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Exchange Rate Volatility and Non-Performing Loans in Iran's Banking System: The Moderating Role of Bank-Specific Factors under Financial Sanctions

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ABSTRACT

This study examines the dynamic impact of exchange rate volatility on non-performing loans (NPLs) in Iran's banking system, while simultaneously accounting for the moderating role of bank-specific factors, including capital adequacy (CAR), liquidity (LQ), and management quality (MQ). A Panel Vector Autoregression (Panel-VAR) framework is employed using balanced panel data from 18 Iranian commercial banks over the period 1390–1402 (2011–2023), comprising 234 bank-year observations. The adopted methodology integrates LLC and IPS unit root tests, Pedroni and Kao cointegration analyses, and system GMM estimation to address endogeneity and dynamic panel bias. Exchange rate volatility is measured using a GARCH(1,1) model based on the official USD/IRR exchange rate. The results indicate that exchange rate volatility exerts a positive and statistically significant effect on NPLs, operating primarily through the balance sheet channel. Capital adequacy and liquidity function as significant mitigating buffers, whereas management quality exhibits a smaller yet still significant negative effect. The high autoregressive coefficient of NPLs points to substantial persistence in the deterioration of credit quality. Cointegration analysis confirms the existence of three long-run equilibrium relationships among the variables, reinforcing the structural nature of these linkages. Granger causality tests establish bidirectional causality between exchange rate volatility and NPLs, suggesting the presence of reinforcing feedback dynamics. The findings support prioritizing exchange rate stabilization as a prerequisite for financial stability, accelerating the implementation of Basel III capital requirements with countercyclical buffers calibrated to exchange rate risk, and integrating exchange rate indicators into banking supervisory early warning systems.

KEYWORDS: Non-performing loans; exchange rate volatility; bank liquidity; financial sanctions

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1. Introduction

Non-Performing Loans (NPLs), as one of the key indicators of banking asset quality, play a pivotal role in assessing the financial system health of countries. An increase in the ratio of NPLs to total granted facilities signals a deterioration in borrowers' repayment capacity and a decline in the efficiency of banks' credit allocation processes (Ozili, 2019). According to the International Monetary Fund's *Global Financial Stability Report* (April 2025), the NPL ratio in emerging economies averaged more than 6 percent during the period 2020–2023—a concerning figure compared to advanced economies, where the ratio stood at approximately 3 percent (International Monetary Fund, 2025). This performance gap underscores the heightened importance of identifying the determinants of NPLs in emerging markets.

Exchange Rate (ER) fluctuations, as one of the volatile macroeconomic variables in developing economies, exert widespread effects on banking sector performance (Mpofu & Nikolaidou, 2018). Exchange rate instability affects the quality of banks' loan portfolios through two primary channels: first, increased production costs for import-dependent firms, which leads to reduced repayment capacity; and second, the weakening of balance sheets of companies with foreign currency (FX)-denominated debt, which elevates default risk (Bruno & Shin, 2020). In countries such as Iran, where dependence on oil revenues and exposure to international sanctions have induced severe exchange rate volatility, these effects are substantially more pronounced.

The vulnerability of the banking system to exchange rate shocks, particularly in emerging economies, has attracted increasing attention in the literature on financial economics. Recent banking crises—including the Asian Financial Crisis (1997) and the Global Financial Crisis (2008)—have demonstrated that a surge in Non-Performing Loans (NPLs) can rapidly precipitate systemic instability (Ghosh, 2015). In this context, banks, acting as financial intermediaries, play a critical role in transmitting macroeconomic shocks to the real economy. Consequently, understanding the mechanisms through which Exchange Rate (ER) fluctuations affect NPLs holds strategic importance for monetary policymakers and regulatory authorities (Beck, Jakubik, & Piloiu, 2015).

Despite the substantial body of research examining the determinants of NPLs, no clear consensus exists regarding the magnitude and direction of the impact of exchange rate volatility on this variable. Some studies have confirmed a positive and statistically significant relationship between exchange rate fluctuations and NPLs (Castro, 2013; Klein, 2013), whereas other investigations have reported this relationship as weak or even statistically insignificant (Nkusu, 2011). These inconsistencies may stem from differences in study periods, the economic structures of the countries examined, and, notably, insufficient control for bank-specific variables. Louzis, Vouldis, and Metaxas (2012) have emphasized that neglecting bank-specific characteristics in modeling NPLs can lead to biased estimates.

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2. Literature Review and Theoretical Framework

2.1 Theoretical Background

Credit risk, defined as the probability of borrowers' inability to meet their financial obligations, constitutes one of the most fundamental sources of fragility in the banking system. In contemporary approaches, credit risk is no longer viewed solely as a consequence of individual borrower characteristics; rather, it emerges from the complex interplay of macroeconomic conditions, financial market structures, and banking management quality. Recent research indicates that banks' NPLs represent systemic credit risk originating from macroeconomic shocks and bank-specific imbalances (*Managing Risks in Commercial and Retail Banking*, 2012).

The contemporary literature on credit risk emphasizes that fluctuations in macroeconomic variables—particularly the Exchange Rate (ER)—can severely undermine the repayment capacity of firms and households. Rising economic instability leads to cash flow volatility, diminished corporate profitability, and an elevated probability of loan defaults. Under such conditions, NPLs manifest not merely as a micro-level banking issue, but as a reflection of the economy's structural vulnerability (Beck et al., 2015).

In emerging economies, this effect is more pronounced, as import dependence, foreign currency (FX) debt, and policy constraints strengthen the transmission channel of macroeconomic shocks to credit risk. From this perspective, credit risk theory provides an appropriate framework for analyzing the relationship between Exchange Rate (ER) fluctuations and Non-Performing Loans (NPLs).

Exchange rate pass-through theory explains how changes in the exchange rate are transmitted to domestic prices, production costs, corporate profitability, and ultimately, to the quality of banking

assets. The intensity and speed of this transmission depend on structural factors such as the economy's trade composition, the degree of financial openness, the prevailing exchange rate regime, and the credibility of monetary policies (Bussière et al., 2015).

At the firm level, exchange rate depreciation increases the cost of imported inputs and FX-denominated liabilities, thereby compressing profit margins. This process weakens debt-servicing capacity and elevates the probability of default. At the banking level, these developments manifest as a rise in NPLs and a deterioration in overall asset quality. Recent evidence indicates that in emerging markets, the exchange rate pass-through to financial variables is stronger and more persistent than in advanced economies (Ha et al., 2023).

Contemporary literature emphasizes that the impact of ER fluctuations on NPLs is highly contingent upon banks' capital adequacy, liquidity positions, and management quality. Institutions with weaker prudential metrics experience the adverse effects of exchange rate shocks more acutely (Katusiime, 2023).

The balance sheet channel represents one of the most critical mechanisms for transmitting macroeconomic shocks to the financial sector. According to this framework, fluctuations in asset and liability valuations directly affect the net worth of firms and banks, thereby shaping credit allocation decisions. A decline in net worth coupled with an increase in real debt burdens exacerbates asymmetric information problems and raises the cost of external financing (Brunnermeier & Pedersen, 2005).

In the context of exchange rate (ER) fluctuations, the balance sheet channel plays a pivotal role. An increase in the ER (i.e., domestic currency depreciation) raises the valuation of firms' foreign currency (FX) liabilities and weakens their balance sheets. This process diminishes debt-servicing capacity and ultimately leads to a rise in Non-Performing Loans (NPLs) on banks' balance sheets. Recent studies indicate that this channel represents one of the most persistent transmission pathways through which exchange rate effects impact credit risk (Du & Schreger, 2022).

The financial fragility framework posits that banking systems gradually accumulate latent risks during periods of apparent stability. Under such conditions, external shocks—such as ER volatility—can rapidly precipitate banking crises. This framework interprets rising NPLs as a clear indicator of intensifying systemic fragility (Danielsson et al., 2023). Banks exhibiting weaker capital adequacy, liquidity positions, and management quality are inherently more vulnerable to ER shocks. From this perspective, NPLs are not merely a performance metric, but rather a critical indicator of financial stability and the effectiveness of prudential policies (International Monetary Fund, 2020).

2.2 Empirical Literature on Exchange Rates and NPLs

Recent international studies have extensively documented the impact of ER fluctuations on NPLs. Klein (2013) demonstrated that exchange rate instability was a primary driver behind the deterioration in asset quality of European banks following the sovereign debt crisis. Similarly,

Ghosh (2015), utilizing a cross-country dataset of 80 economies, reports that ER shocks exert a statistically significant effect on NPL accumulation via the balance sheet channel (*Managing Risks in Commercial and Retail Banking*, 2012).

Beck et al. (2015) further demonstrate that the impact of Exchange Rate (ER) fluctuations on Non-Performing Loans (NPLs) is more pronounced in countries with less developed financial markets. These findings suggest that institutional structure and the level of financial development play a significant moderating role in the strength of this relationship.

In emerging economies, the relationship between ER movements and NPLs has been reported as more complex and intensified. Abid et al. (2014) showed that even during periods of economic growth, increased ER volatility can elevate the level of NPLs. Similarly, Ha et al. (2023) emphasize that unstable exchange rate policies exacerbate the adverse effects of ER shocks on the banking system.

Studies conducted in emerging markets indicate that foreign currency (FX) debt and import dependence heighten the sensitivity of credit risk to ER fluctuations, underscoring the necessity of incorporating bank-specific variables into empirical analyses (Katusiime, 2023).

Despite extensive evidence, empirical findings are not always consistent. Some studies in export-oriented economies have reported that ER depreciation can improve firms' repayment capacity through increased foreign currency revenues, thereby exerting no significant negative effect on NPLs (Galiana & Bouvatier, 2025).

This heterogeneity in results is primarily attributable to differences in methodology, study periods, countries' economic structures, and the neglect of bank-specific (intra-bank) variables. A considerable portion of prior research has employed static models, which are incapable of capturing dynamic interactions and long-run equilibrium relationships. These limitations underscore the necessity of adopting dynamic multivariate approaches, such as Panel Vector Autoregression (Panel-VAR) (Galiana & Bouvatier, 2025).

2.3 Bank-Specific Determinants of Non-Performing Loans

Beyond macroeconomic variables such as Exchange Rate (ER) fluctuations, contemporary banking literature increasingly emphasizes the role of bank-specific characteristics and internal policies in explaining Non-Performing Loans (NPL) dynamics. This perspective, grounded in credit risk management theory and microprudential regulatory frameworks, conceptualizes banks as active agents capable of mitigating or amplifying their vulnerability to macroeconomic shocks—including ER shocks—through their capital structure, liquidity management, and management quality (Beck et al., 2015). In this study, three key bank-specific variables—namely, the Capital Adequacy Ratio (CAR), Liquidity Quality (LQ), and Management Quality (MQ)—are incorporated as primary control factors.

The Capital Adequacy Ratio (CAR) is one of the most fundamental indicators of a bank's financial health, reflecting its capacity to absorb unexpected losses and sustain operations during adverse

economic conditions. Theoretically, a higher CAR mitigates moral hazard and constrains managerial risk-taking behavior, thereby improving the quality of the loan portfolio and ultimately reducing NPLs (*Managing Risks in Commercial and Retail Banking*, 2012).

Substantial empirical evidence confirms this negative relationship between CAR and NPLs (Beck et al., 2015). Studies utilizing global samples demonstrate that banks with higher capital buffers experience a more muted increase in NPLs when exposed to macroeconomic shocks, including ER fluctuations. Similarly, Abid et al. (2014), in a study focusing on banks in emerging economies, conclude that adequate capital serves as a buffer against the deterioration of asset quality.

In the context of the Iranian economy, where banks simultaneously face regulatory constraints, international financial sanctions, and severe ER volatility, the CAR is expected to play a more decisive role in mitigating the adverse effects of ER shocks on NPLs. Accordingly, it is hypothesized that an increase in the CAR is associated with a reduction in NPLs.

Liquidity constitutes another fundamental component of banking stability, referring to a bank's ability to meet short-term obligations and effectively manage funding inflows and outflows. Theoretically, banks with weak liquidity positions, when confronted with external shocks, may resort to riskier lending practices or the evergreening of problem loans, which can ultimately precipitate an increase in NPLs (Ari et al., 2021).

Empirical studies also indicate that higher Liquidity Quality (LQ) is associated with reduced credit risk and improved asset quality. Katusiime (2021) demonstrates that banks with more favorable liquidity ratios experience a smaller increase in Non-Performing Loans (NPLs) during periods of economic instability. Similarly, Demirgüç-Kunt et al. (2021) emphasize that liquidity pressures stemming from crises—particularly in emerging economies where access to interbank markets and external funding sources is constrained—can lead to an increase in NPLs by undermining banks' lending capacity.

In the context of the Iranian economy, Exchange Rate (ER) fluctuations can weaken banks' liquidity positions by exerting pressure on deposits and altering depositor behavior. Consequently, higher LQ is expected to play a moderating role in the relationship between ER shocks and NPLs, thereby contributing to a reduction in NPL accumulation.

Management Quality (MQ), as a multidimensional construct, reflects the capacity of bank managers to assess credit risk, monitor loan portfolios, enforce underwriting standards, and respond adaptively to changes in the macroeconomic environment. In theoretical literature, poor management is associated with adverse selection and inadequate monitoring, which ultimately culminate in the accumulation of NPLs (*Managing Risks in Commercial and Retail Banking*, 2012).

Empirical evidence substantiates this perspective. Beck et al. (2015) demonstrate that banks exhibiting weak managerial performance indicators experience higher levels of Non-Performing Loans (NPLs), even under identical macroeconomic conditions. Similarly, Ozili (2020), in a comparative analysis of systemic and non-systemic European banks, shows that managerial

inefficiency—proxied by the cost-to-income ratio—is one of the most significant factors differentiating NPL levels across institutions.

Management Quality (MQ) can also shape the transmission mechanism of Exchange Rate (ER) shocks to bank balance sheets. More efficient managers are better positioned to mitigate the adverse effects of currency fluctuations through risk hedging policies, currency diversification, and credit portfolio rebalancing. In this study, MQ is incorporated as a key control variable, and it is expected to exhibit a negative relationship with NPLs.

2.4. Methodological Review of Previous Studies

A substantial portion of prior research on the determinants of NPLs has relied on static panel models, such as Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE). While these models are useful for identifying contemporaneous relationships and cross-sectional associations, they suffer from two fundamental limitations. First, they neglect temporal dynamics: NPLs are inherently a dynamic process that exhibits significant dependence on their own lagged values and the lags of explanatory variables (Ari et al., 2021). Second, they inadequately address the endogeneity problem: in financial systems, the causal relationship between macroeconomic variables (such as the ER) and banking indicators (such as NPLs) is predominantly bidirectional and feedback-driven, a feature that single-equation models cannot capture (Jordà et al., 2016).

In response to these limitations, more recent studies have shifted toward dynamic modeling approaches, such as System Generalized Method of Moments (System GMM; Arellano-Bond/Blundell-Bond) and Vector Autoregression (VAR) frameworks. However, GMM also presents specific constraints. First, it requires an explicitly defined dependent variable and does not permit the simultaneous examination of reciprocal relationships among all variables in the system. Second, in panel datasets where the time dimension (T) is small relative to the cross-sectional dimension (N), the problem of instrument proliferation can lead to estimation bias.

Vector Autoregression (VAR) models allow all variables to be modeled as endogenous, enabling the simultaneous examination of reciprocal and feedback relationships among them. Within the VAR framework, a system of kkk simultaneous equations is estimated as follows:

$$Yit = A1Yi, t - 1 + A2Yi, t - 2 + \cdots + ApYi, t - p + ui + \varepsilon it$$

where Yit is a 1×k vector of endogenous variables, including non-performing loans (NPLs), the exchange rate, and banking indicators; Aj represents the coefficient matrices; ui denotes the individual fixed effects; and εit refers to the disturbance terms.

This structural feature renders VAR a highly suitable tool for analyzing complex economic systems, particularly the dynamic interactions between macroeconomic variables and banking indicators (Canova & Ciccarelli, 2013). In the context of NPLs, the VAR approach permits the evaluation of macroeconomic shocks—such as ER fluctuations—on banking variables without imposing a predetermined causal structure.

However, traditional VAR models primarily rely on time-series data from a single country or institution, thereby neglecting cross-sectional heterogeneity across units. This limitation paved the way for the development of Panel-VAR models.

The Panel Vector Autoregression (Panel-VAR) model, theoretically grounded in the foundational work of Holtz-Eakin et al. (1988) and subsequently extended for financial analyses by Love and Zicchino (2006), integrates the strengths of panel data with the VAR architecture. This synthesis provides a flexible and robust framework for analyzing both common and heterogeneous dynamics across banks.

These objectives are strategically designed to facilitate the formulation of practical policy recommendations for banking regulatory authorities and monetary policymakers (Akins et al., 2016).

Drawing on the theoretical framework of credit risk and the balance sheet channel of exchange rate shock transmission (Bernanke & Gertler, 1995), the testable hypotheses of this study are formulated as follows:

Table 1. Testable Hypotheses

Code	Hypothesis	Theoretical Basis
H_1	Exchange rate fluctuations exert a positive and significant impact on bank non-performing loans (NPLs).	Balance sheet channel; rising costs for import-dependent firms and diminished repayment capacity (Mishkin, 1997)
H_2	The capital adequacy ratio (CAR) exerts a negative and significant impact on NPLs.	Capital buffer theory; well-capitalized banks possess a greater loss-absorption capacity (Shrieves & Dahl, 1992)
H_3	Liquidity quality (LQ) exerts a negative and significant impact on NPLs.	Liquidity theory; enhanced flexibility in crisis management (Diamond & Dybvig, 2000)
H_4	Management quality (MQ) exerts a negative and significant impact on NPLs.	Bad management hypothesis; managerial inefficiency leads to an increase in NPLs (Berger & DeYoung, 1997)

These hypotheses will be empirically tested utilizing the estimated coefficients derived from the Panel-VAR model alongside standard statistical significance tests.

The present study offers distinct scientific contributions and methodological innovations across several dimensions, setting it apart from prior literature:

First, Empirical Contribution: This study represents the first comprehensive investigation to examine the relationship between Exchange Rate (ER) fluctuations and Non-Performing Loans (NPLs) within a dynamic multivariate framework, utilizing panel data from Iranian banks. In contrast to previous studies that have predominantly relied on static methodologies (Makri et al., 2014), this research enables the rigorous analysis of endogenous relationships and temporal dynamics.

Second, Methodological Contribution: The application of the Panel Vector Autoregression (Panel-VAR) approach, coupled with the Johansen cointegration test, facilitates the simultaneous examination of both short-run and long-run relationships among the variables. This methodology

offers substantial advantages over static panel models and even dynamic Generalized Method of Moments (GMM) estimators when analyzing complex multivariate systems (Canova & Ciccarelli, 2013).

Third, Theoretical Contribution: By integrating macroeconomic variables (ER fluctuations) and bank-specific factors (CAR, LQ, and MQ) into a unified framework, this study provides a more comprehensive understanding of the mechanisms driving NPLs. This integrated approach effectively addresses longstanding criticisms directed at prior one-dimensional studies (Messai & Jouini, 2013).

Fourth, Practical Contribution: The findings of this research can serve as actionable guidance for central bank policymakers in formulating prudential regulations, for senior bank executives in optimizing capital and liquidity structures, and for regulatory authorities in designing robust early warning systems (Cucinelli, 2015).

The remainder of this article is organized as follows: Section 2 reviews the literature and theoretical framework, examining key domestic and international studies on the determinants of Non-Performing Loans (NPLs). Section 3 outlines the research methodology, including data description, variable definitions, and a detailed exposition of the Panel Vector Autoregression (Panel-VAR) econometric model. Section 4 reports the empirical results, comprising descriptive statistics, diagnostic tests, cointegration findings, and model coefficient estimates. Section 5 discusses and interprets the results in light of theoretical foundations and prior literature. Finally, Section 6 presents conclusions, policy recommendations, research limitations, and directions for future studies.

2.5 Research Gap and Positioning of the Present Study

A systematic review of the literature, as presented in the preceding sections, reveals five fundamental gaps in existing research:

First Gap: Insufficient Differentiation between Macro and Micro Dimensions. Many studies have focused exclusively on macroeconomic variables—as seen in predominantly macro-level analyses (Jordà et al., 2016)—or have examined bank-specific factors without accounting for their interaction with macroeconomic shocks. The simultaneous integration of these two dimensions within a unified framework, particularly for the Iranian economy, remains highly limited.

Second Gap: Methodological Limitations of Domestic Studies. A substantial portion of Iranian domestic research has employed static models or single-equation regressions, which are incapable of capturing endogeneity and dynamic feedback mechanisms. The application of Panel Vector Autoregression (Panel-VAR) to investigate the determinants of Non-Performing Loans (NPLs) in Iranian banks represents a significant methodological innovation.

Third Gap: Lack of Consensus on the Exchange Rate–NPL Relationship. As demonstrated in Section 2.2, empirical findings regarding the direction and magnitude of the Exchange Rate (ER) effect on NPLs are inconsistent. Part of this discrepancy stems from the omission of bank-specific control variables, which can moderate the observed relationship.

Fourth Gap: Neglect of Iran's Sanctions Context. Iran, as an economy characterized by structural exchange rate volatility induced by international sanctions, possesses unique features not adequately addressed in existing international studies. The ER–NPL relationship under sanctions conditions may deviate from conventional patterns observed in other emerging economies (International Monetary Fund, 2025).

Fifth Gap: Failure to Distinguish between Static and Dynamic Analyses. Prior studies have predominantly presented long-run analyses (equilibrium coefficients and cointegration) and short-run analyses (Impulse Response Functions [IRF] and Variance Decomposition [VDC]) within a single article, leading to ambiguity in result interpretation. Explicitly separating these two dimensions enhances analytical clarity.The present study, through careful design, endeavors to address all five aforementioned gaps:

Table 2. Identified Research Gaps and Corresponding Addressing Strategies

Identified Research Gap	Addressing Strategy in the Present Study
Insufficient differentiation between macro/micro dimensions	Simultaneous integration of ER (macro) with CAR, LQ, and MQ (micro) within a unified Panel-VAR system
Methodological limitations of prior domestic studies	Adoption of Panel-VAR instead of static single-equation models
Lack of consensus on the ER–NPL relationship	Incorporation of bank-specific controls to isolate the net effect of ER → NPL
Neglect of Iran's sanctions context	Focused analysis on Iranian banks over the period 2006–2022
Failure to distinguish static/dynamic analyses	This article focuses exclusively on long-run relationships and equilibrium coefficients

Accordingly, by integrating an empirical contribution (Iranian banking data), a methodological contribution (Panel-VAR framework), a theoretical contribution (macro-micro integration), and a policy-oriented contribution (actionable recommendations for the Central Bank and banking regulators), the present study establishes a distinct and value-added position within the existing literature.

3. Methodology

3.1. Data Description

This study utilizes panel data from 18 active commercial banks in Iran over the period 2011–2023. The sample selection was based on the following criteria:

- **Continuous Operation:** Banks that remained operational throughout the entire study period and published audited financial statements annually.
- **Data Accessibility:** Banks whose financial information is publicly available and extractable from official databases, namely CODAL (Comprehensive Database of All Listed Companies) and the Central Bank of Iran (CBI).
- **Operational Homogeneity:** Focus on commercial banks, with the exclusion of non-bank credit institutions, to ensure sample homogeneity and comparability.

The final sample comprises 8 state-owned or quasi-state banks and 10 private banks, collectively accounting for over 92 percent of total assets in the Iranian banking system. This extensive coverage enhances the generalizability of the findings to the broader banking sector (Ozili, 2025). The 13-year study period (2011–2023) was selected based on several methodological and contextual considerations:

- **Coverage of Diverse Exchange Rate Cycles:** The period encompasses multiple distinct exchange rate (ER) shock episodes, including the 2012 depreciation (approximately 120% increase), the 2018 currency crisis (approximately 200% increase), and the volatility associated with renewed sanctions in 2022–2023. This variation provides sufficient exogenous variation to identify the dynamic effects of ER fluctuations on Non-Performing Loans (NPLs).
- **Adequacy of Observations:** The panel structure yields a total of 234 bank-year observations (N=18N = 18N=18, T=13T = 13T=13), which is sufficient for the consistent estimation of Panel Vector Autoregression (Panel-VAR) models with multiple endogenous variables (Canova & Ciccarelli, 2013).
- **Relative Stability of the Regulatory Framework:** Following the implementation of revised loan classification standards by the Central Bank of Iran in 2010, the reporting methodology for NPLs has maintained relative consistency, thereby enhancing the comparability of data across time and institutions.
  - The data for this study were extracted from the following official sources:

Table3. Data Sources and Variable Construction

Variable Type	Source	Description / Construction Method
Non-Performing Loans Ratio (NPL)	Audited bank financial statements (CODAL)	Ratio of overdue and doubtful loans to total granted facilities

Variable Type	Source	Description / Construction Method
Official Exchange Rate (ER)	Central Bank of Iran (CBI) – USD time series	Annual average of market exchange rate (USD/IRR)
Capital Adequacy Ratio (CAR)	CBI regulatory reports	Ratio of regulatory capital to Risk-Weighted Assets (RWA)
Liquidity Quality (LQ) & Management Quality (MQ)	Detailed financial statements	Calculated based on standard banking formulas (see Section 3.2)

The utilization of official, audited sources enhances data credibility and minimizes potential reporting bias (Ferreira, 2022).

Dependent Variable: Non-Performing Loans Ratio (NPL)

$$NPL_{it} = \frac{\text{Overdue Claims}_{it} + \text{Doubtful Claims}_{it}}{\text{Total Loans Granted}_{it}} \times 100$$

This definition aligns with the standards of the Central Bank of Iran and the official asset classification guidelines. Overdue claims refer to facilities with installment payment delays of 2 to 6 months, while doubtful claims encompass facilities delayed for more than 6 months or those backed by insufficient collateral (Im, Pesaran, & Shin, 2003).

Key Independent Variable: Exchange Rate Fluctuations (ER)

$$ER_t = \ln(E_t) - \ln(E_{t-1}) = \ln(\frac{E_t}{E_{t-1}})$$

where Et denotes the nominal USD/IRR exchange rate at the end of year t. This indicator offers several methodological advantages:

- **Scale Invariance:** Captures percentage changes independently of the absolute exchange rate level.
- **Symmetry:** Measures appreciations and depreciations in a symmetric manner.
- **Favorable Statistical Properties:** Exhibits a distribution closer to normality compared to absolute changes (Sardana, 2024).

Bank-Specific Control Variables a) Capital Adequacy Ratio (CAR):

$$CAR_{it} = \frac{\text{Regulatory Capital}_{it}}{\text{Risk-Weighted Assets}_{it}} \times 100$$

This ratio reflects a bank's capacity to absorb unexpected losses. Under Basel III requirements, the minimum CAR is established at 8 percent, whereas the Central Bank of Iran mandates a higher minimum threshold of 12 percent (Badev et al., 2025).

b) Liquidity Quality Ratio (LQ):

$$LQ_{it} = \frac{\text{Total Deposits}_{it}}{\text{Liquid and Near-Liquid Assets}_{it}} \times 100$$

This metric assesses a bank's ability to meet deposit withdrawal demands and prevent the forced liquidation of assets. Institutions with higher liquidity levels demonstrate greater operational flexibility during periods of financial stress (Ozili, 2025).

3.2. Operational Definition of Variables

Dependent Variable: Non-Performing Loans Ratio (NPL)

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Key Independent Variable: Exchange Rate Fluctuations (ER) To measure exchange rate fluctuations, the logarithmic growth rate is employed:

$$ER_t = \ln(E_t) - \ln(E_{t-1}) = \ln(\frac{E_t}{E_{t-1}})$$

where EtE_tEt denotes the nominal USD/IRR exchange rate at the end of year ttt. This indicator offers several methodological advantages:

- **Scale Invariance:** Captures percentage changes independently of the absolute exchange rate level.
- **Symmetry:** Measures appreciations and depreciations in a symmetric manner.
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b) Liquidity Quality Ratio (LQ):

$$LQ_{it} = \frac{\text{Total Deposits}_{it}}{\text{Liquid and Near} - \text{Liquid Assets}_{it}} \times 100$$

This metric assesses a bank's ability to meet deposit withdrawal demands and prevent the forced liquidation of assets. Institutions with higher liquidity levels demonstrate greater operational flexibility during periods of financial stress (Ozili, 2025).

c) Management Quality (MQ):

$$MQ_{it} = \frac{\text{Operating Income}_{it}}{\text{Operating Expenses}_{it}} \times 100$$

Also referred to as the cost-to-income ratio, this indicator evaluates management efficiency in controlling operational expenses relative to revenue generation. A lower value denotes superior management quality (Louzis, Vouldis, & Metaxas, 2012).

Descriptive Statistics Summary

Table 4. Descriptive Statistics of Research Variables

Variable	Mean	Std. Dev.	Min	Max	Observations
NPL (%)	11.24	8.67	1.12	42.38	234
ER (log growth)	0.29	0.38	-0.02	1.12	234
CAR (%)	9.87	4.52	2.14	24.31	234
LQ (%)	18.43	9.21	4.67	48.92	234
MQ (%)	64.28	18.73	31.45	112.67	234

Table4 presents the descriptive statistics for the research variables across 234 observations. The results indicate that the mean values for NPL, ER, CAR, LQ, and MQ are 11.24, 0.29, 9.87, 18.43, and 64.28, respectively. The dispersion of these variables is reflected in their standard deviations of 8.67, 0.38, 4.52, 9.21, and 18.73. Furthermore, the range of variation for each variable, from minimum to maximum, is reported in the table.

3.3. Model Specification

Panel Vector Autoregression (Panel-VAR) Framework

To examine the dynamic relationships among the variables, the Panel Vector Autoregression (Panel-VAR) model is employed. This approach integrates the advantages of Vector Autoregression (VAR) models—namely, the treatment of endogeneity and reciprocal relationships—with the benefits of panel data techniques, which account for cross-sectional heterogeneity (Abrigo & Love, 2016).
The general form of the model is specified as follows:

$$Y_{it} = A_{\cdot} + \sum_{j=1}^{p} A_j Y_{i,t-j} + \mu_i + \varepsilon_{it}.$$

Where

- $\mathbf{Y}_{it}$: The vector of endogenous variables for bank i at time t
- $\mathbf{A}_{\cdot}$: Intercept vector (vector of constant terms)
- $\mathbf{A}_j$: Coefficient matrix for the j-th lag
- P : Optimal lag order (optimal number of lags)
- μ_i : Bank-specific fixed effects (unobserved heterogeneity)
- ε_{it} Error term (disturbance/innovation term), assuming $E(\epsilon it) = 0$ و $\mathbb{E}(\varepsilon_{it}\varepsilon_{is}^{'}) = \sum \; t = s$

Given the defined variables,

the five-variable Panel-VAR system is specified as follows:

$$\begin{bmatrix} NPL_{it} \\ ER_t \\ CAR_{it} \\ LQ_{it} \\ MQ_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \sum_{j=1}^{p} \begin{bmatrix} a_{11}^j & a_{12}^j & a_{13}^j & a_{14}^j & a_{15}^j \\ a_{21}^j & a_{22}^j & a_{23}^j & a_{24}^j & a_{25}^j \\ a_{31}^j & a_{32}^j & a_{33}^j & a_{34}^j & a_{35}^j \\ a_{41}^j & a_{42}^j & a_{43}^j & a_{44}^j & a_{45}^j \\ a_{51}^j & a_{52}^j & a_{53}^j & a_{54}^j & a_{55}^j \end{bmatrix} \begin{bmatrix} NPL_{i,t-j} \\ ER_{t-j} \\ CAR_{i,t-j} \\ LQ_{i,t-j} \\ MQ_{i,t-j} \end{bmatrix} + \begin{bmatrix} \mu_i^1 \\ \mu_i^2 \\ \mu_i^3 \\ \mu_i^4 \\ \mu_i^5 \end{bmatrix} + \begin{bmatrix} \varepsilon_{it}^1 \\ \varepsilon_{it}^2 \\ \varepsilon_{it}^3 \\ \varepsilon_{it}^4 \\ \varepsilon_{it}^5 \end{bmatrix}$$

Justification of Variable Endogeneity

The Panel-VAR approach rests on the assumption that all variables within the system are potentially endogenous. This assumption is justified for the present study on the following grounds:

- **Bidirectional NPL–ER Causality:** Rising NPLs can exert pressure on the exchange rate by undermining confidence in the banking system (reverse feedback effect).
- **NPL–CAR Interaction:** An increase in NPLs reduces profitability, thereby eroding capital buffers; conversely, weakened capital adequacy diminishes loss-absorption capacity, which may further elevate NPLs (Ghosh, 2015).
- **Liquidity–NPL Dynamics:** Banks experiencing high NPL levels are compelled to maintain larger liquidity buffers to mitigate deposit withdrawal risks (Ozili, 2025).
- **Management Efficiency and Loan Quality:** Inefficient management simultaneously drives up operational costs and leads to suboptimal credit allocation decisions (Louzis et al., 2012).

These complex interdependencies render single-equation models inappropriate and necessitate a systemic VAR approach (Sigmund & Ferstl, 2021).

3.4. Econometric Procedure

The estimation strategy of this study comprises four sequential stages, which are detailed below.

Panel Unit Root Tests

Prior to model estimation, the stationarity of all variables is examined. Non-stationarity can lead to spurious regression results. In this study, three panel unit root tests are employed.

Table 5. Panel Unit Root Test Results

Variable	LLC	IPS	ADF-Fisher	Conclusion
NPL (Level)	-2.847**	-1.923**	54.21**	Stationary I(0)
ER (Level)	-4.132***	-3.421***	71.34***	Stationary I(0)
CAR (Level)	-1.124	-0.876	28.43	Non-stationary
CAR (First Difference)	-5.621***	-4.892***	89.67***	Stationary I(1)
LQ (Level)	-2.341**	-1.876*	48.92**	Stationary I(0)
MQ (Level)	-1.987**	-1.654*	42.18**	Stationary I(0

The results indicate that most variables are stationary at levels, except for CAR, which achieves stationarity after first-differencing. This mixture of integration orders necessitates conducting a panel cointegration test to examine the existence of long-run equilibrium relationships among the variables.

Optimal Lag Length Selection

Selecting the appropriate lag length is critical for the proper performance of VAR models. An insufficient lag order may omit important dynamic information, whereas an excessive lag order reduces degrees of freedom and leads to estimation inefficiency. In this study, three information criteria are employed to determine the optimal lag length.

Table 6. Lag Order Selection Test Results

Lag	AIC	BIC	HQIC
1	-12.432	-11.876*	-12.198
2	-12.687*	-11.654	-12.287*
3	-12.543	-10.987	-11.923

Based on the results, the optimal lag order is selected as 2. Both the AIC and HQIC criteria suggest lag 2, whereas BIC, due to its stronger penalty for additional parameters, favors lag 1. Given the dynamic nature of the banking system and the necessity of capturing shock transmission lags, lag 2 is deemed more appropriate for the final Panel-VAR specification (Abrigo & Love, 2016).

Johansen Cointegration Test

Given the presence of variables with mixed orders of integration, it is essential to examine the existence of long-run equilibrium relationships (cointegration). In this study, the Johansen-Fisher panel cointegration test is employed.
The Johansen test is based on the eigenvalue decomposition of the matrix Π\PiΠ in the Vector Error Correction Model (VECM):

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Y_{t-j} + \varepsilon_t$$

Where Π=αβ and β denotes the cointegrating vectors and α represents the adjustment coefficients.
Two Test Statistics:

Trace Statistic:

$$\lambda_{\text{trace}}(r) = -T \sum_{i=r+1}^{k} \ln(1 - \hat{\lambda}_i)$$

Maximum Eigenvalue Statistic (Max-Eigen):

$$\lambda_{max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1})$$

Table 7. Johansen Panel Cointegration Test Results

Null Hypothesis	Trace Statistic	5% Critical Value	Max-Eigen Statistic	5% Critical Value
r=0	142.87***	69.82	68.43***	33.87
r≤1	74.44***	47.86	38.21***	27.58
r≤2	36.23**	29.80	21.67**	21.13
r≤3	14.56	15.49	9.87	14.26
r≤4	4.69	3.84	4.69	

The results indicate that both test statistics confirm the existence of at least three cointegrating vectors. This finding implies the presence of long-run equilibrium relationships among the system variables, thereby justifying the application of VAR/VECM frameworks (Maddala & Wu, 1999).

Estimation Strategy: Generalized Method of Moments (GMM)

To estimate the Panel-VAR model with fixed effects, the System-GMM approach is employed, following Arellano and Bover (1995) and Blundell and Bond (1998).
Main Challenge: In dynamic panel models, the lagged dependent variable is correlated with the fixed effects (μi\mu_iμi), which leads to Nickell bias (Beggs & Nerlove, 1988).
Solution: Fixed effects are eliminated through first-differencing, and internal instruments are utilized:

$$\Delta Y_{it} = \sum_{j=1}^{p} A_j \Delta Y_{i,t-j} + \Delta\varepsilon_{it}$$

The instrumental variables consist of second and higher-order lags of the variables in levels.

Panel Granger Causality Test

To investigate the direction of causality among the variables, the Granger causality test is conducted within the Panel-VAR framework. The null hypothesis of this test states that variable X does not Granger-cause variable Y:

$$H_0: a_{12}^{(1)} = a_{12}^{(2)} = \cdots = a_{12}^{(p)} = 0$$

Wald Test Statistic:

$$W = nT(\hat{\beta}_R - \hat{\beta}_U)'[\text{Var}(\hat{\beta}_R - \hat{\beta}_U)]^{-1}(\hat{\beta}_R - \hat{\beta}_U) \sim \chi^2(p)$$

Table 8. Panel Granger Causality Test Results

Causality Direction (From → To)	Wald Statistic	Degrees of Freedom	ppp-value	Conclusion
ER → NPL	12.87***	2	0.002	Causality confirmed
CAR → NPL	8.43***	2	0.015	Causality confirmed
LQ → NPL	6.21**	2	0.045	Causality confirmed
MQ → NPL	7.89***	2	0.019	Causality confirmed
NPL → ER	2.14	2	0.343	Causality rejected
NPL → CAR	5.67**	2	0.059	Weak evidence of causality

The results indicate that exchange rate fluctuations and bank-specific variables (CAR, LQ, and MQ) Granger-cause NPLs, whereas reverse causality from NPLs to ER is not supported. This finding aligns with empirical evidence suggesting that the transmission of exchange rate shocks to asset quality is predominantly unidirectional (Almanaseer, 2023).

3.5. Software and Robustness Considerations

The econometric analyses in this study were conducted using the following software packages:

- **Stata 17:** For estimating the Panel-VAR model using the pvar package developed by Abrigo and Love (2016).
- **EViews 13:** For performing panel unit root tests and Johansen panel cointegration analysis.
- **Microsoft Excel:** For preliminary data processing and structuring.

Robustness Checks

To ensure the stability and reliability of the results, the following sensitivity analyses were performed:

a) **Alternative Lag Lengths:** The model was re-estimated using lag orders of 1 and 3. The qualitative findings remained consistent with the baseline specification (lag = 2), confirming that the results are not driven by arbitrary lag selection.

b) **Subsample Analysis:** Separate estimations were conducted for state-owned and private banks. Although the magnitude of coefficients varied across subsamples, the direction and statistical

significance of the key relationships remained unchanged, supporting the robustness of the main findings.

c) **Time Fixed Effects Control:** In addition to bank-specific fixed effects, time fixed effects were incorporated into the model to account for common macroeconomic shocks. The inclusion of time dummies did not alter the core results, indicating that the estimated relationships are not confounded by aggregate time trends.

d) **Alternative Exchange Rate Volatility Measure:** As a robustness check, the three-year rolling standard deviation of the exchange rate was substituted for the logarithmic growth rate as an alternative proxy for ER volatility. The coefficient on this alternative measure remained positive and statistically significant, reinforcing the baseline conclusion that exchange rate fluctuations exert a positive effect on NPLs.
Academic integrity requires acknowledging the following limitations:

Data Limitation: Due to the unavailability of consistent quarterly data, annual observations were employed, which entail a lower frequency and may limit the detection of short-term dynamics.

Endogeneity of the Exchange Rate: In Iran, the exchange rate is influenced by non-economic policy factors, notably international sanctions, the comprehensive modeling of which poses significant challenges.

Structural Heterogeneity: Structural differences between state-owned and private banks may not be fully captured by bank-specific fixed effects alone, potentially leaving residual heterogeneity unaddressed.

Exclusion of Macroeconomic Controls: Key macroeconomic variables such as GDP growth and inflation were not incorporated into the model, given the study's primary focus on bank-specific determinants.

These limitations have been carefully considered in the interpretation of the results, and directions for future research are proposed in the concluding section.

4. Empirical Results

Table 9 presents the descriptive statistics for the research variables across 18 Iranian commercial banks over the period 2011–2023. The statistics include measures of central tendency, dispersion, and distributional shape.

Table 9: Descriptive Statistics of Research Variables

Variable	Mean	Median	Std. Dev.	Skewness	Kurtosis	Min	Max
NPL (%)	11.24	9.87	8.67	1.43	4.21	1.12	42.38
ER (log growth)	0.29	0.18	0.38	1.87	5.34	-0.02	1.12
CAR (%)	9.87	8.92	4.52	0.89	3.12	2.14	24.31
LQ (%)	18.43	16.21	9.21	0.76	2.87	4.67	48.92
MQ (%)	64.28	61.34	18.73	0.54	2.94	31.45	112.67

Notable Observations from Descriptive Statistics

Non-Performing Loans Ratio (NPL): The mean value of 11.24 percent indicates a relatively elevated level of NPLs in the Iranian banking system, exceeding the global average (approximately 4–5 percent). The high standard deviation (8.67) reflects substantial heterogeneity across banks. Positive skewness (1.43) suggests a right-tailed distribution, implying that a subset of banks experiences significantly higher NPL ratios.

Exchange Rate Fluctuations (ER): The mean logarithmic growth rate of 0.29 corresponds to an approximate annual exchange rate depreciation of 34 percent. The high standard deviation (0.38) and pronounced positive skewness (1.87) reflect the occurrence of severe exchange rate shocks in certain years, notably during the 2012 and 2018 episodes.

Capital Adequacy Ratio (CAR): The average CAR of 9.87 percent falls below the Central Bank of Iran's regulatory minimum requirement of 12 percent, indicating capital adequacy challenges for a substantial segment of the banking sector.

4.2. Diagnostic Tests

Prior to model estimation, diagnostic tests were conducted to verify the validity of underlying statistical assumptions.

Normality Test

Table 10: Jarque-Bera Normality Test Results

Variable	JB Statistic	p-value	Conclusion
NPL	87.43	0.000	Normality rejected
ER	156.21	0.000	Normality rejected
CAR	28.67	0.000	Normality rejected

Variable	JB Statistic	p-value	Conclusion
LQ	19.34	0.000	Normality rejected
MQ	11.23	0.004	Normality rejected

Although the null hypothesis of normality is rejected for all variables, this deviation is not problematic in large samples (n>200n > 200n>200) under the Central Limit Theorem. Consequently, the System-GMM estimators remain consistent and asymptotically valid (Arellano & Bover, 1995).

Autocorrelation Test

Table 11. Autocorrelation Test Results

Test	Statistic	p-value	Conclusion
Wooldridge AR(1)	2.34	0.089	Failure to reject
Arellano-Bond AR(1)	-3.87	0.000	Rejection
Arellano-Bond AR(2)	-1.24	0.215	Failure to reject

The results indicate the presence of first-order autocorrelation in the first-differenced residuals, which is expected in dynamic panel models. However, second-order autocorrelation is not detected, confirming the validity of the instrumental variables employed in the System-GMM estimation.

Heteroskedasticity Test

Table 12. Heteroskedasticity Test Results

Test	Statistic	Degrees of Freedom	p-value	Conclusion
Modified Wald	287.43	18	0.000	Heteroskedasticity present
Breusch-Pagan	43.21	5	0.000	Heteroskedasticity present

Given the presence of heteroskedasticity, robust standard errors are employed in the final estimation. These standard errors are consistent in the presence of both heteroskedasticity and within-group correlation, ensuring the reliability of statistical inference.

4.3. Panel Unit Root Test Results

Table 13. Panel Unit Root Test Results

Variable	Level/Difference	LLC	IPS	ADF-Fisher	PP-Fisher	Conclusion
NPL	Level	-2.847**	-1.923**	54.21**	52.87**	I(0)
ER	Level	-4.132***	-3.421***	71.34***	69.43***	I(0)

Variable	Level/Difference	LLC	IPS	ADF-Fisher	PP-Fisher	Conclusion
CAR	Level	-1.124	-0.876	28.43	27.91	Non-stationary
CAR	First Difference	-5.621***	-4.892***	89.67***	91.23***	I(1)
LQ	Level	-2.341**	-1.876*	48.92**	47.34**	I(0)
MQ	Level	-1.987**	-1.654*	42.18**	40.87**	I(0)

The results indicate that NPL, ER, LQ, and MQ are stationary at levels, whereas CAR achieves stationarity only after first-differencing. This mixture of I(0)I(0)I(0) and I(1)I(1)I(1) variables suggests the potential presence of cointegrating relationships, thereby necessitating the Johansen panel cointegration test.

4.4. Cointegration Results

Johansen Panel Cointegration Test

Table 14. Johansen-Fisher Panel Cointegration Test Results

Null Hypothesis	Trace Statistic	5% Critical Value	Max-Eigen Statistic	5% Critical Value
r=0r = 0r=0	142.87***	69.82	68.43***	33.87
r≤1	74.44***	47.86	38.21***	27.58
r≤2	36.23**	29.80	21.67**	21.13
r≤3	14.56	15.49	9.87	14.26
r≤4	4.69	3.84	4.69	

Both the Trace and Max-Eigen statistics confirm the existence of three cointegrating vectors at the 5 percent significance level. This finding indicates the presence of three long-run equilibrium relationships among the variables in the system.

Normalized Long-Run Relationships

Table 15. First Cointegrating Vector (NPL Normalized)

Variable	Normalized Coefficient	Std. Error	ttt-Statistic
NPL	1.000	—	—
ER	0.342***	0.087	3.931
CAR	-0.287***	0.064	-4.484
LQ	-0.198***	0.052	-3.808
MQ	-0.156***	0.048	-3.250
Constant	-2.143	—	—

The normalized long-run relationship can be expressed as follows:

$$NPL = 2.143 + 0.342 \cdot ER - 0.278 \cdot CAR - 0.198 \cdot LQ - 0.156 \cdot MQ$$

This equation indicates that, in the long run, a one-unit increase in exchange rate volatility leads to a 0.34 percentage-point increase in the NPL ratio, while improvements in bank-specific indicators (CAR, LQ, and MQ) exert a mitigating effect on NPLs.

4.5. Panel-VAR Estimation Coefficients

Table 16. Panel-VAR Estimation Results (NPL Equation)

Variable	Coefficient	Robust Std. Error	Z-Statistic	P-value
NPL_{t-1}	0.624***	0.078	8.000	0.000
NPL_{t-2}	0.187**	0.065	2.877	0.004
ER_{t-1}	0.283***	0.072	3.931	0.000
ER_{t-2}	0.098*	0.054	1.815	0.070
CAR_{t-1}	-0.234***	0.058	-4.034	0.000
CAR_{t-2}	-0.087*	0.049	-1.776	0.076
LQ_{t-1}	-0.189***	0.047	-4.021	0.000
LQ_{t-2}	-0.062	0.041	-1.512	0.131
MQ_{t-1}	-0.163***	0.044	-3.705	0.000
MQ_{t-2}	-0.054	0.038	-1.421	

Table 17. Model Diagnostic Tests

Test	Statistic	ppp-value	Conclusion
Hansen JJJ (Over-identification)	18.43	0.362	Instruments are valid
AR(2)	-1.24	0.215	No second-order autocorrelation
Wald (Overall Model)	287.65	0.000	Model is statistically significant

Exchange Rate Fluctuations: The positive and highly significant coefficient ($p<0.01p < 0.01p<0.01$) indicates that a one-standard-deviation increase in exchange rate volatility leads to a 0.28-standard-deviation increase in the NPL ratio with a one-period lag. This finding is consistent with the balance sheet channel: currency depreciation increases the foreign-currency debt burden of borrowers and weakens their repayment capacity.

Capital Adequacy: The significant negative coefficient confirms that banks with stronger capital buffers exhibit lower NPL levels. On average, a one percentage-point increase in CAR is associated

with a 0.23 percentage-point reduction in NPLs. This result supports the moral hazard hypothesis: higher capital adequacy reduces incentives for excessive risk-taking.

Liquidity Quality: The significant negative relationship indicates that banks with higher liquidity levels possess greater capacity to manage financial distress and avoid forced asset liquidation, thereby contributing to the preservation of portfolio quality.

Management Quality: The significant negative coefficient (noting the inverse definition of MQ as a cost-to-income ratio) implies that banks with more efficient management (lower MQ values) do not exhibit higher NPLs. Correctly interpreted: improvements in managerial efficiency are associated with reductions in non-performing loans.

Persistence of NPLs: The substantial coefficient on NPL indicates strong persistence in non-performing loans. This finding suggests that elevated NPL levels tend to be self-reinforcing and that their correction is a time-intensive process.

Table 18. Results of Research Hypothesis Testing

Hypothesis	Statement	Expected Sign	Estimated Coefficient	ppp-value	Conclusion
H_1	Exchange rate fluctuations have a positive effect on NPL	+	+0.283***	0.000	Supported
H_2	Capital adequacy has a negative effect on NPL	–	-0.234***	0.000	Supported
H_3	Liquidity quality has a negative effect on NPL	–	-0.189***	0.000	Supported
H_4	Management quality has a negative effect on NPL	–	-0.163***		

All four research hypotheses are supported at the 1 percent significance level. The results indicate that:

Exchange rate shocks constitute a serious threat to the asset quality of Iranian banks, and this vulnerability is amplified in a sanctions-constrained environment.

Bank-specific factors play a protective role. Institutions with stronger capital positions, superior liquidity management, and higher operational efficiency demonstrate greater resilience against exchange rate shocks.

Relative effect sizes: Exchange rate volatility exhibits the largest impact (β=0.28\beta = 0.28β=0.28), followed by capital adequacy (β=0.23\beta = 0.23β=0.23), liquidity quality (β=0.19\beta = 0.19β=0.19), and management quality (β=0.16\beta = 0.16β=0.16).

The confirmed cointegration relationships suggest that these associations are not merely short-term phenomena but reflect stable long-run equilibrium dynamics.

5. Conclusion

The findings of this study regarding the positive and significant effect of exchange rate volatility on non-performing loans extend beyond a mere statistical association and are deeply rooted in the structural characteristics of the Iranian economy. Unlike developed economies, where the exchange rate channel primarily operates through export and import dynamics, in Iran, this channel is directly linked to production costs and borrowers' debt repayment capacity.

The transmission mechanism can be delineated in three stages: First, depreciation of the national currency increases the cost of importing raw materials and intermediate goods. Second, under conditions of sluggish domestic demand, these elevated costs cannot be fully passed through to final product prices, thereby compressing corporate profit margins. Third, the resulting decline in profitability weakens firms' capacity to service loan installments, ultimately leading to default.

Notably, the magnitude of the estimated coefficient is relatively higher than those reported in studies of other emerging economies. This discrepancy can be attributed to the exacerbating effect of international sanctions. Under normal market conditions, firms could mitigate exposure through foreign exchange hedging instruments; however, financial sanctions have severely restricted access to such risk-management tools (Ghasseminejad & Jahan-Parvar, 2021). Furthermore, limited access to international capital markets has diminished the financial flexibility of domestic firms in absorbing exchange rate shocks.

The high persistence of NPLs further corroborates this analysis. This persistence indicates that exchange rate shocks exert cumulative and long-lasting effects on banks' asset quality, and their reversal requires a substantial adjustment period. In other words, even following exchange rate stabilization, the adverse impacts of past currency shocks continue to linger on banks' balance sheets for several years.

The significant negative effect of capital adequacy on NPLs can be theoretically explained from two perspectives. On the one hand, the Moral Hazard Hypothesis predicts that undercapitalized banks have stronger incentives to assume excessive risks, as the majority of potential losses are shifted to depositors and deposit guarantee funds (Keeley, 1990). On the other hand, the Signaling Hypothesis suggests that well-capitalized banks possess greater capacity to attract specialized personnel and implement advanced risk management systems.

In the Iranian context, a more precise interpretation can be offered. Given that the sample average CAR falls below the regulatory minimum, banks with higher capital are likely subject to stricter financial discipline, which is also reflected in their credit assessment and loan collection processes.

Regarding liquidity, the transmission mechanism operates differently. Banks with higher liquidity exhibit greater flexibility in restructuring debt when clients face financial distress. These institutions can grant repayment extensions without resorting to forced asset sales or cutting off

credit lines. Conversely, liquidity-constrained banks are compelled to classify loans as non-performing more rapidly.

Importantly, the significance of liquidity increases under conditions of sanctions and macroeconomic instability. Acharya and Mora (2015) demonstrate that during crises, banks face deposit runs, and those lacking sufficient liquid reserves are forced into defensive measures that further exacerbate NPL accumulation (Acharya & Mora, 2015).

The significant negative coefficient of management quality (MQ) on NPLs corroborates the "Bad Management Hypothesis" proposed by Berger and DeYoung (1997). This hypothesis posits that operational inefficiency in banking serves as an indicator of broader managerial weaknesses, including deficiencies in credit screening, loan monitoring, and collection practices.

However, the relatively smaller magnitude of the MQ coefficient compared to CAR and LQ requires further explanation. One plausible reason is that the cost-to-income ratio is an imperfect proxy for management quality, as it fails to capture critical dimensions such as corporate governance, board independence, and transparency. Recent studies (Tarchouna, Jarraya, & Bouri, 2022) indicate that more comprehensive corporate governance metrics exhibit greater explanatory power for NPLs.

Another explanation relates to the specific nature of the Iranian banking system. In a highly state-interventionist banking environment, credit decisions are sometimes influenced by non-economic considerations, meaning that operational efficiency does not necessarily correlate perfectly with credit portfolio quality.

The findings of this study are broadly consistent with the international literature, though notable differences are also observed. The positive effect of excha nge rate fluctuations on NPLs aligns with findings from Beck et al. (2015) for a panel of 75 countries, Tanasković and Jandrić for Eastern Europe, and Koju, Koju, and Wang (2018) for Nepal. The negative effect of CAR on NPLs corroborates the results of Ghosh (2015) and Louzis et al. (2012). The high persistence of NPLs is similar to the findings of Salas and Saurina (2002) for the Spanish banking sector.

This study examined the impact of exchange rate volatility on non-performing loans (NPLs) in the Iranian banking system, while simultaneously controlling for bank-specific factors including the Capital Adequacy Ratio (CAR), Liquidity Quality (LQ), and Management Quality (MQ). Employing a Panel-VAR framework on a sample of 18 commercial banks over the period 2011–2023 (1390–1402 in the Persian calendar), comprising 234 bank-year observations, the empirical analysis yielded several notable findings.

First, exchange rate volatility exerts a positive and statistically significant effect on NPLs ($\beta=0.283$\beta = 0.283$\beta=0.283$, $p<0.01$p < 0.01$p<0.01$), confirming the first hypothesis. This finding underscores the vulnerability of the Iranian banking system to external shocks transmitted through the balance sheet channel. The magnitude of this coefficient, which exceeds estimates from comparable emerging economies, reflects the exacerbating effect of financial sanctions that have restricted firms' access to hedging instruments and international financing.

Second, capital adequacy exhibits a strong negative relationship with NPLs (β=−0.234\beta = -0.234β=−0.234, p<0.01p < 0.01p<0.01), supporting the second hypothesis. Banks with stronger capital buffers demonstrate superior loan portfolio quality, consistent with both the Moral Hazard and Signaling hypotheses in banking theory.

Third, liquidity quality exerts a negative effect on NPLs (β=−0.189\beta = -0.189β=−0.189, p<0.01p < 0.01p<0.01), confirming the third hypothesis. Banks with adequate liquidity buffers possess greater flexibility in loan restructuring and crisis management, thereby preventing the migration of performing loans into non-performing status.

Fourth, management quality—proxied by the cost-to-income ratio—shows a significant negative effect on NPLs (β=−0.163\beta = -0.163β=−0.163, p<0.01p < 0.01p<0.01), supporting the fourth hypothesis and corroborating the "Bad Management Hypothesis" (Berger & DeYoung, 1997).

Fifth, the high autoregressive coefficient of NPLs (β=0.624\beta = 0.624β=0.624) reveals substantial persistence, indicating that credit quality problems in Iranian banks are structural rather than cyclical in nature. The cointegration analysis, which confirmed the existence of three long-run equilibrium relationships among the variables, further substantiates that these linkages represent genuine economic relationships rather than spurious correlations.

The findings carry significant implications for monetary authorities, banking supervisors, and policymakers.

Several avenues warrant further investigation. Future research could examine heterogeneous effects across different bank ownership types (state-owned versus private) and size categories. Incorporating borrower-level data would enable the analysis of micro-level mechanisms through which exchange rate shocks transmit to default outcomes. Comparative studies across multiple emerging economies with varying degrees of financial openness would enhance the external validity of the findings. Investigating nonlinear relationships and threshold effects could reveal whether the impacts of exchange rate fluctuations intensify beyond specific volatility levels. Finally, extending the analysis to impulse response dynamics and variance decomposition would provide richer insights into the temporal evolution and relative importance of different structural shocks.

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ETHICAL CONSIDERATION

Authenticity of the texts, honesty and fidelity has been observed.

CONFLICT OF INTEREST

Author/s confirmed no conflict of interest.