FDIC, 2023.

[26] G. T. H. Vuong, P. T. T. Phan, C. X. Nguyen, D. M. Nguyen, and K. D. Duong, "Liquidity creation and bank risk-taking: Evidence from a transition market," *Heliyon*, vol. 9, no. 9, p. e19141, 2023. https://doi.org/10.1016/j.heliyon.2023.e19141

[27] M. Arellano and O. Bover, "Another look at the instrumental variable estimation of error-components models," *Journal of Econometrics*, vol. 68, no. 1, pp. 29-51, 1995. https://doi.org/10.1016/0304-4076(94)01642-D

[28] L. P. Hansen, "Large sample properties of generalized method of moments estimators," *Econometrica*, vol. 50, no. 4, pp. 1029–1054, 1982. https://doi.org/10.2307/1912775