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Micro-Macroprudential Integration in Banking Stress Testing: Evidence from Liquidity and Solvency Shocks in the MENA Region

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Abstract
This study develops a unified microprudential–macroprudential stress testing framework to examine how key financial risks—credit risk, interest rate risk, and exchange rate risk—affect the liquidity and solvency of conventional banks in the MENA region. Using a balanced panel of 81 banks from 2007 to 2023, we uncover significant nonlinear effects and complex interactions between risk factors and bank soundness indicators. The findings reveal that heightened credit risk and rising interest rates strengthen liquidity buffers, reflecting precautionary behavior and regulatory compliance, while simultaneously undermining solvency. Exchange rate fluctuations negatively impact solvency under moderate stress but trigger adaptive liquidity responses under extreme scenarios. Mediation analysis confirms that liquidity risk acts as a key transmission channel through which financial shocks deteriorate capital strength. Our results offer novel insights for policymakers aiming to enhance banking sector resilience through integrated stress testing, dynamic liquidity regulation, and robust risk governance, particularly under rising financial and geopolitical uncertainty in the MENA region.
***Keywords**: Financial risk, Liquidity risk, Solvency, Credit risk, Exchange rate volatility, Interest rate risk, Stress testing, MENA banks, Macroprudential policy, Bank stability*

1. Introduction

The MENA region faces an increasingly uncertain future due to escalating regional threats, including potential spillovers from the Gaza-Israel conflict and Red Sea disruptions impacting trade and tourism (Rashed & Wu, 2025). In this volatile environment, the implementation of effective crisis prevention and management strategies is critical. Determining the role of combined microprudential and macroprudential financial risk stress tests is essential to strengthen the region's resilience and anticipate systemic vulnerabilities. Combining microprudential, macroprudential liquidity, and solvency stress testing in emerging markets involves integrating various risk assessment frameworks to enhance the resilience of financial systems. This approach is crucial for emerging markets, where financial systems are often more vulnerable to external shocks and systemic risks. The integration of these stress tests allows for a comprehensive evaluation of both individual institutions and the financial system as a whole, addressing the interconnectedness of liquidity and solvency risks. This synthesis of stress testing methodologies can provide a more robust framework for identifying vulnerabilities and informing policy responses in emerging markets.

Bakoush et al. (2022) propose a macroprudential stress test that integrates liquidity and solvency risks, providing a method to estimate changes in these risks based on systemic distress within the banking system. This approach captures both idiosyncratic and systemic risks, offering insights into the resilience of individual banks and the banking system as a whole. Cont et al. (2020) introduce a structural framework for joint stress testing of solvency and liquidity, emphasizing the solvency-liquidity nexus. This framework models liquidity and solvency risks coherently, accounting for external solvency shocks and endogenous liquidity shocks. The concept of "Liquidity at Risk" quantifies the liquidity resources needed under stress scenarios, highlighting the amplification of equity losses due to liquidity needs.

Caballero and Krishnamurthy (2002) dual liquidity model distinguishes between domestic and foreign financial constraints, offering a tailored approach for emerging markets. This model provides insights into the behavior of firms and governments during financial crises and suggests optimal policy responses. Krznar and Matheson (2017) emphasize the importance of macro-feedback effects in stress testing, which are crucial for understanding the amplification and propagation of shocks in emerging markets. Their framework incorporates these effects, ensuring consistency between macroeconomic variables and banks' balance sheets.

Puhr and Schmitz (2014) highlight the significant interaction between solvency and liquidity stresses, which has been underexplored in both research and practice. Their framework quantifies these interactions, revealing trade-offs between quantitative impacts and model risks. This understanding is vital for emerging markets, where such interactions can exacerbate financial instability. MENA Banks need to integrate macro- and microprudential dimensions, emphasizing the need for coordinated policy responses to financial instability. This includes using regulatory and supervisory policies countercyclically and ensuring the financial system's robustness to shocks. While the integration of microprudential, macroprudential liquidity, and solvency stress testing offers a comprehensive approach to assessing financial stability, it also presents challenges, particularly in emerging markets. These include the need for accurate data, the complexity of modeling interactions between different types of risks, and the potential for model risk and parameter uncertainty. Additionally, the unique characteristics of emerging markets, such as higher volatility and external dependencies, require tailored stress testing frameworks that account for these factors. Despite these challenges, the integrated approach provides valuable insights into systemic vulnerabilities and can guide effective policy interventions to enhance financial stability.

This study makes several key contributions to the literature on banking stability in emerging markets. First, it presents a unified framework that integrates microprudential and macroprudential stress testing to evaluate how credit risk, interest rate risk, and exchange rate risk affect both liquidity and solvency in MENA banks. Second, it captures nonlinear dynamics across varying stress scenarios, offering nuanced insights into how financial shocks propagate through liquidity channels to undermine solvency. Third, the mediation analysis uncovers the critical role of liquidity risk as a transmission mechanism linking market and credit stress to bank capital vulnerability. The study offers empirical evidence from a unique panel dataset covering 81 conventional banks in the MENA region over 17 years, delivering policy-relevant implications for enhancing regional financial resilience.

The paper is structured as follows: Section 1 introduces the research background. Section 2 reviews relevant literature, followed by Section 3 detailing the data, variables, and methodology. Section 4 presents empirical results, then Section 5 presents the conclusion, policy recommendations, and suggests future research directions.

2. Literature Review and hypothesis development

2.1. Credit risk and liquidity risk

Despite theoretical foundations suggesting a clear link between credit risk and liquidity risk, empirical studies provide conflicting evidence, revealing three distinct relationships: positive, negative, and neutral. A dominant stream of post-global financial crisis literature supports a positive correlation between the two risks. This view is grounded in financial intermediation theory, which argues that both risks stem from uncertainties in lending and maturity mismatches in banks. Some studies highlight that high non-performing loans (NPLs) can constrain banks' liquidity positions, especially in larger and foreign-owned institutions. Similarly, empirical research across various countries—including Nigeria, Iran, Greece, and the MENA region—confirms this positive association using diverse methodologies and bank samples (Acharya & Viswanathan, 2011; Cai & Zhang, 2017; Cornett et al., 2011).

Conversely, some studies find a negative relationship, suggesting that banks with conservative credit risk management practices tend to maintain higher liquidity, thereby minimizing both exposures. Some studies support this inverse relationship, showing that increased credit risk may prompt banks to hold more liquid assets as a precaution (Hassan et al., 2019; Le & Pham, 2021; Louati et al., 2015). In contrast, a few studies report no significant correlation, implying that the two risks may evolve independently depending on the regulatory environment or bank strategies. For example, Imbierowicz and Rauch (2014) & Ghenimi et al. (2017) did not find any consistent reciprocal or time-lagged relationship between credit and liquidity risks.

Moreover, nonlinear perspectives have recently gained attention. Some studies highlight that the relationship between credit and liquidity risks is not constant but varies across thresholds of key indicators like loan-to-deposit ratios and liquid asset levels using panel smooth transition regression models (Boussaada et al., 2022; Pop et al., 2018). In summary, while a significant portion of the literature supports a positive association between credit risk and liquidity risk, there remains considerable debate. Given these insights, the following hypothesis is proposed:

H_1: Credit risk has a significant impact on liquidity risk.

2.2. Interest rate, Exchange rate, and liquidity risk

Interest rate and liquidity risk are critical components of financial markets, influencing the behavior of banks, governments, and investors. The interest rate risk arises from fluctuations in interest rates, which can affect the value of financial instruments and the cost of borrowing. Liquidity risk, on the other hand, pertains to the ability to quickly convert assets into cash without significant loss in value. Both risks are interconnected and play a significant role in the stability and functioning of financial systems. Banks are inherently exposed to interest rate risk due to their maturity-mismatched balance sheets. When interest rates rise, banks may incur losses, but they also have the opportunity to earn larger spreads on deposits, which provide liquidity. This dynamic is part of banks' optimal hedging strategies and amplifies the effects of monetary shocks on liquidity costs (Di Tella & Kurlat, 2021). The exposure of banks to interest rate fluctuations is a predictor of excess Treasury bond returns. This relationship suggests that banks are compensated for bearing interest rate risk, which is reflected in the bond risk premium (Haddad & Sraer, 2020).

Local governments, such as those in China, face liquidity risk when issuing bonds to support economic development. A multi-period stochastic optimization approach can help manage this risk by minimizing expected costs while considering liquidity constraints. This involves measuring liquidity risk through conditional payment-at-risk (CPAR) and managing it over an extended planning horizon (Yang et al., 2022). In the European sovereign bond market, liquidity dynamics are influenced by market conditions. During periods of crisis, investors exhibit a flight-to-liquidity, preferring shorter-term benchmarks. This behavior highlights the systematic dimension of liquidity as both a characteristic and a risk factor (O'Sullivan & Papavassiliou, 2020).

Global financial conditions, including interest rates, significantly affect exchange rate risks. Currencies of countries with higher interest rates and fiscal deficits are more susceptible to large losses when global financial conditions tighten. This underscores the interconnectedness of interest rate and liquidity risks on a global scale (Eguren-Martin & Sokol, 2022). The COVID-19 crisis demonstrated how changes in funding liquidity conditions can asymmetrically impact stock portfolio volatilities. High-risk portfolios are more sensitive to deteriorations in liquidity conditions, especially during periods of high volatility (Kocaarslan & Soytas, 2021).

The risk-taking channel of monetary policy illustrates how changes in interest rates can alter investors' risk appetite, affecting asset prices and financial stability. This channel highlights the broader implications of interest rate changes on market dynamics (Bauer et al., 2023). In emerging economies, such as the BRICS nations, country-specific risks, including political and economic instabilities, exacerbate credit risk in the banking sector. This relationship is further influenced by interest rates and global risk factors (Saliba et al., 2023). While interest rate and liquidity risks are often analyzed separately, they are deeply interconnected, influencing each other and the broader financial system. These risks require a comprehensive understanding of their dynamics and the implementation of strategies that consider both current and future conditions. This interconnectedness is evident in various contexts, from banking and government bond issuance to global financial conditions and emerging market risks, thus, we formulate the following hypothesis:

H_2: The Interest rate has a significant impact on liquidity risk.

Exchange rate risks are significantly influenced by global financial conditions. A tightening of these conditions can lead to large swings in currency returns, particularly for countries with high interest rates, low international reserves, and large fiscal deficits. This increases the likelihood of substantial losses for banks operating in these environments (Eguren-Martin & Sokol, 2022). In emerging markets, flexible exchange rates can act as both shock absorbers and drivers of economic cycles. These rates, when combined with external shocks, can lead to boom-bust cycles, affecting banks' foreign currency debt and overall financial stability (Kohler & Stockhammer, 2023).

Banks' exposure to interest rate movements is a key factor in liquidity risk. Higher interest rates can increase the cost of liquidity, as banks earn larger spreads on deposits but face greater risks from maturity mismatches. This exposure amplifies the effects of monetary shocks on liquidity costs (Di Tella & Kurlat, 2021). Liquidity management is crucial for banks, especially in the context of monetary policy. The functioning of interbank markets and liquidity frictions can significantly impact banks' ability to manage liquidity risk, as seen during the 2008 financial crisis (Bianchi & Bigio, 2022). Banks' balance sheet exposure to interest rate fluctuations can forecast excess returns on Treasury bonds, indicating a link between exchange rate risk and liquidity management. This relationship suggests that banks are compensated for bearing interest rate risks, which are influenced by exchange rate movements (Haddad & Sraer, 2020). Political and economic risks in a country can exacerbate both exchange rate and liquidity risks (Saliba et al., 2023). Based on the debate above, we propose the following hypothesis as follows:

H_3: The Exchange rate has a significant impact on liquidity risk.

2.3. Credit risks and solvency

The relationship between credit risk and bank solvency has long been central to discussions on financial stability. In emerging economies, such as those in the BRICS group, country-specific risks, particularly political and economic instability, are key contributors to rising credit risk.

Saliba et al. (2023) argue that political uncertainty, more than any other factor, drives an increase in non-performing loans, which in turn deteriorates the capital position of banks and jeopardizes their solvency. This insight highlights the importance of local governance conditions in shaping credit outcomes and the resilience of banking systems. The transmission of credit risk also occurs through funding structures. Aldasoro et al. (2022) show that when funding costs rise, especially during periods of economic uncertainty, regulatory capital requirements increase, further raising the cost of funding, a negative feedback loop that erodes bank solvency. These findings underscore how market-based signals and regulatory demands interact to magnify stress within banks. Moreover, credit risk is not limited to direct lending. It can also spread indirectly through supply chains. Xie et al. (2023) argued that when one firm defaults, the shock can ripple across its network of suppliers and customers, affecting the banks that finance them. Dual-channel financing systems offer a potential safeguard by diversifying financing sources and reducing contagion. Uncertainty in economic policy adds another layer of complexity. De Silva et al. (2023) suggest that in times of policy ambiguity, banks face higher loan spreads and shift toward riskier non-traditional activities. These changes increase operational and credit risk, further endangering bank solvency. Regulatory frameworks, such as Basel II, are designed to strengthen bank resilience, yet they may have unintended effects. Gopalakrishnan et al. (2021) find that stricter capital rules can reduce credit access for lower-rated firms, altering risk exposures within the banking sector. During crises, banks often cut credit lines to preserve capital, exacerbating economic downturns and creating solvency concerns (Pelzl & Valderrama, 2023).

Finally, macroeconomic shocks can skew credit risk profiles drastically. Abdolshah et al. (2021) show that sudden economic dislocations increase credit losses and capital needs, leaving banks vulnerable and financially unstable.

Despite growing consensus on the threat posed by credit risk, scholars continue to debate the best mechanisms to manage it. Some advocate for stronger risk management and regulatory oversight, while others warn of the unintended consequences of rigid capital rules. Nonetheless, a shared view persists that credit risk is a critical determinant of bank solvency. Therefore, we posit the following hypothesis:

H_4: Credit risk has a significant impact on bank solvency.

2.4. Interest rate, Exchange rate, and Solvency

Some scholars argued that higher interest rates increase the cost of bank funding and exert pressure on capital adequacy. For example, Aldasoro et al. (2022) provide evidence of a feedback loop, where a 100-basis-point rise in funding costs can lead to a 265-basis-point increase in regulatory capital requirements, intensifying solvency concerns. Moreover, Ahnert et al. (2024) highlight that rising real interest rates increase the probability of creditor runs, especially in high-rate environments, which can destabilize banks. Additionally, maturity mismatches between assets and liabilities become more problematic in tightening cycles, as banks face elevated interest rate risk (Di Tella & Kurlat, 2021). In Vietnam, interest rate fluctuations have also been linked to systemic risk, with varied responses across institutions, further illustrating the broad and uneven impact of monetary tightening on banking sector solvency (Nguyen et al., 2023).

Exchange rate volatility introduces currency risk, especially for banks with significant exposure to foreign currency lending. Delis et al. (2022) show that a one-standard-deviation increase in exchange rate volatility raises foreign loan spreads by 5.5 to 16.1 basis points, thereby increasing credit risk and capital strain. However, internationalized banks—those with access to diversified funding sources—may be less vulnerable to these shocks. According to recent findings, such banks are better able to hedge against domestic monetary tightening and exchange rate fluctuations, suggesting a moderating role of bank globalization (Morales et al., 2022).

While interest and exchange rates play a central role in shaping bank solvency, their effects are mediated by regulatory frameworks, institutional characteristics, and economic structures. Hatmanu et al. (2020) stress that business cycle conditions and structural shifts alter the transmission of these macro shocks to bank outcomes. Similarly, Saeed et al. (2020) show that Islamic banks, due to their unique contractual structures, may respond differently to these risks compared to conventional banks, highlighting model-specific sensitivities. Based on the above debate, we formulate the following hypotheses:

H_5: The Interest rate has a significant impact on bank solvency.

H_6: Exchange rate has a significant impact on bank solvency.

2.5. The mediation effect of liquidity risk

Liquidity risk significantly impacts bank solvency by influencing the stability and risk-taking behavior of banks. This risk is particularly pronounced in low-income countries where banks are less able to transform short-term deposits into long-term loans, thereby reducing the supply of long-term finance and investment (Choudhary & Limodio, 2022). Lower funding liquidity risk can lead to increased risk-taking by banks, as they feel more secure in their financial position. However, this effect is less pronounced in Islamic banks compared to conventional banks (Smaoui et al., 2020). During financial crises, banks with lower funding liquidity risk were observed to take more risks, which could potentially compromise their solvency if not managed properly (Smaoui et al., 2020). Increased funding costs are directly associated with higher solvency risk, as banks need to maintain higher regulatory capital. This creates a feedback loop where higher solvency risk further increases funding costs, exacerbating liquidity issues (Aldasoro et al., 2022).

The relationship between funding costs and solvency risk is influenced by monetary policy, with the link being weaker during periods of monetary policy tightening (Aldasoro et al., 2022). Regulatory requirements for capital and liquidity can negatively impact bank stability by constraining lending growth. However, these effects can be mitigated by increased credit levels, which enhance stability (Polizzi et al., 2020).

Banks' liquidity management is also affected by market shocks and regulatory constraints, with banks often increasing liquidity buffers during crises to meet regulatory requirements (De Bandt et al., 2021). The systemic nature of liquidity risk can lead to socially inefficient outcomes, where banks either overinvest in risky assets or hold insufficient liquidity, depending on the degree of systemic risk (Lutz & Pichler, 2021). During the COVID-19 pandemic, banks with higher financial stability were better able to manage tail risks, suggesting that strong financial health can act as a buffer against liquidity-induced solvency issues (Sydow et al., 2024).

Banks need to manage their liquidity ratios effectively to minimize liquidity risk. Deviations from optimal liquidity ratios can serve as indicators of potential liquidity problems, which can threaten solvency if not addressed (Zhang et al., 2020). While liquidity risk poses significant challenges to bank solvency, it is important to consider the broader financial environment and regulatory landscape. For instance, the expansion of peer-to-peer lending has been shown to decrease banks' illiquidity risk, even as it increases insolvency risk, suggesting that diversification of financial services can have mixed effects on bank stability (Yeo & Jun, 2020). Additionally, the interaction between liquidity and solvency is not uniform across different legal and institutional environments, highlighting the need for tailored regulatory approaches. Based on the above debate, we formulate the following hypotheses:

H_7: Liquidity risk has a significant impact on bank solvency.

From a financial fragility theory perspective, credit risk elevates liquidity pressure as defaulted loans reduce cash inflows, leading banks to struggle with meeting short-term obligations—thus liquidity risk acts as a transmission channel linking credit deterioration to insolvency (Van der Kwaak & Van Wijnbergen, 2014). While traditional banking theory suggests capital buffers can absorb credit losses directly, for example, Tri Kurniawati et al. (2025) support a risk interaction view, arguing that unresolved credit risk triggers liquidity drains that ultimately undermine solvency, indicating that ignoring liquidity mediation may underestimate systemic risk. Thus, we proposed the following hypothesis as follow:

H_8: Liquidity risk mediates the relationship between credit risk and bank solvency.

According to the maturity mismatch theory, rising interest rates increase banks' cost of funding and reduce asset liquidity, thereby amplifying liquidity risk, which in turn weakens solvency—especially for banks relying heavily on short-term liabilities (Avalos & Mamatzakis, 2023). The monetary transmission theory views interest rate hikes as affecting solvency directly via asset repricing. However, others argue that the liquidity channel is more critical, as rising rates tighten liquidity before solvency declines, showing a gap between macroeconomic and microprudential views of solvency risk (Wang, 2023); thus, we proposed the following hypothesis as follow:

H_9: Liquidity risk mediates the relationship between interest rate and bank solvency.

Under the currency mismatch theory, exchange rate volatility increases withdrawal pressure and hedging costs, heightening liquidity risk, thereby indirectly affecting bank solvency, particularly in banks exposed to foreign currency liabilities (Abbassi & Bräuning, 2023). While the traditional exchange rate exposure model focuses on solvency through valuation losses, recent findings (Delis et al., 2022) support a liquidity-driven mediation pathway, where currency fluctuations first constrain liquidity positions, which then erode solvency, challenging the direct exposure-only view. Thus, we proposed the following hypothesis as follow:

H_{10}: Liquidity risk mediates the relationship between the exchange rate and bank solvency.

3. Research Methodology

3.1. Sample and Data Collection

Our sample includes 81 conventional banks listed in the MENA region from 2007-2023. The final sample covers all banks except Islamic banks and banks located in geopolitical tensions like Yemen, Syria, Iran, and Libya. The research sample covers a period of 17 years from 20107 to 2023 with 1377 year-end observations after removing all outliers. Thus, the final sample consists of 81 banks and 1377 bank-year observations. The distribution of the sample according to the MENA region is shown in Table (1).

Table 1 shows that the final sample is 1377 banks and 1377 bank-year observations. Banks in the United Arab Emirates represent 16% of the total sample then followed both Tunisia and Jordan with 12.35% then followed both Saudi Arabia and Egypt with 9.88%, and the last ratio in our sample is, banks located in Bahrain with a percentage of 4.94%.

Table 1: Sample Distributions

	Freq.	Percent	Cum.
Bahrain	68	4.94	4.94
Egypt	136	9.88	14.81
Iraq	119	8.64	23.46
Jordan	170	12.35	35.80
Kuwait	85	6.17	41.98
Morocco	102	7.41	49.38
Oman	85	6.17	55.56
Qatar	85	6.17	61.73
Saudi Arabia	136	9.88	71.60
Tunisia	170	12.35	83.95
United Arab Emirates	221	16.05	100.00
Total	1377	100.00	

3.2. Model specification

We investigate the effect of credit risk, interest rate, and exchange rate on liquidity risk based on the following equations (1-3):

$$LR_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (1)}$$

$$LR_{i,t} = \beta_0 + \beta_1 IR_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (2)}$$

$$LR_{i,t} = \beta_0 + \beta_1 EX_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (3)}$$

We explore the effect of credit risk, interest rate, and exchange rate on solvency based on equations (4-6):

$$SV_{i,t} = \beta_0 + \beta_1 CR_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (4)}$$

$$SV_{i,t} = \beta_0 + \beta_1 IR_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (5)}$$

$$SV_{i,t} = \beta_0 + \beta_1 EX_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (6)}$$

We examine the effect of liquidity risk on solvency based on equation (7) as follows:

$$SV_{i,t} = \beta_0 + \beta_1 LR_{i,t} + \beta_2 BS_{i,t} + \beta_3 ROA_{i,t} + \beta_4 INF_{i,t} + \beta_5 GDP_{i,t} + \beta_6 UN_{i,t} + \varepsilon_{i,t} \quad \text{Eq (7)}$$

Finally, we explore the mediation effect of liquidity risk on the relationship between credit risk, interest rate, exchange rate, and solvency using Sobel Z as the following equations:

$$ZT = \frac{x.m}{\sqrt{m^2 . SE_x^2 + x^2 . SE_m^2}} \qquad \text{Eq (8)}$$

Where: $X = \beta_{it}(CR_{it} \rightarrow LR_{it})$ & $m = \beta_{it}(LR_{it} \rightarrow SV_{it})$

$$ZT = \frac{r.b}{\sqrt{b^2 . SE_r^2 + r^2 . SE_b^2}} \qquad \text{Eq (9)}$$

Where: $r = \beta_{it}(IR_{it} \rightarrow LR_{it})$ & $b = \beta_{it}(IR_{it} \rightarrow SV_{it})$

$$ZT = \frac{k.n}{\sqrt{n^2 . SE_k^2 + k^2 . SE_n^2}} \qquad \text{Eq (10)}$$

Where: $k = \beta_{it}(EX_{it} \rightarrow LR_{it})$ & $n = \beta_{it}(EX_{it} \rightarrow SV_{it})$

Figure (1) shows the research model, while Table (2) shows the description of all variables with data sources as follows:

Table 2: Variables Measurements

Variables		Measure	Symbol	Sign	Source
Solvency	Dependent	CAR is measured by the sum of Tier 1 Capital and Tier 2 Capital, scaled by risk-weighted assets	SV		Bank scope and author calculations
		The sum of return on assets and equity ratio, scaled by the standard deviation of return on assets	ZROA		
Stress Test	Credit Risk	The ratio of non-performing loans to total loans	CR	+/-	
	Interest rate	Interest rate	IR	+/-	
	Exchange rate	Exchange rate	EX	+/-	
Liquidity Risk	Mediator	Liquidity coverage ratio is measured by the liquid asset amount divided by the net cash flow amount.	LCR	+/-	
		Net stable funding ratio is measured by the ratio of available stable funding (ASF) scaled by required stable funding.	NSFR	+/-	
Control variables	Control	The natural logarithm of the total assets	BS	+/-	Bank scope and author calculations
	Control	The percentage of net profit scaled by total assets	ROA	+/-	
	Control	Inflation rate	INF	+/-	World Bank (WB)
	Control	Gross domestic product	GDP	+/-	
	Control	Unemployment rate	UN	+/-	

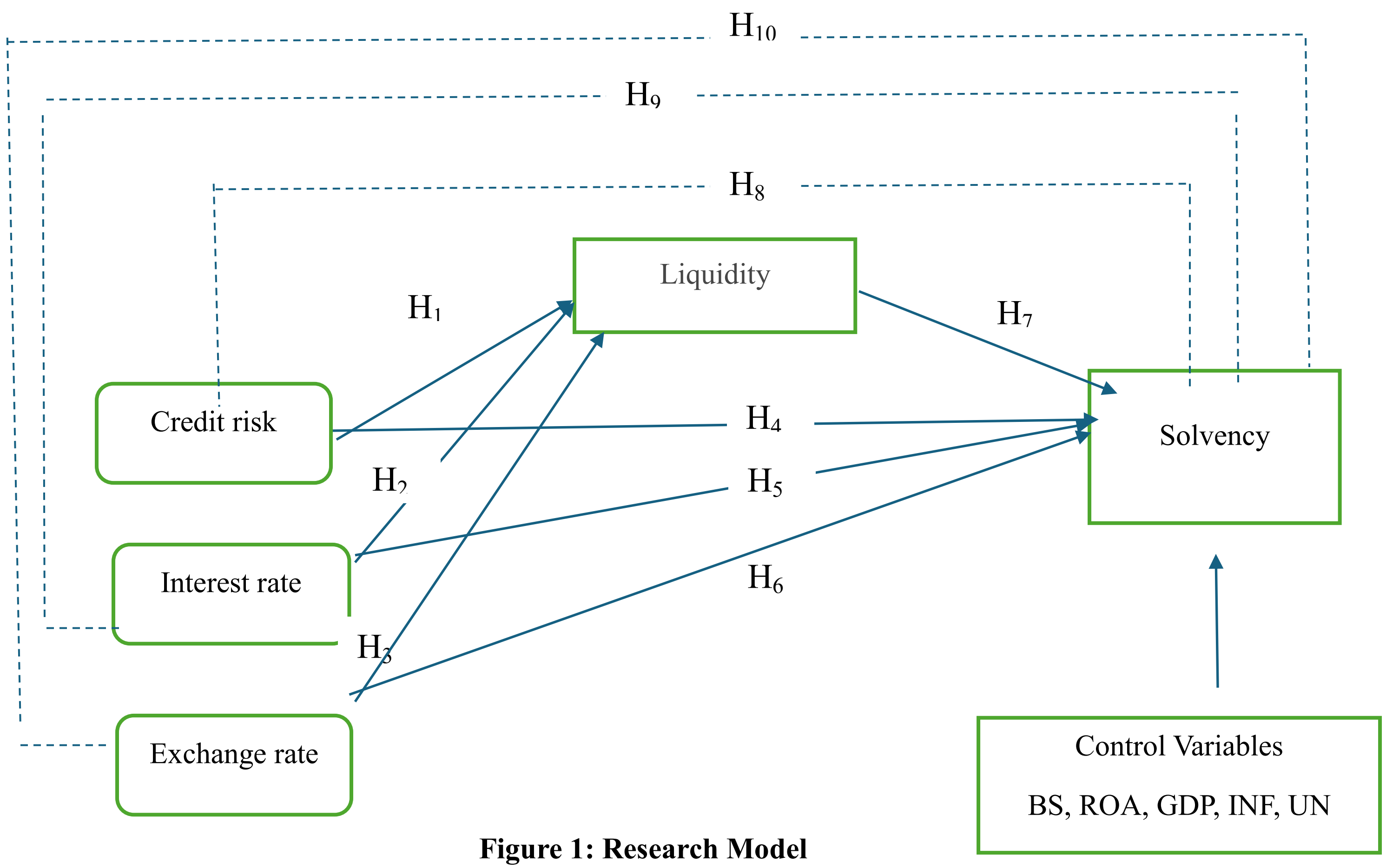

Figure 1: Research Model

Figure 2 shows the development of solvency (CAR) & ZSC_ROA within the period 2007-2023. Solvency shows a steady upward trend from 2006 to 2023, indicating improved financial stability, while ZSC_ROA remains mostly stable, with a sharp dip in 2014–2015 followed by a strong recovery. The trends suggest resilience in solvency despite short-term profitability fluctuations.

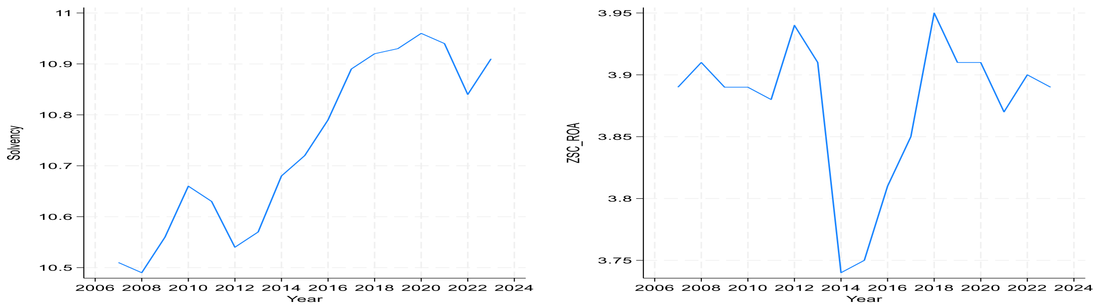

Figure 2: The development of Solvency from 2007-2023

Figure 3 shows the development of liquidity risk (LCR &NSFR) within the period 2007-2023. The Liquidity Coverage Ratio (LCR) has experienced some fluctuations over the years but shows a generally stable to slightly declining trend from 2007 to 2023, hovering between 1.54 and 1.62. In contrast, the Net Stable Funding Ratio (NSFR) has shown a clear upward trend since 2012, peaking around 2019 before a minor decline and partial recovery by 2023. Overall, while short-term liquidity remains steady, long-term funding stability has improved, reflecting enhanced financial resilience.

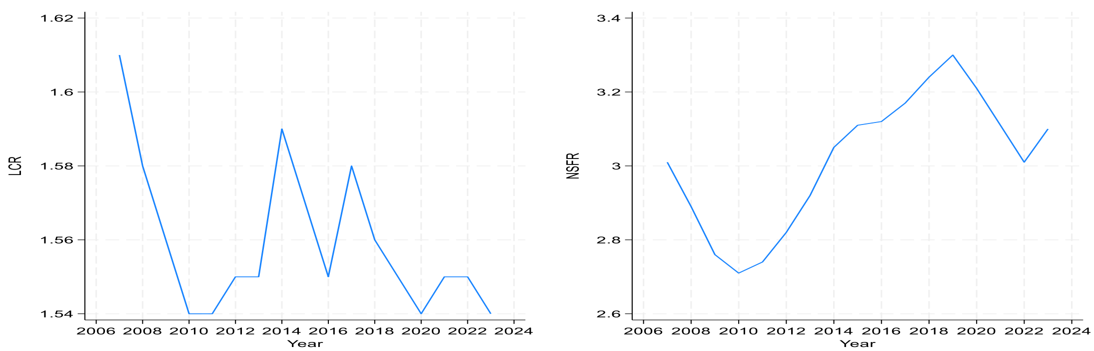

Figure 3: The development of liquidity risk

Figure 4 shows the development of credit risk, interest rate, and exchange rate from 2007-2023. Credit risk (CR) fluctuated slightly over the years, with a dip around 2016 followed by a recovery, maintaining values between 0.56 and 0.64. Interest rates (IR) show a clear declining trend from 2007 to 2014, followed by periodic ups and downs without a strong directional trend. Exchange rates (EX) gradually increased from 2007 to 2018, plateaued, then dipped slightly before recovering again in 2023.

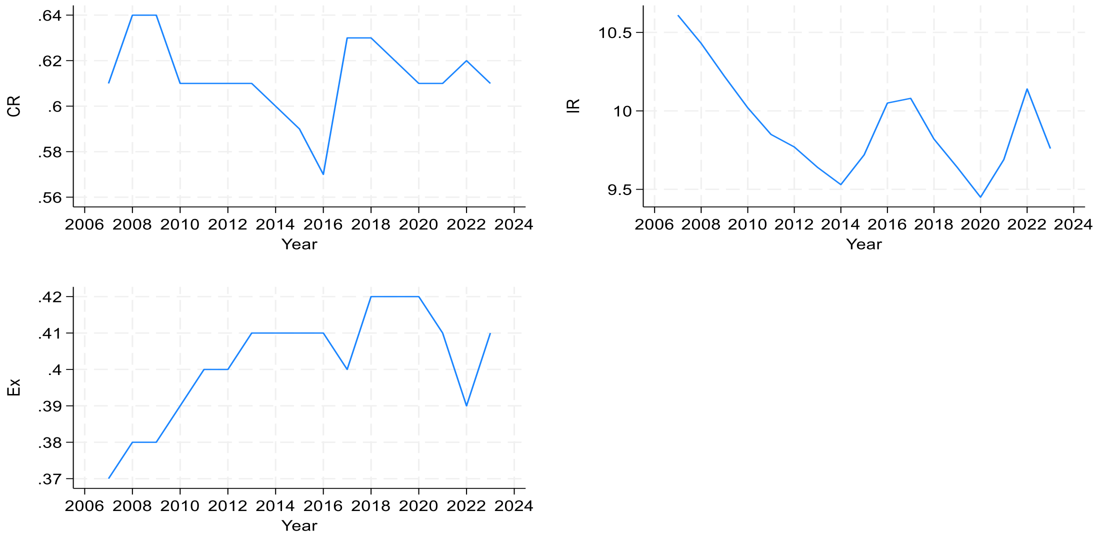

Figure 4: The development of credit risk, interest rate, and exchange rate

Figure 5 shows the development of control variables (BS, ROA, INF, GDP, and UN) within the period 2007-23. Bank size (BS) remains quite stable over time, with only minimal variation between 7.12 and 7.20. Inflation rate (INF) decreased until around 2014, then steadily increased to a peak in 2022 before dipping slightly. Unemployment (UN) and GDP show opposite movements: UN peaked between 2015–2020 while GDP dipped, but both reversed directions afterward, suggesting a potential recovery phase.

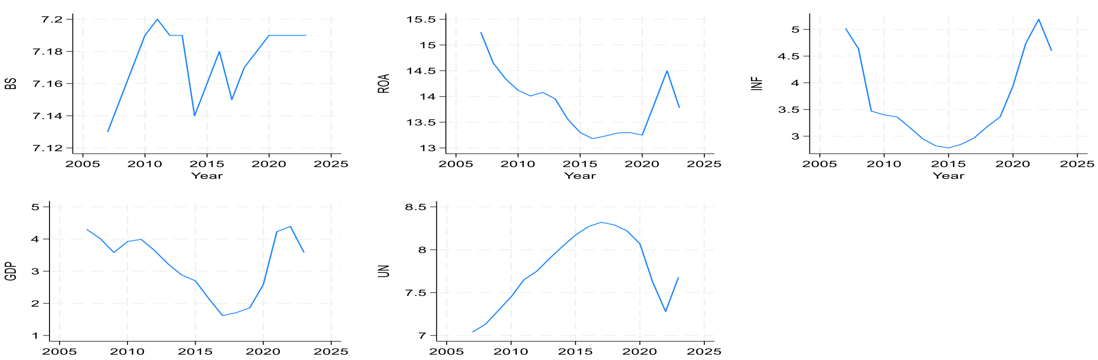

Figure 5: The development of control variables

4. Empirical analysis

4.1. Descriptive Statistics

Table 3 presents the descriptive statistics of the variables, the mean of solvency is 10.738, with a standard deviation of 2.669, whereas the min (max) values are 6.53 (14.4), indicating there are significant differences in solvency among the MENA banks and that a considerable proportion of the MENA banks have a significant variability in solvency across banks, reflecting differing levels of financial health. The mean ZSC_ROA of 3.876 suggests stable profitability among MENA banks, with most banks maintaining consistent performance. The low variability (0.264) highlights uniformity in asset utilization efficiency across these banks. The average LCR of 1.559 suggests that banks in the MENA region meet regulatory liquidity requirements. The moderate variability (0.305) implies differing approaches to managing short-term liquidity across banks, while the mean value of NSFR is 3.017, indicating MENA banks generally maintain stable funding positions. However, the high standard deviation (1.181) indicates that liquidity management practices vary significantly between banks in the region.

The mean credit risk ratio of 0.616 indicates moderate exposure to credit risk among MENA banks. The high standard deviation (0.366) suggests significant variation in the risk profiles of banks, with some more exposed to defaults than others. The mean value of interest rate is 9.907; borrowing costs for MENA banks vary widely, reflecting differences in credit risk and monetary policy across the region. The high standard deviation (3.134) points to significant disparities in loan rates offered by banks. The average exchange rate is 0.402 and suggests moderate stability in currency values across the MENA region. However, the variability (0.125) reflects differences in currency stability, particularly in countries with more volatile economies.

With an average bank size of 7.173, the MENA banking sector is dominated by medium to large institutions. The low variability (0.343) indicates that most banks in the region are of similar size, with fewer smaller banks represented. A high mean ROA of 13.863 suggests that banks in the MENA region are generally profitable, but the wide range (9.15 to 21.95) and high standard deviation (3.992) indicate significant variability in profitability levels across banks.

The mean inflation rate of 3.673 reflects moderate inflation across the region, but the high standard deviation (2.417) indicates significant inflationary volatility in certain MENA countries, impacting banking conditions. The average GDP growth rate of 3.197%, MENA countries experience moderate economic expansion. The wide range (-0.72 to 7.16) and high standard deviation (2.017) suggest diverse economic growth experiences across the region.

The mean unemployment rate of 7.774 reveals moderate labor market challenges in the MENA region, but the high standard deviation (5.445) shows significant variation in unemployment rates, with some countries facing much higher rates than others. The distribution of all variables in the dataset appears approximately normal, as their skewness and kurtosis values lie within acceptable limits (±3 for skewness and ±10 for kurtosis), indicating no serious departures from normality. Furthermore, the large sample size of 1,377 enhances the credibility of the analysis by mitigating the influence of slight irregularities in the data distribution.

Table 3: Descriptive Statistics

Variables	Obs	Mean	SD.	Min	Max	Skew.	Kurt.
Solvency	1377	10.738	2.669	6.53	14.4	-.469	1.646
ZSC ROA	1377	3.876	.264	3.48	4.16	-.396	1.628
NSFR	1377	3.017	1.181	1.664	5.179	.681	2.313
LCR	1377	1.559	.305	1.19	2.2	.547	2.261
CR	1377	.616	.366	.2	1.4	.878	2.747
IR	1377	9.907	3.134	4.69	15.76	.067	2.113
EX	1377	.402	.125	.24	.68	.722	2.614
BS	1377	7.173	.343	6.49	7.71	-.297	2.321
ROA	1377	13.863	3.992	9.15	21.95	.806	2.563
INF	1377	3.673	2.417	.78	8.53	.647	2.382
GDP	1377	3.197	2.017	-.72	7.16	-.002	2.486
UN	1377	7.774	5.445	.38	16.84	.246	1.62

Table 4 shows three scenarios of street tests, indicating that the majority of banks (52.29%) face moderate credit risk, with a significant portion (32.24%) experiencing adverse conditions. Only 15.47% of banks are in the extreme credit risk category, indicating a generally balanced risk exposure. A vast majority of banks (71.02%) operate under extremely low-interest rates, reflecting a generally favorable borrowing environment. However, a smaller portion of banks face either moderate (21.64%) or adverse (7.33%) interest rate scenarios. Most banks (69.57%) experience moderate exchange rate conditions, with 21.50% facing extreme exchange rate scenarios.

A small portion (8.93%) is exposed to adverse exchange rate fluctuations, indicating relative stability in currency conditions.

Table 4: Three scenarios of street tests

	Scenarios	Freq.	Percent
CR_SE	Extreme (> 0.75)	213	15.47
	Moderate (0.5-0.75)	720	52.29
	Adverse (<0.5)	444	32.24
IR_SE	Extreme (> 0.07)	978	71.02
	Moderate (0.05-0.07)	298	21.64
	Adverse (<0.05)	101	7.33
EX_SE	Extreme (> 0.75)	296	21.50
	Moderate (0.5-0.75)	958	69.57
	Adverse (<0.5)	123	8.93
Total		1377	100.00

4.2. Correlation matrix

Table 5 illustrates the correlation matrix concerning the empirical model. Solvency demonstrates a strong negative relationship with credit risk (CR) (r=-0.552, $p < 0.05$) and Interest Rates (IR) (r=-0.616, $p < 0.05$), indicating that banks with higher solvency tend to face lower credit risk and benefit from lower interest rates. It also shows a negative correlation with liquidity ratios (NSFR, LCR), suggesting that solvent banks may not need as much stable funding or liquidity buffers. On the other hand, solvency is positively correlated with Bank Size (BS) (r=0.539, $p < 0.05$), implying that larger banks tend to have better solvency.

For ZSC ROA, there is a weak positive relationship with liquidity and funding Ratios (NSFR, LCR), which suggests that more profitable banks might also have slightly better liquidity. However, the correlation with Bank Size (BS) (r=-0.086, $p < 0.05$) is negative, indicating that larger banks tend to show lower profitability. Additionally, ZROA exhibits a weak positive correlation with Exchange Rates (EX) (r=0.151, $p < 0.05$), suggesting that more profitable banks are slightly more exposed to exchange rate fluctuations. There are no multicollinearity problems because there is no correlation higher than 0.9 between variables, thereby confirming the absence of a multicollinearity issue.

Table 5: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Solvency	1.000											
(2) ZSC_ROA	-0.127* (0.000)	1.000										
(3) NSFR	-0.765* (0.000)	0.102* (0.000)	1.000									
(4) LCR	-0.441* (0.000)	0.085* (0.002)	0.344* (0.000)	1.000								
(5) CR	-0.552* (0.000)	0.091* (0.001)	0.457* (0.000)	0.450* (0.000)	1.000							
(6) IR	-0.616* (0.000)	0.017* (0.020)	0.510* (0.000)	0.436* (0.000)	0.518* (0.000)	1.000						

(7) EX	-0.013*	0.151*	-0.058*	-0.137*	-0.112*	-0.628*	1.000					
	(0.042)	(0.000)	(0.030)	(0.000)	(0.000)	(0.000)						
(8) BS	0.539*	-0.086*	-0.537*	-0.875*	-0.517*	-0.483*	0.159*	1.000				
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
(9) ROA	-0.584*	0.112*	0.406*	0.157*	0.211*	0.339*	0.105*	-0.206*	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(10) INF	-0.423*	0.175*	0.307*	0.162*	0.207*	0.350*	0.089*	-0.186*	0.578*	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)			
(11) GDP	-0.115*	-0.035	0.159*	-0.023	-0.041	0.069*	-0.079*	-0.071*	0.301*	0.307*	1.000	
	(0.000)	(0.193)	(0.000)	(0.391)	(0.127)	(0.010)	(0.003)	(0.009)	(0.000)	(0.000)		
(12) UN	-0.471*	0.149*	0.290*	0.553*	0.436*	0.484*	-0.203*	-0.545*	0.180*	0.272*	-0.116*	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

*Note: * p<0.05*

4.3. Main Tests

The main test focuses on whether credit risks affect liquidity risk across the MENA banks during the period 2007-2023. Correlation analysis cannot detect the influence of a factor in the presence of other variables. Therefore, we employed panel corrected standard error (PCSE) regression analysis to solve autocorrelation issues and examine the hypotheses more reliably, as shown in Table 6. The panel-corrected standard error regression shows that credit risk (CR) is positively and significantly associated with both NSFR and LCR, with coefficients of 0.719 and 0.025, respectively. This finding is supported by risk management theory and the liquidity preference theory, which suggest that banks facing higher credit risk increase their liquidity buffers (NSFR and LCR) to reduce default risk and ensure stability under uncertainty (Acharya & Viswanathan, 2011; Cai & Zhang, 2017; Cornett et al., 2011). This result supports the first hypothesis (H_1), suggesting that higher exposure to credit risk prompts banks to maintain stronger liquidity positions.

Bank size (BS) negatively affects both NSFR and LCR, with coefficients of -1.385 and -0.750, respectively, and high levels of statistical significance, indicating that larger banks tend to operate with lower liquidity buffers. Bank profitability (ROA) shows a positive and significant impact on NSFR (0.074), implying that more profitable banks are better positioned to maintain long-term stable funding. However, its effect on LCR is not statistically significant. Inflation and GDP growth are modestly but significantly associated with NSFR, suggesting a slight upward influence of macroeconomic stability on long-term liquidity. Conversely, GDP exerts a negative and significant impact on LCR, indicating that during economic expansions, banks might reduce short-term liquidity buffers. Finally, unemployment (UN) is negatively associated with NSFR and positively with LCR, showing differing effects of labor market conditions on various liquidity measures. Finally, R^2 indicated that the credit risks explain 78% of LCR and 42% of NSFR across the MENA banks within the period 2007-2023.

Table 6: The relationship between Credit risk and liquidity risk

Var	NSFR	LCR
CR	0.719***	0.025**
	(4.938)	(1.972)

BS	-1.385***	-0.750***
	(-3.922)	(-5.898)
ROA	0.074***	-0.001
	(5.625)	(-0.943)
INF	0.025*	0.002
	(1.928)	(0.978)
GDP	0.023*	-0.011***
	(1.747)	(-5.216)
UN	-0.017***	0.005***
	(-3.050)	(5.897)
Year FE	Included	Included
Country FE	Included	Included
Constant	5.454***	4.957***
	(8.919)	(9.881)
Observations	1,377	1,377
Wald chi2	1028.91***	18629.79***
R-squared	0.418	0.780
Note: T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table 7 shows that under extreme credit risk, banks significantly increase both their NSFR (0.240, p <0.01) and LCR (0.014, p <0.01), suggesting a cautious liquidity management approach during high-risk periods. In contrast, during moderate and adverse risk scenarios, both NSFR and LCR significantly decrease, with stronger effects observed in the adverse state (-0.544 for NSFR and -0.113 for LCR), reflecting reduced liquidity cushions as credit conditions worsen. In other words, under extreme credit risk, banks increase both NSFR and LCR significantly, reflecting stronger liquidity buffers during heightened uncertainty. However, in moderate and adverse conditions, both indicators decline, suggesting diminished liquidity management as risk intensifies. According to control variables, bank size consistently reduces liquidity, while profitability enhances NSFR but not LCR. Inflation and unemployment show selective, scenario-dependent effects, and GDP generally weakens LCR.

Table 7: Three scenarios for the relationship between credit risk and liquidity risk

Var	NSFR			LCR		
	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)
CR_EX	0.240***			0.014***		
	(3.332)			(2.975)		
CR_MO		-0.490***			-0.083***	
		(-4.482)			(-4.400)	
CR_AD			-0.544***			-0.113***
			(-5.507)			(-4.711)
BS	-1.702***	-1.586***	-1.548***	-0.739***	-0.757***	-0.769***
	(-4.244)	(-4.307)	(-4.583)	(-3.836)	(-6.850)	(-5.724)
ROA	0.082***	0.072***	0.065***	-0.002	-0.000	0.002
	(4.490)	(5.446)	(4.303)	(-1.247)	(-0.080)	(1.420)
IINF	0.034**	0.018	0.011	0.002	0.004**	0.006***
	(2.559)	(1.352)	(0.834)	(0.799)	(2.092)	(3.054)
GDP	0.018	-0.005	-0.023*	-0.011***	-0.008***	-0.004*
	(1.309)	(-0.381)	(-1.658)	(-5.170)	(-3.871)	(-1.694)
UN	-0.009	-0.002	-0.002	0.005***	0.004***	0.004***
	(-1.530)	(-0.414)	(-0.355)	(5.632)	(4.519)	(4.168)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	3.932***	3.622***	4.096***	3.871***	4.926***	5.049***
	(7.514)	(7.593)	(6.483)	(5.214)	(6.147)	(7.333)
Observations	1,377	1,377	1,377	1,377	1,377	1,377

Wald chi2 (6)	1342.33***	2265.69***	1705.89***	17293.04***	13825.73***	9746.95***
R-squared	0.389	0.422	0.415	0.779	0.795	0.799
Number of banks	81	81	81	81	81	81
Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table (8) reveals a significant positive relationship between interest rates and both NSFR (0.083, p <0.01) and LCR (0.003, p <0.10), indicating that rising interest rates are associated with improved bank liquidity, thus, we accepted H_2, suggests that in a higher rate environment, banks tend to strengthen their liquidity positions, possibly due to tightened funding conditions or regulatory prudence. This result aligns with monetary transmission theory and precautionary liquidity theory, which suggest that rising interest rates tighten funding conditions, prompting banks to enhance liquidity buffers (NSFR and LCR) as a risk-mitigation strategy (Eguren-Martin & Sokol, 2022; Saliba et al., 2023). Based on control variables, the unemployment rate exerts a strong negative effect on NSFR, while bank size significantly reduces LCR. Interest rate explains 85.5% of LCR and 83.8% of NSFR, demonstrating high explanatory power.

Table 8: The relationship between Interest rate and liquidity risk

Var	NSFR	LCR
IR	0.083***	0.003*
	(3.366)	(1.793)
BS	0.064	-0.906***
	(0.408)	(-4.302)
ROA	-0.013*	-0.001
	(-1.954)	(-0.440)
INF	-0.015	-0.002
	(-0.565)	(-0.925)
GDP	0.003	0.001
	(0.171)	(0.509)
UN	-0.164***	0.002
	(-8.584)	(1.064)
Year FE	Included	Included
Country FE	Included	Included
Constant	1.809*	1.005***
	(1.665)	(4.018)
Observations	1,377	1,377
Wald chi2	48713.49***	10126.02***
R-squared	0.838	0.855
Number of banks	81	81
Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table 9 highlights that under extreme interest rate conditions, banks significantly increase both NSFR (0.324; p <0.01) and LCR (0.008; p <0.10), indicating stronger liquidity positions. However, during moderate and adverse rate scenarios, both liquidity measures decline, especially for NSFR (-0.359; -0.050) and LCR (-0.001;-0.019), suggesting tighter liquidity amid persistent rate pressures. Across all scenarios, bank size reduces liquidity, while profitability supports NSFR but not LCR. Overall, liquidity management appears sensitive to the degree of interest rate stress.

Table 9: Three scenarios for the relationship between interest rate and liquidity risk

Var	NSFR			LCR		
	Extreme (> 0.07)	Moderate (0.05-0.07)	Adverse (<0.05)	Extreme (> 0.07)	Moderate (0.05-0.07)	Adverse (<0.05)
IR_EX	0.324***			0.008*		
	(2.996)			(1.810)		
IR_MO		-0.359***			-0.001*	
		(-3.944)			(-1.702)	

IR_AD			-0.050*			-0.019***
			(1.764)			(-2.906)
BS	-1.674***	-1.673***	-1.690***	-0.739***	-0.739***	-0.739***
	(-2.827)	(-2.877)	(-2.151)	(-3.709)	(-4.820)	(-4.270)
ROA	0.076***	0.072***	0.080***	-0.001	-0.001	-0.001
	(3.983)	(3.936)	(4.130)	(-1.332)	(-1.258)	(-1.294)
INF	0.028	0.027	0.032	0.002	0.002	0.002
	(1.182)	(1.159)	(1.367)	(0.824)	(0.845)	(0.877)
GDP	0.007	0.018	0.013	-0.011***	-0.011***	-0.011***
	(0.234)	(0.627)	(0.431)	(-3.417)	(-3.309)	(-3.413)
UN	-0.019	-0.015	-0.008	0.003***	0.004***	0.005***
	(-1.554)	(-1.373)	(-0.643)	(7.118)	(7.648)	(7.074)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	3.774***	4.007***	3.942***	3.865***	3.870***	3.875***
	(5.002)	(6.020)	(5.720)	(5.444)	(5.520)	(4.147)
Observations	1,377	1,377	1,377	1,377	1,377	1,377
Wald chi2	1740.14***	1371.91***	1330.46***	16866.3***	17231.75***	18362.47***
R-squared	0.396	0.398	0.384	0.779	0.779	0.779
Number of Banks	81	81	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table (10) indicates a statistically significant positive relationship between the exchange rate and both NSFR (0.199, $p < 0.01$) and LCR (0.007, $p < 0.10$), implying that exchange rate appreciation enhances both long- and short-term liquidity in MENA banks; thus, we accepted H_3. This finding is supported by exchange rate risk theory and financial fragility theory, which posit that currency fluctuations can increase uncertainty and exposure to foreign liabilities, thereby elevating banks' liquidity risk (Haddad & Sraer, 2020; Kohler & Stockhammer, 2023; Saliba et al., 2023). However, while the NSFR response is more robust, the LCR effect is weaker and marginal. Additionally, unemployment negatively affects NSFR, and bank size substantially reduces LCR. Other macroeconomic variables, such as inflation and GDP, show no significant impact on liquidity risk.

Table 10: The relationship between exchange rate and liquidity risk

Var	NSFR	LCR
Exch	0.199***	0.007*
	(2.920)	(1.817)
BS	0.063	-0.906***
	(0.404)	(-3.292)
ROA	-0.012*	-0.000
	(-1.759)	(-0.409)
INF	-0.004	-0.002
	(-0.159)	(-0.768)
GDP	0.001	0.001
	(0.044)	(0.455)
UN	-0.176***	0.001
	(-4.289)	(0.775)
Year FE	Included	Included
Country FE	Included	Included
Constant	2.032*	2.013***
	(1.840)	(4.224)
Observations	1,377	1,377
Wald chi2	37109.82	13278.60
R-squared	0.837	0.855

Number of banks	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table (11) shows that under extreme exchange rate conditions, liquidity improves significantly as shown by positive and significant effects on both NSFR (0.156) and LCR (0.015), while in moderate scenarios, exchange rate changes negatively impact liquidity, with a strong negative effect on NSFR (–0.594) and LCR (–0.047). However, in adverse conditions, the exchange rate strongly enhances liquidity, especially NSFR (1.168), suggesting that banks may benefit from currency movements during severe market stress.

Table 11: Three scenarios for the relationship between exchange rate and liquidity risk

Var	NSFR			LCR		
	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)
Exch_EX	0.156*			0.015**		
	(1.808)			(2.038)		
Exch_MO		-0.594***			-0.047***	
		(-5.300)			(-4.948)	
Exch_AD			1.168***			0.088***
			(6.080)			(4.743)
BS	-1.696***	-1.567***	-1.406***	-0.739***	-0.749***	-0.761***
	(-3.950)	(-4.724)	(-3.762)	(-4.042)	(-5.545)	(-4.642)
ROA	0.078***	0.079***	0.088***	-0.001	-0.001	-0.002**
	(4.071)	(4.367)	(4.994)	(-1.176)	(-1.242)	(-2.054)
INF	0.030	0.039*	0.057**	0.002	0.001	-0.000
	(1.314)	(1.685)	(2.420)	(0.950)	(0.640)	(-0.066)
GDP	0.018	0.042	0.023	-0.011***	-0.013***	-0.012***
	(0.614)	(1.439)	(0.870)	(-3.456)	(-3.787)	(-3.757)
UN	-0.005	0.011	-0.004	0.006***	0.004***	0.004***
	(-0.352)	(0.932)	(-0.370)	(6.689)	(4.096)	(6.833)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	3.929***	3.211***	4.526***	5.872***	4.929***	5.053***
	(5.328)	(6.494)	(7.612)	(6.534)	(7.940)	(8.961)
Observations	1,377	1,377	1,377	1,377	1,377	1,377
R-squared	0.386	0.429	0.454	0.779	0.783	0.785
Number of banks	81	81	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table 12 shows a significant negative impact of credit risk on both ZROA (–0.045; p<0.1) and solvency (–1.992; p<0.01); thus, we accepted H_4. This result is supported by bank risk-taking theory and the financial instability hypothesis, which suggest that higher credit risk undermines profitability (ZROA) and solvency, leading to increased vulnerability and financial instability (Abdolshah et al., 2021; Gopalakrishnan et al., 2021; Pelzl & Valderrama, 2023). Bank size positively influences both indicators, suggesting larger banks tend to be more stable, while the unemployment rate weakly improves ZROA and significantly reduces solvency. Overall, solvency appears more sensitive to changes in risk and macroeconomic factors than ZROA.

Table 12: The relationship between credit risk and solvency

Var	ZSC_ROA	Solvency
CR	-0.045*	-1.992***
	(-1.821)	(-6.941)
BS	0.102***	1.771***
	(3.347)	(3.830)
ROA	0.002	-0.292***
	(0.542)	(-3.065)

INF	-0.003	-0.044
	(-0.752)	(-1.291)
GDP	-0.005	0.024
	(-1.361)	(0.638)
UN	0.008*	-0.067***
	(1.800)	(-4.604)
Year FE	Included	Included
Country FE	Included	Included
Constant	3.030***	3.918**
	(3.054)	(2.495)
Observations	1,377	1,377
Wald chi2	2088.83***	2791.04***
R-squared	0.212	0.608
Number of banks	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table 13 shows significant relationships between credit risk (CR) and both solvency and ZROA in different scenarios. For solvency, in extreme and adverse conditions, credit risk positively influences solvency (1.198; 0.841, p<0.01), while in moderate conditions, credit risk has a negative impact (-0.076, *p<0.05). Inflation negatively affects solvency (0.079, p<0.05), while it has a positive effect on ZROA (0.016, p<0.01). Additionally, unemployment reduces solvency (-0.085, p<0.01), but increases ZROA (0.004, p<0.01). Bank size and return on assets significantly affect solvency in all scenarios, with consistent signs. Unemployment consistently decreases solvency but improves the Z-score in all scenarios.

Table 13: Three scenarios for the relationship between credit risk and solvency

Var	Solvency			ZSC		
	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)
CR_EX	1.198***			0.068**		
	(3.544)			(2.147)		
CR_MO		-0.076*			-0.017*	
		(-1.690)			(-1.846)	
CR_AD			0.841***			0.029*
			(2.982)			(1.686)
BS	2.574***	2.658***	2.426***	-0.017	-0.010	-0.021
	(3.055)	(3.279)	(3.983)	(-0.609)	(-0.378)	(-0.809)
ROA	-0.288***	-0.303***	-0.280***	0.003	0.002	0.003
	(-7.032)	(-6.508)	(-6.233)	(1.018)	(0.669)	(1.039)
INF	-0.079**	-0.093**	-0.055	0.016***	0.015***	0.017***
	(-2.221)	(-2.420)	(-1.326)	(3.035)	(2.789)	(2.892)
GDP	0.081	0.058	0.123**	-0.013***	-0.015***	-0.012***
	(1.460)	(1.186)	(2.200)	(-3.539)	(-3.526)	(-3.128)
UN	-0.085***	-0.085***	-0.097***	0.004***	0.005***	0.004***
	(-4.599)	(-6.083)	(-7.681)	(4.231)	(4.967)	(3.867)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	-2.862**	-2.971**	-1.693	3.910***	3.899***	3.949***
	(-2.008)	(-2.402)	(-1.471)	(5.005)	(5.366)	(4.381)
Observations	1,377	1,377	1,377	1,377	1,377	1,377
Wald chi2	1435.46***	2409.30***	1896.56***	652.29***	692.13***	821.86***
R-squared	0.584	0.561	0.575	0.198	0.189	0.192
Number of banks	81	81	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table 14 indicates that interest rate (IR) hurts both ZROA (-0.006, p<0.1) and solvency (-0.258, p<0.01); thus, we accepted H_5. This finding is supported by the interest rate risk theory and the financial accelerator theory, which argue that rising interest rates increase funding costs and reduce asset values, thereby weakening bank solvency (Ahnert et al., 2024; Di Tella & Kurlat, 2021; Nguyen et al., 2023). Bank size (BS) positively affects both ZROA and solvency (0.108, 1.985, p<0.01), respectively. Return on assets (ROA) has a significant negative effect on solvency (-0.271, p<0.01) but no significant effect on ZROA. Inflation (INF) negatively affects solvency (-0.043, p<0.1) but has no significant impact on ZROA. GDP shows a positive effect on solvency (0.057, p<0.05), while unemployment (UN) reduces solvency (-0.046, p<0.01) without a significant effect on ZROA.

Table 14: The relationship between interest rate and solvency

Var	ZSC	SV
IR	-0.006*	-0.258***
	(-1.877)	(-4.334)
BS	0.108***	1.985***
	(3.410)	(3.971)
ROA	0.002	-0.271***
	(0.564)	(-4.778)
INF	-0.002	-0.043*
	(-0.507)	(-1.666)
GDP	-0.005	0.057**
	(-1.036)	(2.107)
UN	0.008	-0.046***
	(1.478)	(-4.284)
Year FE	Included	Included
Country FE	Included	Included
Constant	3.007***	3.534***
	(4.374)	(2.690)
Observations	1,377	1,377
Wald chi2	3931.27***	2010.53***
R-squared	0.210	0.619
Number of banks	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table 15 shows that both extreme interest rate conditions significantly improve solvency (0.410, p < 0.001) but have a modest positive effect on ZROA (0.008, p < 0.01), while moderate interest rates (IR_MO) negatively affect both solvency (-0.26, p < 0.05) and ZROA (-0.078, p < 0.05). Adverse conditions (IR_AD) boost solvency (0.346, p < 0.001) and slightly increase ZROA (0.197, p < 0.001). Bank size consistently improves solvency (2.630, p < 0.001), inflation negatively affects solvency (-0.087, p < 0.05), and unemployment hurts solvency (-0.078, p < 0.001), but has a positive effect on ZROA (0.007, p < 0.001).

Tale 15: Three scenarios for the relationship between interest rate and solvency

Var	Solvency			ZSC		
	Extreme (> 0.07)	Moderate (0.05-0.07)	Adverse (<0.05)	Extreme (> 0.07)	Moderate (0.05-0.07)	Adverse (<0.05)
IR_EX	0.410***			0.008***		
	(3.828)			(2.716)		
IR_MO		-0.266**			-0.078**	
		(-2.434)			(-2.469)	
IR_AD			0.346***			0.197***
			(2.660)			(3.434)
BS	2.630***	2.623***	2.643***	-0.017	-0.014	-0.014
	(4.288)	(4.564)	(4.871)	(-0.634)	(-0.516)	(-0.479)
ROA	-0.299***	-0.298***	-0.302***	0.003	0.002	0.002

	(-3.421)	(-3.369)	(-3.467)	(1.085)	(0.766)	(0.863)
INF	-0.087**	-0.083**	-0.089**	0.017***	0.016***	0.015***
	(-2.314)	(-2.125)	(-2.233)	(3.242)	(2.899)	(3.014)
GDP	0.064	0.053	0.053	-0.013***	-0.014***	-0.008**
	(1.261)	(1.058)	(1.030)	(-3.551)	(-3.798)	(-2.369)
UN	-0.078***	-0.080***	-0.092***	0.007***	0.004***	0.008***
	(-5.873)	(-6.300)	(-6.522)	(6.122)	(5.002)	(6.063)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	-2.750**	-2.962**	-2.858**	3.961***	3.905***	3.860***
	(-2.220)	(-2.399)	(-2.353)	(5.904)	(5.749)	(5.969)
Observations	1,377	1,377	1,377	1,377	1,377	1,377
Wald chi2	2319.72***	2494.36***	2419.40***	671.29***	663.62***	628.64***
R-squared	0.562	0.564	0.562	0.104	0.091	0.122
Number of banks	81	81	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table 16 shows that the exchange rate (Ex) negatively impacts both ZROA (-0.072, $p < 0.001$) and solvency (-0.113, $p < 0.10$); thus, we accepted H_6. This result is supported by exchange rate exposure theory and currency mismatch theory, which suggest that exchange rate volatility can erode asset values and increase foreign currency liabilities, thereby weakening bank solvency (Ahnert et al., 2024; Hatmanu et al., 2020; Saeed et al., 2020). Bank size (BS) has no significant impact on ZSC (-0.033, $p > 0.05$) but significantly improves solvency (2.613, $p < 0.001$). Return on assets (ROA) has no significant impact on ZSC (0.001, $p > 0.05$) but significantly reduces solvency (-0.303, $p < 0.001$). Inflation (INF) positively affects ZROA (0.013, $p < 0.05$) and negatively affects solvency (-0.095, $p < 0.05$). Unemployment (UN) has a positive effect on ZROA (0.006, $p < 0.001$) but a negative effect on solvency (-0.083, $p < 0.001$). GDP's impact is more limited, with a negative effect on ZROA (-0.012, $p < 0.001$) and a non-significant effect on solvency (0.066, $p > 0.05$).

Table 16: The relationship between the exchange rate and solvency

Var	ZROA	SV
Ex	-0.072***	-0.113*
	(-3.068)	(-1.895)
BS	-0.033	2.613***
	(-1.064)	(4.471)
ROA	0.001	-0.303***
	(0.369)	(-3.501)
INF	0.013**	-0.095**
	(2.532)	(-2.414)
GDP	-0.012***	0.066
	(-3.173)	(1.300)
UN	0.006***	-0.083***
	(6.419)	(-5.543)
Constant	4.192***	-2.488*
	(5.290)	(-1.695)
Year FE	Included	Included
Country FE	Included	Included
Observations	1,377	1,377
Wald chi2	614.30***	2133.54***
R-squared	0.109	0.561
Number of banks	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1		

Table 17 shows that the relationship between the exchange rate and solvency varies across different scenarios. In extreme conditions, a positive and significant impact is observed (0.235, $p < 0.01$), while in moderate conditions, the relationship is negative (-0.209, $p < 0.05$). In adverse scenarios, the effect becomes positive but less significant (0.242, $p < 0.10$). For ZROA, the exchange rate shows similar trends, with a small but significant positive effect in both extreme and adverse conditions (0.045, $p < 0.05$; 0.017, $p < 0.10$) and negative effects in moderate conditions (-0.061, $p < 0.05$).

Table 17: Three scenarios for the relationship between exchange rate and solvency

Var	Solvency			ZSC		
	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)	Extreme (> 0.75)	Moderate (0.5-0.75)	Adverse (<0.5)
Exch_EX	0.235***			0.045**		
	(2.955)			(2.232)		
Exch_MO		-0.209**			-0.061**	
		(-1.991)			(-2.530)	
Exch_AD			0.242*			0.017*
			(1.840)			(1.861)
BS	0.003	0.018	-0.008	0.102***	0.101***	0.108***
	(0.015)	(0.090)	(-0.041)	(4.085)	(4.241)	(4.502)
ROAA	-0.033*	-0.037**	-0.035*	0.002	0.003	0.002
	(-1.917)	(-2.040)	(-1.878)	(0.804)	(1.003)	(0.620)
Inf	-0.044	-0.050	-0.047	-0.002	-0.001	-0.003
	(-1.356)	(-1.499)	(-1.378)	(-0.563)	(-0.332)	(-0.641)
GDP	0.025	0.024	0.030	-0.003	-0.004	-0.005
	(1.034)	(1.051)	(1.228)	(-0.934)	(-1.036)	(-1.329)
UN	0.047*	0.057**	0.069**	0.011**	0.008*	0.007
	(1.733)	(2.136)	(2.325)	(2.451)	(1.923)	(1.564)
Year FE	Included	Included	Included	Included	Included	Included
Country FE	Included	Included	Included	Included	Included	Included
Constant	2.963***	2.681***	3.021***	2.987***	3.033***	2.963***
	(4.694)	(4.514)	(5.079)	(5.428)	(5.151)	(5.251)
Observations	1,377	1,377	1,377	1,377	1,377	1,377
Wald chi2	11266.54***	17993.78***	19712.19***	3920.01***	4019.30***	3984.12***
R-squared	0.902	0.902	0.902	0.213	0.213	0.210
Number of banks	81	81	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1						

Table 18 shows that NSFR and LCR both exhibit strong negative relationships with solvency (-1.221; -1.479, $p < 0.01$), indicating that lower funding ratios are associated with worse solvency; thus, we accepted H_7. This finding is supported by the liquidity–solvency interlinkage theory and the maturity mismatch theory, which suggest that inadequate liquidity undermines a bank's ability to meet long-term obligations, thereby increasing solvency risk (Yeo & Jun, 2020; Zhang et al., 2020). In contrast, the BS shows a strong positive effect on solvency (3.711, $p < 0.01$). Additionally, ROA negatively impacts solvency (-0.307, $p < 0.01$), while inflation (INF) shows a negative relationship (-0.065, $p < 0.10$). For ZROA, NSFR, and LCR continue to exhibit negative effects (-0.015; -0.032, $p < 0.05$), while the relationship with BS is less pronounced (0.146, $p < 0.05$). Inflation (INF) positively impacts ZROA (0.015, $p < 0.01$), and GDP has a negative effect (-0.015, $p < 0.01$).

Table 18: The relationship between liquidity risk and solvency

Var	Solvency		ZROA	
NSFR		-1.221***		-0.015**
		(-3.905)		(-2.242)
LCR	-1.479***		-0.032**	
	(-4.219)		(-1.992)	
BS	3.711***	0.554***	0.146**	0.011

	(5.898)	(3.904)	(2.425)	(0.405)
ROA	-0.307***	-0.212***	0.002	0.001
	(-3.852)	(-3.763)	(0.747)	(0.288)
INF	-0.065*	-0.023	0.004	0.015***
	(-1.833)	(-0.662)	(0.763)	(2.783)
GDP	0.074	0.072*	-0.004	-0.015***
	(1.612)	(1.654)	(-0.916)	(-3.955)
UN	-0.098***	-0.101***	0.003	0.004***
	(-4.313)	(-4.240)	(0.786)	(4.631)
Year FE	Included	Included	Included	Included
Country FE	Included	Included	Included	Included
Constant	-1.171***	1.028***	2.591***	3.709***
	(-4.530)	(4.057)	(5.138)	(4.629)
Observations	1,377	1,377	1,377	1,377
Wald chi2	5317.82***	5242.58***	1491.06***	624.71***
R-squared	0.563	0.737	0.264	0.193
Number of banks	81	81	81	81
Note: Z-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1				

4.4. Mediation effect of liquidity risk

In this section, we explored the mediation effect of liquidity risk on the relationship between credit risk and solvency. Table 19 shows that credit risk (CR) has a direct negative effect on solvency (-0.842, $p < 0.01$), while liquidity risk (NSFR) has a negative influence on solvency (-1.183, $p < 0.01$). The results show that credit risk has a positive influence on liquidity risk (0.162, $p < 0.01$).

Table 19: The mediation effect of liquidity risk on the credit risk-solvency relationship

	Solvency		NSFR
NSFR		-1.183***	
		(-34.790)	
CR	-0.842***	-0.650***	0.162***
	(-9.260)	(-11.500)	(3.030)
BS	2.357***	0.417***	-1.640***
	(3.950)	(3.210)	(-5.940)
ROA	-0.277***	-0.190***	0.073***
	(-3.810)	(-4.440)	(3.040)
INF	-0.022	0.006	0.024*
	(-0.900)	(0.360)	(1.780)
GDP	0.136***	0.131***	-0.004
	(3.530)	(4.410)	(-0.260)
UN	-0.100	-0.109***	-0.007
	(-4.030)	(-5.010)	(-1.270)
Constant	-0.083	1.757***	1.392***
	(-0.060)	(3.340)	(4.810)
Observations	1,377	1,377	1,377
F(7, 1370)	630.51	1290.95***	144.20
R-squared	0.5878	0.755	0.3897
Note: T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1			

The degree of the direct and indirect impact of liquidity risk on solvency is shown in Table 20. As a result, the indirect effect/total effect ratio is 22.8, implying that liquidity risks mediate approximately 22.8% of the credit risk influence on solvency. The mediated impact is roughly 0.1 times as great as the direct effect of credit risk on solvency, as measured by the indirect effect/direct effect ratio of 29.5%. Based on the Baron and Kenny method, we have partial mediation because the coefficient of credit risk is less through the mediation role of liquidity risk (NSFR). Also, following Zhao, Lynch, and Chen's method, we have complementary partial mediation because the direct and indirect effects have a negative influence on solvency. Finally, we conclude that credit risk (CR) has a negative influence on solvency, with a mediating effect of liquidity risk (NSFR); thus, we accept H_8. This relationship is supported by the risk transmission theory and financial fragility theory, which suggest that higher credit risk weakens asset quality, leading to increased liquidity strain that further deteriorates solvency. Liquidity risk thus acts as a transmission channel through which credit risk impacts bank stability.

Table 20: Sobel Mediation Tests on the Credit Risk-Solvency Relationship

	Est	Std_err	Z	P>z
Sobel	-0.192	0.064	-3.022	0.003
Aroian	-0.192	0.064	-3.021	0.003
Goodman	-0.192	0.064	-3.023	0.003
Indirect, Direct, and Total Effects	Est	Std_err	Z	P>z
a_coefficient	0.162	0.054	3.033	0.002
b_coefficient	-1.183	0.034	-34.788	0.000
Indirect_effect_aXb	-0.192	0.064	-3.022	0.003
Direct_effect_c'	-0.650	0.057	-11.500	0.000
Total_effect_c	-0.842	0.091	-9.263	0.000
Ratio of indirect to total effect	0.228			
Ratio of indirect to direct effect	0.295			
Baron and Kenny approach	The mediation is partial.			
Zhao, Lynch, and Chen's approach	Complementary Partial mediation			

We explored the mediation effect of liquidity risk on the relationship between interest rate and solvency, as shown in Table 21. Results show that the interest rate (IR) has a direct negative effect on solvency (-0.256, $p < 0.01$), while liquidity risk (NSFR) has a negative influence on solvency (-1.115, $p < 0.01$). The results show that interest rates have a positive influence on liquidity risk (0.05, $p < 0.01$).

Table 21: The mediation effect of liquidity risk on the interest rate-solvency relationship

	Solvency		NSFR
NSFR		-1.115***	
		(-29.570)	
IR	-0.256***	-0.139***	0.105***
	(-14.180)	(-8.540)	(11.310)
BS	1.958***	0.375***	-1.420***
	(11.450)	(2.620)	(-15.800)
ROA	-0.277***	-0.203***	0.067***
	(-3.930)	(-4.560)	(5.940)
INF	-0.016	-0.002	0.013
	(-0.670)	(-0.110)	(1.000)
GDP	0.055**	0.069***	0.012
	(2.220)	(3.680)	(0.890)
UN	-0.051***	-0.079***	-0.025***
	(-4.040)	(-7.940)	(-4.440)
Constant	3.364***	16.005***	11.341***
	(2.500)	(14.080)	(15.980)
N	1377	1,377	1,377
F(7, 1369)	602.62	1099.16	173.11
R-squared	0.6145	0.7523	0.433

Note: T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The degree of the direct and indirect impact of the interest rate on solvency is shown in Table 22. As a result, the indirect effect/total effect ratio is 45.7%, implying that liquidity risks mediate approximately 45.7% of the interest rate influence on solvency. The mediated impact is roughly 0.1 times as great as the direct effect of interest rate on solvency, as measured by the indirect effect/direct effect ratio of 84.2%. Based on the Baron and Kenny method, we have partial mediation because the coefficient of interest rate is less through the mediation role of liquidity risk (NSFR). Also, following Zhao, Lynch, and Chen's method, we have complementary partial mediation because the direct and indirect effects have a negative influence on solvency. Finally, we conclude that interest rate (IR) has a negative influence on solvency, with a mediating effect of liquidity risk (NSFR); thus, we accept H_9. This finding aligns with the interest rate channel of monetary policy and liquidity stress theory, which suggests that rising interest rates increase funding costs and reduce liquid asset values, thereby heightening liquidity risk and, in turn, undermining bank solvency. Liquidity risk thus mediates the adverse impact of interest rate shocks on financial stability.

Table 22: Sobel Mediation Tests on the interest rate-solvency relationship

	Est	Std_err	Z	P>z
Sobel	-0.117	0.011	-10.565	0.000
Aroian	-0.117	0.011	-10.560	0.000
Goodman	-0.117	0.011	-10.571	0.000
Indirect, Direct, and	Est	Std_err	Z	P>z
a_coefficient	0.105	0.009	11.312	0.000
b_coefficient	-1.115	0.038	-29.573	0.000
Indirect_effect_aXb	-0.117	0.011	-10.565	0.000
Direct_effect_c'	-0.139	0.016	-8.537	0.000
Total_effect_c	-0.256	0.018	-14.180	0.000
Ratio of indirect to total effect	0.457			
Ratio of indirect to direct effect	0.842			
Baron and Kenny approach	The mediation is partial.			
Zhao, Lynch, and Chen's approach	Complementary Partial mediation			

We explored the mediation effect of liquidity risk on the relationship between exchange rate and solvency, as shown in Table 23. Results show that the exchange rate (EX) hurts solvency (-0.087, $p < 0.05$), while liquidity risk (NSFR) has a positive influence on solvency (1.466, $p < 0.01$). The results show that exchange rates have a negative influence on liquidity risk (-0.017, $p < 0.05$).

Table 23: The mediation effect of liquidity risk on the interest rate-solvency relationship

	Solvency		NSFR
NSFR		1.466***	
		(4.780)	
EX	-0.087**	-0.062**	-0.017**
	(-1.977)	(-2.068)	(-2.350)
BS	2.594***	3.684***	-0.744***
	(5.090)	(3.710)	(-3.630)
ROA	-0.310***	-0.308***	-0.002
	(-9.630)	(-19.580)	(-1.390)
INF	-0.065**	-0.067**	0.001
	(-2.430)	(-2.540)	(0.680)
GDP	0.061**	0.076***	-0.010***
	(2.370)	(2.990)	(-4.200)
UN	-0.088***	-0.096***	0.005***
	(-6.330)	(-6.710)	(5.380)

_cons	-2.674**	-12.841***	6.935***
	(-2.020)	(-5.400)	(11.980)
N	1,377	1,377	1,377
F(7, 1370_	605.19	553.54	587.42
R-squared	0.557	0.563	0.7797
Note: T-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1			

The degree of the direct and indirect impact of the exchange rate on solvency is shown in Table 24. As a result, the indirect effect/total effect ratio is 28.5%, implying that liquidity risks mediate approximately 28.5% of the exchange rate influence on solvency. The mediated impact is roughly 0.1 times as great as the direct effect of exchange rate on solvency, as measured by the indirect effect/direct effect ratio of 39.8%. Based on the Baron and Kenny method, we have partial mediation because the coefficient of exchange rate is less through the mediation role of liquidity risk (NSFR). Also, following Zhao, Lynch, and Chen's method, we have complementary partial mediation because the direct and indirect effects have a negative influence on solvency. Finally, we conclude that the exchange rate (EX) has a negative influence on solvency, with a mediating effect of liquidity risk (NSFR); thus, we accept H_{10}. This result is consistent with the exchange rate pass-through theory and currency mismatch theory, which posits that exchange rate volatility can strain liquidity, especially for banks with foreign currency exposures, thereby indirectly weakening solvency. Liquidity risk thus mediates the negative impact of exchange rate fluctuations on bank stability.

Table 24: Sobel Mediation Tests on the exchange rate-solvency relationship

	Est	Std_err	Z	P>z
Sobel	-0.025	0.012	-2.111	0.035
Aroian	-0.025	0.012	-2.075	0.038
Goodman	-0.025	0.011	-2.149	0.032
Indirect, Direct, and Total Effects	Est	Std_err	Z	P>z
a_coefficient	-0.017	0.007	-2.353	0.019
b_coefficient	1.466	0.307	4.780	0.000
Indirect_effect_aXb	-0.025	0.012	-2.111	0.035
Direct_effect_c'	-0.062	0.030	-2.068	0.042
Total_effect_c	-0.087	0.044	-1.977	0.046
Ratio of indirect to total effect	0.285			
Ratio of indirect to direct effect	0.398			
Baron and Kenny approach	The mediation is partial.			
Zhao, Lynch, and Chen's approach	Complementary Partial mediation			

Conclusion and policy recommendations

This study investigates the complex interplay between financial risks—credit risk, interest rate risk, and exchange rate risk—and two critical dimensions of bank soundness: liquidity and solvency, using a panel dataset of 81 conventional banks in the MENA region over 2007–2023. The findings underscore that banks facing higher credit risk, rising interest rates, and exchange rate volatility tend to adjust their liquidity buffers, with effects varying under different stress conditions. Notably, credit risk consistently amplifies liquidity risk, particularly under extreme scenarios, indicating the adoption of a more cautious liquidity management strategy during heightened uncertainty. Similarly, rising interest rates are associated with stronger liquidity positions, reflecting regulatory prudence and precautionary behavior in tighter monetary environments.

On the solvency front, the analysis reveals that both credit and interest rate risks exert negative effects, although their impact varies across stress levels. Liquidity risk emerges as a key mediating factor in the transmission of financial shocks to solvency, reinforcing the interconnectedness of liquidity and capital strength. Interestingly, while exchange rate fluctuations generally weaken solvency under moderate conditions, banks appear to respond more strategically in extreme and adverse scenarios, possibly leveraging favorable currency movements.

The mediation analysis provides additional insight into the underlying mechanisms. Liquidity risk serves as a significant channel through which credit, interest rate, and exchange rate shocks propagate to solvency outcomes, emphasizing the systemic relevance of liquidity management in maintaining banking sector resilience.

Given these insights, several policy implications emerge. First, regulatory authorities should adopt a more integrated approach by combining microprudential and macroprudential supervision, particularly in stress testing frameworks that capture both liquidity and solvency dimensions. Banks should be required to maintain dynamic and forward-looking liquidity buffers, especially during periods of elevated credit and market risks. Second, policymakers must enhance the capacity of financial institutions to manage interest rate and exchange rate risks through stronger risk governance, asset–liability management practices, and hedging mechanisms. Stress testing should account for nonlinear and scenario-specific responses to ensure adequate capital and liquidity coverage. Finally, financial sector reforms that promote transparency, risk disclosure, and countercyclical buffers will be essential in improving the resilience of MENA banks to external shocks, including geopolitical uncertainties, volatile capital flows, and macro-financial instability.

While this study offers comprehensive insights, future research could explore cross-country heterogeneity in bank responses to risk shocks, particularly in the presence of different regulatory regimes or macroeconomic environments. Further analysis incorporating Islamic banks or digital banking trends could also shed light on comparative risk behaviors. Additionally, the role of institutional quality, geopolitical stability, and ESG integration in moderating these financial linkages represents a valuable direction for expanding this research agenda.

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