BANK DIGITALIZATION AND FINANCIAL STABILITY IN CENTRAL ASIA: ASSESSING RISK AND RESILIENCE

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ABSTRACT

The digitalization of banking services is transforming financial institutions worldwide, yet its impact on financial stability remains a subject of debate, particularly in emerging economies. This study examines the relationship between bank digitalization and financial stability, focusing on commercial banks in Kazakhstan, Kyrgyzstan, and Uzbekistan from 2013 to 2023. Using a two-step system GMM approach, the findings reveal that bank digitalization significantly enhances financial stability by reducing risk exposure and improving resilience. Key digitalization components, such as electronic money, QR payments, and online platforms, contribute positively to stability by lowering operational costs, enhancing transaction efficiency, and strengthening risk management through real-time credit monitoring. Robustness tests reveal heterogeneity based on ownership structure, with private banks benefiting more from digitalization than government-controlled banks. The findings underscore the importance of digital adoption in strengthening banking systems and highlight the need for policies that foster a balanced and secure digital transition in emerging banking markets.

Keywords: bank digitalization, financial stability, Central Asia, emerging economies, system GMM

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INTRODUCTION

The digital revolution has fundamentally transformed the global banking sector, reshaping how financial institutions operate, manage risk, and interact with customers. Technological advancements such as financial technology, mobile banking, electronic payments, and automated risk assessment tools have improved operational efficiency and financial accessibility while altering traditional banking structures (Jia & Liu, 2024). While digital transformation is expected to enhance efficiency and expand financial inclusion, its impact on stability remains an open debate, particularly in emerging markets where financial systems are still evolving.

Financial stability is a crucial pillar of economic sustainability, ensuring the resilience of banking institutions against liquidity shortages, market fluctuations, and systemic risks. Past financial crises, such as the 2007–2008 Global Financial Crisis, the 2014 oil price shock, and recent economic disruptions caused by geopolitical conflicts and the COVID-19 pandemic, have underscored the need for a robust and adaptable banking sector (Clark et al., 2018; Soedarmono et al., 2011). In Central Asia, where financial markets are still developing, the expansion of digital banking offers both opportunities and challenges. Kazakhstan, Kyrgyzstan, and Uzbekistan have witnessed rapid growth in digital financial services (Statista, 2024). Yet, their banking sectors continue to face various

concerns over financial stability (Begimkulov, 2024; Yudaruddin, 2022).

The relationship between bank digitalization and financial stability remains inconclusive in the existing literature. Some studies suggest that digitalization enhances stability by improving transaction efficiency, reducing operational costs, and enabling real-time credit monitoring (Chao et al., 2024). Other studies caution that excessive reliance on digital platforms can expose banks to cyber risks, data breaches, and IT infrastructure failures, increasing financial vulnerabilities (Carbó-Valverde, 2017; Khattak et al., 2023). Additionally, in markets with weak banking systems, digitalization may incentivize excessive risk-taking and non-traditional lending practices, amplifying instability (Lestari et al., 2023).

Despite the growing importance of digitalization in banking, empirical research on its impact on financial stability, particularly in emerging economies, remains limited (Begimkulov, 2023). This study aims to bridge this gap by examining the relationship between bank digitalization and financial stability in Central Asia. Specifically, it addresses the question: *Does bank digitalization strengthen or weaken financial stability in Kazakhstan, Kyrgyzstan, and Uzbekistan?*

In contributing to literature, this study pursues several key objectives. First, it aims to establish a comprehensive method for measuring bank digitalization, considering country-specific financial infrastructures. Second, it empirically examines the effect of digitalization on financial stability, providing insights into whether digital adoption fosters resilience or introduces new risks. The Central Asian banking system presents a particularly relevant case study due to its unique financial landscape, characterized by underdeveloped capital markets, high reliance on bank intermediation, and exposure to economic shocks stemming from political transitions, financial crises, and global downturns (Batsaikhan & Dabrowski, 2017; Chortareas et al., 2011; Ruziev & Majidov, 2013).

The study's significance is further underscored by the role of Central Asian banks as primary financial intermediaries in the region, where capital markets remain underdeveloped (Clark et al., 2018). A stable and innovative banking system is essential for economic recovery, financial accessibility, and sustainable growth. As Central Asian countries seek to modernize their financial markets, this research provides timely insights into how digitalization can enhance or undermine financial resilience. By analyzing the effects of digitalization on financial stability, this study contributes to the broader discourse on technology in banking. The study results can be used by policymakers, regulators, and financial institutions aiming to balance technological progress with financial stability.

The paper is structured as follows: the next section reviews relevant literature and develops hypotheses. Section 3 outlines the methodology and econometric approach. Section 4 presents and discusses the empirical findings. Finally, Section 5 concludes with recommendations and future research directions.

LITERATURE REVIEW

The theoretical foundation of this study builds on the resource-based view (RBV), which argues that banks can gain a competitive advantage by deploying valuable, rare, and hard-to-imitate capabilities, such as digital technologies (Barney, 1991). In banking, digital transformation represents a strategic resource that can enhance operational efficiency, reduce risk exposure, and improve decision-making processes (Chesini & Giaretta, 2024; Fuster et al., 2019). Additionally, the theory of financial intermediation suggests that technologies that reduce information asymmetry, such as AI-based credit scoring and big data analytics, can stabilize banking operations (Lestari et al., 2023).

Digitalization in banking is broadly defined as integrating digital technologies across financial service delivery, operations, and customer interaction channels (Shanmugam & Nigam, 2020). While there is no universally agreed definition, it includes innovations in payments, lending, deposits, risk management, and digital platforms (Lestari et al., 2023; Versal et al., 2022). The rapid expansion of mobile banking, online services, and electronic payment systems has significantly reshaped the financial services landscape (Khattak et al., 2023).

From an empirical perspective, the effects of digitalization on financial stability remain mixed. Advanced bank technologies, like data analytics and machine learning, accelerate decision-making and foster stability (Demirguc-Kunt et al., 2018). Digitalization is found to be essential in optimizing and stabilizing bank operations

and improving financial inclusion, especially in emerging economies (Ozili, 2018). Some studies propose that excessive investment in digital technologies by all market players may weaken financial stability by leading to risk-taking behaviors among banks (Khattak et al., 2023). Broad adoption of digital tools by fintech organizations may also lower credit screening standards, potentially heightening long-term financial risks (Fuster et al., 2019). As a result, banks and other financial institutions may accumulate high-risk financial assets (Carbó-Valverde, 2017).

Nevertheless, studies highlight the stabilizing effects of digitalization on banks. Digital technology enhances speed, improves service delivery, and strengthens stability through seamless financial system integration (Casu et al., 2016; Khattak et al., 2023). Research indicates that digitalization lowers banks' marginal costs, enhances competitiveness, and reduces systemic risk in the banking sector (Shanmugam & Nigam, 2020).

Furthermore, digitalization enhances the accuracy of loan default predictions both under normal conditions and during periods of significant external shocks, demonstrating superior information processing and modeling capabilities (Huang et al., 2020). Digital innovations improve lending efficiency by streamlining borrower application processes (Fuster et al., 2019). Adopting digital technologies allows banks to improve data collection and processing, leading to accurate customer identification (Guo & Liang, 2016). Furthermore, digital innovations also enhance data analytics, enabling better decision-making and risk management (Jia & Liu, 2024).

Additionally, online platforms allow banks to cross-sell complementary bank products and provide more cost-efficient services, strengthening their market position (Chao et al., 2024; Kriebel & Debener, 2019). Innovative banking solutions reduce marginal costs and lead to more cost-effective operations, which enable banks to secure higher returns (Carbó-Valverde, 2017; Shanmugam & Nigam, 2020). As a result, bank technology leads to a rise in profit margins, providing banks with stable fee-based income and additional resources to withstand adverse shocks (Guo & Liang, 2016; Lestari et al., 2023). Based on the existing literature, the following hypotheses are proposed:

H1: Bank digitalization improves financial stability.

H0: Bank digitalization does not improve financial stability.

Context of Central Asia

Over the past two decades, Central Asian countries have begun to transform from cash-based to digital banking systems (Begimkulov & Kuti, 2025). Kazakhstan, Kyrgyzstan, and Uzbekistan each exhibit distinct trajectories in the evolution of digital banking, influenced by their respective economic conditions.

Kazakhstan. Digital banking in Kazakhstan began in the early 2000s, following the privatization of Kaspi Bank in 2002, which sparked a drive toward technological innovation at one of the nation's largest financial institutions. By 2012, over 10 million payment cards had been issued. In 2022, the country's National Payments System launched instant payments that underpinned the expansion of cashless transactions (Yegorin, 2024). The pivotal moment came in 2017 with the debut of super-apps (Kaspi.kz), which integrated marketplace services, digital wallets and point-of-sale credit, placing Kazakhstan among the regional leaders in bank digital adoption. Today, three national super-apps (Kaspi.kz, Halyk Homebank, and Freedom App) serve over 70% of adults. Economically, Kazakhstan's higher GDP provides local banks with the customer base and capital to underwrite advanced digital offerings (National Bank of the Republic of Kazakhstan, 2023).

Kyrgyzstan. Kyrgyzstan's journey toward digital finance began with the launch of Elsom in 2011, the country's first bank-supported mobile wallet. This was followed by incremental digital payment infrastructure through the mid-2010s, with the World Bank's start of the Digital CASA program to expand networks and harmonize ICT regulation in 2018. After the COVID-19 pandemic, bank digitalization has further accelerated, with the transformation of a former local commercial bank in Kyrgyzstan into mobile-first MBank. Despite the lowest GDP per capita among all three countries, Kyrgyzstan's digital finance growth is supported by remote onboarding, QR-based payments, and expanded broadband access in rural areas (National Bank of the Kyrgyz Republic, 2023).

Uzbekistan. Reforms have reshaped Uzbekistan's digital banking landscape since 2017, which included the introduction of licenses for payment organizations and digital banks. The sector's modern era began in 2011 with a local USSD-based money-transfer system (Click) that popularized cashless payments, then followed by the launch of Payme. Later, Georgia's TBC Bank acquired a majority stake in Payme, beginning the foreign bank's presence in Uzbek digital finance (Central Bank of the Republic of Uzbekistan, 2023). Today, Click and Payme serve the majority of the adult population in Uzbekistan. In 2024, TCB introduced instant, paperless account opening and round-the-clock payment services tailored to small enterprises, further increasing the bank's digitalization processes (Khandelwal et al., 2022).

METHODOLOGY

Bank digitalization

Researchers employ various proxies to measure bank digitalization, including text mining of annual reports (Kriebel & Debener, 2019; Lestari et al., 2023), indices derived from published reports such as the Internet Transformation Index (Jia & Liu, 2024), data from the S&P Global Market Database (Khattak et al., 2023), and the Peking University Digital Transformation Index (Chao et al., 2024). However, these methods have faced criticism regarding the selection of digitalization-related keywords (Nguyen et al., 2023) and the availability of relevant publications in regions with limited data accessibility, such as Central Asia.

To address these limitations, this study adopts an adapted version of the methodology developed by Versal et al. (2022), tailored to the data accessibility of the banking sectors in Central Asia. Bank Digitalization (BD) comprises five key components: Payment Cards (Cards), Electronic Money (E-Money), Electronic Facilities (E-Facility), QR Systems (QR), and Online Platforms (OP), as detailed in Table 1.

Cards, E-Money, and QR comprise the issued cards and e-wallets, the total volume of transactions as a percentage of the population, and the annual transaction volume as a percentage of GDP. E-Facility includes the number of ATMs and POS terminals per 100,000 people, calculated according to the World Bank methodology. OP comprises the proportion of mobile application users, the number of website visitors, and the complexity of these digital interfaces.

Table 1: Estimating bank digitalization

Indicator *(h)*	**Estimation components**
Payment Cards (Cards)	
Payment cards	Total quantity of cards/population
Volume of card payments	Total volume of payments/GDP
Quantity of card transactions	Total quantity of payments/population
Electronic Money (E-Money)	
E-wallets	Total quantity of electronic wallets/population
Volume of EM transactions	Total volume of transactions/GDP
Number of EM transactions	Total quantity of transactions/population
Electronic Facilities (E-Facility)	
ATMs	(Total quantity of ATMs/population) *100,000
POS Terminals	(Total quantity of POS/population) *100,000
QR Systems (QR)	
Volume of QR payments	Total volume of QR payments/GDP
Quantity of QR payments	Total quantity of QR payments/population
Online Platforms (OP)	
Mobile banking	Bank application users/total users
Online banking	Web Index

Source: based on the work of Versal et al. (2022)

The estimation components were derived from highly reliable sources, including the official annual reports of National Banks and World Bank databases, which ensure the reliability and accuracy of data. Next, the components were used to estimate each indicator. Finally, the BD index was calculated as the sum of all individual indicators:

$$BD_t = \sum_i h_{i,t} \quad (1)$$

where BD_t represents the overall bank digitalization level at time *t*, and $h_{i,t}$ denotes the value of each digitalization component *i* at time *t*.

Financial stability

The study assesses financial stability using the Z-score, a commonly utilized measure in banking research to gauge financial soundness and the likelihood of a banking crisis (Clark et al., 2018; Lestari et al., 2023). The Z-score reflects a bank's distance from insolvency and is computed as follows:

$$Z - score = \frac{ROA + Equity/Total\ Assets}{\sigma(ROA)} \quad (2)$$

The Z-score measures how much a bank's earnings can fall before capital is exhausted. A higher score indicates greater financial stability, while a lower score signals increased risk of insolvency.

Control variables

To ensure robust estimations, this study incorporates control variables that may affect the relationship between bank digitalization and stability. These variables are selected based on prior research, considering bank-specific characteristics, market structure, and macroeconomic conditions.

Bank-specific characteristics include *return on assets* (ROA), which accounts for the potential link between profitability, risk-taking behavior, and financial resilience (Tan, 2016). Additionally, the *diversification ratio* (Div), measured as the proportion of non-interest income to total income, is included to assess the role of alternative revenue sources in mitigating risk (Suryanto et al., 2022). Given that the impact of digitalization may vary across banks of different sizes, *bank size* (Size), proxied by the natural logarithm of total assets, is also considered (Chao et al., 2024).

To reflect market structure dynamics, the study incorporates the *Herfindahl-Hirschman Index* (HHI), a widely used measure of market concentration. At the macroeconomic level, *GDP* growth is included to control for broader economic fluctuations that may influence financial stability and digitalization trends (Tan, 2016). A detailed summary of these variables is provided in Table 2.

Table 2: Summary of variables used in the study

Variable	Estimation
Bank Digitalization	Table 1, Equation 1
Z-Score	Equation 2
ROA	Net income / Average total assets
Diversification	Non-interest income/gross revenue
Bank size	Ln(Total Assets)
Concentration	Herfindahl-Hirschman Index
GDP growth	Annual growth

Source: author's work

Regression

The regression model to estimate the relationship has the following form:

$$BS_{bt} = \alpha_0 + \alpha_1 BS_{bt-1} + \alpha_2 BD_{bt} + \alpha_3 Control_{bt} + \varepsilon_t \quad (3)$$

In the equation above BS_{bt} is bank stability and BS_{bt-1} is a period lag of bank stability, BD_{bt} - bank digitalization and $Control_{bt}$ - control variables of bank *b* at time *t* of a country *c*.

Considering the specificity of the dataset, this study employs the two-step system Generalized Method of Moments (GMM) estimator, which offers advantages over alternative methods like difference GMM and dynamic fixed effects. While the difference GMM eliminates

unobserved heterogeneity by first-differencing, it often suffers from weak instruments when variables exhibit high persistence. Conversely, system GMM improves efficiency by incorporating both level and differenced equations, reducing small-sample bias and ensuring better instrument validity (Blundell & Bond, 1998). Additionally, unlike dynamic fixed effects, which are subject to Nickell bias in short panels, system GMM provides consistent estimates by addressing dynamic panel bias.

Furthermore, system GMM effectively addresses potential endogeneity concerns, which can occur due to the simultaneous determination of variables, omitted variable bias, or reverse causality, all of which can bias standard regression estimates (Khattak et al., 2023). Therefore, this study uses internal instruments, specifically lagged values of the explanatory variables, to mitigate endogeneity. The lags of bank digitalization and stability are used as instruments to control simultaneity and reverse causality. The two-step iteration provides efficient standard errors through the Windmeijer correction, improving inference accuracy, which is particularly good considering the relatively small sample of our study (Blundell & Bond, 1998).

DISCUSSION

Data description

The research initially aimed to cover banks from all five Central Asian countries. However, due to data availability and quality issues in Tajikistan and Turkmenistan, the analysis includes banks from Kazakhstan, Kyrgyzstan, and Uzbekistan. Data was collected from the audited financial statements published on the websites of 67 commercial banks, including Kazakhstan - 20 banks, Kyrgyzstan - 23 banks, and Uzbekistan - 24 banks. Financial information was extracted using character recognition software and transferred into an Excel database, ensuring reliability.

Table 3 provides an overview of the descriptive statistics for the variables. The findings suggest that the Central Asian banking system exhibits a relatively high-risk profile. The mean Z-score of 42.52 indicates moderate stability, surpassing that of banks in the Middle East and North African (MENA) region (Khattak & Ali, 2021; Zoghlami & Bouchemia, 2021) but falling below the levels observed in Chinese banks (Tan, 2016).

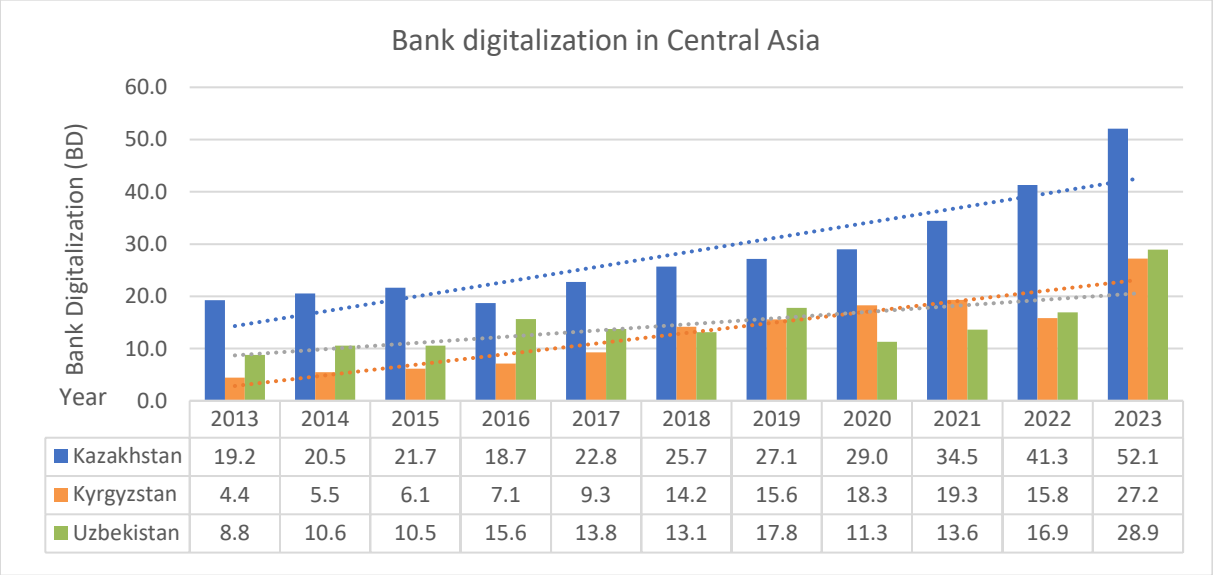
Table 3: Descriptive statistics of variables used in the study

	Pooled				Private banks				State-owned banks			
Variable	**Mean**	**St. dev.**	**Min**	**Max**	**Mean**	**St. dev.**	**Min**	**Max**	**Mean**	**St. dev.**	**Min**	**Max**
BD	17.89	10.63	3.31	52.06	28.11	12.11	5.51	52.06	16.57	13.16	3.31	34.16
Z-score	42.52	78.54	0.98	345.3	60.52	85.45	58.31	345.3	24.52	71.63	0.98	332.6
ROA	0.03	0.08	0.01	0.45	0.09	0.09	0.03	0.45	0.07	0.09	0.01	0.42
DIV	0.31	0.07	0.22	0.50	0.36	0.07	0.31	0.50	0.26	0.07	0.22	0.50
Size	18.64	2.79	14.69	22.70	17.5	2.06	14.69	20.12	19.78	3.52	15	22.70
HHI	0.16	0.11	0.08	0.57	0.24	0.12	0.08	0.51	0.08	0.1	0.11	0.57
GDP	4.18	3.26	-7.15	10.92	-	-	-	-	-	-	-	-

Note(s): BD – Bank digitalization index (aggregated value), Z-score – bank stability (ratio), ROA – return on assets (ratio), DIV – bank diversification (ratio), HHI – Herfindahl-Hirschman Index (ratio), GDP – Gross Domestic Product (growth rate)

Source: author's work

Regarding profitability, the sample generally reflects positive ROA, with an average of 3%, highlighting variations in asset management and revenue generation strategies across banks. Diversification averages 0.31, indicating that non-interest income constitutes approximately 30% of total revenue, contributing to risk mitigation. The average bank size is 18.64, with a standard deviation of 2.79, indicating differences in the scale of banking operations, with some institutions being significantly larger. Market concentration has a mean of 0.16 and a standard deviation of 0.11, indicating varying levels of competition, with some markets being between perfect competition and monopoly. GDP growth suggests periods of economic contraction, while the maximum of 10.92% reflects a substantial economic expansion in some years.Digitalization scores an average of 17.89 with a wide range (3.31 to 52.06), showing significant disparities in technological adoption, which can impact operational efficiency and competitiveness. A closer examination of BD index trends across Kazakhstan, Kyrgyzstan, and Uzbekistan (Figure 1) reveals a consistent upward trajectory in digital banking adoption. Kazakhstan leads the region with a BD index of 52.1 (in 2023), with a strong focus on digital financial services. Uzbekistan follows with a BD index of 28.9, though its digitalization growth lags behind its regional counterparts. Kyrgyzstan, while demonstrating a lower overall BD index, exhibits steady and moderate progress in digital banking integration, highlighting its gradual adoption of financial technologies.



Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Kazakhstan	19.2	20.5	21.7	18.7	22.8	25.7	27.1	29.0	34.5	41.3	52.1
Kyrgyzstan	4.4	5.5	6.1	7.1	9.3	14.2	15.6	18.3	19.3	15.8	27.2
Uzbekistan	8.8	10.6	10.5	15.6	13.8	13.1	17.8	11.3	13.6	16.9	28.9

Figure 1: Bank digitalization index evolution by country.
Source: author's work

Each country has followed a distinct digitalization trajectory shaped by its financial infrastructure, consumer preferences, and regulatory environment (Figure 2). *Kazakhstan* leads in card transactions, electronic wallets, and QR payments, benefiting from a well-developed network of ATMs and POS terminals. Between 2013 and 2023, digital payments in Kazakhstan surged from 17% to 120% of GDP, reflecting widespread adoption of cashless transactions. On the other hand, *Kyrgyzstan* has seen rapid expansion in alternative payment systems, with e-wallet usage rising from 28.4% in 2019 to 63.4% in 2023. This trend highlights the increasing reliance on mobile financial services, particularly in rural areas where traditional banking infrastructure remains limited. Meanwhile, *Uzbekistan* has made significant strides in card-based transactions, with the number of ATMs growing by 33% between 2019 and 2023.

However, other digital payment methods, such as e-wallets and QR-based systems, remain

in their early stages of adoption, leaving room for further expansion and potential incentives to accelerate digital financial inclusion.

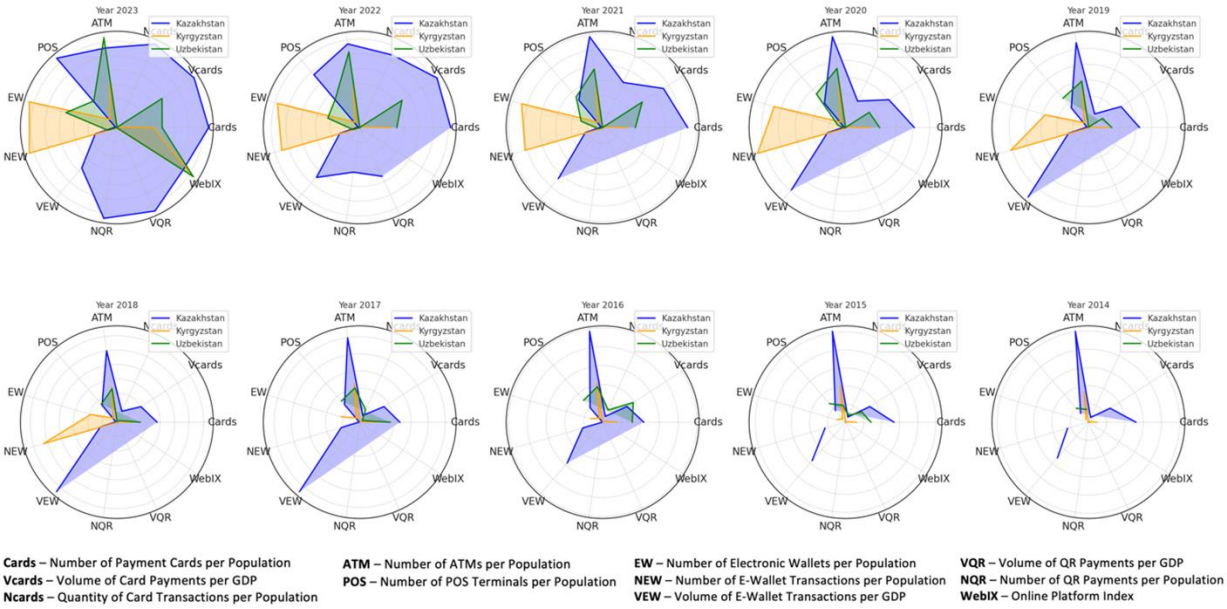


Figure 2: Timeline of key developments of Digital Banking in Central Asia.
Source: author's work

Correlation matrix

Table 4 displays the results of the correlation matrix and the Variance Inflation Factor (VIF) test. The results confirm the absence of multicollinearity, as all correlation coefficients remain below 80%, and VIF values are well below the critical threshold of 10, indicating no significant multicollinearity concerns.

Table 4: Correlation Matrix

	Z-score	BD	HHI	ROA	Div	Size	GDP	VIF
Z-score	1							n/a
BD	-0.40	1						1.78
HHI	-0.34	0.14	1					5.43
ROA	-0.06	-0.11	0.24	1				2.86
Div	-0.27	-0.06	0.29	0.40	1			1.91
Size	-0.39	0.36	0.33	-0.08	-0.11	1		2.96
GDP	0.19	-0.23	0.37	0.05	0.21	0.27	1	1.23

Source: author's work

Regression results

Table 5 presents the empirical results on the impact of bank digitalization on financial stability. Column (1) reports the effect of BD on financial stability, Column (2) incorporates additional control variables, and Column (3) examines the effects of individual bank digitalization components. First, the positive lag coefficient of the Z-score indicates a gradual reduction in risk, reflecting improvements in risk management among Central Asian banks over time. This is due to bank regulatory legislation in the region, which has driven Central Asian banks to enhance their risk management practices over time (Yudaruddin, 2022).

Overall, the findings indicate that BD has a statistically significant and positive effect on financial stability, supporting our hypothesis that greater digitalization enhances financial resilience among Central Asian banks. The coefficient of BD (Column 2) demonstrates that a one-unit increase in digitalization is associated with a 0.7582 increase in stability. Given that the average Z-score in the region is 42.52, this effect represents approximately a 1.8% increase in financial stability per unit increase in digitalization.

A deeper analysis (Column 3) reveals that electronic money, QR payments, and online platforms contribute to financial stability. Digital payments and online infrastructure lower operational costs by automating and facilitating transactions (Carbó-Valverde, 2017; Shanmugam & Nigam, 2020). As a result, increased efficiency leads to overall improvements in financial performance, increasing bank stability (Lestari et al., 2023). These platforms facilitate real-time monitoring, credit scoring, and predictive analytics, enabling banks to identify risky borrowers earlier and adjust their lending practices (Guo & Liang, 2016). Also, such tools allow banks to generate stable fee-based income (Lestari et al., 2023). Additionally, digital banking channels and applications support the cross-sale of complementary products (Chao et al., 2024), increasing operational efficiency and bank revenues. Overall, the findings align with previous studies that have identified a positive relationship between digitalization and bank stability (Carbó-Valverde, 2017; Lestari et al., 2023).

Table 5: Regression – baseline results

	Z-score (1)		Z-score (2)		Z-score (3)	
Variable	Coeff.	Robust S.E.	Coeff.	Robust S.E.	Coeff.	Robust S.E.
Lag	0.3569*	0.0593	0.0181**	0.0098	0.1028*	0.0698
BD	0.2768***	0.0972	0.7582***	0.2790		
Cards					-0.4403	0.2346
E-Money					0.3425***	0.0166
E-Facilities					-0.7844	0.0485
QR					1.0990*	0.3059
OP					0.1936***	0.0043
HHI			0.3311***	0.0454	0.0088***	0.0013
ROA			-0.6672***	0.1046	-0.0001	0.0001
Div			0.3831**	0.0231	0.0109***	0.0012
Size			-0.9963	0.2197	0.9664***	0.1254
GDP			-0.8322***	0.1756	0.2270***	0.0345
Inst-s	20		30		38	
J-Test (p-value)	1		1		1	
AR1 (p-value)	0.0423		0.0325		0.001	
AR2 (p-value)	0.3192		0.3804		0.732	
Wald test	216.68***		877***		1343***	
Significance codes: '***', '**' and '*' denote p-values less than 1%, 5% and 10%						

Source: author's work

In conducting the regression, considerable focus was placed on ensuring the robustness of the estimates. First, the Hansen J-Test of overidentifying restrictions yielded insignificant p-values, affirming the validity of the instruments used in the model. Next, the

Arellano-Bond tests confirmed the absence of second-order serial correlations. Finally, significant Wald tests confirmed that the variables included in the models are jointly significant, demonstrating robust explanatory power.

Robustness tests

To verify the robustness of the findings, several validation tests were conducted. First, the baseline regression model was re-estimated using an alternative measure of financial stability, replacing the Z-score with the loan loss provisions to the total loans (LLPTL) ratio (Table 6). The results remain consistent with the primary analysis, confirming the stabilizing effect of bank digitalization. The negative and significant relationship between BD and LLPTL further supports the conclusion that digitalization reduces credit risk and enhances financial resilience, reinforcing the validity of the initial findings.

Table 6: Robustness test – replacing the dependent variable

	LLPTL (1)		LLPTL (2)	
Variable	Coeff.	Robust S.E.	Coeff.	Robust S.E.
Lag	0.2821***	0.2958	0.00003	0.00002
BD	-0.0011*	0.0006	-0.00080***	0.00018
HHI			-0.00001*	0.00000
ROA			0.00001**	0.00000
Div			0.00002	0.00000
Size			0.00318	0.00198
GDP			-0.00993	0.00811
Inst-s	20		30	
J-Test (p-value)	1		1	
AR1 (p-value)	0.0283		0.0252	
AR2 (p-value)	0.2852		0.2909	
Wald test	159.23***		591***	
Significance codes: '***', '**' and '*' denote p-values less than 1%, 5% and 10%				

Source: author's work

Next, the relationship between digitalization and financial stability may differ based on bank ownership. State-controlled banks, often larger in scale with extensive customer bases and diversified financial operations, may be better equipped to capitalize on digital transformation, improving risk management and operational efficiency. Conversely, private banks, particularly smaller institutions, may face financial and technological constraints that limit the effectiveness of digital adoption. Therefore, a segmented analysis was conducted between private and government-owned banks to assess ownership-based heterogeneity.

Table 7 (Sections 1 and 2) shows that digitalization significantly enhances stability in private banks. A 1% increase in BD leads to a 0.1583-point rise in stability for private banks, supporting our finding that greater digital adoption enhances bank resilience. Profit-driven private banks leverage digital tools effectively to reduce risks, improve operational efficiency, and strengthen lending accuracy. In contrast, the effect of digitalization on stability is insignificant for state-owned banks, which receive substantial government support, including funding and subsidies, which allow them to issue loans without fully integrating digital risk mitigation strategies.

After controlling for bank size and other factors (Sections 3 and 4), the positive effect of digitalization on financial stability remains significant for private but not government-owned banks. This suggests that the observed

heterogeneity is not driven by size alone but reflects institutional differences such as reliance on state support or limited incentives for digital innovation in public banks.

Table 7: Robustness test – heterogeneous effects based on bank ownership type

	Private banks (1)		Government banks (2)		Private banks (3)		Government banks (4)	
Variable	Coeff.	Robust S.E.	Coeff.	Robust S.E.	Coeff.	Robust S.E.	Coeff.	Robust S.E.
Lag	0.4211*	0.2187	1.1735*	0.7938	0.1908	0.3015	0,4882*	0,3681
BD	0.1583***	0.0766	0.0004	0.01466	0.4399**	0.3552	0.6836	0.169
HHI					0.8892**	0.7074	-0.1141*	0.0097
ROA					-0.0483**	0.0169	0.1854*	0.0439
DIV					0.1705**	0.0574	-0.3160	0.1381
Size					0.7829**	0.2959	0.9048*	0.4485
GDP					1.0390**	0.4083	0.2817	0.2213
Inst-s	20		20		30		30	
J-Test (p-value)	1		1		1		1	
AR1 (p-value)	0.0337		0.0485		0.0455		0.0331	
AR2 (p-value)	0.5959		0.2970		0.6412		0.7745	
Wald test	520.72***		706.69***		111.55***		656.3***	
Significance codes: '***', '**' and '*' denote p-values less than 1%, 5% and 10%								

Source: author's work

CONCLUSION AND RECOMMENDATION

This study investigates the impact of bank digitalization on financial stability in Kazakhstan, Kyrgyzstan, and Uzbekistan using a dataset of 67 commercial banks from 2013 to 2023. The findings indicate that while the Central Asian banking sector maintains moderate financial stability, it exhibits a relatively high-risk profile compared to other global regions. The digitalization index trends show a steady rise in digital banking adoption, with Kazakhstan leading, followed by Uzbekistan and Kyrgyzstan. Despite distinct digitalization trajectories, all three countries have significantly expanded digital payment infrastructure, including e-wallets, QR payments, and online banking platforms.

Empirical results confirm that bank digitalization enhances financial stability by reducing risk and improving resilience. Components, such as electronic money, QR payments, and online platforms, contribute positively to stability by lowering costs, streamlining transactions, and enhancing risk management through real-time credit assessments and predictive analytics. The study further reveals disparities in the effects of digitalization across different bank types and ownership structures. Digitalization has a stronger stabilizing impact on private banks, driven by their profit-oriented strategies and competitive adaptability. In contrast, state-owned banks exhibit no significant effect, as government subsidies and financial support reduce the urgency for digital-driven efficiency and risk management improvements, leading to structural inefficiencies.

These findings underscore the need for policies and regulatory frameworks that promote the sustainable integration of financial technologies in banking. Policymakers should strengthen regulatory frameworks that enhance cyber resilience, data protection, and digital risk management. Regulators should enforce mandatory cybersecurity protocols, stress testing, and digital risk audits to prevent cyber threats that could destabilize the banking

system. Furthermore, enhancing digital regulatory preparedness is essential. Policymakers should establish guidelines for the adoption of emerging technologies, such as AI-driven credit scoring and blockchain-based transactions. For state-controlled banks, targeted regulatory reforms should address structural inefficiencies by linking government support to digital transformation milestones, incentivizing risk-mitigating digital adoption rather than relying on state subsidies.

For bank managers, the results emphasize the importance of strategic investment in digital solutions to enhance operational efficiency and risk mitigation. Private banks, which experience stronger positive effects from digital adoption, should continue leveraging digital channels to expand customer outreach, optimize lending practices, and diversify revenue streams. Banks of all sizes should invest in digital risk assessment tools, data-driven credit analysis, and digital onboarding solutions to strengthen financial resilience.

This study has several limitations. First, it focuses on Central Asian economies, where financial reporting standards, data transparency and digitalization disclosures are still developing, limiting the generalizability of the findings to regions with different regulatory environments and technological maturity. Second, the research relies on available quantitative indicators of digitalization, which may not fully capture qualitative dimensions such as user adoption, technological readiness, or customer experience, potentially affecting the full impact of digital transformation. Some data were sourced from national reports and public records, which may vary in completeness, especially in cross-country comparisons. Third, while the study examines the short- to medium-term effects of digitalization, the long-term impact of emerging technologies, such as blockchain, artificial intelligence, and decentralized finance, remains open. Finally, the empirical approach relies on a two-step system GMM estimator to manage endogeneity and dynamic panel structure. While appropriate for this context, the validity of lagged instruments may be constrained by limited periods and cross-country heterogeneity. These model assumptions and data availability may affect the generalizability of the results.

Future research should explore how emerging technologies such as blockchain, AI-driven financial models, and decentralized finance impact financial stability, specifically within the Central Asian banking sector. As these technologies continue to reshape global finance, it is crucial to assess how their adoption influences financial stability, risk management, and regulatory compliance in developing economies. Additionally, cross-country comparative studies focusing on digital financial inclusion, cybersecurity, and regulatory preparedness would provide deeper insights into optimal policy frameworks for economic resilience.

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