



Is FinTech beneficial to green finance? An empirical analysis of listed banks in China

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ABSTRACT

This study investigates how financial technology (Fintech) influences green finance within China's banking sector, a critical topic amid global sustainable development goals. Using a Fintech index and panel data from 26 listed Chinese banks from 2011 to 2022, a two-way fixed-effects model is employed. The results show that Fintech significantly promotes green credit growth, with a 1% increase in the Fintech index associated with approximately 0.23% increase in green credit ($p < 0.01$). However, this effect is highly heterogeneous, while Fintech positively affects green credit in eastern China but shows an inhibitory effect in western China (coefficient = 0.31, $p < 0.01$). A scale effect also exists, whereas large banks benefit more from Fintech than small banks. Specifically, the sensitivity of green credit in small-scale banks to Fintech is lower than that in large-scale banks, indicating greater potential for Fintech in larger institutions. Based on these findings, this study proposes several evidence-based policy recommendations, which includes large-scale banks (Bank of China, ICBC and so on) promotes capacity-building and institutional correlation, while medium-scale (Ping An, Everbright and so on) and regional banks (Bank of Nanjing, Zhengzhou etc.) still underdeveloped in FinTech infrastructure. These include formulating differentiated policies to encourage Fintech innovation, improving green capital adequacy standards of large-scale banks in China, maintaining sound capital ratios, and promoting cross-sectoral and cross-regional cooperation. This study emphasizes Fintech's important role in advancing green finance, extending the sample to other emerging economies and exploring additional mechanisms such as digital inclusion and green innovation spillovers.

1. Introduction

The concepts of "green finance" and "financial technology (FinTech)" are relatively new in academia, and fewer scholars have studied the interaction between them in depth (Zhi et al., 2026). Green finance plays a crucial role in China's transition to a sustainable and environmentally friendly economy, and an in-depth understanding of the drivers of green finance development is the basis for a successful transition (Wang et al., 2026). Fintech is a collection of advanced technologies applied in the financial industry, the study of its impact on green finance is crucial, and this research will not only fill the existing research gaps but also have a far-reaching effect on the field of practice (Wang et al., 2025). This study can provide key information for governments and regulators to formulate sustainable financial policies, as well as useful recommendations for financial institutions' strategic planning in the field of green finance.

The purpose of this paper is to examine how Fintech can contribute to the development of green finance in the Chinese context by innovating and improving financial services. It also analyzes the interaction mechanism between Fintech and green finance and its potential role in achieving peak carbon and carbon neutral targets as previous reported by Li et al. (2026a) to integrate modern AI-based technologies to monitor carbon emission and carbon trading mechanisms. It provides a new perspective of promoting the transformational development of green finance through Fintech. The research results not only help to fill the gaps in theoretical research, but also provide empirical data support for policy makers and financial practitioners to guide their decision-making in the field of green finance. Overall, the investigation makes three novel contributions, first, it bridges the FinTech-green finance and regional innovation systems, offering a theoretical perspective. Second, it provided a long-run datasets to highlight major

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trends of China's banking system and, third, demonstrating policy implantation in green finance.

This paper contributes in the following ways: (I) It offers a unique perspective to the existing literature. While numerous studies have examined the impact of Fintech development on environmental protection and the green economy, there remains a relatively limited body of literature specifically focused on quantitatively analyzing the relationship between Fintech and green finance from a banking perspective. This study fills this research gap and expands the academic discussion in related fields. (II) Develop a bank-level fintech development index. Current research on FinTech indices typically focuses on city or national levels, which can result in inaccurate and unreliable data when analyzing individual banks. Although some researchers use bank-level fintech indexes, directly using the number of relevant news searches from Baidu, a major Chinese search engine, often yields inaccurate results. In this paper, we use Google search and optimize the algorithm to enhance the text mining effect and make our research results more credible. First, we restrict the keywords to the body of the search news. Second, and specify the time when the news appeared. Specify the Google news search interface and use selenium library to automate the search, the specific search syntax is *all in text: bank name fintech keyword after: start year before: end year*, (III) Examine the impact mechanism of fintech on green finance. To accurately measure the effect of FinTech development on green finance growth, we conduct endogeneity, robustness, heterogeneity, and exogenous tests. Additionally, we analyze the moderating effect, mediating effect, and their interactions within the influencing mechanisms. Studying the moderating effect of the influence mechanism is the starting point of the influence mechanism of FinTech on green finance, examining how the strength of the influence mechanism varies with the characteristics of the object and the real conditions. It is concluded that there is a "scale effect" in the promotion of green finance by bank fintech, i.e., large banks invest and innovate more significantly in green finance programs than small banks. The mediating effect of the impact mechanism is examined in order to investigate the channels through which FinTech influences green finance (Jiang et al., 2026). It is concluded that FinTech can indirectly enhance banks' investment in and support for green finance programs by improving their risk management capabilities. On the premise that both the moderating effect and the mediating effect are significant, the moderating effect is investigated to be influenced by the mediating effect. It is concluded that FinTech has a scale effect on green finance, and this "scale effect" is exerted by improving banks' risk management capacity (Li et al., 2024).

The paper is organized as follows: Part II presents the theoretical framework and research hypotheses following a review of relevant literature. Section III explains the creation of the FinTech index. Section IV provides details on the research design, including the sample, data sources, variable selection, and econometric modeling. Section V gives the results of the study, while Section VI summarizes the findings and implications. Finally, section VII gives policy recommendations.

2. Literature review and hypothesis development

2.1. Financial technology

The concept of green finance originated in Sweden and Germany during the 1970s, when these countries began to recognize that environmental preservation is essential for long-term economic growth. This early awareness later evolved into broader international frameworks, including the Sustainable Development Goals (SDGs), disaster risk reduction (DRR), and global climate governance (Hasan et al., 2024). In March 2016, 'FinTech' is more commonly used. the Financial Stability Board (FSB) defined FinTech as financial innovation driven by technology, encompassing advancements like big data, cloud computing, artificial intelligence, and blockchain. These innovations can lead to new business models, applications, processes, or products, significantly

impacting financial markets, institutions, and service delivery methods (Yan et al., 2026). The People's Bank of China highlighted in the Financial Technology (Fintech) Development Plan (2019-2021) that the essence of Fintech lies in leveraging modern technological advancements to enhance or innovate financial products, business models, and processes. Both definitions underscore that Fintech relies on technological innovation to transform how financial products and services are provided. The rapid growth of financial technology continues to shape the industry. The rapid development of financial technology has profoundly changed people's life, consumption and financial management habits, causing fundamental changes in the market ecology on which banks rely (Na, 2019; Lyu et al., 2025). The application of financial technology makes banks step into the period of networked processing, share information with credit-related industries, eliminate the impact of information asymmetry, and realize the new mode of personal loan business development spawned by financial technology innovation (Weihuan, 2020). Through the use of science and technology, the bank's financial services can be expanded, abandoning the traditional "two-eight theory" and realizing comprehensive coverage of a wide range of customer groups. In this way, regardless of the size of customers, they can experience the bank's attention to their needs and satisfaction. However, at the same time, the development of fintech has led to a clear upward trend in the risk of banks' personal business (Guangzi, 2022; Yao et al., 2025). The risk of personal information being improperly collected, leaked and misused, or even traded is becoming increasingly prominent, and strengthening the legal protection of personal information has become an urgent issue for commercial banks (Baocai, 2020). Fintech can reduce the collection cost and risk supervision cost of banks and other financial institutions in obtaining enterprise information through digital technology, accurately assess the creditworthiness of enterprises, reduce the credit deviation of non-state-owned SMEs, and improve the financial support of non-state-owned SMEs (Mengdie, 2023; Liu et al., 2025).

2.2. Green finance

Although the concept of green finance is gaining popularity, there is currently no unified and standardized definition. The concept of green finance was first introduced by the United Nations Environment Programme (UNEP) in 2007. The European Investment Bank (EIB) defines it as supporting investments and financial flows that reduce greenhouse gas emissions, adapt to climate change effects, and protect the environment and biodiversity. Some scholars consider green finance as the innovation of financial products and services developed for ecological and environmental protection (Lu et al., 2026). With the continuous development and maturity of the financial market, the related tools of green finance have been continuously developed, and these products and services have affected the ecological environment and economic development in various aspects in practice. Green credit, as a core product of green finance, is an important pillar of green finance development, while green banking is an important support for green finance development (He et al., 2026).

Theoretical and empirical studies have explored both macro and micro factors influencing green finance. Researchers have studied various macro-level factors, including government regulations, legislation, policies, and financial markets (Wan et al., 2023; Yu et al., 2026). Government intervention in the rational allocation of funds for the development of green industries and the formulation of appropriate regulatory policies can promote the development of green finance (Porter and Linde, 1995; Hu et al., 2026). The government's strict control and regulation of pollution in the production activities of enterprises can not only enhance the efficiency of energy use, but also incentivize enterprises to develop in the direction of green innovation (Xuelin, 2022). Although most researchers have affirmed the government's role in promoting green finance, some scholars have put forward a different point of view, enterprises in the process of development to implement

energy saving and emission reduction and other technologies, the government should implement vigorously promote, but in the development of new energy and innovation and new technology to improve the innovation is difficult to play an important role (Xuelin, 2022).

Several micro-level factors influence the development of green finance, including technological innovation, green technology, and investor collaboration (Yu et al., 2021). In addition, the main challenges facing the development of green finance in China now include the singularity of the main supplier and the lack of green investors. In the face of these problems, it is crucial to form an effective pricing mechanism in order to accurately reflect the true cost and value of green projects and to incentivize more investment flows to the environmental protection sector. It is also equally important to cultivate a mature green financial investor group (Xiaoying, 2018; Li et al., 2026b).

2.3. Research on the impact of fintech on green finance

According to the literature review above it can be seen that there are more studies on FinTech and green finance alone, and the studies are also more segmented. While green growth has emerged as an economic development strategy for numerous countries worldwide, and various studies have examined its influencing factors from multiple angles, there is a scarcity of research specifically investigating the impact of fintech and green finance on green growth (Zhou et al., 2022).

Owing to its asset-light and low-cost nature, fintech could adapt quickly and efficiently to market needs, while its customer-centric service model ensured broad coverage and personalization of services. In addition, decentralization reduces the problem of information asymmetry, which is particularly important for riskier green projects, which usually require more information and data to assess and regulate. The popularization and application of fintech can not only optimize the existing green financial structure, but also attract more participants to green projects, thus expanding the influence and coverage of green finance (Yiju, 2020). Fintech innovation impacts green growth by fostering the development of green finance through mechanisms such as green credit and green investment, thereby promoting sustainable economic expansion (Zhou et al., 2022; Li et al., 2026c). Fintech innovation can play a good role in promoting the level of green financial development in a province, and this promotion is more obvious in regions with better green financial development (Mingchong, 2022).

Some scholars also pay attention to the impact of key technologies of financial technology on green finance. Blockchain technology can circumvent the risk of business information leakage and establish a cross-platform sharing mechanism for green information through a coalition chain composed of financial institutions, enterprises, regulatory agencies, environmental protection departments and relevant investors (Yiju, 2020). Blockchain enhances the transparency and reliability of the green financial credit system, while the smart contract function in blockchain can realize the automated execution of financial transactions, improve transaction efficiency and reduce operational risks. In addition, blockchain can optimize the payment and clearing mechanism, providing a safe and efficient payment solution for green financial transactions. So, blockchain provides new tools and methods for building a more efficient and credible green financial system (Yihui, 2019).

2.4. Impact of FinTech on green finance impact hypothesis

2.4.1. Technology spillovers

Technological Spillover Effect (TSE) refers to an economic externality whereby FDI by TNCs in host countries leads to advances in local technology or productivity, and TNCs are unable to capture all of the benefits.

Innovations in financial technology, in terms of automation and process streamlining, can often reduce costs. Such cost efficiencies, through technology spillovers, can enable banks and other financial

institutions to offer green credit at more competitive rates while maintaining business operations. Reduced operational costs enable financial institutions to support more environmentally friendly businesses and projects, promoting investment by individuals and businesses in environmentally sustainable sectors. While competition in the marketplace may intensify operational pressures on banks, sometimes even forcing them to cut back on riskier green credit programs to remain competitive in the marketplace, the application of fintech and technological spillovers have actually improved the operational capabilities of banks in a number of areas. This includes improved risk management, marketing innovations, improved operational efficiency, and increased capacity for product innovation. Through these enhanced internal capabilities, banks can be more confident and capable of aggressively developing and expanding their green credit business. This impact of fintech can improve the overall profitability model of banks and provide lower loan costs, which not only benefits the financial institutions themselves, but also helps drive society and the economy in a greener and more sustainable direction. Thus, technology spillovers do not merely enhance the internal operations of banks, but also facilitate the wider application and diffusion of green finance by lowering market barriers to green finance.

2.4.2. Long tail theory

The Long Tail Theory, in describing websites like Amazon and Netflix, emphasizes that the low-cost nature of online platforms and digital distribution allows them to sell a large number of niche goods or content in a cost-effective manner. These goods or content, while individually not selling as much as the bestsellers, may match or even exceed the bestsellers in terms of cumulative total sales and total profits because of their variety. This model contrasts with the traditional law of two-eight (also known as the Pareto principle). The traditional banking industry follows the law of two-eight in believing that roughly 80% of a bank's profits tend to come from 20% of its customers, and that the marginal cost of servicing large customers is usually lower for a bank than servicing small customers. Therefore, despite the large number of small customers, they may not contribute as much to total profit as large customers due to higher marginal costs. So, it is more willing to spend more cost to maintain large customers. The Long Tail Theory, which suggests that 80% of the tail market (consisting of many niche products and services) also creates a significant portion of value, is particularly notable in areas such as the internet, fintech, and green finance. These areas benefit from the lower marginal costs associated with digitization, making it more feasible and profitable to offer and distribute niche products or services.

2.4.3. Information asymmetry theory

In traditional financial markets, information asymmetries may lead to adverse selection. For example, in the lending market, banks may not be able to accurately distinguish between riskier and less risky borrowers. The result may be that banks set higher interest rates to counteract potentially higher risks, which in turn leads to the exit of creditworthy borrowers from the market. This phenomenon also exists in the insurance market, where the inability of insurance companies to fully assess the risk level of the insured may lead to a general increase in premiums, which in turn drives low-risk individuals out of the market. In green finance, information asymmetry may make it difficult for investors to distinguish between truly green projects and "pseudo-green" projects. This can lead to capital flowing to projects that are labeled as green but are less effective than those that are genuinely beneficial to the environment. For financial products such as green bonds, investors may not be able to effectively assess their environmental benefits and risks, resulting in inaccurate pricing of these products in the market. Information asymmetry can also give rise to Moral Hazard, which occurs after a transaction is completed when one party takes unobserved actions that affect the interests of the other party. For example, a borrower may engage in risky investments after receiving a loan because the cost of

failure is partially borne by the bank. And in the case of green finance, when a company or project receives funds labeled as "green," it may reduce its efforts to maintain or improve environmental standards because it is difficult for investors to monitor actual environmental performance. In the absence of mandatory reporting mechanisms and transparency requirements, firms may be tempted to publicize the potential benefits of their green projects while hiding the risks associated with the environment.

Fintech's big data, blockchain, artificial intelligence and other technologies can help investors and other stakeholders better assess and monitor the authenticity and performance of green projects, thus reducing the occurrence of adverse selection and moral hazard. Based on the theory as above we can make the following assumptions.

H1. Fintech has a significant positive contribution to green finance in banks.

2.5. Hypothesis on the impact mechanism of fintech on green finance

As banks grow in size, their average costs decrease significantly. Large banks are able to amortize their fixed costs more effectively due to their large resources and capital reserves, and thus are more capable and willing to make large-scale investments and innovations in fintech and green finance projects. The theory of technology spillover effect further supports this view, suggesting that large banks have a significant advantage in absorbing and applying advanced technologies, and are able to drive the development of green finance across the industry through technology diffusion and demonstration effects. In addition, the strong influence and voice of large banks in the market gives them a unique advantage in promoting policies and regulations favorable to the development of green finance. In terms of the extension of the information asymmetry theory, large banks are able to more accurately assess the risks and returns of green projects through fintech, reduce information asymmetry, and enhance the science and transparency of investment decisions. Due to their higher market reputation and credibility, large banks also show greater advantages in attracting funds and investors to participate in green financial projects. Therefore, the following hypotheses can be formulated.

H2. There is a "scale effect" in the contribution of bank fintech to green finance. That is, large banks invest and innovate more significantly in green finance projects than small banks.

By identifying, assessing and managing financial risks, banks are able to reduce potential losses and improve financial stability. Fintech tools allow banks to analyze extensive customer data and financial transactions to identify patterns, trends, and anomalies that could pose risks to their operations. Through big data and artificial intelligence technologies, banks can more accurately assess risks and predict possible future risk events, leading to more effective risk management strategies. Fintech solutions can automate numerous risk management processes, enhancing speed, accuracy, and reducing errors. Automated risk management systems reduce the impact of human intervention and subjective judgments, decreasing the likelihood of human error and bias, thus improving overall risk management. Fintech can facilitate standardization and transparency of information disclosure and enhance banks' ability to identify and assess green projects. For example, blockchain technology can provide tamper-proof transaction records and ensure the transparent use of funds for green projects, thereby reducing information asymmetry and lowering investment risks (Xiaohua et al., 2023). Therefore, based on this premise, we propose the following hypothesis.

H3. Fintech can improve banks' risk management capabilities, indirectly enhancing their investment in and support for green finance projects.

Fintech can significantly enhance banks' investment in and support for green finance projects by improving risk management capabilities

and reducing information asymmetry. In particular, large banks, with their resource and technological advantages, have demonstrated significant scale effects in fintech application and green finance development (Mengdie, 2023). explored the application of technology spillover effect in the banking industry and found that the technology application of large banks can drive other banks to improve their risk management capability through demonstration effect. Based on this.

H4. There is a "scale effect" in the contribution of bank fintech to green finance, which is realized through the enhancement of banks' risk management capabilities.

3. Fintech index construction

3.1. Selection of keywords

Currently, there are two main means of measuring Fintech, one is to rely on data published by official agencies or corresponding industry organizations. This method is mainly based on data released by official agencies or industry organizations, such as government statistics, annual reports of financial institutions, and industry research reports. The data includes a variety of aspects such as market size, user coverage, transaction volume, technology investment, innovation, etc., which can provide an authoritative and relatively comprehensive view of the FinTech market (Table 1). The second is to build the metrics independently, which usually involves utilizing the frequency of keyword appearances or search indices to build the metrics system. This method mostly relies on self-collected data for construction, using techniques such as web crawlers, text analysis, keyword word frequency analysis, and search indexes. For example, web crawlers are used to extract data from a variety of fintech-related websites, news reports, online forums and social media, and the frequency of occurrence of specific keywords is analyzed to construct an index reflecting fintech heat or attention.

Both methods have their advantages and limitations. Directly using the data released by the organization can obtain a high level of data reliability, but there is the problem that the data is not updated in a timely manner or is not comprehensive enough. Self-constructed fintech indexes, on the other hand, are more flexible and can be customized for research needs. However, their effectiveness may be constrained by the availability and accuracy of data, as well as the scientific rigor of the analytical methods used. In order to improve the quality and credibility of the construction of the FinTech index, this study using the combination of these two methods and cross-validation of the resulting data. Firstly, the People's Bank of China (PBOC) released the FinTech index,

Table 1
Research keywords.

Categorization	Byword
Technology base and platform	Blockchain technology, big data analytics, cloud computing services, artificial intelligence applications, machine learning finance
Financial Services Applications	Mobile payment systems, e-wallet applications, cryptocurrency trading, P2P lending platforms, crowdfunding financing models, InsurTech, Robo-Advisory, and seamless integration of financial services, Supply Chain Finance, Digital Banking Model, API Open Banking
Risk Management and Compliance	Credit assessment technology, anti-money laundering technology (AML), risk management systems, financial compliance monitoring, regulatory technology
Support and Infrastructure	Financial market infrastructure, financial data security
Development and popularization category	FinTech innovation, FinTech companies, FinTech investment, financial services penetration, customer experience innovation
Education and Regulations	Fintech Education and Training, Fintech Policy and Regulations

while the Peking University Digital Transformation Index of Chinese Commercial Banks (2010-2021) was published by the Peking University Digital Finance Research Center (DFRC). From these sources, 30 key FinTech terms were identified.

3.2. Keyword search

The number of articles containing specific keywords that appear in Google News that are related to fintech are collected annually. As the frequency of occurrence of these news items can indirectly indicate the level of attention paid by the business community to the fintech sector, accordingly its importance in the industry can be assessed.

The Requests module is used to send HTTP requests and receive response objects that include data such as content, encoding, and status. It effectively simulates a user accessing a website from a web server. The Urllib package, a Python module for URL processing, was employed to obtain URLs and encode Chinese keywords into binary code for further analysis. BeautifulSoup, another Python package, was used to parse HTML and XML documents from websites, including those with malformed tags, by creating a parse tree that extracts data, making it valuable for web crawling. To bypass Google Search's defense mechanisms, an anti-crawler program was developed using the Random and Time modules. This program specifies a random number of seconds for a delay between requests. The Time module handles time-related tasks, while the Random module generates random numbers in Python. Lastly, the Pandas package facilitated the conversion of data results from PyCharm format to Excel format.

3.3. Construction of a fintech index

It is necessary to assign weights to the indicators of each keyword, and the commonly used methods include expert rating method, Delphi method, hierarchical analysis method (AHP), data envelopment analysis (DEA), principal component analysis (PCA), entropy weighting method and so on (Wu et al., 2026). Considering the availability of data, the availability of expert opinions, the complexity of the calculation and the interpretability of the results, this study chooses the entropy weight method to assign weights to the indicators of each keyword. When objectively reflecting the amount of information and differentiation of each keyword, the entropy weight method can assign weights to the keywords according to their distribution in the data set, which reduces subjective intervention. The following are the specific calculation steps.

3.3.1. Data standardization

Due to the large difference in the size of the values of different indicators, it is necessary to standardize the raw data first, and in this study, we use the approach of Min-Max Scaling (Min-Max Scaling) to process the data, which linearly scales the raw data to between the specified minimum and maximum values (usually 0 and 1), making the data comparable to each other. In the sample, we assume that the number of years is x , the number of individuals is n , and the number of evaluation indicators is m , with Y_{tij} is the value of indicator j for bank i in year t . Since overall, the 30 selected keywords are positive factors for FinTech, there is no need to consider the calculation of negative factors.

$$V_{tij} = \frac{Y_{tij} - Y_{\min}}{Y_{\max} - Y_{\min}}$$

In the formula, the value of t is equal to 1, 2, 3, ..., x , the value of i is equal to 1, 2, 3, ..., n . Y_{tij} and V_{tij} are the values before and after the normalization process, respectively.

Calculate the proportion of normalized data. For each bank (i) on indicator (j) the normalized value (V_{tij}), the proportion (p_{tij}) is calculated as follows:

$$p_{tij} = \frac{V_{tij}}{\sum_{i=1}^x \sum_{j=1}^n V_{tij}}$$

3.3.2. Determine the weights of the indicators

Calculate the entropy value of indicator (j) (E_j). The entropy value can be calculated using the following formula:

$$E_j = -k \sum_{t=1}^x \sum_{i=1}^n \ln p_{tij}$$

$$k = \frac{1}{n(n * x)}$$

Calculate the coefficient of variation (i.e., information utility value) for indicator (j) (D_j) and from there determine its weight (W_j).

$$D_j = 1 - E_j$$

$$W_j = \frac{D_j}{\sum_{j=1}^m D_j}$$

where m is the number of all indicators. Thus, the weight of each indicator (j) (W_j) of each indicator (j) represents its importance in the comprehensive evaluation index system. The sum of the weights of all indicators should be 1.

3.3.3. Calculate the value of each indicator after weight adjustment

$$C_{tij} = W_j * p_{tij}$$

Sum the values of all indicators for an individual over a one-year period: $F_{tij} = \sum_{j=1}^m C_{tij} * 100$

See [Appendix I](#) for final index results.

4. Research design

4.1. Data sources and sample selection

In this paper, a series of 26 listed commercial banks from 2011 to 2022 is selected as the research sample predominantly for all these banks are listed in China and hold more than 80% of total assets and 90% of net profit. Additionally, these banks are selected based on the banking classification of the China Securities Regulatory Commission (CSRC), and their share of total assets and net profits fully justifies their prominence in China's banking industry and their representativeness to the overall banking industry (Fig. 1). The rationale for choosing this sample period is that China only formalized the implementation of its green credit policy in 2007, and it usually takes a process from the concrete implementation of the policy to the response and adaptation of enterprises and banks. In fact, the vast majority of banks began to gradually disclose data on this issue only after 2010. In view of the significant differences between financial leasing companies and traditional commercial banks in terms of business model, revenue structure and risk management, this study excludes such institutions from the sample to ensure the consistency and accuracy of the analysis. Relevant data are mainly sourced from banks' annual reports, social responsibility reports, the Cathay Pacific database, and the Discovery Research database, etc. A list of the 26 banks is provided in [Appendix 2](#).

4.2. Definition of variables

4.2.1. Explained variable: green finance

This study uses green credit to represent green finance, because compared with green bonds, green stocks, green insurance and other tools, China's green credit is large in scale, the system development is

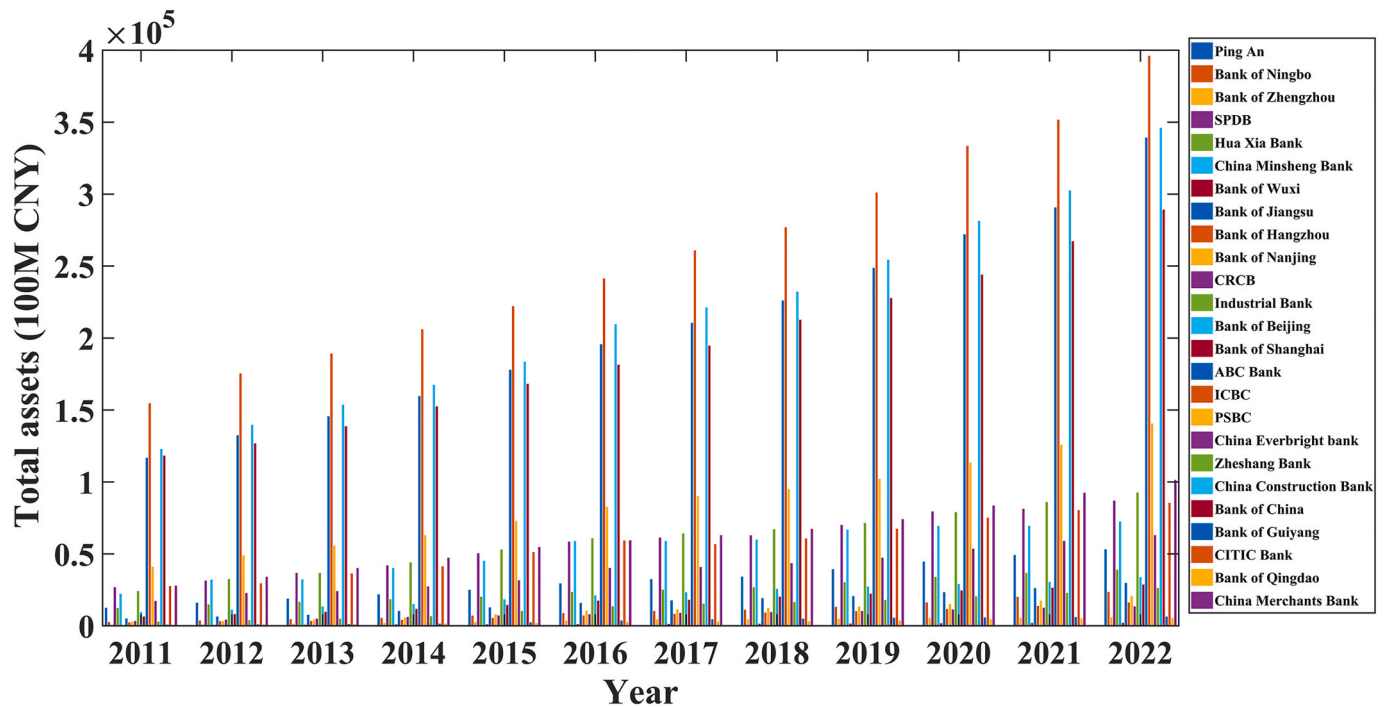


Fig. 1. Distribution of total assets (in CNY) across the selected banks in China.

relatively mature, and there are more perfect policy support, evaluation standards and market practice, which makes the research foundation more solid. Moreover, credit is one of the most important asset classes of banks, so green credit can, to a certain extent, represent the attitudes and behaviors of banks and even the entire financial system towards green investment. In terms of data availability, because banks generally record the use of loans, compared with other green financial instruments, data on green credit are easier to count and obtain, making it easier to collect and analyze data.

4.2.2. Explanatory variable: financial technology

The data on FinTech comes from the bank panel data obtained from official published indicators with FinTech indicators constructed by a keyword search approach, as described in.

4.2.3. Moderating variables

Bank size, total assets of commercial banks were used to control for the effect of bank size. Total assets indicate a bank's market share and scale of operations; larger banks may have more resources and capacity to engage in green finance and may have different decision-making

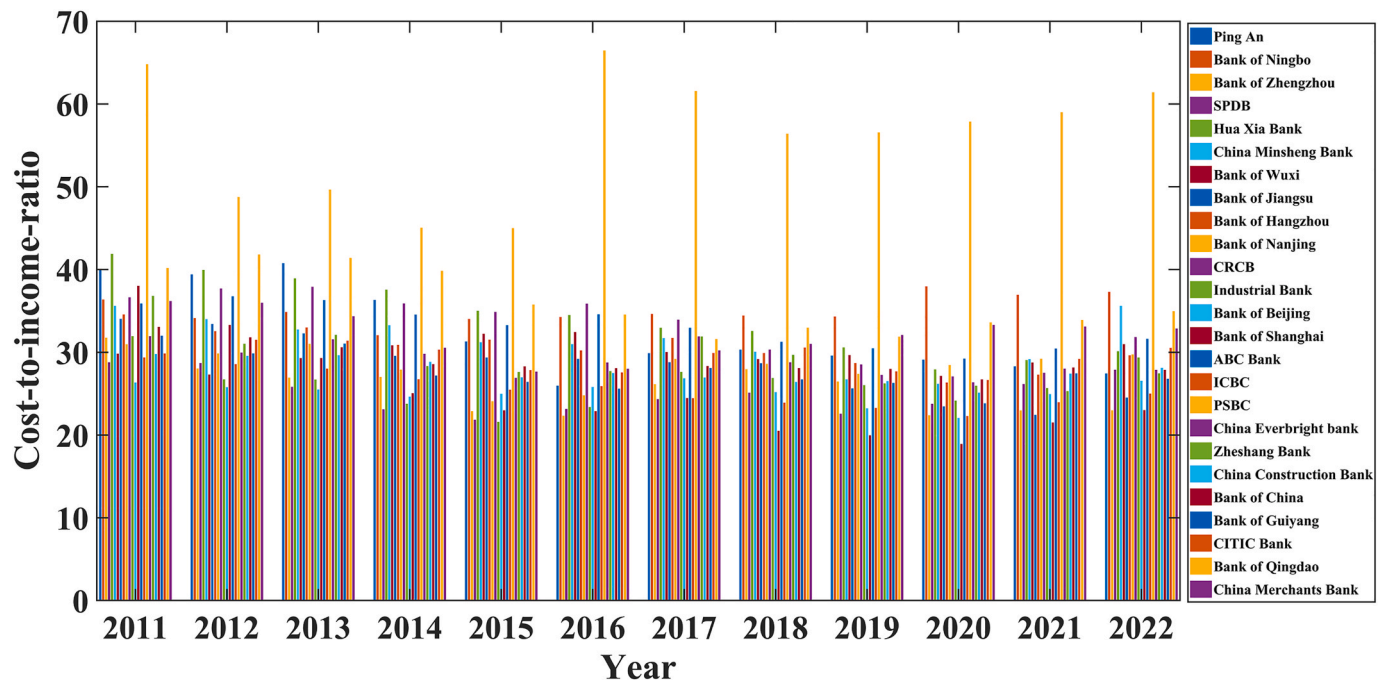


Fig. 2. Bank-wise distribution of cost-income ratio in China.

processes, risk tolerance, and market behavior than smaller banks.

4.2.4. Mediating variables

The Capital Adequacy Ratio (CAR) serves as an indicator to evaluate risk management within the banking sector. It measures a bank's ability to absorb losses using its own capital before depositors and creditors face asset losses. A higher CAR signifies a stronger capital buffer, making the bank more resilient to adverse economic conditions.

4.2.5. Control variables

Ensuring the accuracy of the findings, consideration was given to controlling for other factors that may affect the dependent variable but are not the focus of the study. In this study, the deposit to loan ratio and cost to income ratio of commercial banks were chosen as control variables to capture the impact of key aspects of banks' liquidity position and operational efficiency (Fig. 2).

The deposit/loan ratio reflects the ability of banks to manage deposits and loans. A higher deposit/loan ratio may indicate that the bank has more liquid funds, which can facilitate the bank's ability to provide more loans and support in green investment projects. Cost-income ratios measure the efficiency of a bank's operations, with lower cost-income ratios indicating that a bank is able to realize higher revenues at lower costs. Efficient banks may be better able to invest in green finance projects that are more technically complex or have higher initial costs.

Controlling for these factors and more accurately assessing the impact of fintech on green finance can help ensure that the conclusions drawn are the true relationship between fintech itself and green finance, all else being equal.

4.3. Empirical modeling

This study is based on panel data and a two-way fixed effects model is chosen for the study. Compared to random effects model (REM) or mixed OLS (ordinary least squares) model, two-way fixed effects model does not require the assumption that unobserved variables are uncorrelated with explanatory variables, and it is more advantageous when confronted with possible endogeneity problems. Each commercial bank (cross-sectional unit) in the panel data may have unique, time-invariant attributes, such as management style, corporate culture, or specific

strategic positioning, that affect the bank's acceptance of green finance. Individual fixed effects capture these attributes and ensure that the model estimates reflect the true impact of fintech changes on green finance, rather than the impact of inherent bank characteristics.

Meanwhile, time fixed effects can control for external influences that may be common to all commercial banks at a given point in time, such as macroeconomic fluctuations, changes in regulatory policies, or turmoil in global financial markets. These factors can collectively affect the green finance performance of commercial banks independently of the development of fintech (Fig. 3). By controlling for these time-specific variables, the study is able to isolate the impact of FinTech on green finance more accurately. Multiple significant policy changes and shifts in the economic environment do occur during the time span analyzed, 2011–2022. The Paris Agreement of 2015, has had a significant impact on policy changes in green finance. The agreement has facilitated investments in low-carbon and sustainable projects. The impact of the 2008 financial crisis lasted for many years, leading to tighter financial regulations and a restructuring of banking business models. COVID-19, which began in 2020, has had a profound impact on the global economy and the financial sector, forcing financial institutions and regulators to consider more digitally enabled and flexible operating models. This has led to the emergence of a new financial sector, which is expected to be the first of its kind in the near future. After a prolonged period of low-interest rate environment in various countries, central banks started to gradually adjust their monetary policies to cope with inflationary pressures, which directly affected banks' operations and investors' behavior.

Three tests — Fisher test, Lagrange multiplier test, and Hausman test are combinedly conducted on the panel data to validate the regression model selection. As the p-values for these tests are all less than 5%, we opt for the double fixed effect model over the random effect model or pooled regression model. Validation H₁, we use the following econometric model.

The equation for the two-way fixed model is as follows:

$$GF_{it} = \alpha + \beta_1 FT_{it} + \beta_2 LDR_{it} + \beta_3 CIR_{it} + BBANK_i + T_t + \varepsilon_{it} \quad (1)$$

In this model, the α is a constant term, and β_1 , β_2 , and β_3 are the parameters to be estimated, and denote the effects of the explanatory and

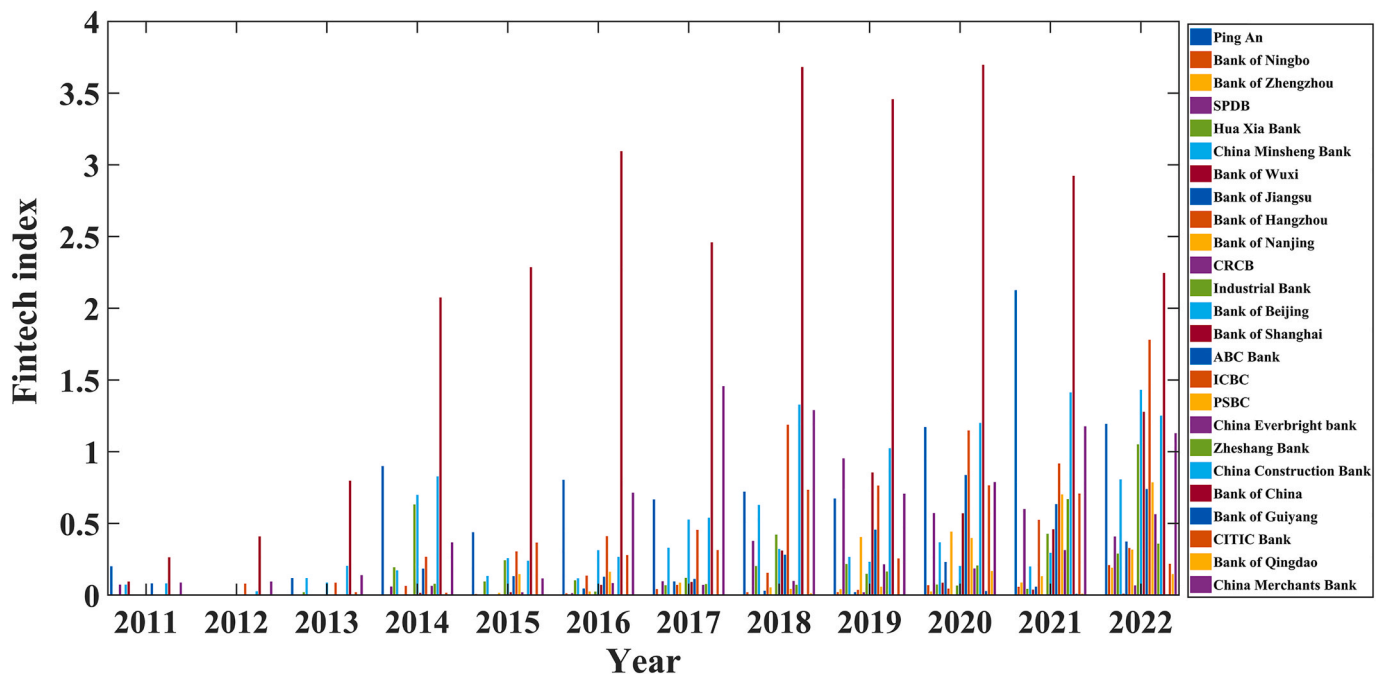


Fig. 3. Yearly distribution of Fintech index across selected banks in China.

control variables on the explained variables, respectively. GF_{it} is the level of green finance of bank (i) at time (t). FT_{it} is the level of fintech development of bank (i) at time (t). LDR_{it} and CIR_{it} are the deposit-to-loan and cost-to-income ratios of bank (i) at time (t), respectively. $BBANK_i$ are individual fixed effects, controlling for individual-specific unobserved factors that do not vary over time but may affect (GF) T_t is a time fixed effect that controls for effects that may be experienced jointly by all individuals at different points in time, such as the effect of macroeconomic policy changes on all individuals. ε_{it} is a random error term representing other factors not included in the model.

5. Analysis of empirical results

5.1. Descriptive statistics

Table 2 provides a summary of the descriptive statistics for the variables, including the mean, standard deviation, minimum and maximum values for each category. Table 2 presents the descriptive statistics of the seven variables, viz. GF_{it} , LDR_{it} , CIR_{it} , CAR_{it} , $BSIZE_{it}$, NPR_{it} , FDL_{it} . The mean values of these variables are highly variable. With CAR_{it} The mean of these variables was the lowest at 13.3, $BSIZE_{it}$ has the highest mean value of 59,653.46. The standard deviation of these variables varies significantly. CAR_{it} has the lowest standard deviation at 1.75, while $BSIZE_{it}$, green credit, and fintech exhibit substantial differences, ranging from a minimum of 0 to a maximum of 78,616.84. The minimum value of FinTech is 0, and the maximum value is 369.74; the minimum value of green credit is 0, and the maximum value is 39784.58 (Fig. 4). These data indicate that there is an imbalance in the structure of green credit and FinTech, and that there is a significant difference in these variables between different banks. Therefore, it is necessary to test the significant effect of FinTech on green credit of banks by heterogeneity test.

5.2. Benchmark regression results

We used the method of gradually adding control variables to the original model and obtained four regressions, as shown in Table 3. In the first regression model (column 1), we did not add any control variables. In the second regression model (column 2), we added the savings and loan ratio as a control variable (Fig. 5). In the latter regression model (column 3), we continue to add the cost-to-income ratio as our control variable. In the last model (column 4), we continue to add the total assets CNY ratio as our control variable. To minimize the effects of heteroskedasticity, we also use robust standard errors in all four regression analyses.

In column (1), there is no control variable and the FT_{it} The coefficient is 25.698, which is highly significant at 1% level. This implies that the development of FinTech has a positive and significant impact on green finance. Adding control variables in the model LDR_{it} and CIR_{it} the results are unchanged after adding control variables to the model, as

Table 2
Descriptive statistics of variables.

	Mean	STD	Min	Max	Variable meaning
GF_{it}	2565.91	4882.15	5.04	39784.58	Green credit balance of \$ billion
LDR_{it}	74.35	15.44	26.43	116.23	Deposit and loan ratios
CIR_{it}	30.6	6.75	18.93	66.47	Cost-to-income ratio
$BSIZE_{it}$	59653.46	78616.84	599.41	396096.57	Total assets in CNY
NPR_{it}	121.33	39.79	22	247	non-performing loan ratio
CAR_{it}	13.3	1.75	8.84	19.26	capital adequacy ratio
FT_{it}	32.05	57.7	0	369.74	FinTech Index

Note: Descriptive statistics are dependent, independent, and control variables, and span the period from 2011 to 2022. All variables are defined in Appendix 2.

shown in columns (2) and (3). From the fitting results in column (3), further adding control variables CIR_{it} . After that, the coefficient of FT_{it} the coefficient of 25.522 is highly significant at 1% level. For every 1% increase in the level of FinTech development, green credit of banks will increase by 2552.2 million dollars. Based on such results, the positive impact of FinTech on banking business is mainly manifested in two aspects. First, the application of FinTech significantly improves banks' ability to identify customers and effectively reduces information asymmetry, thus enhancing their risk management capabilities. Second, FinTech also expands banks' marketing channels, enabling them to attract new customers and ultimately boosting their profit levels by reducing operating costs. Together, these factors contribute to banks' greater propensity to provide credit support to green industries. Synthesizing the results of the three columns in Table 2 and it can be found that there is a significant positive impact between the development of FinTech and the expansion of green credit. This verifies the hypothesis H_1 that FinTech has a significant positive promotion for banks' green finance.

5.3. Endogeneity test

The initial regression results show that FinTech has a positive impact on green finance. However, green finance can also affect fintech and technological innovation. For example, bank credit can alleviate a firm's internal and external financing constraints, thereby facilitating its technological innovation. In addition, due to challenges related to data availability, fintech variables may contain measurement errors that may establish a link between fintech and unobservable variables that affect green credit. Thus, there may be reverse causality between fintech and green finance, creating a potential endogeneity problem. Therefore, we use an instrumental variables approach, which utilizes the lagged terms of the FinTech variables in place of the original lagged terms to mitigate the potential endogeneity problem. The requirement for instrumental variable estimation is that they must be correlated with the explanatory variables and not with the random error terms or control variables. While our baseline two-way fixed-effects model panels for time-invariant bank heterogeneity and common time trends, it may still suffer from endogeneity concerns arising from: (I) reverse causality for banks with stronger green finance recital may invest more in Fintech, rather than Fintech driving green finance; (II) omitted variable bias for unobserved time-varying factors (such as, bank-level innovation culture, managerial risk) may influence both Fintech adoption and green lending decisions; and (III) measurement error includes Fintech index, constructed from keyword frequencies, may contain noise that attenuates the estimated coefficient.

Referring to the treatment of Peng and Xu (2021), this paper takes the mean value of fintech of banks other than our bank (hereinafter referred to as "mean value of fintech other than our bank (TV)") as an instrumental variable. The reasons for this instrumental variable are: first, the mean value of FinTech other than the Bank can be considered as the level of FinTech development outside the Bank is related to the level of FinTech development in the Bank; and second, due to the competitive relationship between the Banks, the level of FinTech development outside the Banks is not directly related to the development of green finance in the Bank, which fulfills the exogenous requirement of instrumental variable.

First, we will utilize IV-2SLS two-stage regression for the instrumental variable approach. In this process, we will use TV as an instrumental variable to address endogeneity. The first stage of IV-2SLS fits TV to the endogenous variable FT, and then the results of the first stage are utilized in a second stage regression to obtain the final estimates.

First, we will fit the IV-2SLS model in the first stage with FT as the dependent variable and TV as the independent variable, where Controls are the control variables (LDR_{it} vs. CIR_{it}).

The Phase I IV-2SLS model is:

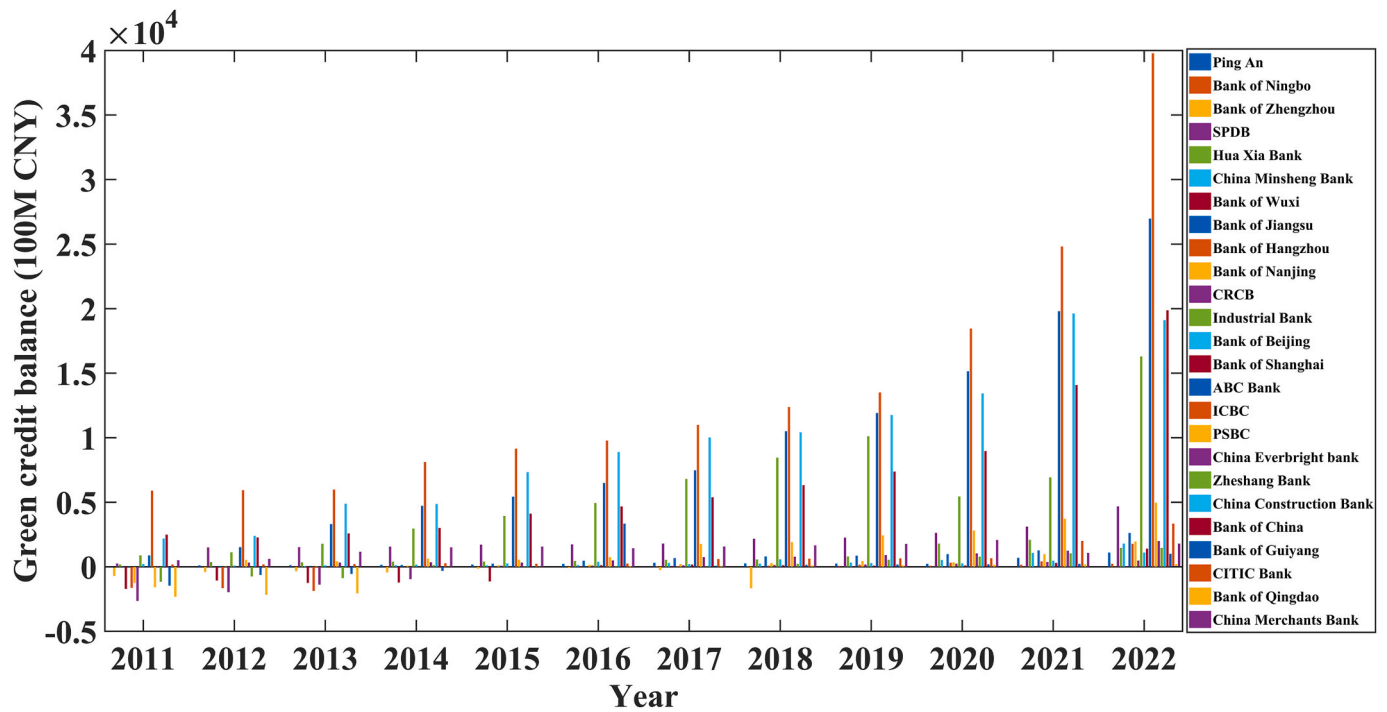


Fig. 4. Bank-wise distribution of green credit balance between 2011 and 2022. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Benchmark regression results.

	(1) GF _{it}	(2) GF _{it}	(3) GF _{it}
FT _{it}	25.698***	25.503***	25.522***
LDR _{it}		−40.920*	−40.488*
CIR _{it}			42.427
Intercept	1493.2***	4541.8***	3210.6*
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observation	312	312	312
Adj. R ²	0.0851	0.0937	0.0954

Note: The symbols ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

$$\widehat{FT}_{it} = \alpha_{11} + \beta_{11}TV_{it} + \beta_{21}LDR_{it} + \beta_{31}CIR_{it} + BBANK_i + T_t + \varepsilon_{it}$$

Then, in Stage 2, we will utilize the results of Stage 1 for IV-2SLS regression. The second stage IV-2SLS model is:

$$GF_{it} = \alpha_{12} + \beta_{12}\widehat{FT}_{it} + \beta_{22}LDR_{it} + \beta_{32}CIR_{it} + BBANK_i + T_t + \varepsilon_{it}$$

Here, it is estimated using the first stage $\widehat{FT}_{it}$ values.

Table 4 presents the IV-2SLS two-stage regression using the instrumental variables approach. As can be seen from the regression results in Column 3(1), the instrumental variable fintech other than the Bank has significant mean values and the direction of the coefficients is positive, implying that the higher the level of fintech development outside the Bank, the higher the level of fintech development of the Bank, which is in line with the expectation. Column (2) reports the results of the second-stage regression estimated using the instrumental variable method, which shows that the impact of FinTech on green finance is still significant and the direction of the coefficients is positive, which is basically consistent with the results of the baseline regression. The values of the Cragg-Donald Wald F-statistic and the Kleibergen-Paap rk Wald F-statistic indicate that there is no problem of weak instrumental variable problem. After the endogeneity problem is dealt with, the

regression results still show that fintech has a positive impact on fintech. In addition to the instrumental variables approach, we also utilize the 1-year lagged fintech variables instead of the original fintech variables to mitigate the endogeneity problem Table 4 (3) columns, aiming to mitigate the endogeneity problem. The rationale behind this approach is that the current level of green finance is unlikely to affect the level of fintech in the previous period (the index), while the level of fintech in the previous period can indeed affect the current level of green finance.

5.4. Robustness analysis

For the stability assessment of the regression analysis, the sample period and variable settings were adjusted and the regression was re-executed (Table 5). The original sample covered the time span from 2011 to 2022. However, in the Chinese context, despite the fact that the green credit policy has been introduced since 2007, data collection targeting this area actually started in 2013, due to the fact that the banking regulator required state-owned banks to start reporting their green credit data and imposed a semi-annual reporting cycle. Given the general incompleteness of the data for 2011 and 2012, it was decided to exclude this time period to minimize the impact of data incompleteness on the results of the analysis. Therefore, the analysis in this study focuses on a sample of 26 banks for the period 2013 to 2022. As Table 4 demonstrates, when the initial period of data is excluded, the positive impact of fintech on the development of green finance remains significant and reaches a statistical significance level of 5%, which reinforces our previous regression results.

Secondly, state-owned banks usually bear broader social responsibilities, including supporting national policies and promoting local economic development (Table 6). These additional responsibilities may affect their business decisions and performance in the area of green finance. In contrast, while commercial banks also bear social responsibilities, they focus more on business operations and profitability, which may make their performance in green finance more stable and predictable. Here we exclude commercial bank data and observe the impact of fintech on green finance when only state-owned banks are involved.

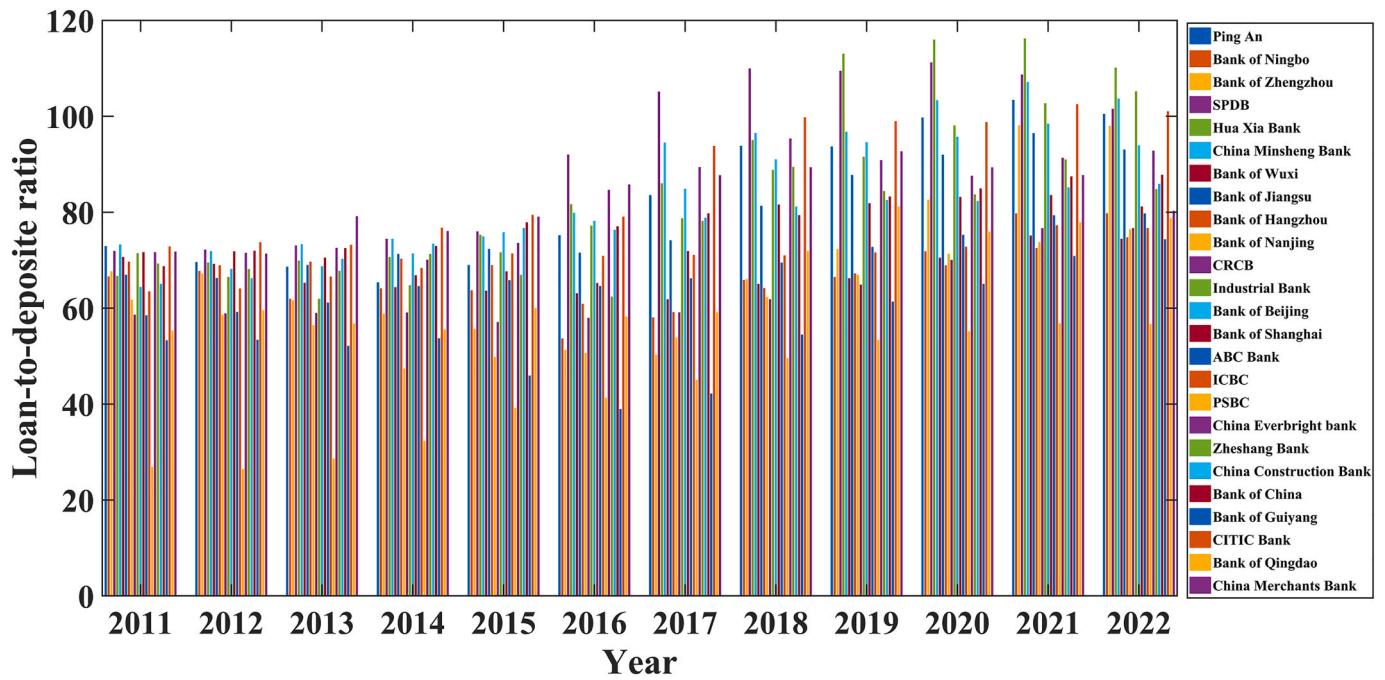


Fig. 5. Temporal distribution of loan-deposit ratio in selected banks in China.

Table 4
Results of endogeneity test.

	(1) FT_{it}	(2) GF_{it}	(3) GF_{it}
TV_{it}	37.020 **		
$\widehat{FT}_{it}$		152.99***	
Last- FT_{it}			20.13**
Controls	Controlled	Controlled	Controlled
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observation	312	312	312
Cragg-DonaldWald F		1049.39	
Kleibergen-Paap rkWald F		456.709	
Adj. R^2		0.635	0.78

Note: The symbols ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5
Results of robustness analysis (excluding 2011–2012 data).

	(1) GF_{it}	(2) GF_{it}	(3) GF_{it}
FT_{it}	24.302***	22.902*** (1.099)	22.845*** (1.099)
LDR_{it}		−62.298** (1.099)	−62.281** (1.299)
CIR_{it}			20.517 (1.198)
Intercept	1730.7***	6525.2***	5911.7*
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observation	260	260	260
Adj. R^2	0.1823	0.1901	0.3462

Note: The symbols ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Values in parentheses represent covariate covariance.

At the time of aggregation, it was noted that the regression model revealed a positive correlation between fintech and green financial development, but this was not sufficient to establish a causal relationship between the two. In addition, in order to verify the reliability of the model, the model multiple covariance test found that the variance inflation factor (variance inflation factor) is much less than 5, there is also an indication of the robustness of the model.

Table 6
Results of robustness analysis (excluding commercial banks).

	(1) GF_{it}	(2) GF_{it}	(3) GF_{it}
FT_{it}	8.4875**	8.4913** (1.390)	8.3135*** (1.394)
LDR_{it}		0.8043 (1.390)	3.0812 (1.456)
CIR_{it}			66.592* (1.085)
Intercept	836.61***	770.56*	−1301.1*
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observation	240	240	240
Adj. R^2	0.1203	0.1501	0.1932

Note: The symbols ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Values in parentheses represent covariate covariance.

5.5. Exploration of impact mechanisms

5.5.1. Moderating effects

In order to examine the starting point for examining the impact of fintech on green finance, i.e., that an impact mechanism may not act homogeneously and invariably on all individuals and at all points in time, it is necessary to examine how the strength of the impact mechanism varies with the characteristics of the target audience and the real-world conditions. Below we consider the impact of fintech on green finance under different bank asset sizes. In the following, we develop a moderating model, and first we verify that fintech FT_{it} is associated with the moderating variable $BSIZE_{it}$ low linear correlation. To verify in the model, we introduce the moderating variable $BSIZE_{it}$ with the interaction term $FT_{it} * BSIZE_{it}$

$$GF_{it} = \alpha + \beta_1 FT_{it} + \beta_2 BSIZE_{it} + \beta_3 FT_{it} * BSIZE_{it} + \beta Controls + BBANK_i + T_t + \varepsilon_{it} \quad (2)$$

To test for the moderating effect, we examine whether the coefficients on the interaction terms are significant, which determines if a moderating effect exists, where Controls denotes the control variables. The β_3 coefficient is 8.607e-05 and highly significant, indicating that the promotion of green finance by fintech increases significantly with asset

size. This finding aligns with the heterogeneity test of the basic model, where the FT_{it} coefficient is 17.654* for small-scale banks and 31.991*** for large-scale banks. This consistency further verifies that the promotion effect of fintech on green finance is moderated by bank size, supporting hypothesis H₂. It shows that large banks can promote the development of green finance more effectively through the adoption of financial technology; compared with small banks, large banks invest and innovate more significantly in green finance programs.

5.5.2. Mediating effects

In order to investigate the channels of action of the mechanism of influence of FinTech on green finance, i.e., the causal relationship between the phenomena of this mechanism of influence may contain multiple logical links, FinTech is not directly acting on green finance. Therefore, it is necessary to examine through which intermediary variable in the causal chain FinTech influences the outcome. To this end, we develop a mediation model in which fintech acts on green finance through the mediating variable capital adequacy (CAR_{it}) acts on green finance.

$$GF_{it} = \alpha + \beta_1 FT_{it} + \sum \beta \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (3)$$

$$CAR_{it} = \alpha + \beta_2 FT_{it} + \sum \beta \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (4)$$

$$GF_{it} = \alpha + \beta_3 FT_{it} + \beta_4 CAR_{it} + \sum \beta \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (5)$$

The mediation effect test methods are Baron method, Kenny method, Sobel test and Bootstrap method, Baron method, Kenny method are the most traditional mediation effect test while Sobel test is used to test the significance of mediation effect. It is based on the standard error of the mediating variable to calculate the z-statistic. However, the mediating effect is for causal analysis of the influence mechanism and can be simply returned to the statistical test, so the stepwise test method is used here. Table 7 highlights that model (3) β_1 is significantly greater than 0, indicating that FinTech for green finance by positive promotion, model (4) in the β_2 , β_4 is significantly not 0, indicating that the moderating effect holds, i.e., FinTech promotes green finance by affecting capital adequacy. The high capital adequacy ratio and low non-performing loan (NPL) ratio observed among FinTech-adopting banks suggest that they have greater capital availability to support a wide range of investments, including green finance. By providing more efficient services and products for green finance, FinTech facilitates the development of green finance. These findings validate Hypothesis H₃, which posits that FinTech can indirectly enhance banks' investment in and support for green finance projects by strengthening their risk management capabilities.

5.5.3. Impact of mediating effects on moderating effects

Regulation effect and mediation effect are significant case, can be further comprehensive analysis, consider the relationship between the regulation effect and mediation effect, consider whether the mediation effect is affected by the regulation effect, that is, different asset size, the mediation effect is strengthened or weakened, whether it is significant or not, this paper through the test to verify that there is a regulation of

mediation variables do not hold. The following consideration, there are mediated regulation variables, that is, the regulation effect is affected by the mediation effect. The scale effect of fintech on green finance, this "scale effect" is played through the enhancement of the bank's risk management capabilities.

$$GF_{it} = \alpha + \gamma_1 FT_{it} + \gamma_2 BSIZE_{it} + \gamma_3 BSIZE_{it} \cdot FT_{it} + \sum \gamma \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (6)$$

$$CAR_{it} = \alpha + \gamma_4 FT_{it} + \gamma_5 BSIZE_{it} + \gamma_6 BSIZE_{it} \cdot FT_{it} + \sum \gamma \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (7)$$

$$GF_{it} = \alpha + \gamma_7 FT_{it} + \gamma_8 CAR_{it} + \gamma_9 BSIZE_{it} + \gamma_{10} BSIZE_{it} \cdot FT_{it} + \sum \gamma \cdot \text{Controls} + BBANK_i + T_t + \varepsilon_{it} \quad (8)$$

γ_3 The value of 8.489e-05 and highly significant indicates the presence of moderating effect. γ_6 The value of -3.65e-08 and highly significant indicates that moderating effect on mediating variables CAR_{it} . The value is -32.498 and the p-value is 0.7307. γ_8 The value of -32.498 with p-value 0.7307 is not significant indicating that the mediating variable is completely affected by the moderating effect. Test Hypothesis H₄: In the past, bank fintech has promoted green finance through a "scale effect," which is realized by enhancing the bank's risk management capabilities.

6. Justification of results

In this study, fintech is explored to influence the green finance mechanism. A benchmark model (1) is constructed based on previous theories and studies, and a two-way stationary model is used to verify that fintech has a significant positive promotion for banks' green finance. Fintech enables banks to assess investment risks more accurately, which enables them to maintain a lower non-performing loan ratio and improves their risk management ability.

At the same time, we discuss the endogeneity between the treatment variable FinTech and the dependent variable green finance by means of the instrumental variable "Mean value of FinTech other than our bank", which still indicates that FinTech positively promotes green finance after excluding the endogeneity. In addition, we verify the robustness of the benchmark model by excluding part of the data.

In equation models (3) to (5), a series of recursive equations are constructed to test the mechanism of moderating role, the mechanism of mediating role, and the influence of moderating role and mediating role on each other between the development of FinTech and the growth of green finance.

In model (2), we construct a model to test the existence of the moderating effect, to verify the hypothesis that H₂ There is a "scale effect" in the promotion of green finance by bank fintech. That is, compared with small banks, large banks invest and innovate more significantly in green finance programs. This can be considered to be due to the fact that large banks, due to their size, are able to share fixed costs and thus enjoy a cost advantage when adopting new technologies. The existence of such economies of scale may lead large banks to be more active in fintech investments. At the same time, fintech can help banks better assess and manage the risks associated with green finance, and large banks may be better positioned to benefit from these technologies due to their sophisticated risk management systems. Finally, regulators may encourage or require banks to increase their investments in green finance. Large banks may be better able to respond to these requirements and improve compliance and efficiency through fintech.

In model (3) we construct a model to test whether the mediation effect exists and verify the hypothesis H₃: Fintech can improve banks' risk management ability, which indirectly enhances banks' investment in and support for green financial projects. The reason may be that

Table 7
Mediating effects test.

	(1) GF_{it}	(2) CRA_{it}	(3) GF_{it}
FT_{it}	25.522***	0.0086***	22.845***
LDR_{it}	-40.488*	0.0138	-62.281**
CIR_{it}	42.427	0.0333	20.517
Controls	Controlled	Controlled	Controlled
Intercept	3210.6*	10.972***	5911.7*
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observation	312	312	312
Adj. R ²	0.0954	0.1901	0.3247

FinTech, especially big data analytics and artificial intelligence, can provide more accurate risk assessment tools to help banks identify and assess the risks of green finance projects. Secondly, through real-time data monitoring and early warning systems, fintech can improve banks' ability to monitor the risks of green finance projects, identify potential problems and take measures in a timely manner.

In model (4), we construct a model to test the existence of the mediation effect and verify the hypothesis that H₄: There is a "scale effect" in the promotion of green finance by banks' fintech, and this "scale effect" is exerted through the enhancement of banks' risk management capabilities. This "scale effect" can be attributed to the fact that FinTech provides advanced risk assessment tools that enable large banks to more accurately quantify the risks of green finance projects, thus increasing their confidence in investing in these projects. At the same time, fintech can improve the efficiency of large banks' capital allocation, enabling them to invest more capital in risk-controlled projects that meet green finance standards.

7. Policy recommendations

7.1. Developing differentiated policies to encourage fintech innovation

Studies have shown that fintech has a facilitating effect on green finance, and the development of fintech is closely related to its innovative capacity, so the government and regulators should encourage and support fintech innovations, including financial products and services with technologies such as blockchain, big data, and cloud computing, in order to improve the accessibility and transparency of green finance programs. For example, policies to encourage fintech innovation should be introduced to provide fintech companies with a clear development direction and policy support. And it is important to regularly review and update financial regulations to ensure that they can adapt to the development of fintech while protecting consumer rights and financial stability. A uniform FinTech promotion policy across all banks is inefficient. This study can conclude systematically important Tier-1 banks (BoC, ICBC, CCB and ABC) are substantially focus on mandatory green lending targets to transparent reporting, while Tier 2 (Ping An, Minsheng, CITIC, Everbright, Hua Xia) and Tier 3 (Bank of Nanjing, Jiangsu, Qingdao, Zhengzhou and so on) banks are specifically demonstrate moderate but inconsistent green credit growth (for instance, Ping An bank jumps from 0.67 in 2017 to 2.13 in 2021, then drops to 1.19 in 2022) and late and minimal green credit uptake respectively.

In terms of funding, the relevant departments should provide appropriate financial support and tax incentives to promote the development of fintech start-ups and projects, and there should be some differentiation in policies for enterprises in the eastern and western regions. For example, a special fund should be set up to provide financial support for fintech startups and projects. The implementation of tax relief policies for fintech enterprises to reduce operating costs, but also allow fintech enterprises to add deductions for R & D expenses in the calculation of taxable income, to encourage innovation. In order to promote fintech enterprises can be given certain subsidies to reduce R&D costs. Provide low-interest or interest-free loans to fintech enterprises within a reasonable range to reduce their financial pressure. The relevant support in the western region should be greater than that in the eastern region. At the same time, in order to make it easier for fintech enterprises to obtain the necessary funds for their development, institutions and individuals should be actively promoted to invest in fintech enterprises, such as giving capital gains tax concessions to individuals or institutions that invest in fintech enterprises when they exit. Inspire individuals and organizations to invest in fintech enterprises. Institutions or individuals who want to invest in fintech enterprises in the western region should be given greater incentives to provide more attention. In terms of the approval process, the approval process should be simplified as much as possible by providing a one-stop service window and streamlining the process of applying for financial

support and tax incentives for fintech enterprises. Fintech is developing rapidly, so some policies that have been implemented may need to be adjusted in a timely manner, so the effectiveness of the implementation of financial support and tax incentives should be evaluated regularly and adjusted and optimized according to the feedback.

7.2. Improving green capital adequacy standards

A green capital adequacy standard is one that imposes special weights or preferences on investments in environmentally friendly, sustainable or green projects in the development and implementation of capital adequacy standards (Fig. 6). The standard is designed to incentivize banks or other financial institutions to invest more in green and sustainable projects to promote an environmentally friendly economy. So, it should involve a reduction in the risk weighting of investments in green projects, so that the impact of such investments on the capital adequacy ratio of banks will be reduced, thus increasing the incentives for banks to invest in such projects. Alternatively, banks should be encouraged to increase their investment in green projects by providing capital supplements to banks investing in such projects. Introduce differentiated capital regulatory measures for fintech firms and banks that are committed to green projects and technologies by setting lower capital adequacy requirements or preferential risk weighting policies. It is worth noting, however, that the precise definition of "green" or "sustainable" projects remains a challenging issue. Clear international standards are therefore needed to ensure fair and equitable implementation and to prevent "greenwashing" resulting from the abuse of such policies. Our analysis confirms that FinTech indorses green finance partially through enhancing bank capital adequacy. However, our data illustrate that banks with the highest green credit (BoC, ICBC, CCB) already have strong capital positions, while banks with low green credit (Guizhang, Wuxi, Yunong) have weaker capital bases. This suggests a virtuous cycle: capital enables green finance, and green finance (via FinTech) further strengthens capital.

7.3. Banks should maintain good capital adequacy ratios

In the study of the impact mechanism, it is further proved that the promotion of financial technology on green finance can affect the green financial development of banks through capital adequacy, so the government as well as supervisory agencies should ensure that commercial banks have good capital adequacy through reasonable regulatory requirements and incentives, and at the same time, banks themselves should also focus on maintaining a good capital adequacy. By providing sufficient capital support for green finance, it can promote the screening and investment of green projects.

Banks themselves, for their part, should strengthen risk management to ensure the quality of their assets. Implement effective credit policies to reduce non-performing loans. Also conduct regular capital adequacy assessments to ensure that capital levels meet regulatory requirements. Formulate and implement reasonable capital replenishment plans, such as increasing capital through retained earnings, issuing new shares or subordinated debt. From the business side, banks should optimize asset-liability management and balance risk and return. Develop diversified business, reduce reliance on a single market or product, and enhance risk resistance. From the regulator's point of view, reasonable capital adequacy requirements should be set to ensure that banks have sufficient capital to withstand risks. Stress tests and capital assessments should be conducted on banks on a regular basis to ensure that they are adequately capitalized. Banks should be required to disclose their capital adequacy ratio and risk profile on a regular basis to enhance transparency. Macroeconomic developments, changes in the meso-market, and the implementation of government policies all have an impact on banks. The government should adopt prudent fiscal and monetary policies to ensure economic stability and mitigate external risks for banks. It should also promote a fair and competitive market

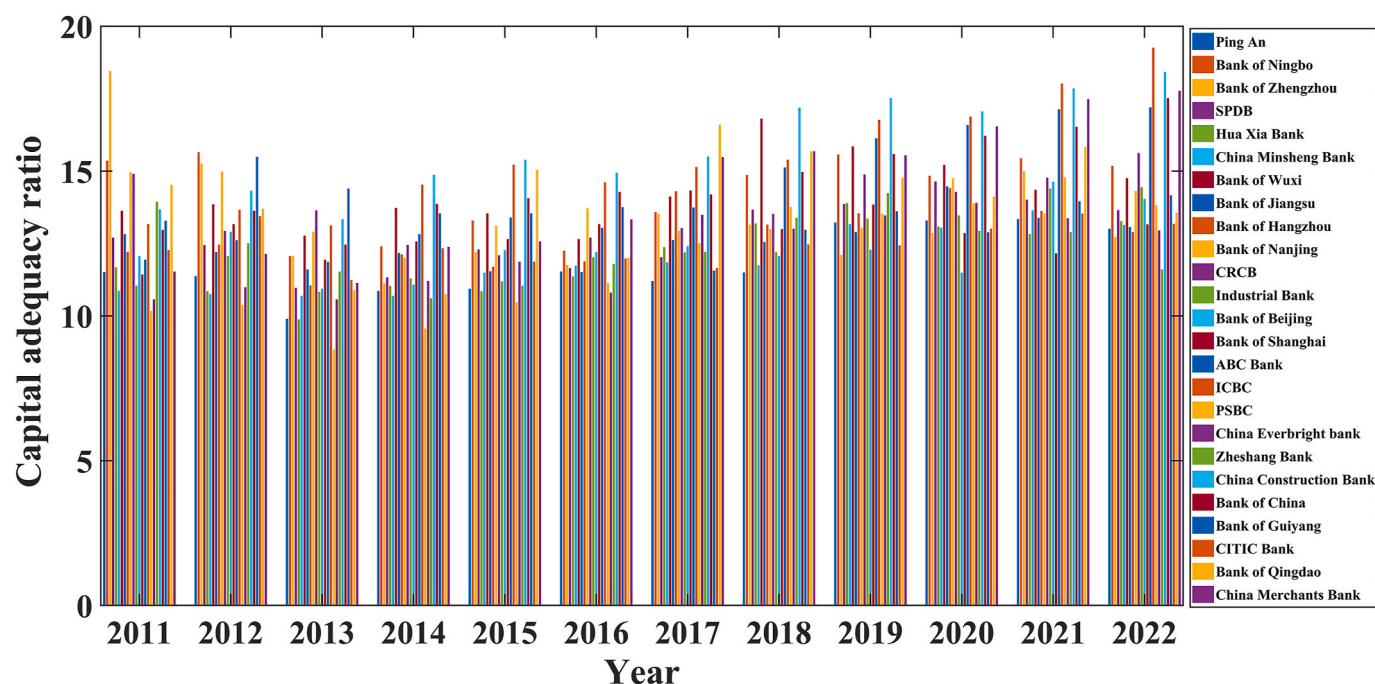


Fig. 6. Yearly distribution of capital adequacy ratio across the selected banks in China from 2011 to 2022.

environment to encourage innovation and efficiency improvement. Improve the financial legal system to provide a clear legal environment and regulatory framework for banks.

7.4. Promoting cross-sectoral and cross-regional cooperation

The study explores that green finance is highly concentrated in Eastern, large, state-owned banks. This concentration suggests that: (a) smaller and Western banks lack access to green finance expertise and technology; (b) there is limited knowledge spillover across regions; (c) the "latecomer" banks (Zhengzhou, Guiyang) face steep learning curves. Therefore, we should continue to promote cooperation between financial regulators, institutional learning, environmental protection, energy and other relevant departments to establish a cross-sectoral green finance promotion mechanism, so as to form a synergy and jointly promote the development of green finance. For example, a working group composed of representatives from financial regulators, environmental protection authorities, energy authorities and other relevant organizations should be set up to formulate and implement green finance development strategies. The group should establish a clear leadership mechanism to ensure that it operates efficiently and has the full support of the government and all relevant sectors. And it should develop a set of commonly recognized green finance standards and evaluation systems. Ensure that financial regulatory policies are harmonized with environmental and energy policies. One of the group's tasks is to establish a data-sharing platform that allows various sectors to share information on green projects, financial products, market demand and policy effects. It also urges the establishment of a platform for the exchange of experiences on fintech and green finance between the eastern and western regions to promote knowledge sharing and technology transfer. Financial institutions in the eastern and western regions are encouraged to carry out cooperative projects to enhance the application of fintech in the western region by cooperating to learn from the successful experiences of the eastern region.

8. Conclusion

The present study includes 26 Chinese banks to investigate the

impact of FinTech on green finance between 2011 and 2022 by employing several statistical modelling approaches at higher significance levels. We find that FinTech substantially promotes green credit, but such effects are largely heterogeneous and region-specific. The majority of eastern banks witnessed ample benefits from FinTech, while western banks show inhibition. Addition to this, large banks (BoC, ICBC, AB and so on) increase disproportionately more than small banks; and the scale effect operates through risk management and transaction cost channels. Evidence-based policy recommendations highlight strong capacity building, cross-regional knowledge-sharing and institutional cooperation between large and small-scale banks to attain green finance. However, the study restricted to 26 banks in China and had significant data scarcity for the western parts of the country to evaluate a strong regional difference on green finance. Therefore, future research should extend the investigation to emerging economies using larger and more diverse samples, and adopt alternative measures of green finance to yield more comprehensive insights.

CRedit authorship contribution statement

Liping Chen: Writing – original draft, Methodology, Funding acquisition, Data curation, Conceptualization. **Le Zhang:** Validation, Methodology, Investigation, Conceptualization. **Yuqiao Ding:** Writing – review & editing, Visualization, Resources, Methodology.

Declaration of competing interests

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.

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Appendix 1. FinTech Index

Banks	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ping An Bank	0.20	0.00	0.12	0.90	0.44	0.80	0.67	0.72	0.67	1.17	2.13	1.19
Bank of Ningbo	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.02	0.02	0.07	0.06	0.21
Bank of Zhengzhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.09	0.19
Bank of Qingdao	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.17	0.01	0.15
Pudong Development Bank (Shanghai)	0.07	0.00	0.00	0.06	0.00	0.01	0.10	0.38	0.95	0.57	0.60	0.41
Hua Xia Bank	0.00	0.00	0.02	0.19	0.10	0.10	0.07	0.20	0.22	0.07	0.04	0.29
Minsheng Bank	0.07	0.00	0.12	0.17	0.13	0.12	0.33	0.63	0.27	0.37	0.20	0.81
China Merchants Bank	0.09	0.09	0.14	0.37	0.12	0.71	1.46	1.29	0.71	0.79	1.18	1.13
Bank of Wuxi	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.04	0.01
Bank of Jiangsu	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.03	0.02	0.23	0.06	0.37
Bank of Hangzhou	0.00	0.00	0.00	0.06	0.00	0.14	0.07	0.16	0.04	0.05	0.52	0.33
Bank of Nanjing	0.00	0.00	0.00	0.00	0.02	0.02	0.09	0.05	0.41	0.44	0.13	0.32
Yunong Commercial Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.07
Société Générale	0.00	0.00	0.00	0.63	0.24	0.02	0.12	0.42	0.15	0.07	0.43	1.05
Bank of Beijing	0.00	0.00	0.09	0.70	0.26	0.31	0.53	0.32	0.23	0.20	0.30	1.43
Shanghai Banking Corporation (SBC)	0.00	0.00	0.00	0.02	0.02	0.07	0.09	0.31	0.86	0.57	0.46	1.28
Agricultural Bank of China (ABC)	0.08	0.00	0.00	0.18	0.13	0.13	0.11	0.28	0.46	0.84	0.63	0.74
Bank of Communications	0.00	0.00	0.00	0.11	0.13	0.07	0.14	0.36	0.44	0.28	0.86	0.48
Industrial and Commercial Bank of China (ICBC)	0.00	0.08	0.09	0.27	0.30	0.41	0.45	1.19	0.76	1.15	0.92	1.78
China Post Bank	0.00	0.00	0.00	0.00	0.15	0.16	0.00	0.04	0.06	0.40	0.70	0.79
China Everbright Bank	0.00	0.00	0.00	0.06	0.02	0.08	0.07	0.10	0.21	0.19	0.31	0.56
Zhejiang Commercial Bank	0.00	0.00	0.00	0.08	0.00	0.00	0.08	0.07	0.16	0.21	0.67	0.36
Construction Bank of China	0.08	0.03	0.20	0.83	0.24	0.27	0.54	1.33	1.02	1.20	1.41	1.25
Bank of China (BoC)	0.26	0.41	0.80	2.07	2.29	3.10	2.46	3.68	3.46	3.70	2.92	2.25
Bank of Guiyang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00
China CITIC Bank	0.00	0.00	0.02	0.02	0.37	0.28	0.31	0.74	0.26	0.76	0.71	0.22

Appendix 2. Listed banks

State-owned commercial bank	National joint-stock banks	Local commercial bank
Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, Construction Bank, Bank of Communications, Postal Savings Bank	Ping A Bank, Pudong Development Bank, Huaxia Bank, Everbright Bank, Minsheng Bank, Industrial Bank, China Merchants Bank, Zheshang Bank, CITIC Bank	Bank of Beijing, Bank of Shanghai, Bank of Jiangsu, Bank of Ningbo, Bank of Qingdao, Bank of Nanjing, Bank of Hangzhou, Bank of Zhengzhou, Bank of Guiyang, Bank of Wuxi, Yu Nongshang Bank

Appendix 3. Variable definitions

Role	Variables	Symbol
Explained variable	Green finance	GF
Explanatory variable	FinTech Index	FT
Moderating variable	Bank size	BSIZE
Mediating variable	Risk control capacity	CAR
control variable	Deposit and loan ratios	LDR
	Cost-to-income ratio	CIR

Data availability

Data will be made available on request.

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