HOW DOES CREDIT RISK INFLUENCE LIQUIDITY RISK? EVIDENCE FROM UKRAINIAN BANKS

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ABSTRACT

This study investigates the link between two major risks in the banking sector: liquidity risk and credit risk. Utilizing a novel sample of Ukrainian banks for the period from Q1 2009 to Q4 2015, we document credit risk as having a positive relationship with liquidity risk. Our findings suggest banks with high level of non-performing loans might not meet depositors' withdrawal demands, which could lower cash flow and trigger depreciations in loan assets, and consequently increase liquidity risk. Furthermore, we find this positive relationship between credit risk and liquidity risk is more pronounced in foreign banks and large banks. Our results are robust with respect to alternative measures of bank risks.

JEL Codes: G21, G31, G33

Keywords: liquidity risk, credit risk, bank size, bank ownership

I. INTRODUCTION

The collapse in 2008 of Lehman Brothers, a global bank, brought down the global financial system, triggering numerous bank failures. In the wake of the crisis, substantial bailouts were required to shore up the financial sector. Anecdotal evidence suggests most bank failures are partly caused by liquidity problems and by the credit crunch. For example, the Material Loss Reports from the Federal Deposit Insurance Corporation (FDIC) state that liquidity risk and credit risk together contributed to most commercial bank failures during the recent crisis.[1]

In the banking sector, *liquidity risk* and *credit risk* are considered the major sources of default risk. Liquidity is viewed as a fundamental part of banking operations (Cornett et al., 2011) and the Basel Committee on Banking Supervision defines *liquidity risk* as the risk of being unable to meet the obligations of depositors or to fund increases in assets, which stems from a shortage of liquid assets (2008). Credit is another important element in banking. *Credit risk* materializes when a bank borrower or counterparty fails to meet obligations per agreed terms (Casu et al., 2006). Additionally, since banks accept deposits from savers and lend those funds to borrowers, a bank's asset and liability structures are closely connected, especially in terms of borrower defaults and deposit outflows (Bryant, 1980). Thus: are *liquidity risk* and *credit risk* closely related in banks?

A large amount of literature has investigated *liquidity risk* and *credit risk* in banks (e.g., Berger and Bouwman, 2009; Castro, 2013; Diamond and Rajan, 2001). The literature contains two main views on the link between the two risks. The first, the classic financial intermediation theory (Bryant, 1980) and the Diamond and Dybvig (1983) model, suggests *liquidity risk* and *credit risk* are positively related in banks, which is supported by empirical studies (e.g., Acharya and Viswanathan, 2011; Gorton and Metrick, 2011; He and Xiong, 2012). More specifically, a loan default can increase *liquidity risk* by leading to a decrease in cash flow and depreciations in loan assets (Dermine, 1986). For example, if a bank lends to distressed projects, it may then struggle to meet depositors' demands for funds. Then, if asset values deteriorate, depositors may demand their funds. On the other hand, some empirical studies also document a negative relation or no relation at all between *liquidity risk* and *credit risk* (e.g., Cai and Thakor, 2008; Wagner, 2007). These studies share a common trait – they focus on specific features of credit risk or liquidity risk, or on/ narrow economic circumstances. Given the contradictory viewpoints presented in the literature, the relationship between *credit risk* and *liquidity risk* remains an open question.

[1] The FDIC publishes Material Loss Reports for all bank defaults that result in a "material loss" to the FDIC insurance fund.

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Ukraine, an emerging market, offers an interesting framework in which to study the relationship between *credit risk* and *liquidity risk*. In the face of the political and economic challenges in recent years, Ukraine is viewed as a struggling economy and its banking sector has been named as one of the least efficient and highest cost emerging markets (Fries and Taci, 2005). Based on the *Banking Industry Country Risk Assessment* (2017) released by S&P Global, the risk in the Ukrainian banking system remains one of the highest in a global comparison due to the country's unstable political and economic environments. During the global financial crisis in 2008, Ukrainian banks experienced a sharp downturn and regional and sectoral imbalances (Liubkina and Borovikova, 2013), with outflows of deposits, a decreased liquidity position, and the threat of default risk. Rising non-performing loans (NPLs) also forced banks' profitability into losses. To relieve the pressure in the banking sector, the National Bank of Ukraine (NBU) introduced a large package of liquidity support.

In 2010, the economy began to recover from the serious recession; confidence in the banking sector returned and deposits returned to growth. After a short recovery, Ukrainian banks began to again accumulate the large imbalances until 2014-2015 when conditions deteriorated. Total deposits decreased 15% in 2014 and returned to growth only in the middle of 2015 as confidence in banks returned. Meanwhile, bad loans surged from 4.6% of all loans at the start of 2014 to 24.3% in late 2014 (Barisitz et al., 2012; Barisitz and Fungáčová, 2015). More recently, as reported in the Financial Stability Report (NBU, 2016), NPLs remain at record highs, while the late recognition of regulation contributes to the minor increase in the bad loans. Furthermore, liquidity risk has not abated because the distribution of high-quality liquid assets in Ukrainian banks is uneven. Overall, Ukrainian banks continue to face high levels of *credit risk* and *liquidity risk*.

To study the relationship between *liquidity risk* and *credit risk* in the Ukrainian banking sector, we use a novel sample of 176 Ukrainian banks from Q1 2009 to Q4 2015. The data were collected from Ukrainian banks' quarterly reports from the NBU website. In terms of the methodology, we use the fixed-effects estimator, justified using the Hausman Test. Using the fixed-effects model enables us to control for unobserved heterogeneity. With respect to the results, we find a positive and significant impact of *credit risk* on *liquidity risk* in Ukrainian banks. The results show that when credit risk increases by 1 percentage point (pp), liquidity drops by 0.061 pp.[2] A lower value of *liquidity* indicates a higher *liquidity risk*, meaning our results suggest that higher *credit risk* leads to higher *liquidity risk* in Ukrainian banks. In other words, a default in loans could easily increase the liquidity problem. Our main results are in-line with the classic financial intermediary theory (Bryant, 1980) and the Diamond and Dybvig (1983) model, as well as available empirical literature (e.g., Bryant, 1980; Dermine, 1986; Nikomaram et al., 2013).

Furthermore, since banks with different characteristics behave differently in terms of risk, we divide the banks into different sub-groups based on *size* and *ownership*. Our further estimation shows the positive relationship between *credit risk* and *liquidity risk* varies across different bank *sizes* and *ownership types*. We observe that the positive effect of *credit risk* is likely to exist only in larger, foreign owned banks. For foreign-owned banks, when *credit risk* increases 1 pp, *liquidity* falls 0.11.8 pp. For large banks, a 1 pp increase in *credit risk* results in an 0.084 pp decrease in *liquidity*. Our results are robust with respect to alternative measures of bank risks.

Our study contributes to the existing literature on bank *liquidity risk* and *credit risk*. Most of the existing literature focuses on investigating these two major bank risks separately, while limited studies estimate the link between the two together (e.g., Berger and Bouwman, 2009; Foos et al., 2010; Houston et al., 2010; Imbierowicz, 2014; Laeven and Levine, 2009). Furthermore, most empirical studies on the relationship between *liquidity risk* and *credit risk* only focus on developed countries. To bridge the gap, we extend the literature to an emerging economy, Ukraine. To the best of our knowledge, this is the first study that estimates the relationship between *liquidity risk* and *credit risk* in Ukrainian banks.

The rest of the paper is organized as follows: section 2 presents a critical review of literature on *liquidity risk* and *credit risk*; section 3 describes the data collection and methodology; section 4 provides the empirical analysis; section 5 contains a series of robustness tests; section 6 contains the summary and conclusion.

II. LITERATURE REVIEW AND DEVELOPMENT OF HYPOTHESIS

2.1. Bank liquidity risk

The financial crisis proved that liquidity, an important factor in the banking sector, has the potential to influence banks' survival (DeYoung et al., 2016). Financial intermediation theories posit liquidity production as a key to banking operations (Cornett et al., 2011). In banks, liquid assets refer to cash and assets that can be converted to cash quickly with limited or no losses (Casu et al., 2006). *Liquidity risk* refers to the risk of being unable to meet the obligations of depositors or to fund increases in assets as they fall due without incurring unacceptable costs or losses (BCBS, 2008).

The opaque nature of banks, with high information asymmetry, may increase *liquidity risk*. If external stakeholders were to receive the same information on the quality of the portfolio as insiders, banks would provide an appropriate price to take in deposits and take portfolio risks (Greenbaum and Thakor, 1995). When depositors are in greater need of withdrawals

[2] In our study, we follow Cornett et al. (2011) to use liquidity (the change in the liquidity position) as a proxy for liquidity risk. Thus, a higher value of liquidity indicates a lower level of liquidity risk.

than normal, *liquidity risks* can occur. To reduce the risk, banks can borrow funds from other banks or from the central bank. However, banks then pay a higher interest rate than the rate at which other banks borrow, which may increase the bank's costs. Banks can also reduce *liquidity risk* by increasing cash or other liquid assets, such as Treasury bills. This improves the bank's ability to sell assets, which can increase its resilience to liquidity shocks and diversify balance sheet risk (Cornett et al., 2011). Banks are therefore required to meet minimum liquidity standards according to the Basel III Accord (2010). However, holding more liquid assets carries associated costs. Holding too much cash can reduce profit because of the low returns of liquid assets (Casu et al., 2006).

Banks' asset and liability structures are closely connected, especially in terms of borrower defaults and deposit outflows (Bryant, 1980). Thus, a bank needs to identify and manage imbalances between assets and liabilities. Loans become illiquid assets when a bank provides liquid assets to borrowers (Diamond and Rajan, 2001), while loans can be used as collateral when banks need liquidity (Bhattacharya and Thakor, 1993). If demand for liquidity is high, banks can limit the supply of credit and change illiquid assets to liquid liabilities (Berger and Bouwman, 2009). However, banks can also create the liquidity by changing the funding on their liability side (Gorton and Winton, 2000). In addition, when borrowers choose to withdraw commitments, an off-balance sheet loan comes onto the balance sheet. In this case, half of commercial banks' liquidity creation occurs through off-balance sheet commitments (Berger and Bouwman, 2013).

2.2. Bank credit risk

Credit risk is another major element of bank default risk. The Basel Committee on Banking Supervision (2000) defines *credit risk* as the potential that a bank borrower or counterparty fails to meet its obligations in accordance with agreed terms. In other words, *credit risk* materializes when a loan is not paid in part or in full to a lender (Castro, 2013). *Credit risk* management is essential in identifying warning signs of a bank's vulnerability. Typically, banks provide credit to clients in one of two ways: banks can originate new loans (on the balance sheet) and provide lines of credit (off the balance sheet) (Allen, 2012).

The agency problem is another major concern that can create bank *credit risk*. Owing to the information asymmetry between a bank and a borrower, a borrower can fail to fulfill their commitment to a bank, which creates moral hazard. To minimize the *credit risk*, banks should adhere to strict underwriting standards and diversify exposures (Casu et al., 2006). In addition, in terms of the problem of adverse selection, banks can screen borrowers by assessing their ability to repay loans before issuing the credit.

2.3. The relationship between liquidity and credit risk in banks

A large amount of literature has been written about *credit risk*, starting with Merton (1974), whereas *liquidity risk* was a largely unexplored topic until 1998 (Imbierowicz and Rauch, 2014). Most authors explore *liquidity risk* and *credit risk* separately, but the link between the two has received only limited attention (e.g., Hertrich, 2015; Imbierowicz and Rauch, 2014). In general, these limited studies provide two arguments regarding the relationship between *credit risk* and *liquidity risk* in banks.

The first, grounded in the classic financial intermediation theory (Bryant, 1980) and the Diamond and Dybvig (1983) model, posits a positive relationship between *liquidity risk* and *credit risk*. In particular, a loan default can trigger a decrease in cash flow and depreciation in loan assets, thus increasing *liquidity risk* (Dermine, 1986). A new body of empirical study also supports this positive relationship. Diamond and Rajan (2001) state that if a bank provides loans to many distressed projects, it is more likely to fail to meet depositors' demands. Furthermore, if the values of those assets deteriorate, many depositors will demand a return of their funds, which will result in cash outflows. In-line with Diamond and Rajan (2001), Nikomaram et al. (2013) document a positive relationship between *credit risk* and *liquidity risk* in the Islamic banking sector. Gorton and Metrick (2011) show a different perspective on how perceived *credit risk* can lead to *liquidity risk*. Perceived *credit risk* (subprime loans) caused a substantial increase in refinancing rates and funding haircuts in the interbank market during the most recent financial crisis. Acharya and Viswanathan (2011) suggest that when asset prices deteriorate, it is more difficult to roll over debt because a liquidity problem exists. Based on the Diamond and Dybvig (1983) model, He and Xiong (2012) also focused on the debt rollover risk and found that lenders will not roll over debt contracts if the value of the underlying asset is below a certain threshold. In addition, Boss and Scheicher (2002) suggest a positive relationship between *credit risk* and *liquidity risk* in the European corporate bond market. Similarly, Ericsson and Renault (2006) established a bond valuation model and found that *credit risk* has a positive relationship with illiquidity.

However, there are other papers that provide negative or null evidence regarding the relationship between *liquidity risk* and *credit risk* (e.g., Cai and Thakor, 2008; Wagner, 2007). In general, these studies only focus on specific features of *credit risk* or *liquidity risk*, such as assets, deposits, and loan commitments, or on narrow economic circumstances. In particular, Nikomaram et al. (2013) use different proxies of *liquidity risk* and *credit risk* in their study and obtain different results regarding the relationship between the two risks, either positive or negative. Imbierowicz and Rauch (2014) failed to find a meaningful impact of *credit risk* on *liquidity risk* in US banks.

Studies with a negative or null relationship between *liquidity risk* and *credit risk* mostly focus on specific aspects of the risks given certain assumptions and economic environments. However, most recent empirical studies support the positive

relationship between *credit risk* and *liquidity risk*, which is consistent with the classic financial intermediation theory (Bryant, 1980) and the Diamond and Dybvig (1983) model. Thus, from a broad perspective, we address the following hypothesis, *H1: Credit risk is positively correlated with liquidity risk*.

III. DATA AND METHODOLOGY

3.1. Data and sample selection

We build a novel sample of Ukrainian banks for the period from Q1 2009 to Q4 2015. All bank-specific information is extracted from the quarterly reports of Ukrainian banks from the website of the National Bank of Ukraine (NBU). We start with the universe of available Ukrainian banks from the NBU and remove the banks that have had their license revoked or have been liquidated during the banking sector clean-up since 2014 (banks are removed from the dataset as of their date of removal from the market). Next, only banks with financial information available for at least two consecutive quarters are retained. Finally, we drop observations with extreme and questionable values. After the filtering process, our final estimation sample consists of 176 Ukrainian banks.

3.2. Liquidity risk and credit risk variables

In this study, we use two main variables to measure *liquidity* and *credit risk*. *Liquidity risk* reflects banks' ability to deal with unexpected liquid demand. Per Cornett et al. (2011), we use liquidity position as a proxy for *liquidity risk*, which is calculated as the change in total liquid assets during a quarter compared with total assets at the start of a quarter.[3] Total liquid assets include cash and other assets a bank can quickly convert to cash.[4] In our study, the value of the *liquidity risk* variable can either be positive or negative. A negative value of *liquidity risk* means a bank has a shortage of *liquidity*. A lower value indicates a higher *liquidity risk*. On the other hand, a positive value is a sign of low *liquidity risk* and is a sign a bank can cover some short-term withdrawals using liquid assets.

Table 1. Definition of variables

Variable name	Definition
Liquidity risk	$\Delta Liquid\ assets_{i,t}$ /Total $assets_{t-1}$
Credit risk	Non-performing loans/Total loans
Capital ratio	Total equity/Total assets
Illiquidity	Illiquid assets/Total assets
Efficiency ratio	Operating expenses/Total income
Deposit ratio	Total deposit/Total assets
Loans ratio	Loans/Total assets
Size	Log(Total assets)
ROA	Pre-tax profit/Total assets
Ownership	Dummy variable: 1 for a foreign-owned bank and 0 for a domestically owned bank

Furthermore, credit risk shows the potential a bank borrower or a counterparty fails to meet obligations in accordance with agreed terms. We follow previous studies (Gonzalez, 2005; Liang et al., 2013) and as a proxy for *credit risk* use the non-performing loans (NPL) ratio – impaired loans divided by total loans. This measure captures the current risk level of a bank's loan portfolio. A higher value of the *credit risk* variable indicates a higher level of *credit risk* at a bank.

3.3. Model specification and descriptive statistics

To estimate the effect of *credit risk* on *liquidity risk*, we use the following model:

$$Liquidity\ risk_{i,t} = \alpha + \beta Credit\ risk_{i,t-1} + X_{i,t-1}\delta + \theta_t + \mu_i + \varepsilon_{i,t}, \quad (1)$$

where *i* is the bank identifier and *t* is the year. Model (1) is estimated using a fixed-effects estimator, justified using the Hausman Test. Using the fixed-effects model enables us to control for unobserved heterogeneity. In this model, *liquidity risk* is the

[3] $Liquidity\ risk = \Delta Liquid\ assets_{i,t}/total\ assets_{i,t-1}$

[4] Due to the availability of data, liquid assets in this study include cash balances, held-to-maturity securities, available-for-sale securities, and financial assets designated at fair value through profit or loss.

dependent variable and α is constant. All independent variables are estimated with a one-quarter lag. The coefficient of key interest, β, captures the impact of *credit risk* on *liquidity risk*. A positive value of β indicates a positive relationship between *credit risk* and *liquidity risk* in Ukrainian banks, while a negative value denotes a negative relationship. μ is an individual-specific effect, which varies across banks, and ε denotes the error term, which varies among banks and across time periods. Additionally, the reported standard errors are adjusted for potential heteroscedasticity. However, our model (1) also has limitations. For example, it fails to address the endogeneity problem even though we use the one-quarter lagged independent variables.

Based on existing studies of bank risk (e.g., Imbierowicz and Rauch, 2014; Nikomaram et al., 2013), we include a set of control variables $X_{i,t}$ that can influence bank *liquidity risk*, namely the *illiquidity ratio*, the *capital ratio*, the *efficiency ratio, deposit ratio, loan ratio, size, return on assets (ROA)*, and *ownership*. The *illiquidity ratio* is the ratio of illiquid assets (assets not easily convertible to cash) to total assets. The *efficiency ratio* is calculated as operating expenses divided by total income, which indicates a bank's ability to turn expenses into revenue. The *capital ratio*, the proportion of total equity to total assets, reflects how well a bank operates and develops. In our study, *deposit ratio* and *loan ratio* are normalized by total assets to normalize differences in bank size. *Size* is defined as the natural logarithm of total assets. *Return on assets (ROA)* is measured as after-tax profit over total assets, which measures a bank's ability to generate profit with its assets. A dummy variable for foreign banks (*ownership*) is also included to account for ownership type; this variable equals 1 if a bank has foreign ownership and 0 if a bank is owned solely by domestic entities.

Table 2 reports the descriptive statistics for each variable in model (1). On average, *credit risk* is 0.123, which implies a low quality of loans in Ukrainian banks, with a slightly elevated NPL ratio. *Liquidity risk* averages 0.027 and ranges from -0.402 to 0.552. This suggests Ukrainian banks in our sample have relatively low liquidity risk. The average *capital ratio* in Ukrainian banks is around 21% and the average *illiquidity ratio* is 15.8%. The average *efficiency ratio* of 0.407 suggests Ukrainian banks are inefficient in converting assets into revenue. On average, the value of normalized *deposit ratio* is 32.6%, while for *loan ratio* it is slightly higher at 56.6%. In terms of operating performance, Ukrainian banks generate an average *ROA* of around -0.003. Approximately 16.9% of banks have foreign *ownership*.

Table 2. Descriptive statistics

Variables	Mean	Std	Min	P25	P50	P75	Max	N
Liquidity risk	0.027	0.122	-0.402	-0.033	0.016	0.075	0.552	3.553
Credit risk	0.123	0.142	0.000	0.033	0.080	0.154	0.971	3.827
Illiquid ratio	0.158	0.132	0.004	0.056	0.118	0.224	0.684	3.773
Efficiency ratio	0.407	0.248	0.050	0.249	0.346	0.507	2.009	3.707
Deposit ratio	0.326	0.161	0.000	0.206	0.335	0.444	0.727	3.784
Loan ratio	0.566	0.176	0.055	0.452	0.583	0.697	0.923	3.786
Size	14.358	1.571	11.501	13.132	14.165	15.308	18.982	3.752
Capital ratio	0.210	0.157	0.000	0.104	0.156	0.259	0.834	3.797
ROA	-0.003	0.022	-0.313	-0.000	0.000	0.001	0.035	3.782
Ownership	0.169	0.375	0.000	0.000	0.000	0.000	1.000	3.505

Note. This table provides summary statistics for the main variable in our study.

Multicollinearity is an important issue in regression models; it occurs when two or more variables are highly correlated. When variable ranges are narrow, a model's specifications can cause multicollinearity. Multicollinearity can also be the result of an over-determined model, which includes models with small numbers of observations but significant numbers of variables. The correlation matrix between the main variables is shown in Table 3. The results show there is no multicollinearity in our main model.

Table 3. Correlation matrix between variables

	Liquidity risk	Credit risk	Illiquid ratio	Efficiency ratio	Deposit ratio	Loan ratio	Size	Capital ratio	ROA	Owner-ship
Liquidity risk	1.000									
Credit risk	-0.110***	1.000								
Illiquid ratio	-0.036***	0.140***	1.000							
Efficiency ratio	-0.079***	0.215***	0.088***	1.000						
Deposit ratio	0.063***	-0.086***	-0.105***	-0.148***	1.000					
Loan ratio	-0.035**	-0.210***	-0.507***	-0.258***	0.201***	1.000				
Size	-0.003	0.202***	0.196***	-0.192***	0.015	0.037**	1.000			
Capital ratio	-0.074***	-0.113***	-0.143***	0.235***	-0.410***	0.010	-0.613***	1.000		
ROA	0.145***	-0.190***	-0.013	-0.049***	-0.022	-0.030*	-0.057***	0.070***	1.000	
Ownership	-0.042**	0.120***	-0.056***	0.090***	-0.187***	0.081***	0.435***	-0.215***	-0.018	1.000

Note: This table shows the correlation between each variable.

IV. EMPIRICAL RESULTS

4.1. The relationship between liquidity risk and credit risk

Table 4 reports the basic results of the relationship between *credit risk* and *liquidity risk* in Ukrainian banks. The coefficient of *credit risk* is negative and significant at 10%, which supports our hypothesis (H1). Since a lower value of *liquidity* indicates a higher *liquidity risk*, our results suggest that higher *credit risk* leads to higher *liquidity risk* in Ukrainian banks. More specifically, when credit risk increases by 1 pp, *liquidity* drops by 0.072 pp.

Similar to Cornett et al. (2001) and Imbierowicz and Rauch (2014), our results provide additional evidence to support the classic financial intermediation theory (Bryant, 1980) and the Diamond and Dybvig (1983) model. As a financial channel between depositors and borrowers, banks allocate deposits and provide loans. Typically, banks maximize profits by increasing the interest spread between deposits and loans. Since liquidity risk is the cost of profit-lowering, a loan default is more likely to lower cash flow and trigger depreciations in loan assets, which can ultimately result in an increase in liquidity risk (Dermine, 1986). Additionally, if a bank issues loans to many distressed projects, depositors can lose confidence in the bank and demand the return of their funds. In the event the bank is unable to meet those depositors' needs, liquidity shortages occur.

With respect to other bank-specific characteristics, the *illiquidity* ratio has a positive effect on *liquidity* at a significance level of 1%. This is consistent with Cornett et al. (2011), who studied the US banking sector. This indicates that banks with a higher fraction of illiquid assets in the investment portfolio tend to increase the holding of liquid assets. The *efficiency ratio* shows a negative relationship with liquidity risk, but it is not statistically significant. *Deposit ratio* and *loan* ratio both have a negative relationship with liquidity risk. More specifically, a 1 pp increase in *deposit ratio* and *loan ratio* results in a increase of 0.083 pp and 0.070 pp in liquidity risk, respectively. Similarly, the *capital ratio* coefficient is also positive, which suggests a negative relationship with *liquidity risk*. By contrast, the *size* coefficient is negative, which indicates a positive impact on *liquidity risk*. Specifically, a 1pp increase in bank size decreases *liquidity* by 0.068 pp.

Table 4. Relationship between liquidity risk and credit risk

	Liquidity risk
Credit risk	-0.072**
	(0.028)
Illiquid ratio	0.154***
	(0.040)
Efficiency ratio	-0.022
	(0.015)
Deposit ratio	0.083**
	(0.037)
Loan ratio	0.070**
	(0.035)
Size	-0.068***
	(0.010)
Capital ratio	0.117**
	(0.048)
ROA	0.387**
	(0.183)
Quarter dummy	Yes
N	3,306
R^2	0.180

Note: This table shows the relationship between credit risk and liquidity risk. Liquidity risk is calculated as the change in liquid assets divided by total assets in the previous quarter. Credit risk is measured as non-performing loans divided by total loans. The capital ratio is total equity divided by total assets. The illiquidity ratio is defined as the ratio of illiquid assets to total assets. The efficiency ratio is calculated as operating expenses divided by total income. Deposit ratio and Loan ratio are both normalized by total assets. ROA is measured as pre-tax profit divided by total assets. Size is the log of total assets. Ownership is a dummy variable that is equal to 1 for a foreign-owned bank and 0 for a domestic-owned bank. The analysis uses the panel fixed-effect estimator with lagged independent variables. A constant is included in the estimation but not reported. The robust error of each coefficient is shown in parentheses. *, **, *** indicate the statistical significance level at 10%, 5%, and 1%, respectively.

4.2. Results for foreign and domestic banks

From the previous study, we see that *credit risk* is positively correlated with *liquidity risk*. To further investigate the link, we explore whether banks of different characteristics behave differently in terms of risk. In Ukraine, nearly 20% of banks have foreign *ownership*. To differentiate the difference between domestic and foreign banks in terms of the behavior on risk, we categorize all Ukrainian banks into two groups: foreign-owned banks and domestically owned banks. Table 5 shows the results of the relationship between *credit risk* and *liquidity risk* by ownership group. The *credit risk* coefficient is negative and significant in columns (1) and (2), which suggests *credit risk* is positively correlated with *liquidity risk* in foreign- and domestic-owned banks. However, the positive correlation is more pronounced in foreign banks. In foreign-owned banks, when *credit risk* rises by 1 pp, *liquidity* falls by 0.116 pp. In domestically owned banks, a 1 pp increase in *credit risk* leads to a 0.061 pp decrease in *liquidity*. Based on the global advantage hypothesis, foreign banks benefit from competitive advantages relative to domestic banks, such as better risk management and advanced information technologies. Accordingly, foreign banks could have lower level of risk than domestic banks. Our results, however, suggest that the positive relationship between credit risk and liquidity risk is more pronounced in foreign banks, which is counterintuitive. Therefore, it might be because domestically owned banks typically underestimate risks in Ukrainian banks. Additionally, in-line with our baseline results, the *illiquidity ratio* is negatively correlated with *liquidity risk* at a 10% significance level in domestically owned banks. By contrast, *size* has a positive relationship with *liquidity risk* in both foreign- and domestic-owned banks. The influence is more pronounced in domestic banks. Fur-

thermore, for foreign banks, *deposit ratio have* a negative effect on *liquidity risk*, while *ROA* is negatively correlated with bank *liquidity risk* only in domestic banks.

Table 5. The relationship between credit risk and liquidity risk by bank ownership

	Foreign banks	Domestic banks
	(1)	(2)
Credit risk	-0.116**	-0.061*
	(0.044)	(0.036)
Illiquid ratio	0.093	0.174***
	(0.072)	(0.050)
Efficiency ratio	-0.022	-0.019
	(0.022)	(0.019)
Deposit ratio	0.165**	0.064
	(0.062)	(0.044)
Loan ratio	0.064	0.062
	(0.065)	(0.043)
Size	-0.055**	-0.077***
	(0.024)	(0.012)
Capital ratio	0.235	0.081
	(0.143)	(0.054)
ROA	-0.040	0.373*
	(0.287)	(0.208)
Quarter dummy	Yes	Yes
N	530	2,494
R^2	0.393	0.171

Note: This table shows the relationship between credit risk and liquidity risk. Column (1) reports the results for foreign-owned banks and column (2) for domestic banks. Liquidity risk is calculated as the change in liquid assets divided by total assets in the previous quarter. Credit risk is measured as non-performing loans divided by total loans. The capital ratio is total equity divided by total assets. The illiquidity ratio is defined as the ratio of illiquid assets to total assets. The efficiency ratio is calculated as operating expenses divided by total income. Deposit ratio and Loan ratio are both normalized by total assets. ROA is measured as pre-tax profit divided by total assets. Size is the log of total assets. Ownership is a dummy variable that is equal to 1 for a foreign-owned bank and 0 for a domestic-owned bank. The analysis uses the panel fixed-effect estimator with lagged independent variables. A constant is included in the estimation but not reported. The robust error of each coefficient is shown in parentheses. *, **, *** indicate the statistical significance level at 10%, 5%, and 1%, respectively.

4.3. Results for large and small banks

Ukraine's banking sector has a lower concentration and is more fragmented than other transition countries, with the prevalence of small "pocket banks" that often lend to related parties. In this section, to distinguish the effect of *credit risk* on *liquidity risk* in different sizes of banks, banks are divided into large and small sub-groups based on total assets. The median total asset size across the sector (UAH 1,166,286,000) is the threshold: large banks have above-median total assets and small banks have below-median total assets. In Table 6, we find that in large banks, credit risk shows a positive relationship with *liquidity risk*, with a 1% significance level. A 1 pp increase in *credit risk* results in an 0.085 pp decrease in *liquidity*. At small banks, *credit risk* has no effect on *liquidity risk*.

In terms of other variables, the *illiquidity ratio* and *loan ratio* in both small and large Ukrainian banks are negatively correlated with *liquidity risk* at a 1% significance level. Similar to previous baseline results, *size* has a positive influence on *liquidity*

risk in both small and large banks, but the impact is greater in small banks. *ROA* is negatively correlated with *liquidity risk* in small banks, while the *efficiency ratio* has a positive relationship with *liquidity risk* in large banks.

Table 6. The relationship between credit risk and liquidity risk by bank size

	Small banks	Large banks
	(1)	(2)
Credit risk	0.005	-0.085***
	(0.059)	(0.029)
Illiquid ratio	0.183**	0.166***
	(0.072)	(0.060)
Efficiency ratio	0.025	-0.061***
	(0.024)	(0.018)
Deposit ratio	0.090	0.070
	(0.063)	(0.057)
Loan ratio	0.091*	0.095*
	(0.052)	(0.054)
Size	-0.122***	-0.083***
	(0.023)	(0.016)
Capital ratio	0.040	0.129
	(0.072)	(0.102)
ROA	1.082***	0.121
	(0.327)	(0.170)
Quarter dummy	Yes	Yes
N	1,605	1,701
R^2	0.148	0.291

Note: This table shows the relationship between credit risk and liquidity risk. Column (1) reports the results for small banks and column (2) for large banks. Liquidity risk is calculated as the change in liquid assets divided by total assets in the previous quarter. Credit risk is measured as non-performing loans divided by total loans. The capital ratio is total equity divided by total assets. The illiquidity ratio is defined as the ratio of illiquid assets to total assets. The efficiency ratio is calculated as operating expenses divided by total income. Deposit ratio and Loan ratio are both normalized by total assets. ROA is measured as pre-tax profit divided by total assets. Size is the log of total assets. Ownership is a dummy variable that is equal to 1 for a foreign-owned bank and 0 for a domestic-owned bank. The analysis uses the panel fixed-effect estimator with lagged independent variables. A constant is included in the estimation but not reported. The robust error of each coefficient is shown in parentheses. *, **, *** indicate the statistical significance level at 10%, 5%, and 1%, respectively.

5. ROBUSTNESS TEST

5.1. Alternative measures

In addition to our previous analysis, we estimate the relationship between *liquidity risk* and *credit risk* using an alternative measure of *credit risk*. In this section, following Liang et al. (2013), we recalculate *credit risk* as the ratio of non-performing loans (NPLs) to total assets. As shown in Table 7, the alternative measure of *credit risk* still has a positive relationship with *liquidity risk*. Specifically, if *credit risk* increases by 1 pp, *liquidity* reduces by 0.160 pp. This result is consistent with our previous analysis and provides additional evidence for our hypothesis (H1): higher *credit risk* at banks leads to higher *liquidity risk*.

As in Table 4 (main model), most of the control variables have a significant influence on *liquidity risk*. Overall, *size* is negatively correlated to *liquidity risk*. By contrast, the *illiquidity ratio*, the *capital ratio, loan ratio,* and *deposit ratio* are positively related to *liquidity risk* in Ukrainian banks.

Table 7. The relationship between credit risk and liquidity risk (robust)

	Liquidity risk
Credit risk	-0.160***
	(0.060)
Illiquid ratio	0.154***
	(0.040)
Efficiency ratio	-0.021
	(0.015)
Deposit ratio	0.084**
	(0.037)
Loan ratio	0.090***
	(0.034)
Size	-0.069***
	(0.010)
Capital ratio	0.119**
	(0.047)
ROA	0.357*
	(0.183)
Quarter dummy	Yes
N	3,306
R^2	0.181

Note: This table shows the relationship between credit risk and liquidity risk. Liquidity risk is calculated as the change in liquid assets divided by total assets in the previous quarter. Credit risk is measured as non-performing loans divided by total loans. The capital ratio is total equity divided by total assets. The illiquidity ratio is defined as the ratio of illiquid assets to total assets. The efficiency ratio is calculated as operating expenses divided by total income. Deposit ratio and Loan ratio are both normalized by total assets. ROA is measured as pre-tax profit divided by total assets. Size is the log of total assets. Ownership is a dummy variable that is equal to 1 for a foreign-owned bank and 0 for a domestic-owned bank. The analysis uses the panel fixed-effect estimator with lagged independent variables. A constant is included in the estimation but not reported. The robust error of each coefficient is shown in parentheses. *, **, *** indicate the statistical significance level at 10%, 5%, and 1%, respectively.

5.2. Potential endogeneity concern

Endogeneity is one area of concern in our analysis. The relationship between *credit risk* and *liquidity risk* may be biased because of a possible correlation between the independent variables and the error term. On one hand, banks with high level of non-performing loans may carry *liquidity risk*. On the other, banks with liquidity shortages may also face *credit risk*. In the previous analysis, we partially address this reverse causality by employing a one-quarter lagged *credit risk*.

As a possible solution, our empirical analysis is extended to use the Arellano-Bond (1991) dynamic Generalized Method of Moments (GMM) estimator, which accounts for unobserved heterogeneity as well as the dynamic relation between *credit risk* and previous *liquidity risk*. We report the GMM regressions in Table 8.

Table 8. The relationship between credit risk and liquidity risk (GMM)

	Liquidity risk
L. Liquidity	-0.065**
	(0.033)
Credit risk	0.171
	(0.108)
Illiquid ratio	-0.022
	(0.119)
Efficiency ratio	-0.240***
	(0.078)
Deposit ratio	0.183**
	(0.078)
Loan ratio	-0.024
	(0.086)
Size	-0.057***
	(0.021)
Capital ratio	0.049
	(0.132)
ROA	1.581***
	(0.497)
Quarter dummies	Yes
N	3,001
AR(2) P-value	0.740
Hansen Test P-value	0.184

Note: This table shows the results of the GMM regression of the relationship between credit risk and liquidity risk. Liquidity risk is calculated as the change in liquid assets divided by total assets in the previous quarter. Credit risk is measured as non-performing loans divided by total loans. The capital ratio is total equity divided by total assets. The illiquidity ratio is defined as the ratio of illiquid assets to total assets. The efficiency ratio is calculated as operating expenses divided by total income. Deposit ratio and Loan ratio are both normalized by total assets. ROA is measured as pre-tax profit divided by total assets. Size is the log of total assets. Ownership is a dummy variable that is equal to 1 for a foreign-owned bank and 0 for a domestic-owned bank. The analysis uses the panel fixed-effect estimator with lagged independent variables. A constant is included in the estimation but not reported. The robust error of each coefficient is shown in parentheses. *, **, *** indicate the statistical significance level at 10%, 5%, and 1%, respectively.

All the independent variables are assumed to be endogenous variables, except the quarter dummies. The lags (t-2 and t-3) of *liquidity* and lags (t-2, t-3, and t-4) of the endogenous variables, together with all the lags of the exogenous variables, are instrument variables. In Table 8, our instruments satisfy the second order serial correlation test and the Hansen Test of over-identification. However, we fail to find a negative and significant impact of *credit risk* on *liquidity risk*.

VI. CONCLUSION

Credit risk and *liquidity risk* are major sources of bank default risk. The existing literature focuses largely on the effect of *credit risk* or *liquidity risk* in the banking sector separately, while limited studies consider the link between the two. We expand the literature by investigating the relationship between *credit risk* and *liquidity risk*, as well as the effect of banks' character-

istics on the link between *credit risk* and *liquidity risk* in an emerging economy, Ukraine. This paper utilizes a novel sample of Ukrainian banks, covering 176 banks over the period from Q1 2009 to Q4 2015. We find that the credit and liquidity risk in Ukraine's banking sector is relatively high compared to other developed economy banking sectors.

Our results provide empirical evidence to support the classic financial intermediation theory (Bryant, 1980) and the Diamond and Dybvig (1983) model. In particular, higher *credit risk* leads to higher *liquidity risk*. Banks maximize profit by increasing the interest spread between deposits and loans. Then, a loan default leads to lower cash flow and triggers depreciations in loan assets, which ultimately increases *liquidity risk* in banks.

Since banks with different characteristics behave differently in terms of risk, we then further estimate the effect of bank *size* and *ownership* on the positive link between *credit risk* and *liquidity risk*. Our findings suggest that the positive relationship is slightly stronger in larger banks and foreign-owned banks. We conduct a robustness check by replacing *credit risk* with an alternative measure, which yields consistent results.

Our empirical findings carry some implications for regulators and policy makers. Managing *credit risk* and *liquidity risk* is important in the banking sector, and risk management practices can affect banking sector stability. Given Ukraine's unstable financial system, more efforts should be placed on the management of *liquidity risk* and *credit risk* in conjunction with asset quality.

References

- Acharya V., Viswanathan S. (2011). Leverage, moral hazard, and liquidity. Journal of Finance, Vol. 66, No. No. 1, pp. 99-138.
- Allen F. (2012). The global macro economy and finance. Basingstoke: Palgrave Macmillan.
- Barisitz S., Fungáčová Z. (2015). Ukraine: struggling banking sector and substantial political and economic uncertainty. Bank of Finland, Helsinki, pp. 1-24.
- Barisitz S., Gunter U., Lahnsteiner M. (2012). Ukrainian banks face heightened uncertainty and challenges. Financial Stability Report, No. 23, Vol. 6, pp. 50-57.
- Barisitz S., Lahnsteiner M. (2009). Investor Commitment Tested by Deep Crisis: Banking Development in Ukraine. Financial Stability Report, No. 18, pp.69-77.
- Basel Committee on Banking Supervision, BCBS (2000). Principles for the Management of Credit Risk. Available at: http://www.bis.org/publ/bcbs75.pdf
- Basel Committee on Banking Supervision, BCBS (2008). Principles for sound liquidity risk management and supervision. Available at: http://www.bis.org/publ/bcbs144.pdf
- Berger A., Bouwman C. (2009). Bank Liquidity Creation. Review of Financial Studies, Vol. 22, No. 9, pp. 3779-3837.
- Berger A., Bouwman C. (2013). How does capital affect bank performance during financial crises? Journal of Financial Economics, Vol. 109, No. 1, pp. 146-176.
- Bhattacharya S., Thakor A. (1993). Contemporary Banking Theory. Journal of Financial Intermediation, Vol. 3, No. 1, pp. 2-50.
- Boss M., Scheicher M. (2002). The determinants of credit spread changes in the euro area. Bank for International Settlements Papers, Vol. 12, No. 2, pp. 181-199.
- Bryant J. (1980). A model of reserves, bank runs, and deposit insurance. Journal of Banking & Finance, Vol. 4, No. 4, pp. 335-344.
- Cai J., Thakor A. (2008). Liquidity Risk, Credit Risk and Interbank Competition. SSRN Electronic Journal.
- Castro V. (2013). Macroeconomic determinants of the credit risk in the banking system: The case of the GIPSI. Economic Modelling, Vol. 31, pp. 672-683.
- Casu B., Girardone C., Molyneux P. (2006). Introduction to Banking. Essex: Pearson Education Limited.
- Cornett M., McNutt J., Strahan P., Tehranian H. (2011). Liquidity risk management and credit supply in the financial crisis. Journal of Financial Economics, Vol. 101, No. 2, pp. 297-312.

- Dermine J. (1986). Deposit rates, credit rates and bank capital: The Klein-Monti Model Revisited. Journal of Banking & Finance, Vol. 10, No. 1, pp. 99-114.
- DeYoung R., Jang K.Y. (2016). Do banks actively manage their liquidity? Journal of Banking & Finance, Vol. 66, No. 5, pp. 143-161.
- Diamond D., Dybvig P. (1983). Bank Runs, Deposit Insurance, and Liquidity. Journal of Political Economy, Vol. 91, No. 3, pp. 401-419.
- Diamond D., Rajan R. (2001). Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking. Journal of Political Economy, Vol. 109, No. 2, pp. 287-327.
- Ericsson J., Renault O. (2006). Liquidity and Credit Risk. Journal of Finance, Vol. 61, No. 5, pp. 2219-2250.
- Foos D., Norden L., Weber M. (2010). Loan growth and riskiness of banks. Journal of Banking & Finance, Vol. 34, No. 12, pp. 2929-2940.
- Gonzalez F. (2005). Bank regulation and risk-taking incentives: An international comparison of bank risk. Journal of Banking & Finance, Vol. 29, No. 5, pp. 1153-1184.
- Gorton G., Metrick A. (2011). Securitized Banking and the Run on Repo. Journal of Financial Economics, Vol. 104, No. 3, pp. 425-451.
- Gorton G., Winton A. (2000). Liquidity Provision, Bank Capital, and the Macroeconomy. SSRN Electronic Journal.
- Greenbaum S., Thakor A. (1995). Contemporary Financial Intermediation. Mason, Ohio: South-Western/Thomson Learning.
- He Z., Xiong W. (2012). Dynamic Debt Runs. Review of Financial Studies, Vol. 25, No. 6, pp. 1799-1843.
- Hertrich M. (2015). Does Credit Risk Impact Liquidity Risk? Evidence from Credit Default Swap Markets. International Journal of Applied Economics, Vol. 12, No. 2, pp. 1-46.
- Houston J.F., Lin C., Lin P., Ma Y. (2010). Creditor rights, information sharing, and bank risk taking. Journal of Financial Economics, Vol. 96, No. 3, pp. 485-512.
- Imbierowicz B., Rauch C. (2014). The relationship between liquidity risk and credit risk in banks. Journal of Banking & Finance, Vol. 40, No. 12, pp. 242-256.
- Liubkina O., Borovikova M. (2013). Imbalances in the financial system of Ukraine and their transmission to the systematic risks in the monetary stability. Bulletin of Taras Shevchenko National University of Kyiv. Economics, No. 152, pp. 57-63.
- National Bank of Ukraine, NBU (2016). Financial Stability Report. Available at: https://bank.gov.ua/doccatalog/document?id=44001454
- Nikomaram H., Taghavi M., Khalili Diman S. (2013). The relationship between liquidity risk and credit risk in Islamic banking industry of Iran. Management Science Letters, Vol. 3, No. 4, pp. 1223-1232.
- Roy A.D. (1952). Safety First and the Holding of Assets. Econometrica, Vol. 20, No. 3, pp. 431-449.
- Wagner W. (2007). The liquidity of bank assets and banking stability. Journal of Banking & Finance, Vol. 31, No. 1, pp. 121-139.