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Fintech's influence on green credit provision: Empirical evidence from China's listed banking sector

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ABSTRACT

We explore the impact of financial technology (fintech) advancements on green credit provision, investigating publicly traded banks in China from 2007 to 2022. We particularly focus on credit modelling innovation, examining the non-linear dynamics between fintech evolution and green credit distribution. Results reveal a positive U-shaped correlation. Initial stages of fintech are associated with increased green credit risk, negatively affecting the volume of green credit. However, more established fintech infrastructures significantly enhance green credit volumes by improving resource allocation and credit risk assessment. Utilizing a multiple linear regression approach, we highlight the transformative nature of fintech in advancing sustainable banking practices, particularly through innovations in credit modeling that enhance green credit risk management and resource allocation efficiency.

1. Introduction

The banking sector's journey toward sustainability has been profoundly influenced by the advent of new technologies, marking a pivotal shift in financial services through the introduction of innovative banking models and the enhancement of green finance. The integration of groundbreaking technological advancements has not only reduced transaction and credit risk costs but also facilitated improved resource allocation (Li et al., 2019; Mirza et al., 2023; Cheng et al., 2024). Among these technologies, artificial intelligence stands out for its role in elevating customer satisfaction with digital banking services and significantly refining green credit risk assessment models, thereby enhancing the competitive edge of corporations (Du et al., 2021; Luo et al., 2021).

In the modern era, fintech has risen as a critical force reshaping the global financial landscape by fusing financial services with digital innovation (Zhao et al., 2022; Guo and Zhang, 2023; Mirza et al., 2023). The adoption of technologies such as blockchain, neural networks, and big data analytics has the potential to drive forward green credit initiatives significantly. Green credit constitutes a pivotal element of sustainable or environmental financing in China, principally encompassing loans disbursed by financial institutions to enterprises for investments in areas such as green environmental protection, clean energy, the circular economy, infrastructure, and the green transformation of traditional industrial services (Cheng et al., 2023; Liu and You, 2023). Scholarly perspectives vary on the influence of financial technology (fintech) on green credit. Some researchers posit that fintech may engender information and technological monopolies, adversely affecting traditional commercial banks by causing them to lose a substantial number of borrowers and diminishing the profitability of their lending operations (Fuster et al., 2019). Concurrently, evidence

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suggests that an escalation in green credit risk diminishes the propensity of banks to offer green loans (Xing et al., 2021). Conversely, fintech is argued to bolster the advancement of green credit in banks by reducing management costs and enhancing the allocation of resources (Eisenbach et al., 2022). Additionally, the enhancement of banks' resource efficiency is deemed supportive of the broader development of green finance (Mirza et al., 2023).

Despite substantial investments by commercial banks in the deployment of new information technologies, there remains a considerable disparity in the levels of green credit across these institutions (Gelsomino et al., 2023). Additionally, the current analytical framework examining the impact mechanisms of financial technology (fintech) on green credit is incomplete. Therefore, investigating the influence mechanisms between fintech and green credit holds significant practical importance. This study seeks to address gaps in the existing literature in several ways. First, while prior research predominantly investigates the impact mechanisms of fintech on green credit through a simplistic linear relationship and acknowledges the critical role of fintech in fostering the development of green credit, it fails to examine how different stages of fintech development may variably influence banks' green credit practices. Second, the nuanced transmission mechanisms through which credit risk and credit allocation affect the complex interrelation between banks' green credit and the developmental stages of fintech remain largely unexplored. This study aims to provide a more comprehensive understanding of these dynamics.

Consequently, this study sets out to empirically investigate the intermediary roles that green credit risk and resource allocation play in the fintech-green credit nexus within China's listed banks over the span of 2007–2022. Specifically, it scrutinizes the direct effects of fintech on green credit provision and delves into how varying levels of fintech maturity impact the expansion of green credit via innovations in credit modeling and the mechanisms of green credit risk and resource efficiency. The rest of this paper is structured as follows: Section 2 provides the theoretical analysis and develops the research hypotheses. Section 3 details the sample selection, data gathering processes, the variables involved, and the construction of the model. Section 4 presents the empirical results, including benchmark regression analyses, mediation mechanism tests, assessments of heterogeneity, and robustness checks. Section 5 offers conclusions and outlines the managerial implications of the findings. Section 6 explores potential future research avenues.

2. Literature review and research hypotheses

2.1. Fintech in the banking industry

Fintech can help resource utilization and sustainable green economic development (Awais et al., 2023; Du et al., 2023; Li et al., 2023; Li et al., 2023). Recently, China has gained extensive experience in fintech, such as the recent stablecoin and centralized digital currency (Allen et al., 2022). The types of fintech innovations in the banking sector include innovations in payment systems (including cryptocurrencies), credit markets (including P2P lending), and insurance (Thakor, 2020: Zhao et al., 2023; Banerjee, et al., 2024), etc. Fintech has a multidimensional impact on the financial performance of banks and firms.

On the one hand, for the banking sector, technological progress and technology gaps are crucial factors for banks' financial performance (Kou et al., 2021). The combination of digital technology and traditional business has impacted lending and deposit services, P2P lending, and social media use, etc. (Murinde et al., 2022). The banking industry is experiencing new technological innovations. The whole industry is looking for new ways of successful business models and new ways to improve management operations (Gomber et al., 2018). More and more banking companies are working on their own fintech platforms in full swing. Fintech applications will reduce costs, increase efficiency, provide higher quality services and improve customer satisfaction (Kou et al., 2021).

On the other hand, for enterprises, the role of fintech in alleviating financing constraints is more obvious in non-state-owned enterprises, small and medium-sized enterprises (SMEs), as well as enterprises in the more economically developed regions in the east. For example, Soni et al. (2022) suggests that banks use information technology to innovate financial services, simplify the lending and transaction processes of SMEs, and optimize the flow of funds in the supply chain. Fintech promotes the supply of bank funds to increase enterprise innovation capital investment (Li et al., 2023). Studies have shown that the role of fintech in promoting technological innovation in enterprises is more prominent in larger and state-owned enterprises (Kong et al., 2022).

2.2. Green credit in the banking industry

Green credit is a financial service provided by banks to encourage borrowers to make green investments and achieve sustainable development (An et al., 2021). Green credit business plays a vital role in promoting sustainable development in the banking sector (Ding et al., 2022). On the one hand, bank green credit innovates profitable and sustainable business models for borrowers, reduces borrower cash flow volatility, and thus generates less lending risk(Umar et al., 2021). On the other hand, green credit promotes green innovation in heavily polluting firms by alleviating financing constraints while increasing credit constraints (Hu et al., 2021).

Scholars generally agree that technological advances have an impact on the scale of green credit in banks. Most studies conclude that the more digitized a bank is, the larger the scale of green credit is. However, some studies have also shown that the development of green finance in China generally negatively affects the scale of bank credit, which in turn inhibits the improvement of renewable energy investment efficiency (He et al., 2019). It has also been found that private firms with stronger credit constraints receive less green credit, but these firms tend to be more innovative. Studies have shown that large, profitable and state-owned banks tend to grant more green credit (Yin et al., 2021).

2.3. Fintech and green credit

Fintech helps lower investment risk, increase trustworthiness, and lessen information asymmetry(Lee et al., 2021). In general, banks with lower levels of fintech are generally unable to mitigate the information asymmetry between creditors, and as a result, banks are cautious in granting green credit (Chen and Zhao, 2022; Gelsomino et al., 2023). Furthermore, the limited market recognition of fintech in its nascent stages could potentially dampen the enthusiasm of commercial banks to utilize fintech for enhancing green credit operations. Consequently, during this initial phase, there may exist an inverse relationship between the advancement level of fintech and the extent of green credit adoption. Banks with a higher level of financial technology will absorb the technological advantages of digital finance, and this technological dynamic ability can improve the early warning, identification and management ability of commercial banks on credit risk, improving the resource allocation efficiency of the lending business and the quality of credit, which in turn reduces the credit risk of commercial banks (Mirza et al., 2023), and thus promote the expansion of the scale of green credit. From the analysis of these two developmental stages, it is evident that during the initial phase of fintech development, commercial banks encounter both technological and market-related challenges, which restrict their ability to effectively deploy fintech in green credit services. As fintech progresses towards greater maturity and acceptance, commercial banks gradually begin to leverage the technological benefits offered by fintech to facilitate and promote the expansion of green credit initiatives. Fintech development and commercial banks' green credit scale show a non-linear curvilinear relationship. Therefore, this paper proposes the following research hypothesis:

H1: There is a positive U-shaped relationship between the level of financial technology of commercial banks and the scale of green credit.

In the new development landscape, the green credit market has great scope for development (Chen and Zhao, 2022; Yang et al., 2023). However, green credit business opportunities and challenges at the same time. Green credit risk is mainly caused by information asymmetry between borrowers and banks. On the one hand, before the issuance of loans, due to the national policy support for environmentally friendly business, green enterprises may appear to have the phenomenon of "fraudulent subsidies", resulting in the unreasonable use of enterprise funds and increase the risk of default, and increase the possibility of adverse selection of the bank's green credit (Scholtens and Dam, 2007). On the other hand, in the process of loan issuance, it is difficult for banks to fully grasp the returns, risks and use of funds of the borrowing enterprise's investment projects, especially some green projects, whose approval process is usually more complex, with a long payback cycle, and in the process of project construction may encounter a great deal of uncertainty, and if there is a change in the policy environment it is likely to lead to an increase in the cost of the project, which affects its returns, and at this time the probability of moral hazard arises also. The probability of moral risk will also become larger. Therefore, assessing, managing and controlling green credit risks can improve the efficiency of bank capital utilization, increase the confidence of financial institutions, and promote the sustainable development of green credit and the high-quality development of green economy (Zhao and Chen, 2022).

With the low level of fintech, commercial banks not easy for them to identify enterprises applying for green credits with high risk of default, they are vulnerable to enterprises' "green labeling" and "green dyeing" behaviors in order to obtain green credits fraudulently (Riikkinen and Pihlajamaa, 2022; Xing et al., 2021). In the business operation, commercial banks can't to monitor the flow of green credit funds in real time due to the lack of advanced technologies such as big data and blockchain, and when green credit applicants divert the green funds for other purposes, commercial banks also can't to freeze and recover the issued green credit funds in a timely manner, which reduces the confidence of commercial banks in the green credit business. This reduces commercial banks' confidence in green credit business, and therefore commercial banks will reduce the investment of green credit (Wu et al., 2022). Therefore, we propose hypothesis 2:

H2: The risk of banks' green lending rises dramatically when fintech is low, which in turn shrinks the scope of green credit.

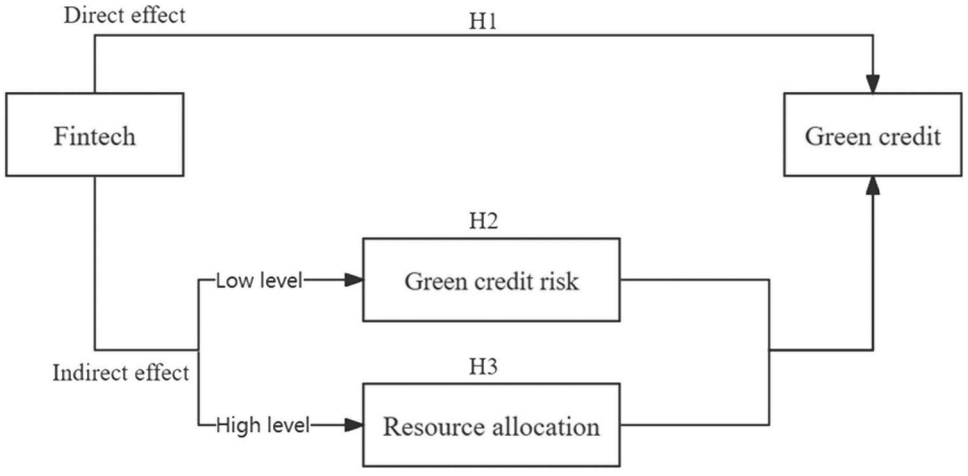

Fig. 1. Diagram of the theoretical model.

Bank resource allocation efficiency is an important standard for measuring the operational performance of banks, and is an important reference for the reasonableness of the ratio of inputs and outputs in the operational activities of banks, it reflects the ability of banks to transform financial resources into financial services and to improve their own competitive advantage. Banks improve resource allocation efficiency, which helps to enhance the ability of financial services to the real economy, and contributes to the sustainable development of the country's economy and environment (Shahbaz et al., 2016). On the contrary, it is difficult that banks with inefficient resource management benefit from technological progress (Cao et al., 2022).

Cardona and Moreno, (2012) suggested that the cost of cash management in banks can be reduced and resource allocation efficiency can be improved through data mining techniques. The emergence of digital finance helps to improve banks' resource allocation efficiency. Specifically, for private enterprises, digital finance reduces the financial mismatch between banks and borrowing enterprises, improves the efficiency of financial resource allocation, and mitigates the widespread phenomena of "ownership discrimination" and "size discrimination" in the credit market (Parnaudeau, 2015). When the level of fintech is high, banks increase the scale of green credit by optimizing the allocation of resources and improving the core competitiveness of enterprises (Kou et al., 2021; Luo et al., 2021). On the resource side, commercial banks, with the soft information advantage from big data technology, have the traits of financial inclusiveness and low-cost, which helps to reduce the cost of bank cash management and the threshold of green loans for small and medium-sized enterprises, and make up for the imbalance of credit supply in the traditional financial market. (Lee et al., 2021; Yin et al., 2021). On the lending side, commercial banks are providing more high-quality green products and specialized services through advanced financial technologies to enhance customer experience(Gomber et al., 2018; Murinde et al., 2022). Therefore, we propose hypothesis 3:

H3: When the level of fintech is high, banks increase the scale of green credit by optimizing resource allocation.

In summary, the theoretical mechanism and research hypothesis of fintech on bank green credit are shown in Fig. 1.

3. Research design

3.1. Research samples and data processing

After excluding the listed banks with incomplete annual financial data during the study period, this paper takes 31 listed commercial banks in China from 2007–2022 as the research object, including 20 state-owned banks and 11 non-state-owned banks. The bank business data and financial data required for this paper are mainly from CSMAR database, Mark Data Network, and the social responsibility reports and sustainable development reports of commercial banks. Some of the missing data were supplemented by consulting the annual reports of commercial banks, and the small amount of missing data was supplemented by linear interpolation.

3.2. Variable definition

3.2.1. Explanatory variables

Green Credit (GR). Referring to previous research, this paper uses the green credit balance in the social responsibility report of commercial banks to measure.

3.2.2. Core explanatory variables

Fintech level (Fintech). Based on the analysis of the research object from a micro perspective, this paper draws on the practice of Guo et al. (2023) to measure the development level of fintech through text mining and the fintech development index constructed by Python scripting language.

Table 1
Variables are defined and explained.

Variable type	Variable	Variable symbol	Variable definitions
Explanatory variables	Green Credit	GR	The logarithm of green credit balance (100 million yuan)
Core explanatory variables	Fintech Level	Fintech	Fintech development index based on text mining method and Python scripting language
Mediation variables	Green Credit Risk	GCR	Based on the ratio of risk-weighted assets to total loans
	Resource Allocation	RA	Total Loans/Total Deposits
Control variables	Net interest margin	NRM	(Total Interest Income/Beginning and End Average of Interest-bearing Assets) - (Gross Interest Statement/Beginning and End Average of Interest-bearing Liabilities)
	Non-performing loan ratio	NPL	Non-performing loan balance/total loan amount at the end of the period
	Cost-to-income ratio	CI	Operating costs/operating income
	Money supply	M2	Broad money M2 growth
	gross domestic product	GDP	Year-on-year growth rate of real GDP

3.2.3. Mediation variables

Green Credit Risk (GCR) and Resource Allocation (RA). According to the above theoretical analysis, GCR and RA are transmission channels where the level of fintech development affects commercial banks' green credit. This paper uses the risk-weighted asset ratio (RISK), that is, the proportion of risk-weighted assets to total loans, to measure the credit risk level of banks, and the deposit and loan ratio (LD) is used as a measure of banks' resource allocation status.

3.2.4. Control variables

Shang and Niu (2023) have demonstrated that variables such as net interest margin (NIM), non-performing loan ratio (NPL), cost-to-income ratio (CI), money supply (M2), and gross domestic product (GDP) significantly influence the volume of green credit extended by banks. While these factors are relevant, the primary aim of this study is to investigate the relationship between the level of fintech development and the scale of green credit, rather than to conduct a detailed analysis of firm-level characteristics. Consequently, while acknowledging their potential impact, these variables are not the focal point of this research. Thus, in this paper, they are incorporated as control variables in relation to the primary variables under study. The specific variable definitions and descriptive statistical results are shown in Table 1.

3.3. Descriptive statistics

After the study variables and sample data were selected, we used descriptive statistics to analyze the statistical characteristics of each variable, as shown in Table 2. Considering the focus of this paper, the statistical characteristics of each variable will not be repeated

3.4. Model building

Based on the previous theoretical analysis and previous research, this paper uses a linear regression model to explore the positive U-shaped impact relationship between fintech and green credit. When constructing the model, we aim to more accurately estimate the impact of fintech on green credit and enhance the explanatory power and reliability of the model by controlling for a series of potential influencing factors and considering the dual fixed effects of individual and time. To the end, the following model is constructed:

$$GR_{i,t} = \alpha + \beta Fintech_{i,t} + \gamma Fintech^{2}_{i,t} + \delta Controls + \mu_i + \lambda_i + \varepsilon_{i,t} \quad (1)$$

Among them, the explanatory variable GRi, t represents the amount of green credit of bank i in year t, i=1,…,31, t=2007,…,2022, the core explanatory variable $Fintech_{i,t}$ represents the level of financial technology development of bank i in year t, and $Fintech^{2}_{i,t}$ is the square term of the financial technology development level of bank i in year t, Controls is the control variable of commercial banks at the micro level and domestic macroeconomic level, μ_i is the fixed effect of individual banks, λ_i is the fixed effect of time, and $\varepsilon_{i,t}$ is the random error term. When the coefficient β is significantly negative and the coefficient γ is significantly positive, it indicates a nonlinear "positive U-shaped" relationship between fintech and green credit.

4. Empirical analysis

4.1. Baseline regression results

The sample data used in this paper is the panel data, and considering that the individual banks and time may affect the model, the fixed-effect model (controlling for individual and time effects) is used for baseline regression, and the results are shown in Table 3.

As it can be seen from column (1) of Table 3, when no control variables are added, the coefficient of the level of fintech development is −0.285, which is significantly negative at the 1% level, and the coefficient of the square term of the level of fintech development is 0.017, which is significantly positive at the 5% level. When considering the control variables such as the micro level and the macroeconomic policy level of commercial banks, the coefficient of the level of fintech development is −0.345, which is significantly negative at the level of 1%, and the coefficient of the square term of the level of fintech development is 0.20, which is significantly positive at the level of 1%. This indicates that there is a nonlinear "positive U-shaped" curve relationship between the level

Table 2
Descriptive statistical results of variables.

Variable	N	Mean	SD	Median	Min	Max
Fintech	397	8.56	1.82	8.82	0.99	13.09
GR	397	5.36	2.42	5.42	-1.61	9.89
GCR%	397	0.62	0.10	0.62	0.05	0.79
RA%	397	1.01	0.28	0.98	0.28	2.13
NRM%	397	2.37	0.60	2.28	1.32	4.48
NPL%	397	1.33	0.52	1.27	0.43	3.71
CI%	397	31.14	5.00	30.36	21.52	44.88
M2%	397	12.47	4.46	11.80	8.10	27.68
GDP%	397	7.19	2.56	7.04	2.20	14.23

Table 3
Benchmark regression results.

Variable	(1) GR	(2) GR
Fintech	-0.285***	-0.345***
	(0.086)	(0.106)
$Fintech^2$	0.017**	0.020***
	(0.006)	(0.008)
NRM		-0.089
		(0.082)
NPL		0.126
		(0.096)
CI		-0.020
		(0.016)
M2		-0.057**
		(0.025)
GDP		-0.213***
		(0.042)
Id Fe	Yes	Yes
Year Fe	Yes	Yes
N	397	397
R^2	0.894	0.895
Adj.R^2	0.880	0.880

Note: ***, **, and * indicate significant at 1%, 5%, and 10% levels, respectively. Numbers in parentheses are either t-values or z-values.

of financial development technology of commercial banks and the amount of green credit. Which means, when the development of fintech is at a low level, due to the immaturity of technology and other reasons, it may lead to the decrease in the amount of GR, and when the development of fintech exceeds the inflection point, the advantages brought by its technological development begin to appear, which can promote the increase of GR in banks. Furthermore, the U-test is carried out, and the calculated inflection point value is 4.32, which is within the range of values. The results show that when the measurement index value of fintech development is lower than 4.32, fintech development will reduce the amount of green credit, and when the measurement index value of fintech development exceeds 4.32, fintech development will increase the amount of green credit. Therefore, assuming that H1 is true, there is a "positive U-shaped" relationship between fintech and green credit scale.

4.2. Mediator effect test

The conclusions of the above research show that different levels of fintech have different impacts on the amount of green credit.

Table 4
Based on the low level of fintech.

Variable	(1) GR	(2) GCR	(3) GR
Fintech	-0.367***	0.028**	-0.291**
	(0.118)	(0.011)	(0.118)
GCR			-2.705**
			(1.075)
NRM	-0.110	-0.020***	-0.164*
	(0.083)	(0.006)	(0.086)
NPL	0.125	-0.008	0.104
	(0.137)	(0.009)	(0.135)
CI	-0.019	-0.005***	-0.032**
	(0.015)	(0.001)	(0.016)
M2	-0.061***	-0.002	-0.066***
	(0.023)	(0.002)	(0.022)
GDP	-0.196***	-0.003	-0.204***
	(0.724)	(0.069)	(0.942)
R^2	0.909	0.764	0.912
Adj.R^2	0.896	0.730	0.899
Sobel Test	The Z-value was −2.732 and the P-value was 0.006, indicating a significant indirect effect.		
Bootstrap Test	The Z-value is −2.1 and the P-value is 0.035, The 95% confidence interval was [-0.075, −0.003].		
Id Fe	Yes	Yes	Yes
Year Fe	Yes	Yes	Yes
N	397	397	397

Note: ***, **, and * indicate significant at 1%, 5%, and 10% levels, respectively. Numbers in parentheses are either t-values or z-values.

This section will refer to the practice of Shin and Grant (2021) to indicate the low level and the high level of fintech respectively by the primary term and the quadratic term of fintech level. In the primary term, we will focus on how low-level fintech banks achieve a restraining effect on green credit by increasing credit risk, and in the quadratic term, we will focus on how high-level fintech banks promote GR by optimizing resource allocation. This paper uses the Sobel test and Bootstrap test to support the evidence, so as to deeply analyze the impact mechanism of fintech on green credit.

4.2.1. Based on the low level of financial technology

First, based on the low-level dimension of fintech, this paper discusses how low-level fintech banks reduce the scale of green credit by increasing credit risk. The amount of green credit provided by banks will be affected by the level of credit risk. The regression results are shown in Table 4, where column (1) shows that the coefficient of fintech to green credit is significantly negative, indicating that the low level of fintech development in banks will lead to a decrease in the amount of green credit, and column (2) in Table 4 shows that the coefficient of fintech level to green credit risk is significantly negative, which indicates that the low level of fintech development will lead to the increase of green credit risk. The coefficient of green credit risk to green credit is significantly negative in column (3) of Table 4, which indicates that the increase of green credit risk will lead to the decrease of green credit volume when the development level of bank fintech is low. Column (3) in Table 4 also shows that after adding the intermediary variable credit risk, the impact of fintech level on green credit is still significant and the coefficient decreases, so it can be considered that there is only a partial mediating effect on green credit risk. It is proved by the Sobel test as well as the Bootstrap test that the mediating effect of credit risk exists. Therefore, hypothesis 2 holds, i.e., low-level fintech banks reduce the scale of green credit by increasing green credit risk.

4.2.2. Based on the high level of financial technology

Secondly, based on the high-level dimension of fintech, this paper explores how high-level fintech banks increase the scale of green credit by optimizing the allocation of resources. The allocation of credit resources plays an important role in bank management. The regression results are shown in Table 5, column (1) of Table 5 shows that the coefficient of the square term of the financial technology level to green credit is significantly positive, which indicates that the high level of development of financial technology will promote the increase of green credit supply, column (2) of Table 5 shows that the coefficient of the square term of financial technology on the allocation of resources is significantly positive, which indicates that the high level of financial technology development will optimize the allocation of bank credit resources, and column (3) of Table 5 shows that the coefficient of resource allocation to green credit is significantly positive, which indicates that high-level fintech banks will promote the increase of green credit by optimizing the allocation of credit resources. Column (3) in Table 5 also shows that after adding the intermediary variable resource allocation, the impact of fintech level on green credit is still significant and the coefficient decreases, so it can be considered that there is only a partial mediating effect in resource allocation. It is proved by the Sobel test as well as the Bootstrap test that the mediating effect of credit resource allocation exists. Therefore, hypothesis 3 is supported, that is, high-level fintech banks increase the scale of green credit by optimizing the allocation of resources.

Table 5
Based on the high level of fintech.

Variable	(1) GR	(2) RA	(3) GR
$Fintech^2$	0.020***	0.001***	0.018***
	(0.008)	(0.000)	(0.007)
RA			0.754**
			(0.312)
NRM	-0.089	0.067**	-0.134
	(0.082)	(0.031)	(0.082)
NPL	0.126	-0.011	0.119
	(0.096)	(0.038)	(0.110)
CI	-0.020	0.003	-0.021
	(0.016)	(0.003)	(0.016)
M2	-0.057**	-0.001	-0.058**
	(0.025)	(0.006)	(0.024)
GDP	-0.213***	0.025***	-0.228***
	(0.042)	(0.008)	(0.041)
R^2	0.895	0.699	0.897
Adj.R^2	0.880	0.656	0.882
Sobel Test	The Z-value was −2.001 and the P-value was 0.045, indicating significant indirect effects.		
Bootstrap Test	The Z-value is −1.97 and the P-value is 0.048, The 95% confidence interval was [-0.002, −0.0001].		
Id Fe	Yes	Yes	Yes
Year Fe	Yes	Yes	Yes
N	397	397	397

Note: ***, **, and * indicate significant at 1%, 5%, and 10% levels, respectively. Numbers in parentheses are either t-values or z-values.

4.3. Heterogeneity analysis

On the basis of testing the impact of fintech level on the amount of green credit, in order to further investigate the difference in the impact of fintech on green credit delivery of different types of commercial banks, this paper divides the whole sample into two subsamples of state-owned banks and non-state-owned banks for empirical testing. Table 6 shows the results of group regression, where column (1) of Table 6 shows the impact of fintech development level on green credit allocation of state-owned banks, and column (2) of Table 6 shows the impact of fintech development level on green credit allocation of non-state-owned banks. The results show that the development of fintech has different impacts on green credit in different types of commercial banks. In column (1) of Table 6, the coefficients of fintech development and its square term are −0.365 and 0.022, respectively, both of which pass the significance level test of 5%, which indicates that fintech development has a "positive U-shaped" relationship with the green credit allocation of state-owned banks. In column (2) of Table 6, the coefficients of fintech development and its square term are 7.868 and −0.426, respectively, which fails to pass the significance level test of 10% and indicates that there is no "positive U-shaped" relationship between fintech development and green credit delivery of state-owned banks, or even no significant impact relationship.

The possible explanation is that when fintech is a low level, state-owned banks will face more regulatory pressure and compliance requirements, and it needs to invest more resources in technology upgrading and data protection at the same time, which may have a certain impact on the volume of green credit. As financial technology advances, state-owned banks have embraced it more actively and have assessed and managed the green credit distribution business more skillfully, leading to a rise in the volume of green credit delivered. For non-state-owned banks, with the limitations of their bank size, market share and available resources, fintech has not been popularized and applied to a large extent, so the development level of fintech has not had a significant impact on their green credit business.

4.4. Robustness test

In order to ensure the non-randomness and credibility of the benchmark regression results, this paper verifies the robustness of the benchmark regression results by adding control variables and performing 1% tailing processing on the sample data. The results are shown in Table 7.

5. Conclusion and implications

5.1. Conclusion

The elucidation of the nexus between financial technology (fintech) and green credit constitutes a pivotal undertaking for delineating the ramifications of fintech innovations on the green business trajectories of Chinese banking entities. This investigation, leveraging panel data from 31 publicly traded commercial banks in China spanning from 2007 to 2022, employs a bi-directional fixed-effect model to scrutinize the influence of fintech on the magnitude of banks' green credit offerings.

Our empirical analysis delineates a distinctive contrast in the impact of fintech evolution vis-à-vis other determinants on the

Table 6
Heterogeneity analysis based on the nature of bank ownership.

Variable	(1) State ownership GR	(2) Non-state ownership GR
Fintech	-0.365***	7.868
	(0.129)	(5.978)
$Fintech^2$	0.022**	-0.426
	(0.009)	(0.329)
NRM	-0.089	-0.362
	(0.093)	(0.263)
NPL	0.239**	-0.388*
	(0.120)	(0.199)
CI	-0.017	-0.013
	(0.025)	(0.024)
M2	-0.034	-0.154***
	(0.030)	(0.049)
GDP	-0.240***	-0.094
	(0.063)	(0.065)
Id Fe	Yes	Yes
Year Fe	Yes	Yes
N	265	132
R^2	0.911	0.859
Adj.R^2	0.895	0.817

Note: ***, **, and * indicate significant at 1%, 5%, and 10% levels, respectively. Numbers in parentheses are either t-values or z-values.

Table 7
Robustness test results.

Variable	(1) GR	(3) GR
Fintech	-0.322**	-0.367***
	(0.130)	(0.118)
Fintech^2	0.019**	0.023***
	(0.009)	(0.009)
NRM	-0.115	-0.110
	(0.086)	(0.083)
NPL	0.109	0.125
	(0.101)	(0.137)
CI	-0.019	-0.019
	(0.017)	(0.015)
LDR	0.002	
	(0.004)	
PC	0.129	
	(0.137)	
ROA	-0.217	
	(0.870)	
M2	-0.062**	-0.061***
	(0.026)	(0.023)
GDP	-0.197***	-0.196***
	(0.050)	(0.037)
Id Fe	Yes	Yes
Year Fe	Yes	Yes
N	397	397
R^2	0.896	0.909
Adj.R^2	0.880	0.896

Note: ***, **, and * indicate significant at 1%, 5%, and 10% levels, respectively. Numbers in parentheses are either t-values or z-values.

1) Add control variables. Because the green credit allocation of commercial banks will be affected by multiple factors, other important variables are omitted, resulting in the non-robustness of the estimation results. Therefore, in addition to the control variables used above, three new control variables were added: Liquidity Ratio (LDR), Provision Coverage Ratio (PC), and Return on Total Assets (ROA), and the benchmark model was re-tested. Table 7 column (1) shows that the impact coefficients of fintech development and its square term are −0.322 and 0.019, respectively, both of which pass the significance level test of 5%, indicating that there is still a "positive U-shaped" relationship between fintech development and green credit delivery, and the benchmark regression results are robust.
2) Tail shrinking of the sample data. In order to avoid the bias effect of outliers on the regression results, this paper performs a 1% bilateral tailing treatment for the selected variables, and re-performs the fixed-effect regression with the tailed data. As shown in column (2) of Table 7, the impact coefficients of fintech development and its square terms are −0.367 and 0.023, respectively, and both pass the significance level test of 1%, indicating that there is a "positive U-shaped" relationship between fintech development and green credit delivery, which effectively passes the robustness test.

expansion of green credit. Utilizing a triadic mediation approach, the study examines the intermediary role of credit risk and resource allocation between varying fintech maturity levels and green credit volume, corroborated by Sobel and Bootstrap tests. Furthermore, the research unveils the heterogeneity in the fintech-green credit interplay across state-owned and non-state-owned banks, revealing that nascent fintech entities inadvertently contract green credit scope through heightened credit risk, whereas their advanced counterparts augment green credit dissemination by refining credit resource distribution, with pronounced effects observed in state-owned banks.

5.2. Theoretical contributions

There are two aspects about the theoretical contribution. First, through empirical research, this study reveals the curvilinear relationship between fintech and green credit, which breaks through the limitations of the linear relationship in previous studies and provides a new perspective for understanding the complex interaction between the two, it helps to enrich the literature related to financial technology. Specifically, previous studies had emphasized the role of fintech in contributing to bank business model innovation and new business development (Mirza et al., 2023). Our findings suggest that there is variability in the current level of digital finance in the banking industry, the high-level banks will lend more on green credit, while the low-level banks lend less. Therefore, our results enrich the study on the impact of fintech. Second, based on the discovery of the curve relationship, we construct the theoretical framework of "fintech level-credit risk and resource allocation-green credit scale". By constructing a new theoretical model, this paper provides more comprehensive and in-depth theoretical support for explaining how fintech affects the scale of green credit. Specifically,

in our opinions, banks with low levels of financial technology increase credit risk and reduce willingness to take green credit, which leads to a reduction in the scale of green credit; banks with a high level of financial technology optimize the allocation of resources and reduce operating costs, thereby expanding the scale of green credit.

5.3. Management implications

The research results provide some management insights.

First of all, for banks, fintech has given rise to new business models, highlighting the key role of innovative technology finance in improving the sustainable operation and development of banks. Banks should increase investment in financial technology tools, accelerate the construction of banking financial infrastructure, and actively explore the integration model of financial technology and green credit, so as to lay the foundation for future market competition. In addition, our research shows that credit risk can reduce the scale of banks' green credit, while resource allocation can increase the scale of banks' green credit. Therefore, how to use fintech to improve resource allocation is something that banks need to explore in depth.

Second, for the government, it should focus on the frontier issues and bottlenecks of fintech applications, relax restrictions and controls, and formulate corresponding policies to guide financial institutions to increase fintech innovation and green development. Moreover, there is obvious heterogeneity between state-owned banks and non-state-owned banks in the relationship between fintech and green credit. It indicates that the current state-owned banks have large differences in the level of financial technology. Therefore, policymakers should ensure that state-owned and non-state-owned banks enjoy equal market opportunities and policy treatment in the field of fintech and green credit, and avoid market monopoly and unfair competition.

6 Limitations and future research

Notwithstanding its contributions, this study is not without limitations. Its focus on the micro-level impact of digital technology on green credit in China's listed commercial banks may circumscribe the generalizability of the findings. Future research endeavors will aim to validate our methodological framework through broader empirical investigations encompassing samples from both developed and developing nations and including unlisted banking institutions. This approach will potentially offer a more comprehensive understanding of the fintech-green credit dynamics and its applicability across diverse banking contexts. In addition, future research can improve the research framework by introducing new theoretical perspectives and constructing more comprehensive analytical models, so as to better reveal the impact mechanism between fintech and green credit.

CRediT authorship contribution statement

Zuojing He: Resources, Investigation, Conceptualization. **Maura Sheehan:** Writing – review & editing, Project administration, Methodology. **Anna Min Du:** Writing – review & editing, Validation, Supervision, Project administration, Investigation. **Shengxi Ban:** Formal analysis, Data curation. **Fangting Ge:** Writing – original draft, Software, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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