THE RELATIONSHIPS BETWEEN CREDIT RISK, LIQUIDITY RISK, AND BANK STABILITY IN UKRAINE

by

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2SLS Two-stage least squares

ATR Acid Test Ratio

CPI Consumer Price Index

CPL Cost per Loan

CR Capital Ratio

CR Current Ratio

CRI Credit Risk

DR Deposit Ratio

ER Efficiency Ratio

GDP Gross Domestic Product

GMM Generalized Method of Moments

LDR Loans to Deposit Ratio

LR Loans Ratio

LRI Liquidity Risk

MENA Middle East and North Africa

MNAR Missing not at random

NA Not available

NPL Non-performing loans

OLS Ordinary least squares

ROA Return on Assets

ROE Return on Equity

SUR Seemingly unrelated regression

CHAPTER 1. INTRODUCTION

As Ukraine is an emerging market, its banking sector provides a compelling context to examine the relationship between credit risk and liquidity risk. Over the past years, the sector has been confronted with various formidable challenges, including political instability, economic turmoil, ongoing war with Russia, and the impact of the COVID-19 pandemic. Consequently, these factors have significantly elevated credit risk and liquidity risk, posing obstacles to banks' profitability and stability.

The Ukrainian banking system is currently facing a challenging situation. On the one hand, there is a dire budget deficit in the country. On the other hand, the banks are inundated with excess liquidity, estimated at around UAH 400 billion, namely deposit certificates plus balances on correspondent accounts. Banks are being reluctant to invest in government bonds due to low interest rates as they are significantly lower than the interest rates of deposit certificates (Vinokurov, Economichna Pravda ("Economic Truth"), 2022).

Excess liquidity may result in significant inflation and instability in the currency market. To overcome this challenge, it is vital to guarantee cooperation between banks, especially those that are state-owned, and the Ministry of Finance. One of the ways to minimize the risk of excess liquidity is to ensure the flow of funds from demand deposit accounts to fixed-term financial instruments. For this, banks and the government must encourage Ukrainian people and businesses to invest in fixed-term financial instruments, mainly using more attractive interest rates. Moreover, the Ministry of Finance should communicate to all financial institutions a clear roadmap regarding the strategy for reforms of the state banking sector (Shevchenko, LB.ua, 2023).

Another point to consider, the credit risk of the banks measured as non-performing loans (NPLs) has been increasing since the start of the full-scale war. In April 2023, it reached 38.8%. In monetary terms, this corresponds to UAH 435 billion. The high NPL ratio in Ukrainian banks is indicative of persistent imbalances within the banking system.

Non-performing loans hurt banks by reducing their profits due to losses and requiring them to set aside funds (provisions) to cover expected losses. This limits their ability to provide new loans and weakens their financial health. When many banks face this issue, it can impact the overall economy by hindering credit availability for businesses, investments, and job creation. To address this issue, it is crucial for banks to update and enhance their strategies for NPL reduction (National Bank of Ukraine. Financial Stability. Loan Portfolio Quality (NPLs), n.d.).

As both credit risk and liquidity risk are generally considered the most important risks in the banking sector, it makes sense to investigate the relationship between them and their influence on the bank's stability. The findings of the research will be helpful for many stakeholders, among them banking managers and policymakers, to help the industry overall manage the risks more efficiently. This will make the banking industry more sustainable and resilient, contributing to long-term stability and the inflow of foreign investment.

The research aims to achieve several goals. First of all, it focuses on the relationship between credit risk and liquidity risk and their effect on each other. Secondly, it is planned to investigate the separate and mutual impact of credit risk and liquidity risk on the banks' stability. Besides, the study intends to distinguish the impact of the abovementioned risk on the different types of banks, depending on their size. Lastly, the study aims to provide practical implications for bank managers and regulators to effectively manage and monitor liquidity and credit risks, particularly during the ongoing war.

In this research, two hypotheses are tested. The first hypothesis suggests a positive relationship between liquidity risk and credit risk, indicating that they tend to increase or decrease in conjunction with each other. The second hypothesis suggests that credit risk and liquidity risk, individually and/or jointly, have a positive effect on the probability of default. This implies that when credit risk and liquidity risk are present, the bank's stability decreases.

The research utilizes panel data for Ukrainian banks covering the period from January 2016 to March 2023 on a quarterly basis. The reason for starting the data collection from 2016 is due to the transformation of the Ukrainian banking system during that year.

The National Bank of Ukraine (Statistics. Supervisory Data) is the source of all bank-specific information collected for the research.

The thesis is organized into several chapters. Chapter 2 provides an overview of the Ukrainian banking industry, incorporating relevant studies that have been conducted in this field. Chapter 3 discusses the data sources and methodology employed in the research, including the regression equations used for analysis. In Chapter 4, the description of the data is provided. In Chapter 5, the findings of the regression analysis are presented and interpreted. Finally, Chapter 6 concludes the study by summarizing the results, providing recommendations for stakeholders in the banking sector, and suggesting avenues for future research.

CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

2.1. Previous studies on the relationship between credit and liquidity risk

The relationship between credit risk and liquidity risk is subject to varying perspectives among the studies.

Cai and Zhang (2015) examined Ukrainian banks and validated the traditional financial intermediation theory, finding a positive relationship between credit risk and liquidity risk. They noted that this positive association was particularly evident in larger and foreign-owned banks. Supporting this viewpoint, Abdelaziz, Rim, and Helmi (2020) studied the Middle East and North African (MENA) countries and found evidence of a positive and reciprocal relationship between credit risk and liquidity risk.

In contrast, Ejoh, Okpa, and Inyang (2014) focused on deposit money banks in Nigeria and emphasized that an increase in credit risk is accompanied by a corresponding rise in liquidity risk. Their findings suggest a linkage between these two risks in the Nigerian banking context.

However, Imbierowicz and Rauch (2014), Ghenimi, Chaibi, and Omri (2017), and Amara and Mabrouki (2019) present alternative viewpoints. Imbierowicz and Rauch (2014) investigated US banks and found no meaningful economic relationship between liquidity risk and credit risk. They suggest that the impact of these risks on default probability should be assessed independently.

Similarly, Ghenimi, Chaibi, and Omri (2017) reported no significant reciprocal relationship between credit risk and liquidity risk in the MENA region. They emphasize the individual effects of each risk on bank stability, suggesting that the two risks should be considered separately. Amara and Mabrouki (2019) conducted research in Tunisia and found no significant relationship between credit risk and liquidity risk in terms of their impact on each other. Their findings suggest a limited influence of the interaction between these risks on the bank's stability.

Overall, some studies suggest a positive relationship and reciprocal nature, while others indicate no significant relationship or limited influence on stability. These findings

contribute to the understanding of the complexities involved in assessing and managing credit and liquidity risks in the banking sector.

2.2. Previous studies on the effects of the risks on bank's performance

The relationship between credit risk, liquidity risk, and a bank's financial stability has been extensively studied in the literature, revealing important insights into the dynamics of these factors.

Imbierowicz and Rauch (2014) shed light on the impact of these risks on the default probability of US banks. They found that the effects are twofold: individually, both credit risk and liquidity risk increase the likelihood of default, and their interaction can either mitigate or exacerbate this probability, depending on various factors.

Contrasting findings are presented by Amara and Mabrouki (2019), who examined the Tunisian banking sector. Their research suggests that the interaction between credit and liquidity risk does not significantly influence the stability of Tunisian banks, highlighting the potential variations in the relationship across different regions and contexts. Cheng, Nsiah, Charles, and Ayisi (2020) explored the impact of these risks on bank profitability in South Africa. Their findings indicate a significant positive relationship between risks, both contributing to the profitability of commercial banks.

Ghenimi, Chaibi, and Omri (2017) focused on the MENA region and highlighted the individual effects of credit risk and liquidity risk on bank stability. Their research revealed that both risks have independent impacts, and when combined, they can lead to instability in the banking sector within the region.

Exploring the Nigerian banking sector, Ejoh, Okpa, and Inyang (2014) found that credit and liquidity risk jointly influence the likelihood of banks facing default. Their study underscores the importance of considering the combined impact of the risks on stability.

Abdelaziz, Rim, and Helmi (2020) corroborated the inverse relationship between credit risk, liquidity risk, and bank profitability in the MENA region. They noted that an increase in the risks adversely affects the profitability of banks, irrespective of whether they are considered separately or in interaction with each other. Adding to the literature, Saputra,

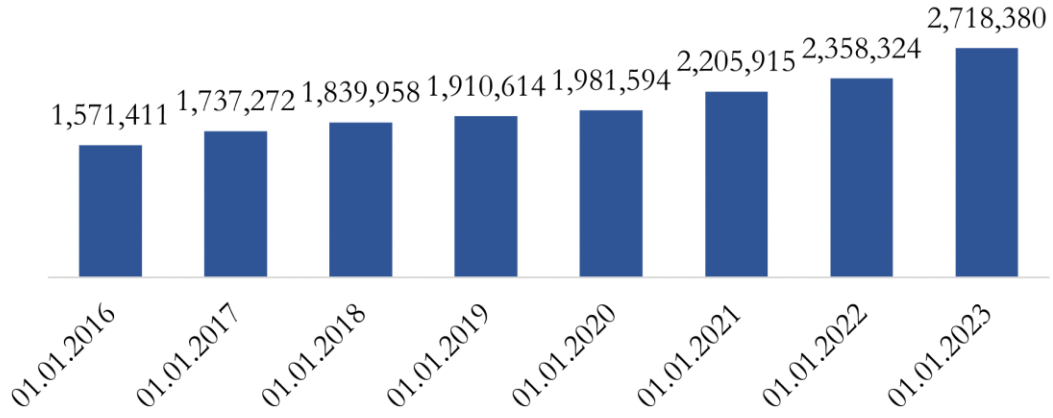
Najmudin, and Shaferi (2020) examined the Indonesian banking sector and found that credit and liquidity risks have a significant negative effect on bank stability, albeit partially.

The abovementioned studies present conflicting studies regarding the separate and joint effects of credit risk and liquidity risk on a bank's stability and/or financial performance. As this issue was not investigated in the European arena, the current study aims to fill this gap while using the existing literature as guidance.

2.3. Ukrainian banking sector overview

The Ukrainian banking system underwent a reform in 2015-2016, leading to a significant reduction in the number of banks from 117 at the beginning of 2016 to just 67 by the end of 2022. Despite the consolidation of the sector, the total assets of the banking system have increased from almost UAH 1.6 trillion to more than UAH 2.7 trillion over the observed period (Figure 1).

Figure 1. Total assets (not adjusted for assets provisions) of the Ukrainian banking sector (2016-2023), UAH million

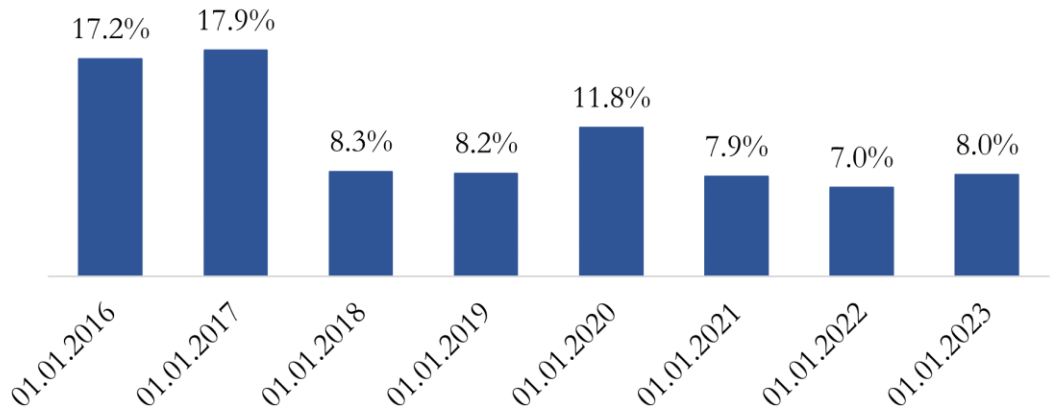


Source: National Bank of Ukraine. Statistics. Supervisory Data

The liquidity ratio (Figure 2) of the Ukrainian banking sector has been volatile over the period of 2016 to 2023, ranging from 7.0% to 17.9%. This ratio represents the proportion of cash and cash equivalents held by banks compared to the total amounts due to banks and due to customers. The highest liquidity ratio of 17.9% was observed in 2017, indicating

a high preparedness of banks to cover all their obligations, while the lowest ratio of 7.0% occurred in 2022, suggesting a problem for banks to meet their short-term obligations.

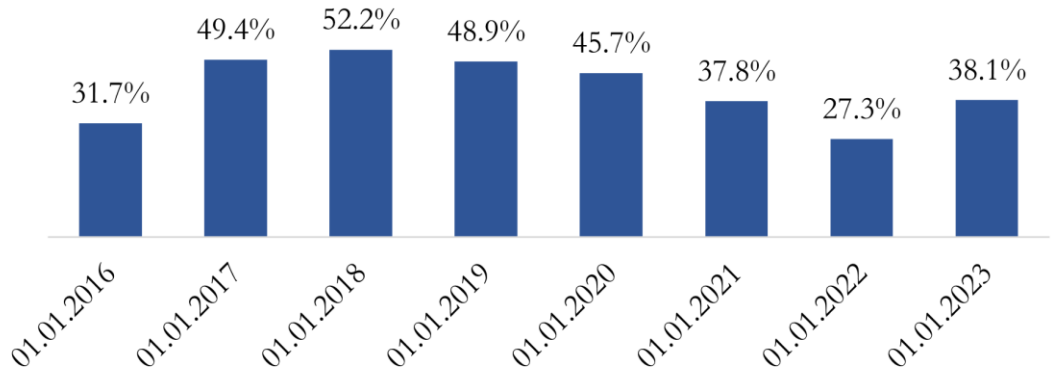
Figure 2. Liquidity ratio (Cash and cash equivalents / (Amounts due to customers + Amounts due to banks)) of the Ukrainian banking sector (2016-2023), %



Source: The author's calculations based on the data from the National Bank of Ukraine. Statistics. Supervisory Data

As of January 1, 2023, the non-performing loans (NPL) ratio in the Ukrainian banking sector stood at 38.1%, equivalent to UAH 432 billion (Figure 3). This increase was primarily due to the recognition of corporate NPLs by the banks. Throughout 2022, the NPL ratio grew from 27.3% in January 2022 by 11.4 percentage points, with a more substantial increase observed in retail loans. Notably, state-owned banks (excluding PrivatBank) and private banks experienced the most significant rise in the NPL ratio over the year, with 14.0 and 13.1 percentage points, respectively.

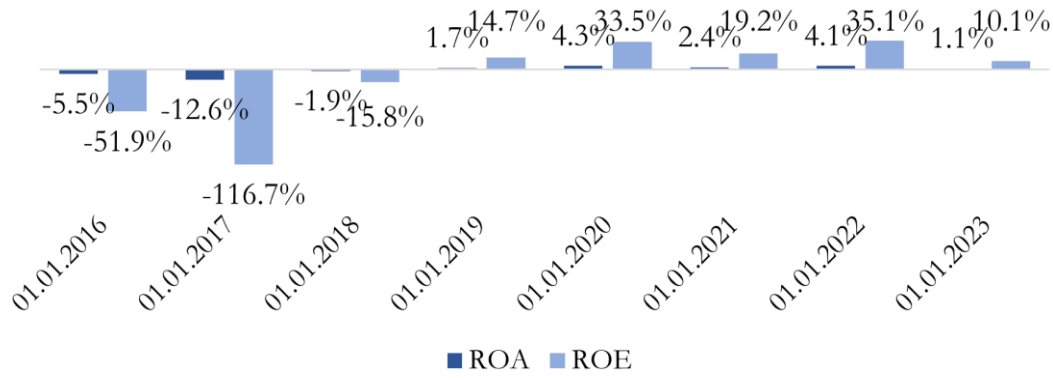
Figure 3. Non-performing loans (NPL) ratio of the Ukrainian banking sector (2016-2023), %



Source: National Bank of Ukraine. Financial Stability. Loan Portfolio Quality (NPLs)

During the observation period, the return on assets (ROA) of Ukrainian banks reached its highest point in March 2020, standing at 6.35%. However, it experienced a declining trend in April-July 2022. By the end of 2022, the ROA of Ukrainian banks had recovered to 1.1 percent, indicating an improvement in their asset profitability compared to the previous downward trend. Return on equity (ROE) stood at 10.1% at the end of 2022 (Figure 4).

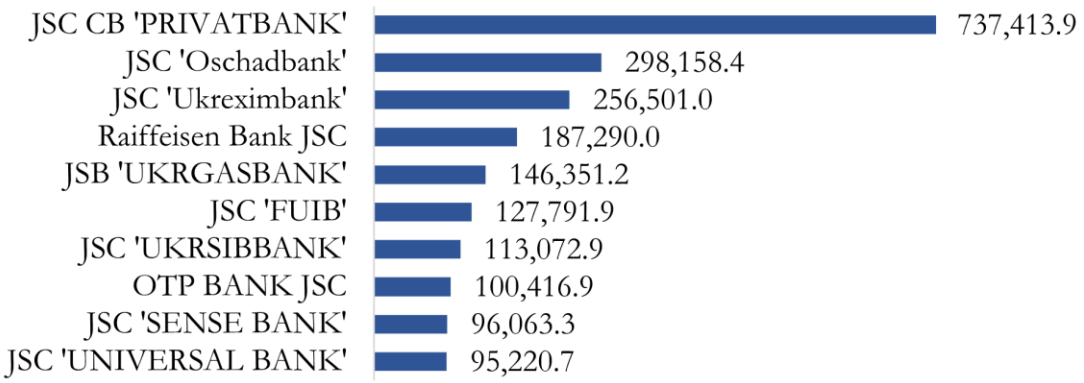
Figure 4. ROA and ROE of the Ukrainian banking sector (2016-2023), %



Source: The author's calculations based on the data from the National Bank of Ukraine. Statistics.Supervisory Data

Privatbank is the largest Ukrainian bank by total assets, with more than two times higher value (UAH 737 billion) than the second-largest bank, Oshadbank, with almost UAH 300 billion at the end of 2022 (Figure 5). Ukreximbank, Raiffeisen Bank, and Ukrgasbank took the third, fourth, and fifth places, respectively. Only two banks among the Top 10 — Sense Bank and Universal Bank — have less than UAH 100 billion in total assets at the end of 2022.

Figure 5. Largest Ukrainian banks by total assets in 2023, UAH million



Source: The author's calculations based on the data from the National Bank of Ukraine. Statistics.Supervisory Data

The findings of the industry description represent, first of all, the instability and volatility of the Ukrainian banking sector and economy overall. After the transformation of the banking sector, the NPLs ratio and profitability indicators (ROA and ROE) started to stabilize; however, they were again disrupted as the full-scale war started. The significant reduction in the number of banks is essential to the research paper, as almost 50% of the banks were liquidated from 2016 to the beginning of 2023, and their licences were revoked due to poor risk management and financial instability. In this context, the sustainability of total assets growth should be further analyzed.

As credit risk and liquidity risk are currently the highest for more than two years, the importance of investigating the relationship is exceptionally high. As many banks face

higher instability due to the war, the relationship between both risks and the bank's probability of default is essential.

2.4. Relevance of the study

This study is highly relevant as it fills a crucial gap in the existing research, particularly regarding the relationship between credit and liquidity risks and their influence on the probability of default among Ukrainian banks. Previous studies on Ukrainian banks, such as Cai and Zhang (2015), have predominantly concentrated on examining the connection between credit risk and liquidity risk, leaving the understanding of how both risks separately and jointly impact the probability of default unexplored.

Moreover, this research aims to examine the influence of various significant factors that have shaped the banking sector in Ukraine, including the banking system transformation in 2015, the COVID-19 pandemic, and the ongoing full-scale war. These events have had substantial implications for the Ukrainian banking sector, and understanding their impact on credit and liquidity risks is crucial.

Additionally, the study considers the high number of non-performing loans, which stood at 38.8% as of April 1, 2023, and the issue of excess liquidity, with UAH 400 billion remaining underutilized. By analyzing these factors, the research provides valuable insights into the relationship between credit and liquidity risks and their consequences for the stability of Ukrainian banks in the current challenging economic context.

CHAPTER 3. METHODOLOGY

3.1. Research methodology

The methodology presented in this paper is based on various previous studies focused on the relationships between the bank's risks and the performance of the bank.

The first objective of this study is to test the hypothesis regarding the positive relationship between credit risk and liquidity risk. This entails examining whether these risks tend to increase or decrease in tandem.

The second objective involves testing the hypothesis regarding the separate and joint negative impact of credit risk and liquidity risk on a bank's stability, represented as the inverse probability of default.

Furthermore, the research explores how the effects of both credit risk and liquidity risk vary depending on the size of the bank, distinguishing between small and large banks based on their total assets.

3.2. Accounting for potential endogeneity

As the direction of the relationship between credit risk and liquidity risk is unknown, it is essential to perform two regressions: in the first, credit risk will be considered the dependent variable, and liquidity risk will be the independent variable.

In the second regression, liquidity risk should be the dependent variable, while credit risk should be the independent. However, this approach may introduce endogeneity issues that need to be addressed.

As a first step to test for endogeneity, credit risk is regressed on liquidity risk, and the residuals from this model are obtained. In the second step, a second inverse regression is performed, where liquidity risk is regressed on credit risk. Residuals saved from the first model estimation are included in the second model as an explanatory variable. The aim is to test whether the residuals are statistically significant in the second regression. If they are statistically significant, it is a sign of endogeneity. Therefore, the two-stage least squares

(2SLS) method should be used instead of the simple OLS to get efficient and unbiased estimates.

In our case, the residuals show statistical significance that indicates endogeneity. Consequently, ordinary least squares (OLS) regression cannot be used. Instead, we will employ the 2SLS regression method to address the endogeneity issue and obtain reliable estimates of the relationship between credit risk and liquidity risk.

3.3. Handling missing data

During the period spanning from the start of 2016 to the close of 2022, the Ukrainian banking landscape underwent a significant transformation marked by substantial legislative alterations.

This transformation led to a notable reduction in the number of active banks, decreasing from an initial count of 117 to a final tally of 67. A considerable portion of these banks faced liquidation and the subsequent revocation of their licenses.

In our dataset, we have complete and comprehensive data for a subset of 69 banks spanning 29 periods. However, there is a notable gap in data for the remaining 43 banks, with a total of 981 missing values (NAs) across the entire dataset.

In our case, the missing data pattern is associated with other variables in the dataset, and, importantly, the missing values do not occur randomly (Harrison, n.d.). We should be cautious with handling data missing not at random (MNAR) because it cannot be deleted as important patterns may be lost. That is why, for our regression estimation, the whole dataset, including the NAs, is used for econometric modelling.

3.4. Hypotheses testing and model specification

Hypothesis 1: Liquidity risk and credit risk have a positive relationship, meaning they tend to increase or decrease together.

To test the first hypothesis that credit risk and liquidity risk have a positive relationship, the following regressions are estimated using a simultaneous equation approach (Imbierowicz & Rauch, 2014; Ghenimi et al., 2017):

$$CRI_{bt} = \beta 0 + \beta 1 CRI_{bt-1} + \beta 2 LRI_{bt} + B_{bt}\delta + M_t\delta + \epsilon_b + \varepsilon_{bt} \quad (1),$$

$$LRI_{bt} = \beta 0 + \beta 1 LRI_{bt-1} + \beta 2 CRI_{bt} + B_{bt}\delta + M_t\delta + \epsilon_b + \varepsilon_{bt} \quad (2),$$

where CRI_{bt} represents the credit risk of bank b in quarter t, measured by the bank's non-performing loans (NPL) ratio. The variable LRI_{bt} represents the liquidity risk of bank b in quarter t, measured by the inverse of the liquidity ratio. Lags of dependent variables are used to account for possible time-lagged relationships between the credit risk and liquidity risk variables.

Vector B_{bt} is a set of bank-specific control variables for bank b at time t, which contains the Return on Assets (ROA), Return of Equity (ROE), Efficiency ratio (ER), Capital ratio (CR), Loans ratio (LR), Size of the bank (SIZE). Vector M_t is a set of macro variables at time t, which contains the Consumer Price Index (CPI) as an inflation measure and real GDP growth.

The equations are estimated using the Generalized Method of Moments (GMM) estimation, specifically the two-steps method, which is suitable for dynamic models with panel data.

Instrumental variables that are likely to affect the dependent variables but are not correlated with the error term control for endogeneity in both models. As instrumental variables, lags of the variable X (credit risk or liquidity risk depending on the regression) from 2 to 29 are used along with specific variables. Return on Equity and Capital Ratio for the credit risk regression and Efficiency Ratio and Loans Ratio for the liquidity risk regression (Ghenimi et al., 2017).

Fixed effects for the abovementioned regressions are included only at the bank level (ϵ_b) to control for unobservable bank-invariant fixed effects. Time-fixed effects are not included, and the model is estimated using the individual effects to prevent overidentification of the model, as confirmed by the Sargan test. Finally, ε_{bt} is the error term.

Hypothesis 2: Individual impact and/or simultaneous presence of credit risk and liquidity risk increases the probability of default for banks, leading to decreased stability.

To test the second hypothesis that credit risk and liquidity risk negatively impact the bank's stability, the following regression is used (Imbierowicz & Rauch, 2014; Ghenimi et al., 2017):

$$Z\_SCORE_{bt} = \beta 0 + \beta 1 Z\_SCORE_{bt-1} + \beta 2 LRI_{bt} + \beta 3 CRI_{bt} + \beta 4 CRI_{bt} * LRI_{bt} + B_{bt}\delta + M_t\delta + \epsilon_b + \varepsilon_{bt} \quad (3),$$

where Z_SCORE_{bt} represents the stability of bank b in quarter t, which is inversely related to the bank's probability of default. The lag of a dependent variable is used to account for the persistence in the stability of a bank over time.

CRI_{bt} represents the credit risk of bank b in quarter t. LRI_{bt} represents the liquidity risk of bank b in quarter t. The interaction between both risks is estimated as $CRI_{bt} * LRI_{bt}$.

Vector B_{bt} is a set of bank-specific control variables for bank b at time t, which contains the Efficiency ratio (ER), Capital ratio (CR), Loans ratio (LR), Size of the bank (SIZE).

Vector M_t is a set of macro variables at time t, which contains the Consumer Price Index (CPI) as an inflation measure and real GDP growth.

This equation is as well estimated using the Generalized Method of Moments (GMM) estimation (one-step method). Lags of thedependent variable Z_SCORE are used as instrumental variables as in the two regressions regarding the first hypothesis.

Individual fixed effects (ϵ_b) control for bank-specific effects that influence the model. As usual, ε_{bt} is the error term.

The research approach explained above draws inspiration from widely established methodologies utilized in relevant papers mentioned in the literature review. Specifically, the econometrics modeling in this study follows a similar approach to Ghenimi, Chaibi, and Omri (2017) and, to a lesser extent, Imbierowicz and Rauch (2014) and Abdelaziz, Rim, and Helmi (2020).

These papers serve as references and provide guidance for the methodological framework adopted in the current research. By building upon the methodologies employed in these previous studies, the current research aims to contribute to the existing body of knowledge in a similar domain.

CHAPTER 4. DATA

4.1. Variables and their measures

The dataset consists of 29 quarterly periods (covering the period from January 2016 to March 2023) in which financial and operational data of 112 Ukrainian banks is presented.

The dataset used in the study consists of 3,248 observations with NAs and 2,267 observations without NA. The number of unavailable observations (981) is explained by the fact that many banks collapsed and/or were liquidated due to numerous reasons. As an indication of the high number of NAs, 117 banks were operating in Ukraine at the beginning of 2016 (the start of the investigated period), while only 67 were financially stable to continue their operation by the end of 2022. By including all banks, even liquidated ones, in the analysis, the selection bias is excluded, as banks that actually defaulted are included in the regression models.

The dataset includes 12 variables of interest, as well as bank identification and time-period variables (Table 1). Data is taken from the National Bank of Ukraine (Statistics. Supervisory Data).

The dependent variables are Credit Risk (CRI), Liquidity Risk (LRI), and Z-Score (Z_SCORE). CRI measures a bank's exposure to potential losses caused by non-performing loans. These are loans where borrowers have stopped repaying, posing a financial risk. CRI assesses a bank's ability to manage credit risk, which is crucial for financial stability.

LRI focuses on a bank's capacity to meet short-term financial obligations. It is linked to the Liquidity ratio, comparing cash and cash equivalents to amounts due to banks and customers. A lower LRI suggests higher liquidity risk, which can affect a bank's solvency.

Z_SCORE assesses a bank's financial stability inversely to the probability of default. It is calculated by summing Return on Assets (ROA) with Total Equity divided by Total Assets. Then, the sum is divided by the standard deviation of the Return on Assets

(ROA) over the given period of 29 quarters. A higher Z-Score indicates greater financial stability, providing insights into a bank's resilience to economic challenges (World Bank, n.d.).

Including bank-specific variables, such as Return on Assets (ROA), Return on Equity (ROE), Efficiency Ratio (ER), Capital Ratio (CR), Deposit Ratio (DR), Loans Ratio (LR), and Size of the Bank (SIZE) allows regression model to account for the unique characteristics of each bank, enabling a better assessment of how several internal factors impact the dependent variables, namely credit risk or liquidity risk.

Table 1. Variables and their measures

1. Dependent variables		
Credit risk (CRI)	Non-performing loans / Total loans	(Cai & Zhang, 2015; Hakimi et al., 2020)
Liquidity risk (LRI)	The inverse of the Liquidity ratio: Cash and cash equivalents / (Amounts due to banks + Amounts due to customers)	(Cai & Zhang, 2015; Amara & Mabrouki, 2019)
CRI:LRI	The interaction between credit risk and liquidity risk	(Hakimi et al., 2017; Ghenimi et al., 2017)
Z-Score (Z_SCORE)	The measure of a bank's stability, which is inversely related to the probability of default: log((ROA + (Total equity / Total assets)) / standard deviation(ROA))	(Imbierowicz & Rauch, 2014; Amara & Mabrouki, 2019)
2a. Independent internal variables		
Return on Assets (ROA)	Pre-tax profit / Total assets	(Cai & Zhang, 2015; Hakimi et al., 2017)
Return on Equity (ROE)	Pre-tax profit / Total equity	(Ghenimi et al., 2017; Amara & Mabrouki, 2019)
Efficiency ratio (ER)	Operating expenses / Total income	(Cai & Zhang, 2015; Imbierowicz & Rauch, 2014)

Capital ratio (CR)	Total equity / Total assets	(Hakimi et al., 2017; Ghenimi et al., 2017)
Deposit ratio (DR)	Total deposit / Total assets	(Cai & Zhang, 2015)
Loans ratio (LR)	Loans / Total assets	(Cai & Zhang, 2015; Ghenimi et al., 2017)
Size of the bank (SIZE)	log(Total assets)	(Hakimi et al., 2017; Ghenimi et al., 2017)
2b. Independent external (macro) variables		
Consumer price index (CPI)	Inflation measure (as of the end of the period, % yoy)	(Amara & Mabrouki, 2019; Hakimi et al., 2020)
Gross Domestic Product (GDP)	Real GDP, at 2016 constant prices (% yoy)	(Ghenimi et al., 2017; Amara & Mabrouki, 2019)

4.2. Descriptive statistics

Table 2 provides a summary of key variables used in the analysis. Notably, Credit Risk (CRI) and Liquidity Risk (LRI) show high volatility, with relatively low means but substantial standard deviations. Return on Assets (ROA) and Return on Equity (ROE) are centered around zero, indicating similar low profitability of all banks. Efficiency Ratio (ER) shows high variability with a wide range from negative to positive values. Capital Ratio (CR), Deposit Ratio (DR), Loans Ratio (LR), and Size of the Bank (SIZE) appear relatively stable. Consumer Price Index (CPI) and Gross Domestic Product (GDP) also display limited fluctuations. Z-Score reveals moderate variability in measuring bank stability.

Table 2. Descriptive statistics

	Mean	St. Dev.	Min	Pctl (25)	Median	Pctl (75)	Max
CRI	0.2	0.2	0.0	0.1	0.1	0.3	1.0
LRI	12.5	20.6	0.000	5.4	9.3	14.2	437.0
ROA	-0.004	0.1	-4.1	0.000	0.004	0.01	0.5
ROE	-0.003	0.5	-11.6	0.001	0.002	0.1	4.1
ER	0.4	10.2	-454.0	0.4	0.6	0.9	99.2
CR	0.2	0.2	-2.7	0.1	0.2	0.3	1.0
DR	0.6	0.2	0.0	0.4	0.6	0.7	1.3
LR	0.4	0.2	0.0	0.3	0.4	0.6	1.0
SIZE	15.1	1.9	9.2	13.7	14.7	16.3	20.4
CPI	0.1	0.1	0.02	0.1	0.1	0.2	0.3
GDP	-0.0	0.1	-0.4	-0.02	0.02	0.03	0.1
Z_SCORE	2.4	1.3	-3.7	1.8	2.5	3.2	7.5

4.3. Correlation matrix

Analyzing the statistically significant correlations of CRI, LRI, and Z_SCORE with other variables (Table 3), the following observations can be made: credit risk (CRI) is negatively correlated with profitability measures such as Return on Assets (ROA) and Return on Equity (ROE), indicating that increased credit risk is associated with lower profitability.

Moreover, CRI displays a positive correlation with bank size (SIZE), suggesting that larger banks may have higher credit risks. Furthermore, CRI exhibits a strong negative correlation with the deposit ratio (DR), indicating that higher credit risk is associated with a lower proportion of deposits to total assets, potentially indicating challenges in attracting stable funding sources.

CRI also demonstrates a strong negative correlation with the loans ratio (LR), suggesting that higher credit risk is associated with a lower proportion of loans to total

assets, reflecting a cautious lending approach by banks. Lastly, CRI has a negative correlation with the Z-SCORE, indicating that higher credit risk may increase the probability of default and reduce the Z-Score, a measure of financial health.

Table 3. Correlation matrix

	CRI	**LRI**	**ROA**	**ROE**	**ER**	**CR**	**DR**	**LR**	**SIZE**	**CPI**	**GDP**	**Z_ SCORE**
CRI	1											
LRI	-0.003	1										
ROA	-0.18 ***	0.02	1									
ROE	-0.18 ***	0.01	0.33 ***	1								
ER	-0.04	0.002	0.14 ***	0.05	1							
CR	-0.08 **	-0.09 ***	0.12 ***	-0.03	-0.01	1						
DR	-0.24 ***	0.03	0.07 *	0.11 ***	0.004	-0.66 ***	1					
LR	-0.22 ***	-0.06	-0.01	0.02	0.01	-0.12 ***	0.24 ***	1				
SIZE	0.16 ***	0.07	0.11 ***	0.05	0.03	-0.65 ***	0.41 ***	0.02	1			
CPI	0.01	-0.02	-0.03	-0.03	-0.01	-0.01	0.03	-0.03	0.01	1		
GDP	0.05	-0.05	-0.01	0.01	-0.02	0.10 ***	-0.07 *	0.20 ***	-0.12 ***	-0.62 ***	1	
Z_ SCORE	-0.27 ***	-0.19	0.17 ***	0.22 ***	0.02	0.38 ***	-0.07 *	0.10 ***	-0.37 ***	-0.03	0.04	1

*p<0.1; **p<0.05; ***p<0.01; Pearson's correlation; p-value adjustment method: Holm (1979)

LRI has a statistically significant negative correlation with capital ratio (CR), which is intuitive. The higher the amount of equity to risk-weighted assets, the lower the liquidity risk. The right balance between liquidity and capital is important to ensure a bank's strong

financial position. The relationship between CRI and LRI is weak and statistically insignificant, indicating no significant relationship between credit risk and liquidity risk.

The strong negative correlation of Z_SCORE with SIZE implies that large banks may have lower Z-Scores, thus a higher probability of default and lower financial stability. This may be explained by the fact that larger banks face more increased challenges while managing risks than smaller banks. The positive correlation of the Z_SCORE variable with CR (capital ratio) suggests that banks with higher levels of capital are less likely to default, as measured by the high Z-Score. This finding is consistent with the expectation that higher levels of capital provide security against financial distress and enhance the bank's stability.

The weak negative correlation between Z_SCORE and DR (deposit ratio) suggests that a higher deposit ratio is associated with a lower Z-Score. This finding indicates that banks with higher dependence on customer deposits may be exposed to increased instability. Regarding the positive correlation between LR (loans ratio) and Z_SCORE, banks that feel confident about their stability tend to be more willing to extend loans and increase their lending activities.

Z_SCORE also has significant positive correlations with profitability measures (ROA and ROE), which is intuitively understandable as banks that are profitable will have higher stability and are less likely to default, as indicated by the higher Z_SCORE.

CHAPTER 5. RESULTS

5.1. Hypothesis 1

Liquidity risk and credit risk have a positive relationship, meaning they tend to increase or decrease together.

Table 4. Individual effect two-steps GMM model with LRI and CRI as dependent variables

	Dependent variable:	
	CRI (1)	**LRI (2)**
lag(CRI, 1)	0.771***	
	(0.052)	
LRI	0.00001	
	(0.0001)	
lag(LRI, 1)		-0.090*
		(0.049)
CRI		4.834
		(5.951)
SIZE	0.013*	3.191
	(0.007)	(3.130)
ROA	-0.204***	10.306
	(0.043)	(11.456)
DR	-0.006	10.615
	(0.033)	(11.332)
LR	-0.059	
	(0.040)	
ER	0.0001	
	(0.0001)	
GDP	-0.025	-6.942
	(0.031)	(5.128)
CPI	0.145**	-1.348
	(0.057)	(8.053)
ROE		-0.235
		(0.943)
CR		-20.696
		(13.559)

Sargan test	chisq(431) = 85.19883 (p-value = 1)	chisq(431) = 85.19883 (p-value = 1)
Autocorrelation test (1)	-3.399653 (p-value = 0.00067471)	-1.606504 (p-value = 0.10816)
Autocorrelation test (2)	normal = 0.6635519 (p-value = 0.50698)	normal = 0.6093592 (p-value = 0.54229)
Wald test for coefficients	chisq(9) = 298.5241 (p-value = < 2.22e-16)	chisq(9) = 19.47452 (p-value = 0.021447)

*p<0.1; **p<0.05; ***p<0.01; standard error in parenthesis

The diagnostics of the models indicate that there is no endogeneity as overidentification restrictions are not violated according to the Sargan test. The autocorrelation test (2) suggests that there is no second autocorrelation in both models. This assumption implies that the error terms in the model are assumed to be uncorrelated with each other. It allows a more consistent model estimation and ensures no underestimation of the true standard deviation of the estimated regression coefficients. The Wald test for coefficients shows that at least one of the coefficients in each model is statistically significant (Table 4).

As the regression models above indicate, credit risk and liquidity risk do not have any meaningful economic relationship. Therefore, the first hypothesis about the positive relationship between credit and liquidity risk cannot be confirmed. This is consistent with most of the findings of other academic research papers (Imbierowicz & Rauch, 2014; Ghenimi et al., 2017; and Amara & Mabrouki, 2019).

However, the study provides conflicting results with the paper of Cai and Zhang (2015), that as well examined the Ukrainian banking industry, although in a different timeframe (2009-2015). There may be two explanations for this result. Firstly, due to the banking system transformation as well as due to challenges posed by COVID-19 and Russian aggression against Ukraine, banking management approaches to overcoming risks may have changed. Previously, risks may have been managed in conjunction with each other, while starting from 2016, the risks may be controlled separately, which results in a lack of co-movement between the two risks. Secondly, significant changes in the variables

and their volatility as a response to the abovementioned challenges may have influenced the co-movement between the two variables.

Another finding worth noting is that the credit risk variable (CRI) has a statistically significant negative effect on the bank's profitability measured by the Return on Assets (ROA). This aligns with the economic intuition, as banks with higher credit risk will have lower financial performance due to increased loan defaults and higher provisions for potential losses.

Two other important findings also relate to the credit risk variable (CRI) that has a statistically significant positive relationship with the consumer price index (CPI) and bank size (SIZE). In the first case, the positive coefficient may be explained by the fact that rising prices and inflation in the country are associated with higher credit risk. As the purchasing power of consumers decreases due to inflation, they may find it hard to repay their debts. The same relates to businesses that attain loans from banks.

The positive coefficient near the bank's size is in line with the results of the correlation matrix (Table 3). That may result from more complex operations and a broader loan portfolio of larger banks that may increase the share of non-performing loans in the total bank's portfolio.

5.2. Hypothesis 2

The separate presence, as well as the interaction between credit risk and liquidity risk, decreases bank stability, increasing the probability of default.

Table 5. Individual effect one-step GMM model with Z_SCORE as the dependent variable

	Dependent variable:
	Z_SCORE (3)
lag(Z_SCORE, 1)	0.098 (0.060)
LRI	0.001*** (0.0004)
CRI	-0.156 (0.096)
LRI:CRI	-0.004** (0.002)
SIZE	-0.140*** (0.060)
CR	3.080*** (0.463)
ER	-0.001*** (0.0005)
LR	0.216* (0.125)
GDP	0.184*** (0.078)
CPI	-0.106 (0.145)
Sargan test	chisq(377) = 89.2475 (p-value = 1)
Autocorrelation test (1)	normal = -3.267217 (p-value = 0.0010861)
Autocorrelation test (2)	normal = -1.221725 (p-value = 0.22181)
Wald test for coefficients	chisq(10) = 414.5484 (p-value = < 2.22e-16)

*p<0.1; **p<0.05; ***p<0.01; standard error in parenthesis

According to the regression diagnostic, the model is not overidentified, as confirmed by the Sargan test. The autocorrelation test (2) indicates that there is no second-order

autocorrelation in the model. The Wald test for coefficients confirms the findings regarding the presence of statistically significant coefficients (Table 5).

Most importantly, the results of the regression above show that the interaction between credit and liquidity risk decreases bank stability, as indicated by the lower Z-Score. These results fail to reject the second hypothesis as the individual presence of credit risk and liquidity risk does not affect the bank's stability. At the same time, their interaction decreases stability, leading to the increased probability of default.

As the economy expands, banks start facing increased demand for loans. This puts pressure on their liquidity, as they need to lend out more money. Simultaneously, the increasing demand leads them to take on slightly riskier borrowers, which raises their credit risk. The interaction between liquidity and credit risk becomes critical in this dynamic environment. Banks' lack of liquidity (e.g., readily available cash) to cover unexpected withdrawals or sudden loan defaults poses a significant risk to their stability. The more they extend themselves by taking on riskier borrowers, the more vulnerable they become to liquidity issues. They need even more liquidity to buffer against potential losses as they take on more credit risk. The situation worsens during a financial crisis, such as a recession. Loan defaults increase, and the value of assets (like real estate) falls, causing losses. With higher credit risk and limited liquidity, banks struggle to cover these losses, potentially leading to defaults or requiring government intervention to prevent a banking system collapse.

Although the coefficient of the liquidity risk variable (LRI) is also statistically significant, its value is minimal: its effect on Z-Score is economically insignificant..

The abovementioned results are in line with almost all studies that investigated the effect of the interaction between credit risk and liquidity risk on banks' financial performance and stability (Ghenimi et al., 2017; Ejoh et al., 2014; Abdelaziz et al., 2020). However, there are some conflicting results regarding the separate effect of each risk on the probability of default (Imbierowicz & Rauch, 2014; Amara & Mabrouki, 2019).

Another meaningful relationship worth noting is that Z-Score is negatively affected by the size of the bank. It suggests that larger banks face increased challenges in the context

of stability. Capital ratio (CR) has a significant positive relationships with bank stability. This is intuitive from an economic point of view. The amount of capital relative to the bank's risk-free assets is one of the crucial factors that increase a bank's stability and financial resilience.

In the context of a positive coefficient between a bank's Z-Score and GDP, the bank's financial health is positively influenced by a growing economy. The bank will likely experience improved financial performance and lower default risk as the economy expands.

A positive coefficient between a bank's Z-Score and the loans ratio indicates that its Z-Score tends to increase as the bank extends more loans relative to its total assets. It implies that the bank is effectively managing its loan portfolio and is likely to generate higher returns from its loans without significantly increasing its risk.

A negative coefficient between a bank's Z-Score and the efficiency ratio suggests that as the bank's efficiency ratio decreases, its Z-Score tends to increase. The efficiency ratio measures how efficiently a bank operates, with lower values indicating better efficiency. Therefore, a negative coefficient implies that as the bank becomes more efficient in managing its operating expenses and generating revenue, its financial stability and creditworthiness, as represented by the Z-Score, tend to improve.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Two hypotheses were tested in the research. The first one stated that the credit risk and liquidity risk of a bank have a positive relationship and, therefore, tend to move in the same direction. The first hypothesis was rejected as no sufficient evidence was found regarding the statistically significant economic relationship between the two risks.

The second hypothesis assumed that each risk separately and their interaction negatively influence the bank's stability, leading to an increased probability of default. Regarding the separate effect, it was found to be statistically insignificant in the case of credit risk and minimal in terms of the coefficient for the liquidity risk. However, as confirmed by the empirical analysis, both risks together negatively influence the bank's stability.

The study expanded the already available literature on the relationship between credit risk and liquidity risk and their individual and joint effect on the bank's stability. For Ukraine, the results of this academic research may help to change the approach to risk management processes and highlight the importance of factors that contribute to the bank's stability.

6.2. Policy implications

The most significant policy implication of the research for bank managers and supervisors is related to the second hypothesis. As was stated before, the interaction between credit risk and liquidity risk decreases the bank's stability. Therefore, it is highly relevant to manage these risks not only separately but in conjunction with each other.

Another policy implication is connected to maintaining a high capital ratio that positively influences the bank's stability. It can be done by reducing the amount of risky assets and optimizing capital allocation strategies overall.

The Ukrainian banks should also try to improve their profitability (measured as ROA and ROE) since it reduces credit risks, as indicated in the regression for the first

hypothesis. This can be done only through further improvement of banking supervision, governance practices, credit decision-making and credit risk management. Both these profitability indicators are very volatile and were negative in the period from 2016 to 2018. The war also negatively impacted ROA and ROE. However, the banking system managed to recover, which is a good sign for risks, especially for credit risk.

The last implication is addressed to the large banks by total assets that face higher challenges in remaining financially stable and maintaining the low non-performing loan ratio. As a large institution, more human and capital investments should be dedicated to better risk management practices. Here, the most attention should be paid to the Top 10 banks, each with total assets more or almost equal to UAH 100 billion.

6.3. Limitations and further research

The study has several limitations. Most of all, other econometrics models may be applicable to better fit the data and purposes of the research, in particular, the SUR model as a system of multiple equations (Abdelaziz et al., 2020).

Besides, as a robustness test, other calculated variables may be used as proxies for credit risk and liquidity risk. Loans to Deposit (LDR) and Cost per Loan (CPL) variables may be used as proxies for credit risk. As liquidity ratio proxy variables, Current Ratio (CR) and Acid Test Ratio (ATR) may be calculated and added to the analysis to perform additional checking of the econometric modeling (Cheng et al., 2020).

A dummy variable indicating a given bank's ownership (OWN) may also be added to distinguish results between banks with foreign capital and domestically owned (Cai & Zhang, 2015). State-owned and private banks may also be distinguished to compare their risk-management practices and stability.

Regarding the direction for further research, first of all, all limitations should be taken into account. Secondly, other risks (e.g., operational risk, market risk, regulatory risk, reputational risk, and systematic risks) may be included in the analysis to better capture the most important factors that influence the bank's stability (Faiz, 2022).

Lastly, the dataset may be increased by adding the two most recent quarters as well as additionally analyzing the pre-reform period to get a more precise understanding of the banking system reform on risk management practices.

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