



Digital Economy, Institutional Environment, and the Credit Risks of Commercial Banks

Guanglin Sun^{a,b}, Ting Li^a, Jingyi Su^a, and Dan Shi^b

^aSchool of Finance, Nanjing University of Finance and Economics, Nanjing, China; ^bInstitute of Industrial Economics, Chinese Academy of Social Sciences, Beijing, China

ABSTRACT

Most emerging economies are in a transition period, and an imperfect institutional environment will lead to inefficient supervision mechanisms in the digital economy. Based on data representing the experiences of China's listed commercial banks from 2013 to 2021, this study empirically examines the impact of the digital economy on credit risk by using a panel fixed-effect model. The findings indicate that the development of the digital economy helps to reduce credit risk faced by commercial banks. Institutional variables, such as financial supervision and the legal institutional environment, have significant mediation effects of the digital economy. By increasing the intensity of financial supervision and improving the legal institutional environment, the digital economy can reduce the credit risk faced by commercial banks. Interestingly, the effect of the digital economy on credit risk is not uniform across all banks. State-owned commercial banks benefit more from the digital economy in terms of reducing their credit risk than on non-state-owned banks. The inhibitory effect of the digital economy on the credit risk of commercial banks is significant in eastern China but not in central and western China.

KEYWORDS

Digital economy; financial supervision; legal institutional environment; bank credit risk





JEL

G20; G30

1. Introduction

The digital economy encompasses all economic activities that rely on the internet and digital technologies. It includes not only internet industries, but also the adoption of digital technologies by traditional financial institutions such as banks. Reflecting on the trajectory of China's digital economy, its rapid growth and the strong emergence of digital enterprises cannot be solely attributable to the synergy between digital technology innovation and the vast market capacity; instead, it is also a consequence of the government's continuous optimization of the institutional environment. China's open and inclusive development environment that the digital economy, digital enterprises, and the digital transformation of commercial banks have all achieved remarkable progress. Nevertheless, the rapid development of the digital economy also brings forth the potential to disrupt existing financial risk management regulations, financial institutions such as commercial banks to new crises. Therefore, in the context of the digital economy, maintaining stable institutional environments becomes essential as they serve as a fundamental safeguard for effective risk management within commercial banks.

For commercial banks, the digital economy presents both opportunities and challenges, particularly in terms of risk management (Hu, Zhao, and Yang 2022). On the one hand, the constant emergence of new digital technologies such as big data, cloud computing, Blockchain, and artificial intelligence, coupled with the development opportunities afforded by the digital economy, can improve the risk management capabilities of commercial banks enhancing their credit risk prevention and control

CONTACT Guanglin Sun  sunguanglin008@126.com  School of Finance, Nanjing University of Finance and Economics, No. 3 Wenyuan Road, Qixia District, Nanjing, Jiangsu Province, China; Dan Shi  shidan01@163.com  Institute of industrial economics of Chinese Academy of Social sciences, No. 1, Dongchang Hutong, Dongcheng District, Beijing, China

capabilities (Zhang et al. 2023). On the other hand, the digital economy has promoted business innovation of commercial banks, leading to systematic changes in their credit business (Chen et al. 2021). This inevitably creates technical and operational risks that may have an adverse impact on credit risk management of commercial banks. It is worth noting that emerging market countries often have incomplete institutional systems, and government departments lack mechanisms for sharing information, which can result in problems like information repetition and information islands. These issues can further hinder the risk management of commercial banks. Therefore, studying the relationship between the digital economy, institutional environment, and commercial bank credit risk has holds both important academic and practical significance.

Academic research on the credit risk of commercial banks has resulted in many economically beneficial advances. In theoretical research, there are three main viewpoints. First, the theory of economic causes holds that increased non-performing loans results from fluctuating economic operation risks (Rajan 1994). Second, the theory of soft budget constraint argues that governmental credit concessions and financial subsidies support the development of state-owned enterprises for non-economic reasons, but these fail to improve the business environment and result in the transferal of credit risk from those state-owned enterprises to commercial banks (Tan, Jian, and Chen 2012). Third, the theory of information asymmetry suggests a data mismatch between commercial banks and enterprises leads to increased risk due to resulting poor decision-making (Stiglitz and Weiss 1981). Empirical research in this area focuses on both macroeconomic and microeconomic factors. The former includes factors such as monetary policy, productivity, credit interest rate, quality of financial supervision, uncertainty of economic policy, and fluctuation of financial market (Antzoulatos and Tsoumas 2014; Lan et al. 2022; Yuan, Zhang, and Lian 2022), and the latter includes bank ownership structures, bank costs, bank sizes, and capital adequacy (Chen et al. 2019; Iqbal and Saeed 2023; Narayan and Phan 2019).

The academic community has formed two distinct views on how the digital economy affects the credit risk of commercial banks. One viewpoint, known as the “risk increase” theory, suggests that the digital economy’s growth will cause an increase in credit risk. Buchak et al. (2018) argued that Fintech’s rise will disrupt the business of commercial banks, leading to an increase in credit risk. Wang, Liu and Luo (2021) suggested that the digital economy will intensify competition among commercial banks, resulting in lower credit standards in order to maintain stability and profitability. This could result in a deterioration of credit asset quality and increased credit risk. Li et al. (2020) suggested that digital finance and traditional commercial banking businesses are engaged in a competitive relationship, which poses inherent risks for traditional banking businesses. If competitive risks are not managed properly, it could result in systemic financial risk. Boot et al. (2021) argued that the growth of the digital economy will transform the conventional business model of commercial banks, potentially leading to the collapse of traditional commercial banking businesses and their risk management systems. Zhao et al. (2023) investigated the relationship between digital technology and bank risk, and found that payment settlement technology, financing technology, and investment management technology have a significant positive impact on bank risk. In addition, digital financial lending services represent an erosion of traditional commercial banking business (Buchak et al. 2018).

Another perspective suggests that the growth of the digital economy can help reduce credit risk for commercial banks. Digital technology has been widely implemented in the field of commercial banking, improving the efficiency of information processing and reducing information asymmetry between commercial banks and credit clients. This has enhanced the risk management level of commercial banks, and thus reducing the credit risk of commercial banks (Banna, Mia, and Nourani Febriana 2022; Zhang et al. 2022). Based on panel data from 138 Chinese commercial banks, Zhang et al. (2023) found that the development of financial technology has a restraining effect on credit risk for commercial banks. The effect is greater on credit risk reduction for small and medium-sized banks. Cheng and Qu (2020) found that financial technology is beneficial for reducing risk for Chinese commercial banks, based on recent data. Chen and Sivakumar (2021) showed that digital finance can significantly promote economic growth and reduce risk as a result. Finally, Wang,

Sui, and Qi (2021) suggested that Big Data can facilitate innovation in service models, reduce transaction costs, and enhance risk control capabilities for commercial banks.

How the digital economy will affect Chinese commercial bank credit risk, and the role of the institutional environment on that relationship, however, has not yet received the attention in academic research. Compared with existing studies, this study makes two main contributions.

Firstly, while numerous studies have explored the impact of financial technology and digital finance on credit risk in commercial banks, very few have systematically studied the relationship between the digital economy and credit risk in commercial banks (Li et al. 2020; Zhang et al. 2023). Therefore, this paper aims to link the development of the digital economy to commercial bank credit risk and analyzes the inherent theoretical relationship between them. By doing so, it also expands the understanding of the digital economy from the micro perspective of commercial bank risk management. Furthermore, the institutional environment plays a crucial role in the impact of the digital economy on commercial bank credit risk. This paper systematically studies the role of financial supervision and legal institutional environments in the relationship. By taking this novel research perspective, this study provides valuable references for subsequent research in this area.

Secondly, effectively managing credit risk is a major challenge for commercial banks in emerging market countries. This challenge has become even more pressing since the outbreak of the COVID-19 pandemic, which has result in a slowdown in the economic growth and weak credit creation by commercial banks. As a consequence, non-performing loan ratios have increased significantly. Against this backdrop, commercial banks in emerging market countries can leverage the opportunities presented by digital economic development to tap into their potential and achieve a leap in risk management levels. However, commercial banks may also widen the gap and create new risks that arise from market competition. Therefore, this paper focuses on Chinese commercial banks as the research object to clarify the relationship between digital economy and commercial bank credit risk. It also explores the role of institutional environment in this process, providing practical guidance for risk management of commercial banks in emerging market countries such as China.

The remaining structure of this paper is arranged as follows: the second part will present the theoretical framework and research hypothesis; the third part outlines the research design, including data sources, variable explanations, and model construction; the fourth part analyzes the empirical results, including baseline regression results, mediation effect regression results, and heterogeneous effect regression results; finally, based on the findings of this paper, the policy recommendations are made.

2. Theoretical Framework

Based on the logical relationship in Figure 1, The study will focus on the effects of the digital economy on credit risk, including financial supervision and legal institutional environment.

2.1. Impact of Digital Economy on Credit Risk of Commercial Banks

Information asymmetry between commercial banks and borrowers is an important cause of increased credit risk (Banna, Kabir Hassan, and Rashid 2021). The traditional credit review model relies on the empirical review of borrowers by financial officers. Meanwhile, artificial intelligence may be implemented to manage credit more scientifically in the digital economy. Not only can risk be analyzed more efficiently, but it can also be reduced because the authenticity of enterprise information flow can be tracked to minimize poor decisions by personnel and reduce moral hazard and adverse selection (Zhao et al. 2023). The powerful information acquisition and processing capabilities of digital technology also vastly improves the efficacy of assessing the business acumen of credit applicants. Internet of Things technology can monitor business activities, capital flow, logistics, and information of credit enterprises in a comprehensive manner. The many positive consequences of this include a better understanding of credit risk, the reduction of the information asymmetry between banks and

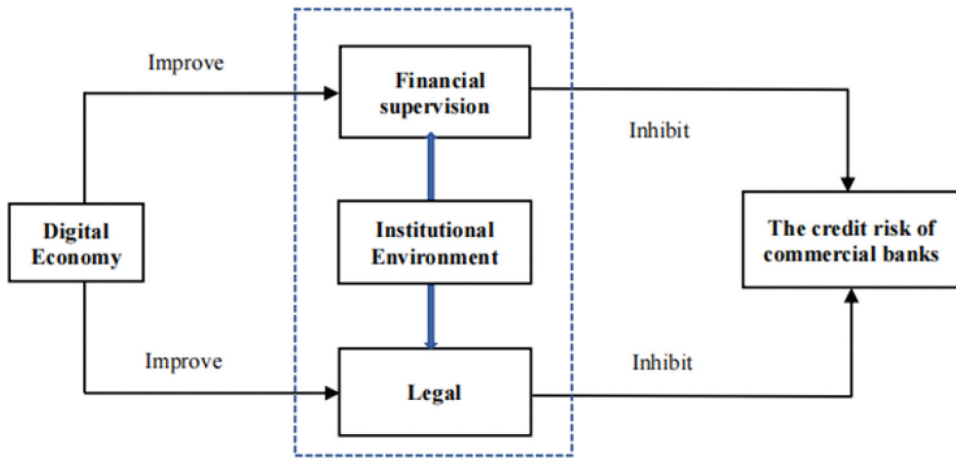


Figure 1. Theoretical framework.

enterprises, and an improved ability of commercial banks to handle credit risks (Li et al. 2020). In addition, the dramatic increase in data inherent to advancements in digital technology, such as that about personnel and transactions, should greatly improve information sharing among producers and between producers and consumers. At the same time, commercial banks can better anticipate customer needs, provide personalized services based upon those individual needs, improve the scope and efficiency of financial services, and promote financial innovation that optimizes financial resources and reduces credit risk. From another perspective, commercial banks must engage in business innovation and digital transformation to adapt to the digital economy. However, these efforts come with the uncertainty risks related to innovation and technical and operational risks associated with digital transformation. These risks may increase the non-performing loan ratio of commercial banks (Wang, Liu, and Luo 2021). Nonetheless, the impact of the digital economy on commercial bank credit risk cannot be a simplified into a single dimension. While there are negative impacts, the positive impact of digital economic development on commercial bank credit risk outweighs them, resulting in greater benefits for commercial banks. Therefore, overall, the digital economy is beneficial for reducing commercial bank credit risk.

Hypothesis 1: *Digital Economy can reduce the credit risk of commercial banks.*

2.2. Mediating Effects of Institutional Environment Variables

The digital economy can not only promote the transformation of commercial banks but also help improve their supervision by government agencies (Kowalewski, Pisany, and Słazak 2022). A digital regulatory network to monitor commercial banks' credit risks in a timely, comprehensive, and objective manner may be developed through technologies such as Big Data and Artificial Intelligence. Digital technology provides the opportunity for dynamic supervision that continuously monitors credit risks by commercial banks, enhances the perception of risks of financial supervision, and makes up for many of shortcomings of traditional supervision measures (Kong et al. 2022). Through the application of mechanisms such as information disclosure and assessment, digital financial supervision increases flexibility and inclusiveness based on measures that are adapted to the different risk characteristics faced by commercial banks and can improve the efficiency of curbing credit risks. In addition, financial supervision authorities have changed the traditional mechanism in which each party makes separate disclosures of information by using Blockchain technology to build a data sharing platform, thus effectively reducing the information distortion between regulators and commercial banks. Supervisors can use Big Data technology to analyze massive amounts of credit data,

evaluate potential credit risks, and designate custom thresholds for commercial banks according to their risk levels. When commercial banks' behaviors may approach these thresholds, financial regulators can obtain information more timely and intervene, which is conducive to preventing credit risks in advance (Li et al. 2020). This study puts forward the basic Hypothesis 2(H2):

Hypothesis 2: *Digital economy can reduce the credit risk of commercial banks by improving the level of financial supervision.*

In the process of traditional legal governance in China, the government must expend significant human and financial resources to ensure the enforcement of legal policies by closely monitoring credit defaulters. However, the existence of multiple delegation and agency chains, as well as information asymmetry, exist between commercial banks and government legal departments results in substantial transaction costs during information transmission (Zhao et al. 2019). Among these costs, legal expenses are a significant cost factor that affect the risk management process of commercial bank credit. The growth of the digital economy is conducive to improving the legal system environment, leading to reduce transaction costs for commercial banks, and lowering the non-performing loan ratio (Kowalewski, Pisany, and Słazak 2022). On one hand, the digital economy has potential to reduce the information asymmetry between commercial banks and government legal departments. This can be achieved through faster and more efficient transmission of information, which can alleviate the distortion of information caused by information twisting or blocking. Moreover, it can enhance communication efficiency between commercial banks and government legal departments, and reduce the adverse selection due to information asymmetry. Ultimately, this can help commercial banks reduce credit default risks (Wang et al. 2023). On the other hand, the digital economy can also improve the efficiency and scope of legal case disclosures by the Chinese government. Through the collection, analysis, summarization, and processing of a large number of credit default cases in a short time, commercial bank and government departments can uncover underlying information behind credit defaults. This can contribute to establishing a fairer and more transparent legal environment, creating a more favorable external environment for commercial banks' credit risk management. Therefore, in the era of the digital economy, digital technology can be utilized to enhance the construction of laws and regulations related to government information disclosure, resource sharing, and website content development. It helps promote the legalization and standardization of legal system environment construction, further helping commercial banks to use legal means to address credit default behavior, thereby reducing credit risks. This study puts forward the basic Hypothesis 3(H3):

Hypothesis 3: *The digital economy can reduce the credit risk of commercial banks by improving the legal institutional environment.*

3. Research Design

3.1. Variables

3.1.1. Credit Risk (NPL)

The latter of which can also be referred to as loan risk. Given this, we draw upon the experience of Papadopoulos (2019), and Cheng and Qu (2020) to measure credit risk using the commercial bank non-performing loan ratio.

3.1.2. Digital Economy (Dige)

There is no unified view in academia on measurable indicators of the digital economy (Zhang et al. 2022). This paper measures the level of digital economic development among Chinese provinces across three dimensions: digital economy infrastructure, digital industrialization, and industrial

Table 1. Construction system of digital economy.

Index	Variables	
Digital economy development infrastructure	Traditional infrastructure	Internet broadband access port
		Number of Internet access users
		Number of domain names per thousand people
Digital industrialization	New digital infrastructure	Number of websites per thousand people
		Total Investment in fixed assets of digital industry
	Industry Scale	Number of mobile phone base stations
		Telecommunication business scale
Industry digitalization	Industry type	Total revenue from software products
		Total revenue from information technology services
		Number of enterprises in the electronics and industrial communication device manufacturing industry
	Agriculture	Number of rural broadband access
		E-commerce volume of agricultural products
Service Industry	Number of computers per hundred people in industrial enterprises	
	E-commerce transactions of industrial enterprises	
	Proportion of enterprises with e-commerce trading activities	
Digital economy development environment	Innovation Environment	Workforce employment in digital industries
		R&D personnel in the digital industry
		Internal funding of R&D in the digital industry

digitization. The object is to provide a comprehensive depiction of the fusion of infrastructure and digital industries in the growth of the digital economy. The research employs eight secondary indicators, which consist of both traditional and new digital infrastructure to capture the progression of the digital economy, industry scale and type to reflect digital industrialization, as well as agricultural digitization, industrial digitization, and service digitization, which reflecting industrial digitization. Please refer to [Table 1](#) for specific index definitions. In particular, this study uses the Entropy Weight Method (EWM) to construct the total digital economic development index (Zhang et al. 2022).

3.1.3. Mediating Variables: Institutional Environment

As indices of the development of China's institutional environment, this study uses two institutional variables: financial supervision and Legal institutional environment.

- (1) **Financial supervision** (*sup*). In this study, “financial supervision expenditure” is used as the proxy variable of financial supervision. The higher the proportion of financial supervision expenditure, the stronger the government's willingness to conduct financial supervision.
- (2) **Legal institutional environment** (*lie*). This paper draws on previous literature and uses the Fan Gang Legal Environment Index to measure the legal institutional environment of various provinces. The index assigns higher value to regions with stronger legal institutional environment (Shi et al. 2017; Zhao et al. 2019).

Table 2. Summary statistics.

Variable	obs	Mean	Std	Min	Max
<i>NPL</i>	531	0.014	0.006	0.001	0.077
<i>Dige</i>	531	0.267	0.164	0.020	0.733
<i>sup</i>	531	23.058	28.179	0.160	161.07
<i>lie</i>	531	12.251	5.496	1.920	24.33
<i>age</i>	531	2.876	0.724	0.693	4.728
<i>ROA</i>	531	0.891	0.276	-0.59	1.81
<i>size</i>	531	9.518	1.983	5.01	13.546
<i>CAR</i>	531	13.253	1.636	8.09	19.58
<i>gdpr</i>	531	10.465	0.705	8.702	11.734
<i>act</i>	531	0.123	0.038	0.055	0.245
<i>M2</i>	531	14.320	0.245	13.916	14.683

3.1.4. Control Variables

In this study, the control variables are selected from two aspects: commercial banks and the macro-environment. The commercial bank level includes the following variables: asset size (*size*), which is measured by the logarithmic value of the total assets of commercial banks; the age of the bank (*age*), measured by the logarithmic value of the established age of the commercial bank; return on total assets (*ROA*); and the capital adequacy ratio (*CAR*). The macro-environmental level includes the following variables: GDP growth rate (*gdpr*), which is measured by the GDP growth rate of province to reflect the level of economic growth; economic activity act (*act*), which is measured by the proportion of fixed asset investment in GDP to reflects the economic activity; and monetary policy (*M2*), which is measured by the growth rate of narrowly defined money to reflect the looseness of monetary policy. Table 2 presents the summary statistics for the main variables.

3.2. Data Source

Since 2013, China has witnessed a rapid development in its digital economy, accompanied by a steady enhancement in pertinent indicators of the digital economy. As a result, to ensure the completeness and accessibility of commercial bank data. This paper adopts panel data spanning from 2013 to 2021 for research purposes. This study including 16 national, 30 urban, and 13 rural banks. Data were obtained from the annual reports of each bank, the China Banking Regulatory Commission, the Wind Database, and the CSMAR Database. Since it is measured at the inter-provincial level, the digital economy evaluation and macro indicators in the control variables were obtained from the official website of the National Bureau of Statistics, China Academy of Information and Communications Technology, industry and information technology related research reports, and the China Statistical Yearbook of each province. However, since the digital economy is provincial level data and indicators such as non-performing loan ratio of commercial banks are micro-data, this study follows Kong et al. (2022) for matching the variables.

3.3. Models

3.3.1. Basic Model

This paper draws on the practice of Kong et al. (2022) during the research process. Specifically, it matches the registration locations of commercial banks with their respective provincial regions to construct a panel data set covering the period from 2013–2021. To evaluate the impact of digital economy on the credit risk of commercial banks, the study constructs the following models for testing:

$$NPL_{i,j,t} = \eta_0 + \eta_1 Dige_{it} + \eta_j Control_{i,j,t} + \delta_i + \tau_t + \varepsilon_{it} \quad (1)$$

The subscripts *i*, *j*, and *t* represent province, commercial bank, and time respectively. $NPL_{i,j,t}$ denotes the non-performing loan ratio of commercial bank *j*, in period *t*, in province *i*. The higher the *NPL* ratio, the higher the credit risk of commercial banks. $Dige_{it}$ denotes the level of digital economy development in province *i* in period *t*. *Control* denotes the vector of control variables. δ_i and τ_t denote the specific effect of province and year that has not been observed. ε_{it} denotes stochastic disturbance term.

3.3.2. Mediation Model

This paper draws on the approach of Sun et al. (2023) to formulate a regression model that tests the mediation effect of financial supervision and legal institutional environment.

$$media_{i,j,t} = \beta_0 + \beta_1 Dige_{it} + \beta_j Control_{i,j,t} + \delta_i + \tau_t + \varepsilon_{it} \quad (2)$$

$$NPL_{i,j,t} = \alpha_0 + \alpha_1 media_{i,j,t} + \alpha_2 Dige_{it} + \alpha_j Control_{i,j,t} + \delta_i + \tau_t + \varepsilon_{it} \quad (3)$$

media represents mediating variables, including three institutional environment variables follows: financial supervision (*sup*) and Legal institutional environment (*lie*). Other variables and symbol definitions are consistent with equation (1).

In this paper, particular attention is paid to the coefficients β_1 , α_1 and α_2 In formula (2) and (3). β_1 represents the extent of the influence of the digital economy on financial supervision and legal institutional environment, while α_1 represents the extent of the influence of the mediation variables on commercial bank credit risk; α_2 represents the extent of the influence of the digital economy on commercial bank credit risk when both the mediation variable and the core explanatory variable are included in the same equation. The process of testing the mediation effect is stepwise as follows: when coefficients β_1 , α_1 and α_2 are all significant at the confidence level, it indicates a significant mediation effect of the financial supervision and legal institutional environment in the process of the digital economy influencing commercial bank credit risk; when coefficients β_1 and α_1 are significant at the confidence level, but α_2 is not, it indicates a complete mediation effect of the financial supervision and legal institutional environment; when at least one of β_1 and α_1 is not significant, a Sobel test is required to determine the significance of the mediation effect of the financial supervision and legal institutional environment.

4. Empirical Results

4.1. Baseline Regression Result

Table 3 shows the baseline regression results of the digital economy on the credit risk of commercial banks. Column (1) presents regression result without control variables, column (2) is the regression result with only control variables about commercial banks, and column (3) is the regression result with all control variables. As can be seen, the coefficient values of *Dige* are -3.471 , -2.431 , and -2.243 , respectively, and all are significant at the 1% confidence level. This indicates that the development of the digital economy can inhibition the increase of non-performing loan ratio of commercial banks, so as to reduce their credit risk. On the one hand, the digital economy promotes the digital transformation of commercial banks and improves the efficiency of credit resource allocation, which helps to reduce credit risks. On the other hand, the information asymmetry between commercial banks and enterprises is one of the main reasons for the increased credit risks, and big data technology provides the opportunity to assess massive amounts of data related to credit enterprises. This helps to improve the ability of commercial banks to process information and thus reduce their credit risks. Therefore, our first research hypothesis (H1) is supported.

Table 3 displays the impact of digital infrastructure, digital industrialization, industrial digitization, Digital economy development environment on credit risk in commercial banks, as demonstrated in columns (4),(5),(6),(7) respectively. The results indicate that all three factors have a significant negative impact on credit risk in commercial banks, with a confidence level of 1%. The reason behind this could be that digital infrastructure as the basis for digital industrialization and industrial digitization to reduce credit risk in commercial banks. Digital industrialization and traditional industrial digitization primarily reduce credit risk in commercial banks by leveraging industrial convergence effects. On the one hand, digitalization breaks down traditional industrial boundaries, and industrial permeation and convergence facilitate the emergence of new industries and new forms of business, which helps to improve corporate performance and enhance their repayment ability. This, in turn, reduces corporate credit default rates. For example, digitalization has led to the development of demand-driven matching models that gather consumer demand information and feed it back to production enterprises, achieving accurate matching between enterprises and consumers. As a result, it increases corporate revenue and reduces credit risk in commercial banks. On the other hand, digitalization helps to reduce the degree of information asymmetry between commercial banks and

Table 3. Baseline regression result.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Dige</i>	-3.471*** (-7.50)	-2.431*** (-4.78)	-2.243*** (-4.15)				
<i>Dige1</i>				-6.628*** (-3.48)			
<i>Dige2</i>					-3.497*** (-3.38)		
<i>Dige3</i>						-9.981*** (-3.36)	
<i>Dige4</i>							-7.146*** (-3.08)
<i>age</i>		-0.214** (-1.99)	-0.209* (-1.93)	-0.215** (-1.98)	-0.224** (-2.06)	-0.208* (-1.91)	-0.207* (-1.90)
<i>ROA</i>		-1.319*** (-12.33)	-1.272*** (-11.60)	-1.332*** (-12.31)	-1.303*** (-11.89)	-1.284*** (-11.57)	1.304*** (-11.81)
<i>CAR</i>		-0.034* (-1.75)	-0.035* (-1.76)	-0.032* (-1.68)	-0.038** (-1.98)	-0.036* (-1.81)	-0.044** (-2.27)
<i>size</i>			-0.136*** (2.84)	-0.087* (-1.91)	-0.161*** (-3.00)	-0.114** (-2.40)	-0.031 (-0.66)
<i>gdpr</i>			-0.813* (-1.90)	-0.865** (-2.00)	-0.927** (-2.16)	-0.991** (-2.32)	-0.952** (-2.21)
<i>M2</i>			2.194*** (4.32)	2.015*** (3.99)	2.024*** (3.98)	2.228*** (4.16)	1.355*** (2.87)
<i>act</i>			0.367 (0.19)	0.727 (0.37)	-1.207 (-0.65)	-0.005 (-0.00)	-1.556 (-0.08)
<i>Cons</i>	0.806*** (5.39)	4.511*** (8.63)	-1.806*** (-3.56)	-1.547*** (-3.07)	-1.422*** (-2.93)	-1.669*** (-3.10)	-1.628*** (3.59)
Control variables	No	Partial controlled	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	531	531	531	531	531	531	531

*, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

borrowers. This improves the efficiency of information processing by commercial banks, enables them to make more informed credit decisions, and reduces credit risk in commercial banks.

4.2. Robustness Test and Endogeneity

4.2.1. Robustness

Firstly, the risk asset ratio (*riskla*) is used to measure the credit risk of commercial banks. The regression results are shown in column (1) in Table 4. The coefficient value of *Dige* is significantly negative at the confidence level of 1%. Secondly, we regressed the digital economy with a one-period lag. The regression results are shown in column (2) of Table 4. The effect of the digital economy on commercial banks' credit risk remains significantly negative at the 1% confidence level. Thus, these indicate that the development of the digital economy is conducive for reducing commercial banks' credit risk, and suggests the results are robust.

4.2.2. Endogeneity

Measurement errors, omitted variables, and simultaneous causality all have the potential to lead to endogeneity problems (Narayan, Narayan, and Tran 2023). This study attempted to alleviate these effects by adopting two types of regressions to overcome bias associated with potential endogeneity problems. Firstly, the regression was carried out using a two-step system GMM method in the dynamic panel model. The regression results are shown in column (3) in Table 4. The coefficient value of digital economy is -2.049, which is significant at 1% confidence level, and the P-value corresponding to *AR* (2) and *Sargan* statistics are both greater than 0.1, which shows that the regression results of dynamic panel are valid. Those results show that the development of digital

Table 4. Robustness regression results.

Variable	(1)	(2)	(3)	(4)
<i>Dige</i>	-1.951*** (-3.09)		-2.049*** (-3.40)	-3.254*** (-4.53)
<i>L.Dige</i>		-2.113*** (-3.47)		
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
<i>Inter</i> t-value				3.89
First stage F-value				108.49
AR(2)			0.227	
Sargan			0.189	
Observations	531	531	531	531

*, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

economy can reduce the credit risk of commercial banks. Secondly, the instrumental variables were selected and estimated using the 2SLS method. Following Kong et al. (2022), we used the internet penetration rate (*Inter*) of each province as an instrumental variable. *Inter* is closely related to the development of digital economy, however, it does not have a direct impact on commercial bank credit risk (Kong et al. 2022). As can be seen from column (4) in Table 4, the t-values of *Inter* are significant at the 1% confidence level and the F-value at the first stage is greater than 10, which shows that the regression results of the instrumental variable are valid. The results indicate that the impact of digital economy on commercial banks' credit risk is still significantly negative at 1% confidence level.

4.3. Mediating Effects Regression Results

4.3.1. Mediating Effects of Financial Supervision

The regression results of the mediating effect of financial regulation are shown in columns (1) and (2) of Table 5. As shown in the columns (1), the digital economy has a significant positive effect on financial supervision at the 1% confidence level, indicating that increasing the level of digital economy development helps to strengthen financial supervision. It can be seen from the columns (2) that the digital economy has a significant negative effect on the credit risk of commercial banks, while the financial supervision has a significant negative effect. This indicates that the mediating effect of financial supervision is significant, and the development of the digital economy can reduce the credit risk of commercial banks by improving it. The development of digital economy strengthens the financial supervision ability, and can better cope with the complexity and variability of credit risk supervision, thus reducing the risk of commercial banks. These results support our third research hypothesis 2.

Table 5. Mediating effect regression results.

Variable	(1)	(2)	(3)	(4)
	<i>sup</i>	<i>NPL</i>	<i>lie</i>	<i>NPL</i>
<i>Dige</i>	1.891*** (4.20)	-2.011*** (-3.19)	3.464*** (4.06)	-2.124*** (-2.96)
<i>sup</i>		-0.089*** (-10.98)		
<i>lie</i>				-0.068** (-2.09)
Control Variables	Yes	Yes	Yes	Yes
Sobel Test	No		No	
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	531	531	531	531

*, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

4.3.2. Mediating Effects of Legal Institutional Environment

In column (3) of Table 5, it is evident that the development of the digital economy has a significant positive impact on the legal system environment, which is statistically significant at the 1% confidence level. This finding indicates that the advancement of the digital economy can conducive contribute to the enhancement of the legal institutional environment. In column (4) of Table 5, it can be observed that both the digital economy and the legal institutional environment have negative effects on commercial bank credit risk, which are significant at the 1% and 5% confidence levels, respectively. This indicates that the legal institutional environment acts as a mediator, and that the digital economy can mitigate commercial bank credit risk by enhancing the legal institutional environment. The digital economy can provide faster and more efficient transmission of information, alleviate information distortion or blockage, improve the communication efficiency between commercial banks and government legal departments, and aid in establishing a more equitable and transparent legal institutional environment, thereby mitigating commercial bank credit risk. Therefore, the basic research hypothesis 3 is verified

4.4. Heterogeneity Analysis

4.4.1. Heterogeneity Based on Property Rights

Differences in assets and liabilities characteristics, operation and management modes, and other factors among different types of banks will impact on their risk acceptance level. Therefore, this study examines the roles that commercial bank property rights play when it comes to the impact of the digital economy on their credit risk. Samples are divided into state-owned banks and non-state-owned banks according to the nature of actual controllers. The regression results are shown in columns (1) and (2) of Table 6. In order to make the grouped regression results comparable, this paper conducted a Chow test, which yielded a test statistic of 5.09 and a corresponding p-value is 0.000. The results indicate that the grouped regression results are significantly different. The digital economy coefficient is significant at 5% confidence level in both state-owned banks -2.637 and non-state-owned banks -1.811 . These indicate that the digital economy has a greater inhibitory effect on credit risk in state-owned commercial banks than that in non-state-owned commercial banks. State-owned banks often have greater financial strength, and their customers are stable, have good business reputations, sufficient mortgage guarantees, and low risks of defaulting. At the same time, the more complete digital risk control platform of state-owned banks can identify risks more effectively. Therefore, the improvement of digital economy has a greater impact on the reducing credit risks by state-owned banks.

4.4.2. Heterogeneity Based on Region

There are regional differences in digital economy development due to variation in the infrastructure, macroeconomy, and legal systems of provinces where commercial banks are located. To assess the impacts of these differences, we analyzed three subsets of the data that included groups representing eastern, central, and western provinces of China. Regression results for these subsets are presented in columns (3) and (4) in Table 6. In order to ensure comparability of the grouped regression results,

Table 6. Regression results based on heterogeneity analysis.

Variable	(1)	(2)	(3)	(4)
	Non-state-owned banks	State-owned banks	Eastern	Central and Western
<i>Dige</i>	-1.811^{***} (-3.36)	-2.637^{**} (-2.43)	-2.149^{***} (-3.01)	-1.216 (0.74)
Control Variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes

*, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

a Chow test was conducted on the data, yielding a test statistic of 4.57 and a corresponding p-value of 0.000, indicating that the grouped regression results are significantly different. The results show that the coefficient value of the digital economy's impact on the credit risk of commercial banks in the eastern China is -2.149 , which is significant at the confidence level of 1% and indicates that the development of digital economy can effectively reduce the credit risk in the region. However, the impact of digital economy on the credit risk of commercial banks in the central and western China was not significant.

5. Conclusion and Recommendations

This study uses data on Chinese listed commercial banks to explore the impact of the digital economy on credit risk and the mediation effect of the institutional environment. The results show that the credit risk of commercial banks is significantly improved by the digital economy, and that further developing it can additionally reduce credit risk. The institutional variables of financial supervision and legal institutional environment are found to have significant mediation effects. The digital economy can reduce the credit risk of commercial banks by enhancing the intensity of financial supervision and improving the legal institutional environment. Heterogeneous effects indicate that the digital economy has a greater inhibitory effect on credit risk for state-owned commercial banks than for non-state-owned commercial banks, and that it has a significantly negative effect in eastern China, but no effect in the central and western regions.

According to the conclusions of this study, the following policy suggestions are put forward: (1) Commercial banks should closely monitor the trajectory of digital economy development and bolster their risk management capabilities through digital transformation. While China has achieved commendable progress in the advancement of its digital economy, there remains substantial potential for further expansion in both scope and depth. Consequently, commercial banks ought to actively foster the seamless integration of digital technologies into traditional banking operations to tackle information asymmetry challenges and fortify their capacity to identify, monitor, and mitigate risks. (2) Improve the government's financial supervision and Legal institutional environment, establish or improve the risk protection mechanisms, and create better an institutional environment for commercial banks. Government regulatory authorities play a crucial role ensuring the stability of the institutional environment, which, in turn, helps ease the concerns of commercial banks regarding the uncertainties linked to the digital economy.

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