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HOW DOES FINTECH DEVELOPMENT DRIVE CORPORATE INNOVATION? NEW EVIDENCE FROM THE PERSPECTIVE OF FINANCIAL SUPPLY

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Abstract. By constructing a city-level financial-technology (FinTech) development dataset, this study examines the impact of FinTech on corporate-innovation behavior from a financial-supply perspective. The results reveal that FinTech promotes corporate innovation by reducing corporate-financing constraints and financing costs, alleviating information asymmetry, and expanding financing channels. This promotion effect is more pronounced for private, small, and young firms, firms with fewer fixed assets, and those located in low-regulation intensity areas. Moreover, credit-based FinTech companies have a greater impact on business innovation. In addition, bank deregulation and increased bank competition crowd out the financial supply of FinTech for innovation financing. Knowledge of these impacts can help corporate managers, governments, and financial regulators to formulate more effective development strategies to promote corporate innovation.

Keywords: FinTech, financial supply, corporate innovation, bank competition.

JEL Classification: C33, G21, G28, D21, O3.

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1. Introduction

The traditional financial system is an important source of funds for innovation activities (Acharya & Xu, 2017; Hsu et al., 2014). The system refers to an established, bank-centric, financial model in which financial institutions, such as commercial and investment banks, insurance companies, and other non-bank financial intermediaries provide financial services through tangible entities (such as branch networks) (Kindleberger, 2005; Allen & Gale, 2000). The traditional financial system has advantages in information and risk sharing, which helps enterprises to reduce their cost of investment and financing of innovation activities to avoid innovation investment risks and to improve innovation output (Chava et al., 2013; Rajan & Zingales, 1998; Lee et al., 2023, 2024). However, innovative project financing is often influenced by information asymmetry, agency problems, and the misallocation of financial resources (Fama & Jensen, 1983; Stiglitz & Weiss, 1981), which makes it difficult for the traditional financial system to match and monitor innovation funds and limit access to finance for firms with

poor financial information and low collateral capacity. Consequently, a problem persists in the traditional financial system's undersupply of funds for firm innovation.

As there remain many imperfections in the traditional financial system in developing countries (Min et al., 2018), the prolonged lack of an effective supply of traditional financial services has severely impacted innovative activities (Berger et al., 2020; Giebel & Kraft, 2020). The financial system in developing countries exhibits a much lower level of financial inclusion than that in developed nations. According to data from the World Bank, in 2014, only approximately 9.6% of adults in developed countries lacked an account at a formal financial institution, while in developing countries, this figure stood at a staggering 77.7% (Chen et al., 2023). The characteristic of low financial inclusion is also reflected in the financial services that enterprises can access. Using China as an example, being the largest developing country, its financial system still revolves around banks. The five major state-owned commercial banks (SOCBs) lead China's commercial banking scene, commanding a significant share of the Chinese market. According to statistics, in 2007, the market share of these five major SOCBs combined stood at 65.9% (Chen et al., 2023). This high concentration significantly reduces the competition in the banking sector, possibly leading to enterprises' higher financing constraints and financial costs, and thus reducing their innovative capacities (Bos et al., 2013; Cornaggia et al., 2015). In addition, these banks' branches are mainly located in larger cities, particularly in coastal and metropolitan areas. Their financial services greatly overshadow those in the central-western and rural areas, resulting in financing constraints for enterprises located in smaller cities and central-western regions.

The shortcomings of the traditional financial system in developing countries are also reflected in the variety of financial products and services. As is well known, a diverse range of financial products and services can assist businesses in obtaining appropriate financing based on their development and needs (Elouaourti & Ezzahid, 2023). However, despite rapid growth in the Chinese financial market, it is still dominated by state-owned banks. A comprehensive financial market encompassing various derivatives, structured products, and alternative investment tools is absent. Under such circumstances, financial resources are more likely to be allocated to enterprises with tangible assets, sufficient collateral, and established relationships with these banks than to innovative startups (Abbasi et al., 2021; Ding et al., 2022). Another imperfection of this financial system lies in the lack of transparency between financial institutions and enterprises. This opacity makes it challenging for financial institutions to obtain information on a company's operational capability and financial status, often at a substantial cost (Lampel et al., 1996; Ye et al., 2022). Such a system is particularly detrimental to startups with inadequate financial records. Consequently, the imperfections in China's financial system result in businesses' difficulties in obtaining financing as well as high financing costs. The financial resources are not channeled toward high-efficiency enterprises, thereby hindering their potential for innovation.

Overall, the traditional financial sector in China has exposed some structural problems in supporting firms' innovative activities, resulting in insufficient financial supply and a lack of effective support for innovative activities. First, due to the structural imbalance in traditional finance and constraints of a prudent risk-assessment system, the supply of financial resources in the economic system lacks equity, and enterprises with innovation potential often do not

have access to innovation funds. Second, given the constrained liquidity in the conventional financial landscape, its efficacy in underpinning innovation is limited. The traditional financial sector, operating within rigorous profitability benchmarks and risk-aversion protocols, is not optimally positioned to champion innovative endeavors. Notably, even when multiple financial sectors collaborate, the aggregated capacity falls short in adequately financing innovative enterprises. Third, a significant disparity exists among enterprises in terms of collateral, guarantee capabilities, and market potential. Due to its uniform approach to financial services or products, the traditional financial system typically favors large-scale, highly profitable, and mature companies. This standardization often leads to the financial marginalization of many innovative enterprises, which, by contrast, might lack such attributes.

The rapid development of FinTech offers new opportunities to address the aforementioned challenges. The inadequacies in the traditional financial sector are a significant reason for the swift growth of FinTech (Hua & Huang, 2021). For developing countries such as China, financial frictions lead to a misallocation of financial resources among innovative entities, especially as small and medium enterprises (SMEs) struggle to acquire capital from the traditional financial sector, facing stringent financing constraints. The swift rise of FinTech offers vital financial support for innovative entities (Bollaert et al., 2021). As an emerging financial industry, FinTech employs technologies such as big data, cloud computing, blockchain, and artificial intelligence (AI) to mitigate the operational risks and costs caused by information asymmetry in traditional finance (Financial Stability Board [FSB], 2017), thus offering cost-effective solutions (Gomber et al., 2018). In traditional financing models, banks evaluate business-credit risks based on businesses' operational history, financial records, and tangible assets, a process often time-consuming and costly (Ryan et al., 2014). For startups and younger firms, this financing model entails significant costs and higher financing constraints (Wang et al., 2019). With the advent of FinTech, banks and FinTech firms can swiftly assess business-credit risks using advanced technologies, even if these businesses lack a long-term credit history. This favors the flow of financial resources to firms unable to secure financing from the traditional financial system, thereby enhancing their innovation capacity (Abbasi et al., 2021; Ding et al., 2022).

In contrast to the cumbersome procedures of traditional financial institutions, the application of FinTech in the modern financial domain has notably streamlined and optimized many conventional financial processes (Abbasi et al., 2021; Agarwal & Zhang, 2020). Platforms such as P2P lending, crowdfunding, digital banking, and online supply-chain financing can swiftly evaluate business-credit risks using technologies and deploy preset smart contracts to automatically grant loans to enterprises (Abbasi et al., 2021). Armed with its innovative techniques and solutions, FinTech is revolutionizing information exchange and handling in the financial domain, substantially reducing information asymmetry, thus enhancing enterprise financing and innovation capabilities (Chen et al., 2022; Lyons et al., 2021). Financial institutions can harness big data to gather and analyze various non-conventional business data, such as online transaction records, social-media activities, and supply-chain information, for a more comprehensive credit assessment (Gabor & Brooks, 2017). Financial institutions can also employ digital technology to directly connect to business accounts and other project systems, enabling real-time monitoring of businesses' financial conditions and fund usage, thus facilitating the early detection and warnings of potential risks (Hua & Huang, 2021).

As the largest developing country, China provides a favorable environment for exploring the relationship between FinTech development and business innovation. First, despite China's rapid economic growth, the financial system centered on SOCBs has led to a highly concentrated financial market and inadequate financial supply. This situation constrains the development of business innovation, particularly for SMEs, which often struggle to obtain financial support from the traditional financial system. Secondly, as one of the developed FinTech countries, China has accumulated a large amount of data and experience in FinTech. Concurrently, as the country transitions from a major innovator to an innovation powerhouse, its investment in innovation is steadily increasing. This provides a wealth of data support for our research and offers valuable lessons for other developing countries. Thirdly, following the Asian financial crisis in 1997, the Chinese government implemented numerous financial reforms to break the financial monopoly and enhance financial supply. This provides an environment conducive to analyzing the impact of the interaction between financial reforms and FinTech on business innovation.

This study seeks to unveil novel insights into how FinTech drives firm innovation, focusing on the financial supply side. Firstly, it gauges the scope of regional FinTech growth by utilizing the metric of FinTech establishments present at distinct local and municipal levels throughout China. Currently, traditional domestic financial institutions have two main types of layouts for this technology: cooperation with external financial-cooperation agencies and the establishment of FinTech departments (subsidiaries). Therefore, the total number of FinTech firms effectively reflects the level of FinTech development in a region. A larger count of such enterprises indicates a correspondingly higher degree of development within that specific area. Second, the Chinese government's branch reform for the banking industry has led to changes in the structure of banks, which provides a sound basis for us to comprehensively explore the interaction between traditional finance and FinTech. In April 2009, the China Banking Regulatory Commission (CBRC) launched *Opinions on the Adjustment to the Market Access Policy for Branches of Small and Medium Commercial Banks* (*Opinions on Market Access*, hereafter), which removed the restrictions on the establishment of branches of joint-equity and city commercial banks in new cities. This reform measure in the Chinese banking sector aims to reduce the banking system's monopoly on credit funds created by government intervention and promote commercial banks to become independent market players; the banks can then compete in accordance with the laws of the market economy so that the allocation of credit funds can truly return to market channels. This reform comes at a time when FinTech is in its infancy, and both bank competition and FinTech development will, to some extent, improve financial supply and thus promote technological innovation. How bank competition and FinTech interact in this process provides the basis for this study.

This study contributes to the literature in four respects. First, our research employs the number of FinTech firms to construct an index representing the level of regional FinTech development. The literature predominantly utilizes the China Digital Inclusive Finance Index as a proxy for FinTech (Ding et al., 2022; Yang et al., 2021). However, this index is formulated based on data from Alipay users (primarily individuals) and hardly reflects financial institutions and firms in general (Hua & Huang, 2021; Li & Li, 2022). Relying on Alipay as the sole data source to construct a FinTech index may lead to issues related to data representativeness

and completeness, as Alipay might not capture the financial activities of the entire market or those of specific user groups. We use the number of FinTech firms as a metric to evaluate the development of urban FinTech, an indicator whose advantage lies in its ability to effectively reveal a city's FinTech-market activity, appeal, and the vibrancy of its entrepreneurial environment. A high value might indicate intensified market competition, which typically fosters innovation and technological advancement. Simultaneously, integrating this numerical metric with corporate financial and innovation data can elucidate the impact of FinTech on business development.

Second, this research delves into the role of FinTech in fostering corporate innovation, with a specific focus on the perspective of financial supply. While Hua and Huang (2021) highlight FinTech's emergence as a response to the deficiencies in traditional financial supply, and Bollaert et al. (2021) suggest that FinTech enhances firms' fundraising abilities, our analysis provides new insights by highlighting the role of FinTech in enhancing financial supply. This study uniquely underscores the significance of FinTech in optimizing financial supply, particularly in contexts where traditional financing is insufficient. By employing micro-enterprise data, we dissect the intrinsic mechanisms through which FinTech acts not merely as an alternative financing solution but as a transformative force in the financial landscape, reshaping how financial resources are distributed and accessed. This financial supply perspective sheds new light on the dynamics of corporate innovation, distinguishing our research from existing literature and contributing a novel understanding of FinTech's influence on the innovation capacities of firms.

Third, this study explores the heterogeneity of FinTech in enterprise innovation from the perspectives of the nature of enterprises, financing capacity, and FinTech company types. It not only enriches the literature academically, but it also provides useful policy thinking on how to promote the deep integration of FinTech and the real economy and spur high-quality economic development through enhancing financial supply.

Finally, we explore the impact of the interaction between bank deregulation and FinTech on corporate innovation. The impact of bank competition on firm innovation has been extensively examined in numerous studies; however, with the development and measurability of FinTech, the competing effects between the two and the impact on firm innovation have not been explored (Biswas & Koufopoulos, 2020; Cornaggia et al., 2015). This study takes advantage of the introduction of the CBRC's *Opinions on Market Access* to investigate how banks interact with FinTech after increased competition and what impact it has on firm innovation. This is important for enhancing the understanding of the development of traditional financial systems and FinTech.

Our empirical evidence suggests that FinTech, by leveraging digital technologies, mines and gathers insights into the potential growth of the industries in which firms operate. Concurrently, by harnessing blockchain and embedding financial- and project-management platforms, FinTech significantly reduces the degree of information asymmetry. Additionally, FinTech can expedite financing workflows using digital platforms and smart-contract technologies. These advantages of FinTech substantially alleviate firms' financing constraints, diminish credit costs, expand financing channels, and provide financial support for business-innovation projects. Regarding the findings from the heterogeneity analysis, given the distinctions be-

tween FinTech firms and traditional financial institutions, the former can assess a business's creditworthiness by employing digital technologies and predictive methodologies, without heavily emphasizing credit history and tangible assets. Consequently, the enhancing effect of FinTech on the innovative capacities of private enterprises, small-sized businesses, and firms with fewer tangible assets is more pronounced. As indicated by Hua and Huang (2021), the evolution of FinTech has been catalyzed by a lenient financial environment. Our findings underscore that in such a permissive financial milieu, the role of FinTech in fostering business innovation is more potent. Finally, utilizing the *Opinions on Market Access* as a lens, we examined whether relaxing banking regulations impacted the relationship between FinTech and business innovation. We observed that softening banking oversight diminished the positive effect of FinTech on business innovation.

2. Literature review and hypotheses

2.1. FinTech and corporate innovation

Financial capital is an essential component of market-factor supply and a core element driving firm innovation (Acharya & Xu, 2017). Financial supply directly influences the unfolding of firms' innovation activities (Hsu et al., 2014; Pagano, 1993). The literature suggests that an improvement in financial development can improve the efficiency of capital transfer between different departments, and accelerate the establishment of high-quality departments or capital transformation of industries (Pagano, 1993). Financial intermediaries and markets also help balance liquidity among different sectors to promote capital transformation, enabling enterprises to break through the original financing constraints and promote their innovative activities (Benfratello et al., 2008; Chang et al., 2019).

However, various imperfections remain in developing countries' financial systems. The chronic undersupply of traditional financial services has substantially hindered corporate innovation and commercial activities (Karabarbounis & Macnamara, 2021). Using China as an example, within its bank-centric traditional financial system, the market share of state-owned banks remains dominant, which curtails healthy market competition. Bos et al. (2013) posit that a competitive market stimulates sectoral innovation, suggesting that higher bank competition would significantly reduce the financing costs and constraints faced by enterprises. In the conventional financing model, banks, aiming to minimize credit-default rates, set high benchmarks for a firm's financial status, collateral, and creditworthiness. For start-ups and financially distressed businesses, the likelihood of obtaining capital from banks is minuscule, compelling them to turn to non-formal financial institutions, which considerably amplifies their financing and operational costs (Acs & Audretsch, 1987). Concurrently, within this financing paradigm, banks rely on the data provided by enterprises, such as financial statements, transaction histories, assets, and guarantees, for assessment. This vetting process is cumbersome and protracted. More detrimentally, to safeguard their interests or secure bank loans under favorable terms, enterprises might embellish their financial performance or conceal certain adverse information, which obstructs banks from grasping the genuine status of the businesses (Hoffmann & Kleimeier, 2021b). These uncertainties cause information asymmetry between banks and businesses and undermining the latter's innovation capabilities.

To address this core issue, all stakeholders, including governments, businesses, and financial institutions, have made significant efforts. Governments have recognized that to promote sustained economic growth and innovation, comprehensive financial reform is necessary. This realization has prompted governments to initiate a series of financial-liberalization measures, including relaxing regulations on banks and other financial institutions and allowing more private and foreign capital to enter the financial markets (Chen et al., 2023; Wang & Hu, 2023). Meanwhile, by introducing a more market-oriented, transparent, and fair financial regulatory mechanism, financial institutions are encouraged to provide more funds to SMEs, startups, and other innovative projects. Governments also attach great importance to providing fiscal and tax support for enterprises. Various subsidies, tax incentives, and policy-oriented credits offer businesses the funds needed for innovation (Fang et al., 2023; Xia et al., 2022). These policies aim to reduce enterprises' research and development (R&D) and innovation costs, making it easier for them to obtain the crucial initial funds and achieve success in the market. Moreover, modern enterprises are experiencing a wave of digital transformation. To cope with the insufficiency of financial supply, many enterprises have started exploring advanced technologies to improve their business models, reduce costs, and seek new financing channels for their innovative projects. Technologies such as blockchain, AI, big data, and cloud computing offer new possibilities for businesses, enabling them to interact more efficiently with financial institutions, suppliers, and other stakeholders (Du et al., 2023; Gaglio et al., 2022; Qin et al., 2023). Digital transformation not only helps enterprises better understand their customers and the market but also provides new, flexible financing opportunities for their innovation projects (Tian et al., 2022).

At the financial-institution level, the integration of finance with digital technology breaks the traditional financial-supply model and enhances enterprises' innovative capacity (Bollaert et al., 2021). By leveraging cutting-edge technologies such as big data, AI, and machine learning, FinTech has endowed financial institutions with superior information-processing abilities (Abbasi et al., 2021; Wang et al., 2019; Abakah et al., 2023). For instance, these technologies enable in-depth mining and analysis of company operations and interactions between businesses and consumers, and thus help realize the growth potential of the sectors in which they operate. This permits more precise evaluations of company creditworthiness, even forecasting future repayment capacities. Compared to traditional assessment methods that rely solely on past financial data or tangible assets, this real-time data-driven approach is more dynamic, allowing the more apt capture of businesses' credit variations. This implies that even entities without a traditional credit history or financial records can access financial markets and obtain essential financing. Crowdfunding platforms such as Kickstarter and Indiegogo offer businesses the opportunity to directly communicate with the public, showcasing unique projects or product ideas to attract funding. Meanwhile, P2P lending platforms such as LendingClub and Prosper connect businesses with potential investors, facilitating swift capital matches. Crucially, these emerging FinTech platforms typically possess more flexible and open characteristics (Abbasi et al., 2021). This means that compared to traditional financial institutions, they exhibit higher efficiency in qualification verification, risk assessment, and fund disbursement. Meanwhile, these platforms commonly employ advanced big-data and machine-learning technologies, ensuring that businesses' credit assessments are not solely reliant on historical financial data but incorporate a comprehensive analysis of various online

and offline behaviors, providing a more holistic and precise credit profile, thereby expanding corporate financing channels (Abbasi et al., 2021; Bollaert et al., 2021; Ding et al., 2022).

Concurrently, blockchain technology offers a transparent, immutable transaction-history platform, ensuring that the information financial institutions acquire while examining a company's financial records is authentic and comprehensive, considerably mitigating the credit risks arising from information concealment or tampering (Bonsón & Bednárová, 2019; Wang et al., 2019). Financial institutions can also integrate data platforms into a company's financial and management systems and monitor real-time fund utilization for compliance; this provides timely warnings and adjusts credit evaluations, thus bridging the data divide between the financial institutions and businesses. Modern FinTech platforms, utilizing sophisticated big-data analytics, AI, and cloud computing, can rapidly and accurately evaluate a company's creditworthiness and repayment abilities. Companies merely need to upload the required data online, and these platforms swiftly analyze the data, generate credit reports, and provide financing recommendations (Abbasi et al., 2021). This online, automated approach considerably accelerates approval speeds and streamlines the financing process, enabling businesses to obtain needed funds more quickly and propelling their business growth. Face-to-face meetings or telephonic communications are no longer necessary as all transactions can be completed online. This immediacy not only enhances operational efficiency but also diminishes the decision-making risks associated with prolonged waiting periods and lagging information updates (Ding et al., 2022). Under this model, companies can promptly adjust strategies in response to market shifts, thus enhancing their market responsiveness.

In summary, FinTech, by transforming traditional financing models, has not only expanded corporate financing channels and reduced financing costs and information asymmetry, but it has also streamlined cumbersome financing procedures, which supports corporate innovative financing from a supply perspective. Following these arguments, we therefore propose the first hypothesis as follows:

H1: *FinTech development significantly contributes to corporate innovation.*

2.2. Bank deregulation, FinTech, and corporate innovation

To promote local financial systems' support for innovation-driven activities, it is imperative to establish a multi-level, multi-type, modern banking institutional framework to cater to the needs of numerous service providers. A significant direction for reform is to encourage joint-stock and city commercial banks to establish branches across regions, expand the number of business outlets, and initiate real-time reforms from the financial-supply side to enhance financial inclusion. Under the guidance and promotion of this reform idea, China has gradually broken the monopolistic banking structure dominated by the five major SOCBs in most regions, thus bringing about an increase in market competition among different types of banking institutions. It has also used the push-back mechanism that arises from the competition mechanism among banks to spur the improvement of a modern corporate-governance system within banking institutions, risk-control ability, and banks' efficiency in allocating capital resources.

The deregulation of banks has enhanced the accessibility of corporate finance and led to a competitive relationship with FinTech companies. On the one hand, loosening bank access

control inevitably leads to the expansion of joint-stock and city commercial banks, which intensifies inter-bank competition and results in a structural competition pattern for banks. As empirical evidence from studies such as Benfratello et al. (2008) and Chava et al. (2013), the intensification of bank competition has increased the opportunities and quantity of state-owned enterprises (SOEs) to obtain bank loans, reduced the distorting effect of credit allocation in the banking system, and eased corporate-financing constraints. On the other hand, the relaxation of regulatory policies may prompt regional small- and medium-sized banks to exploit their flexibility and scale as well as their channel advantages in collecting information to better upgrade SOEs in the region (Chava et al., 2013), which in turn effectively promotes SOEs' innovative activities in the region.

The impact of the interaction of bank deregulation and breakthroughs in FinTech with firm innovation remains unclear. When the financial deregulation of banks increased bank competition and, consequently, lending standards became lower and less costly, banks were able to achieve profitability. Against this backdrop, since the application of FinTech requires a large capital investment, the willingness of banks to use it is not strong, which reduces the impact of FinTech on business innovation. The escape-competition theory argues that intense competition reduces the banking industry's profits, incentivizes the industry to innovate to gain competitive advantages (Bos et al., 2013), promotes better integration between traditional banking and FinTech, and enhances bank efficiency and the role of FinTech in driving business innovation (Lee et al., 2021; Zhao et al., 2022). Based on the exposition above, we propose the following two hypotheses:

H2a: *Bank deregulation amplifies the driving effect of FinTech on firm innovation.*

H2b: *Bank deregulation reduces the driving effect of FinTech on firm innovation.*

3. Methodology

3.1. Panel data with fixed-effects model

Referring to the specification of Giebel and Kraft (2020) and Hsu et al. (2014), we start with the following panel regression model as the benchmark to assess how FinTech development affects corporate innovation (*H1*).

$$Patent_{i,t+1} = \alpha + \beta Fintech_{c,t} + \gamma X_{i,t} + year + industry + \varepsilon_{i,t}, \quad (1)$$

where, subscripts *i*, *c*, and *t* denote firms, cities, and years, respectively. The dependent variable $Patent_{i,t+1}$ is corporate innovation proxied by the number of patent applications. Accounting for the time-lag of patent application impacts, we utilize values that are lagged by one year. $Fintech_{c,t}$ illustrates the stage of FinTech advancement in the firm's respective city, as determined by the FinTech-industry development index created for this study. The parameter β is derived to assess the specific influence of FinTech growth on corporate innovation activities. **H1** is supported if β is significant and positive. The term, $X_{i,t}$ is a group of control variables that affect how firms operate. Given that the process from R&D to patent formation, and subsequently to patent application, typically takes approximately a year, we apply a first-order lag to both the dependent and the control variables.

Following the usual specifications of Acharya and Xu (2017), and Hsu et al. (2014), we control for a series of firm-specific characteristics, such as firm age (*Age*), and size (*Size*), debt ratio (*Debt*), return on assets (*ROA*), Tobin's Q (*TQ*), CEO duality (*Dual*), ownership concentration (*TOP1*), Government subsidy (*Gs*) and industry concentration measured by the Herfindahl-Hirschman index (*HHI*). Referring to Filippopoulos and Fotopoulos (2022), Hsieh et al. (2022), and Kong et al. (2022), we also control for a set of regional-specific factors such as economic development (*GDP*), industrial structure (*IS*), and human capital measured by scientific research and education investment (*EI*). Finally, *year* and *industry* are the control of year and industry fixed effects, and ε stands for the error term.

3.2. Difference in differences (DID) model

Commercial and policy banks, as significant financing sources for enterprises, have a profound impact on corporate innovation. The People's Bank of China spearheaded reforms for policy banks. For instance, in December 2008, the China Development Bank was officially listed. However, policy banks primarily aim to achieve national macroeconomic and social-development objectives. Compared to commercial banks, their operations focus more on national development strategies and goals. In terms of financing loans, policy banks typically set more stringent and specific criteria for admission and requirements. The loaned funds must also meet national policy requirements, such as large-scale infrastructure projects, export trade, and agricultural development. Commercial banks, however, usually offer a more diverse array of financial products and services, including various loans, credit cards, trusts, and wealth-management products, which cater to enterprises' different financing and fund-management needs. Commercial banks are often in competition with one another and tend to offer lower loan-interest rates, emphasizing service quality and efficiency. Their approval processes and loan-disbursement speeds are generally quicker and more flexible than those of policy banks. Building long-term relationships between enterprises and commercial banks can help the former access more specialized financial services. For enterprises, the entry threshold for commercial bank loans is lower, the interest rates on loans obtained are more favorable, and the fund-usage regulations are more lenient. Therefore, combining the effects of the characteristics of policy and commercial banks on firm financing and innovation, we consider the use of Chinese government deregulation of commercial banks to test **H2**. Meanwhile, following Chen's et al. (2023) empirical strategy, we employ a DID approach using *Opinions on Market Access*.

In formulating a nuanced, city-level continuous treatment indicator *Exposure*, our approach is bifurcated into two methodological phases. The first phase is dedicated to identifying cities that remained impervious to the effects of deregulation. According to policy delineations, a city is categorized as deregulated if, preceding the regulatory shock, it accommodated a branch of any of the 12 joint-equity banks or if such entities were present within the capital of its encompassing province[1]. Scrutiny of the distribution of joint-equity bank branches prior to April 16, 2009, reveals that four provinces – Guizhou, Ningxia, Qinghai, and Tibet – lacked

[1] The 12 joint venture banks are China Merchants Bank, CITIC Bank, Everbright Bank, Huaxia Bank, Pudong Development Bank, Industrial Bank, Minsheng Bank, Ping An Bank, Guangfa Bank, Hengfeng Bank, Bohai Bank and Zheshang Bank.

any such branches in their capitals, thereby persisting under stringent restrictions until the conclusion of our study period. As a result, cities within these provinces remained insulated from deregulatory forces, warranting an *Exposure* assignment of zero.

Transitioning to the second phase, we exploit inter-city variations in deregulation, viewing them as a catalyst for FinTech-driven corporate innovation. Among the deregulated cities, we delve into an analysis of the heterogeneity in deregulation risks, with a concentrated lens on the financial volatility experienced by the top five banking institutions. Exposure to deregulation is higher in cities with higher market shares of SOCBs, as the removal of bank branch restrictions intensifies competition between joint venture and SOCBs. Relying on extensive data related to bank branches established before the enactment of the deregulatory policy, we devised the *BIG5%* variable. This metric signifies the market concentration commanded by the five foremost commercial banks and is calculated based on the proportion of branches these major banks operate relative to the total branch count in each city.[2] An escalation in *BIG5%* denotes a heightened vulnerability to policy shocks. In summary, *Exposure* aligns with *BIG5%* values across cities that underwent deregulation, maintaining a consistent zero value for cities unaffected by such regulatory changes.

Based on the above-mentioned settings, we then estimate the following DID regression for both treatment and control groups.

$$Patent_{i,t+1} = \alpha + \beta Fintech_{c,t} + \delta Exposure_c \times Post_t + \theta Exposure_c \times Post_t \times Fintech_{c,t} + \gamma X_{i,t} + year + industry + \varphi_{i,t}, \quad (2)$$

where, $Exposure_c$ represents the intensity of policy shocks in city *c*, thus indicating the impact of bank deregulation on FinTech-driven firm innovation, where Guizhou, Ningxia, Qinghai, and Tibet are not affected and are assigned a value of 0. *Post* represents the policy dummy variable of bank deregulation that equals 1 ever since the issuance of *Opinions on Market Access* in 2009 and 0 otherwise. The interaction term $Fintech_{i,t} \times Exposure_c \times Post_t$ is main focus (Su et al., 2023). Its coefficient reflects the impact of increased bank competition on FinTech-driven firms' innovation.

4. Data description

4.1. Sample selection and data sources

We use data mainly from China's A-share listed companies in Shanghai and Shenzhen, spanning the period 2003–2017. Listed enterprises' financial and patent-application data are obtained from the China Stock Market and Accounting Research (CSMAR) database. Firms are excluded based on the following criteria: (1) companies engaged in financial services and public affairs; (2) companies marked as special treatment (ST); (3) companies with missing data for the main variables; and (4) companies listed for less than one year. All continuous variables are winsorized at the 1st and 99th percentiles. The final sample comprises 23,259 firm-year observations from 2,361 firms.

[2] Commercial bank branch data from: https://xkz.cbirc.gov.cn/jr/

Data on FinTech companies are obtained from the China FinTech Enterprise Database. This database is constructed by collecting data from enterprises whose business areas are Internet banking, Internet brokerage, Internet insurance, Internet fund sales, Internet asset management, Internet small business loans, Internet consumer finance, peer-to-peer, financial information, crowdfunding, digital currency, financial infrastructure, payment, and credit industry in each region. It covers 12,846 samples from 2003–2017 from various provinces and cities in China. Other regional-level data come from the China Urban Statistical Yearbook.

4.2. Variable construction

This study measures firm innovation through patent-based metrics that are commonly used in innovation research (Acharya & Xu, 2017). Unlike innovation-input indicators, such as a firm's *R&D* expenditure, patent data can accurately estimate firms' innovation capacity. Being less susceptible to the patent-granting system than granted patents (Amore & Bennedsen, 2016), patent applications are a better indicator of a firm's innovation capacity. To assess firms' innovation activities in more detail, patents are classified into three types: invention, utility, and design.

In this study, we constructed a city-level FinTech-development index using corporate data. By querying the China FinTech Corporate Database, we obtained registration information for 16,767 FinTech companies. Based on their registered addresses, we derived FinTech company counts and total registered capital amounts for 236 cities or regions. The database also provided registered capital data for these FinTech companies. We matched the city codes with listed-company financial and patent data as well as city statistical yearbooks to create the dataset for this study. Ultimately, we used the logarithm of the total number of FinTech companies as an indicator of the level of FinTech development (*FinTech*) in a region. Listed companies' financial and patent data were obtained from CSMAR, while city-level data were sourced from the China Statistical Yearbook. In subsequent analysis, we also considered the logarithm of total registered capital amount plus one (*FinTech_capital*) and the commonly used Peking University Digital Financial Inclusion Index (*FinTech_index*) as two alternative measures of FinTech development for the robustness test.

As mentioned earlier we also include a series of controls that can be categorized into firm-specific controls and regional-specific controls. Table A1 of the Appendix contains all relevant information about the variables and the related definitions, while Table A2 of the Appendix shows the descriptive statistics for these variables. We find a certain variability in corporate innovation capacity and inter-regional FinTech development, which provides the basis for this paper's research.

5. Regression results

5.1. Baseline regressions and preliminary findings

Column (1) of Table 1 showcases the foundational regression analysis based on Eq. (1). The analysis reveals that the *FinTech* coefficient is both significant and positive at the 1% level, indicating that as FinTech development increases, so does the innovation output of enterprises. This evidence solidly supports **H1**. To further examine FinTech's impact, we segregated

patent applications into distinct classifications, such as invention and utility patents. Presented in Columns (2) and (3) of Table 1, the *FinTech* coefficients persist in demonstrating significant positivity, confirming the robustness of our findings. It's also noteworthy that the FinTech influence is more substantial on invention patents than on utility patents. Given that invention patents inherently represent a higher degree of innovation than utility patents, these observations attest to FinTech development's potent role in significantly enhancing firms' technological innovation capacities.

Table 1. Effect of FinTech on corporate innovation

Variable	(1)	(2)	(3)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
FinTech	0.097***	0.088***	0.074***
	(0.022)	(0.019)	(0.019)
Age	–0.297**	–0.242**	–0.244**
	(0.132)	(0.108)	(0.112)
Debt	–0.957***	–0.767***	–0.416***
	(0.179)	(0.170)	(0.148)
Roa	0.558***	0.385***	0.302*
	(0.181)	(0.141)	(0.156)
Size	0.457***	0.422***	0.312***
	(0.034)	(0.029)	(0.032)
Dual	0.070	0.063	0.036
	(0.055)	(0.043)	(0.052)
Top1	–0.001	–0.002	0.001
	(0.002)	(0.002)	(0.002)
TQ	0.028	0.046**	–0.025
	(0.027)	(0.021)	(0.019)
Gs	8.615***	10.270***	4.776***
	(2.092)	(1.794)	(1.601)
HHI	–0.216	–0.902**	0.684
	(0.484)	(0.443)	(0.419)
GDP	0.025*	0.018*	0.024**
	(0.013)	(0.011)	(0.010)
IS	1.557***	1.005***	1.365***
	(0.381)	(0.306)	(0.319)
EI	2.393***	1.720**	1.333**
	(0.905)	(0.804)	(0.619)
Constant	–9.232***	–8.439***	–6.571***
	(0.870)	(0.719)	(0.895)
FEs	YES	YES	YES
Adj. R^2	0.245	0.242	0.184
Observations	12,169	12,169	12,169

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

The signs and significance of the coefficients of other control variables are basically consistent with those in the literature. Among them, the coefficient of *Age* is significant and negative, which is consistent with Ding's et al. (2022) findings and indicates that younger firms are more willing to engage in innovative activities. The coefficient of *Debt* is significant and negative, which suggests that the more debt firms have, the more pressure they have to repay the debt, the more they tend to have short-term earnings, and the weaker their willingness to engage in innovation (Zhang et al., 2020). The coefficients of *Roa*, *Size*, and *TQ* are all positive, indicating that firms with higher profitability, larger scales, and greater growth opportunities are more capable of conducting innovative activities (Zhang et al., 2020). The coefficients of *IS* and *EI* are both significant and positive. The former result indicates that the larger the proportion of the secondary industry, the stronger the enterprise's innovation capability (Fleisher et al., 2021). The latter result implies that the more a region's government invests in R&D and education, the more intensive the local human and physical capital that provides factor-technology supply for technological innovation (Kong et al., 2022).

5.2. Robustness checks

In this subsection, we conduct a series of robustness tests to assess the credibility of the benchmark regressions. First, we replace the core independent variables with the regional FinTech firms' constituent capital (*FinTech_capital*) and Beijing University's digital financial-inclusion indicators (*FinTech_index*). Columns (1)–(6) in Table 2 showcases the results, maintaining consistency with our initial findings. In addition, given that FinTech companies might be concentrated in major cities where firms generally have stronger innovative capabilities, this could introduce bias into our estimated results. To address this, we exclude Beijing,

Table 2. Robust checks: measurement concerns

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	R&D	IE
FinTech_capital	0.032***	0.028***	0.024***					
	(0.008)	(0.007)	(0.007)					
FinTech_index				0.008***	0.007***	0.007***		
				(0.003)	(0.002)	(0.002)		
FinTech							0.001***	0.007**
							(0.000)	(0.003)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R^2	0.243	0.240	0.182	0.229	0.228	0.169	0.079	0.054
Observations	12,169	12,169	12,169	8,586	8,586	8,586	6,764	6,764

Notes: The FinTech index spans the period 2011–2017, whereas R&D and IE span the period 2007–2017. The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

Guangzhou, Shenzhen, and Shanghai and re-estimate the model. For the sake of brevity, these estimates are not shown but the results indicate that even after removing firms from these major cities, the impact of FinTech on firm innovation remains significant and positive. We also expand upon our prior method, which relied on innovation outputs as surrogates for innovation activities. Acknowledging FinTech's potentially diverse influences, this stage of the study embraces a wider array of innovation metrics, concentrating on both innovation inputs and innovation efficiency. In alignment with the approach utilized by Zhang et al. (2020), our analysis uses firms' R&D expenditures and firms' innovation efficiency (*IE*) index's as proxies for firms' innovation. The findings in Columns (7)–(8) reinforce the positive trajectory that FinTech imparts on innovation, thereby corroborating the foundational assertions of this research.

Second, we check whether our previous findings are sensitive to endogeneity. In Eq. (1), although we aim to control for the possible factors of FinTech-driven enterprises' innovation output, it may still be impacted by some unobservable factors, and the missing-variable problem may bias the estimated FinTech coefficient. In addition, higher corporate innovation may also lead to higher demand for FinTech, and there may be reverse causality between the two. To address potential endogeneity issues, we employ two instrumental variables. One is provincial Internet penetration. Within the FinTech infrastructure, Internet penetration plays a crucial, albeit indirect, role in the evolution of FinTech, while its direct connection to innovation is less pronounced. This distinction renders Internet penetration a suitable instrumental variable for our analysis. The second instrumental variable is the number of fixed-line telephones per 10,000 people in 1984. Theoretically, urban information technology usage and adoption are influenced by historical IT development and fulfill the necessary conditions for correlation. Furthermore, landline telephones, as a form of social infrastructure, do not directly contribute to business innovation, thus satisfying exogeneity conditions. Moreover, considering that the raw data of instrumental variables are cross-sectional and cannot be directly used in the econometric analysis of panel data, we incorporate interaction terms. Specifically, we utilize lagged Internet users multiplied by the number of fixed telephone lines per 10,000 people in each prefecture-level city in 1984. The diagnostic outcomes of the instrumental variable tests, presented in Table 3, confirm no issues with weak instrumental variables or over-identification, thereby strengthening the integrity of the analytical method. Through the strategic application of this instrumental variable approach to counteract inherent endogeneity concerns, the study reaffirms the significant positive influence of FinTech on corporate innovation, thereby solidifying the reliability of the central conclusions.

Finally, we utilize quantile regression to assess the influence of FinTech on corporate innovation. This method helps alleviate concerns regarding the non-normal distributions of certain variables affecting the estimation results (Wooldridge, 2012). Table 4 presents the effects of FinTech on corporate innovation across different quantiles. We note that the coefficient of *FinTech* is not statistically significant except when the dependent variable is *Utility* and at the 75th percentile. In all other cases, the coefficient of *FinTech* is significant and positive at the 10 percent level and below, confirming the robustness of the baseline regression results.

Table 3. Endogeneity (2SLS model)

Variable	(1)	(2)	(3)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
Panel A: provincial Internet penetration			
FinTech	0.068***	0.070***	0.040***
	(0.017)	(0.015)	(0.014)
Controls	YES	YES	YES
FEs	YES	YES	YES
Adj. R^2	0.102	0.118	0.082
Observations	11,762	11,762	11,762
Kleibergen-Paap rk LM statistica	305.502***	305.502***	305.502***
F statistic	412.814	412.814	412.814
Panel B: Lagged Internet users multiplied by the number of fixed telephone lines per 10,000 people in each prefecture-level city in 1984			
FinTech	0.123***	0.090***	0.146***
	(0.023)	(0.019)	(0.019)
Controls	YES	YES	YES
FEs	YES	YES	YES
Adj. R^2	0.108	0.123	0.079
Observations	8,988	8,988	8,988
Kleibergen-Paap rk LM statistic	176.560***	176.560***	176.560***
F statistic	219.146	219.146	219.146

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

Table 4. Robust checks: quantile regression

Variable	(1)	(2)	(3)
	25^{th}	50^{th}	75^{th}
Panel A: The dependent variable is $Patent_{t+1}$			
FinTech	0.081***	0.075***	0.070***
	(0.028)	(0.020)	(0.025)
Controls	YES	YES	YES
FEs	YES	YES	YES
Observations	12,169	12,169	12,169
Panel B: The dependent variable is $Invention_{t+1}$			
FinTech	0.087***	0.078**	0.068**
	(0.028)	(0.030)	(0.035)
Controls	YES	YES	YES
FEs	YES	YES	YES
Observations	12,169	12,169	12,169

End of Table 4

Variable	(1)	(2)	(3)
	25th	50th	75th
Panel B: *The dependent variable is* $Utility_{t+1}$			
FinTech	0.044*	0.042*	0.040
	(0.025)	(0.025)	(0.043)
Controls	YES	YES	YES
FEs	YES	YES	YES
Observations	12,169	12,169	12,169

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.3. Mechanism analysis

5.3.1. Financing constraints

The first view that we consider regarding how FinTech development affects corporate innovation mainly focuses on the incremental supplementation of financial supply. Financing constraints are largely considered as an important factor that hinders firms' innovation capabilities (Hopenhayn, 2014). Insufficient financial supply from the traditional financial system makes it more difficult for enterprises to obtain financing. When companies struggle to secure the necessary funds, they often limit or terminate R&D projects (Broome et al., 2018; Wang et al., 2022). This is especially harmful to businesses that require continuous R&D investment to maintain their technological edge. It not only leads to technological stagnation but can also inhibit their expansion into new markets or sectors. Financial constraints might also drive firms toward short-term, low-risk projects and deter them from embarking on innovative initiatives that could yield long-term rewards but require substantial initial investment. In this regard, solving the financial problems of enterprises from the supply side of finance is crucial for promoting enterprise innovation. To explore the specific mechanism of FinTech-driven enterprise innovation, we apply the mediation-effect model to analyze the transmission path between FinTech and innovation from the perspective of financial constraints. Following Hadlock and Pierce (2010), we construct the financial constraints index (FC) to proxy for the degree of financing constraints a firm face. FC is measured as the natural logarithm of the absolute value of SA, where $SA = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age$. The higher the value of the index, the greater the financial difficulties.

Panel A of Table 5 presents the results for the mediating effects of financing constraints. The results in Column (2) illustrate that FinTech significantly reduces firms' financing constraints. In Columns (3), (5), and (7), the regression coefficients of *FinTech* and *FC* are both significant and positive and negative, respectively, implying that financing constraints are the mediating transmission mechanism between FinTech and corporate innovation. Therefore, FinTech can enhance the supply of finance to enterprises and stimulate innovation by alleviating financing constraints. Meanwhile, FinTech employs big data, AI, and the Internet of Things, thus deepening financial institutions' insights into business operations, expenditures,

and growth prospects while aiding in crafting a more accurate model to gauge a business's credit standing, providing targeted financing for businesses. Furthermore, AI technologies are adept at pinpointing high-potential innovative projects, thus steering funds toward deserving enterprises. Once credit is extended, FinTech platforms, bolstered by technologies such as blockchain, can monitor fund allocations in real time and ensure that these innovative initiatives progress effectively (Abbasi et al., 2021; Bollaert et al., 2021).

Table 5. Transmission channels: Financing constraints and information asymmetry

Panel A: *Financing constraints*							
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$Patent_{t+1}$	FC	$Patent_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$
FinTech	0.097***	–0.001***	0.096***	0.088***	0.087***	0.074***	0.072***
	(0.022)	(0.000)	(0.023)	(0.019)	(0.020)	(0.019)	(0.020)
FC			–3.638***		–3.506***		–4.048***
			(0.959)		(0.867)		(0.730)
Controls	YES	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES	YES
Adj. R^2	0.245	0.818	0.248	0.242	0.247	0.184	0.191
Observations	12,169	12,168	12,169	12,169	12,169	12,169	12,169
Panel B: *Information asymmetry*							
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$Patent_{t+1}$	ASY	$Patent_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$
FinTech	0.097***	–0.003***	0.065**	0.088***	0.061***	0.074***	0.051**
	(0.022)	(0.001)	(0.026)	(0.019)	(0.022)	(0.019)	(0.024)
ASY			–1.564***		–1.339***		–1.071***
			(0.410)		(0.328)		(0.333)
Controls	YES	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES	YES
Adj. R^2	0.245	0.0984	0.274	0.242	0.271	0.184	0.215
Observations	12,169	6,596	6,596	12,169	6,596	12,169	6,596

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.3.2. Information asymmetry

The second aspect is related to the friction of financial supply. Severe information asymmetry is among the main reasons for the difference in innovation output between firms (Shen et al., 2020; Wu et al., 2022, 2023), and it contributes to the reluctance of financial institutions to extend financial resources to these firms. Due to financial institutions' difficulties in accurately assessing the true risks and potential value of a company's innovative projects, companies might face challenges in obtaining funding as well as higher financing costs for innovation (Healy & Palepu, 2001; Hoffmann & Kleimeier, 2021a). Asymmetric information might lead

financial institutions to favor "safe" projects that promise short-term returns while adopting a more cautious stance toward long-term, potentially disruptive innovation projects that entail higher risks. This phenomenon drives companies to opt for short-term, low-risk innovation paths, sacrificing R&D that holds potential for long-term, high returns. Therefore, mitigating information asymmetry stands as a vital approach for financial institutions to enhance financial provisioning and drive corporate innovation. Following Shen et al. (2020), we use a manipulable, three-year average financial index as the information asymmetry index (*ASY*), where a larger index indicates more severe information asymmetry.

The results of the mediating-effect model are presented in Panel B of Table 5, where Column (2) shows that FinTech significantly reduces the level of information asymmetry, and Columns (3), (5), and (7) indicate that information asymmetry significantly lowers firm innovation, which confirms Shen's et al. (2020) findings. Furthermore, the significant signs of the coefficients of *FinTech* and *ASY* in Columns (3), (5), and (7) suggest that channels exist for FinTech to provide financial supply to firms and incentivize them to innovate by alleviating information asymmetry. Relying on information technology, FinTech enhances traditional financial-default prediction models by further utilizing multi-dimensional data, including corporate-transaction information, payment behavior, and third-party platforms, thereby improving the accuracy of default predictions (Bollaert et al., 2021). AI, through deep learning, can train on multiple dimensions of corporate information. This helps to better match capital demands according to a company's specifics, enhancing financial provision, thus promoting corporate innovation (Demertzis et al., 2018). Concurrently, FinTech can utilize digital technologies to connect its platform to corporate financial information and project-management systems, thus providing real-time insights and supervision of financial operations and bridging the information gap.

5.3.3. Financing costs

The third perspective primarily reflects the cost of financial supply. The high cost of financing is among the major obstacles to firms' obtaining financing (Frank & Shen, 2016). Corporate innovation has a long duration and high uncertainty risk and requires large amounts of financial support. In the traditional financing model, banks invest significant human and material resources in auditing the financial status of enterprises. This undoubtedly heightens the complexity of the bank's auditing process, consequently escalating the cost of enterprise financing. Additionally, it dissuades banks from extending funds to financially unsound enterprises. When companies must pay higher interest rates or fees to access external funding, the amount of money available for R&D and innovation tends to decrease (De Blick et al., 2024; Hoffmann & Kleimeier, 2021a). This may cause businesses to invest in short-term projects instead of long-term, potentially disruptive initiatives. Elevated financing costs might push companies toward projects that seem to offer quick returns with lower risks, sacrificing truly groundbreaking innovation (He et al., 2020). Confronted with steep financing costs, companies might shy away from high-risk innovative endeavors as the stakes of failure become higher. They might lean more toward minor improvements in their existing products or services rather than seek brand-new, breakthrough innovations.

We utilize *Financial_rate* as a proxy variable for *Financing costs* to examine whether FinTech can reduce financing costs to promote firm innovation. We use the ratio of financial expenses to operating income to measure the intensity of financial expenses (*Financial_rate*),

which can reflect the cost of obtaining funds. The results from Panel A, Column (2) of Table 6 indicate that FinTech effectively reduces firms' financing costs. Columns (3), (5), and (7) highlight that an increase in financing costs significantly diminishes a firm's level of innovation, which is consistent with Ding's et al. (2022) results. Furthermore, the significant signs of the coefficients of *FinTech* and *Financial_rate* in Columns (3), (5), and (7) suggest lowering financing costs is a crucial mechanism through which FinTech enhances a firm's innovative capabilities. With the broad application of automation and digitization, many FinTech platforms now provide online approvals, electronic contracts, and automated payment functions, significantly simplifying the financing process and reducing the complexity and time required. This not only accelerates the flow of capital but also minimizes the errors and costs related to manual processing (Abbasi et al., 2021). This model allows FinTech firms to offer more competitive interest rates and lower service fees, which reduces businesses' financing costs.

Table 6. Transmission channels: Financing cost and financing channels

Panel A: *Financing cost*							
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$Patent_{t+1}$	Financial_rate	$Patent_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$
FinTech	0.097***	–0.002***	0.091***	0.088***	0.083***	0.074***	0.068***
	(0.022)	(0.000)	(0.022)	(0.019)	(0.018)	(0.019)	(0.019)
Financial_rate			–3.813***		–2.761***		–3.233***
			(0.658)		(0.534)		(0.574)
Controls	YES	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES	YES
Adj. R^2	0.245	0.360	0.249	0.242	0.246	0.184	0.189
Observations	12,169	12,168	12,169	12,169	12,169	12,169	12,169
Panel B: *Financing channels*							
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$Patent_{t+1}$	Loan	$Patent_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$
FinTech	0.097***	–0.004***	0.088***	0.073***	0.074***	0.058***	0.057***
	(0.022)	(0.001)	(0.019)	(0.020)	(0.019)	(0.021)	(0.017)
Loan			–1.568***		–1.082***		–1.627***
			(0.326)		(0.267)		(0.285)
Controls	YES	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES	YES
Adj. R^2	0.245	0.543	0.256	0.242	0.253	0.184	0.204
Observations	12,169	9,751	9,752	12,169	9,752	12,169	9,752

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.3.4. Financing channels

The fourth viewpoint pertains to the expansion of financial inclusion. Limited access to finance constrains firms' financing of innovation and hinders their innovation capabilities (Girma et al., 2008). A lack of adequate financing channels can lead to financial interruptions during pivotal R&D phases, causing delays in promising projects or even terminations (De Blick et al., 2024). Such scarcities not only disrupt project continuity but may also cause businesses to prioritize short-term returns over long-term investments, leading to selection biases. Limited financing options are often accompanied by elevated financing costs (Mbanyele & Wang, 2024). Companies might be compelled to pay exorbitant interest rates for funds, further squeezing their profit margins and subsequently reducing investments in other core operations and innovations (Xiang et al., 2022). Overall, limitations in financing channels impact not only a company's daily operations but also pose severe threats to its long-term innovative capabilities and competitive market position. To drive sustained innovation, businesses urgently need to expand their financing avenues and seek more cost-effective financing solutions. Considering the importance of financing channels, we explore whether FinTech can enhance firms' innovation capabilities by expanding financing channels. We use the ratio of bank borrowing to total assets as a proxy variable (*Loan*) for firms' credit allocation and as a mediating variable for FinTech-driven firm innovation. The higher this ratio, the greater the amount of funds a firm obtains from banks, the greater the repayment pressure, and the more firms will turn to short-term investments for returns, thus negatively affecting firm innovation (Xin et al., 2017).

The results in Panel B of Table 6 support the proposition that FinTech contributes to firms' innovation through expanding financing channels. In Column (2), the coefficient of *FinTech* is significant and negative, suggesting that FinTech assists businesses in reducing loans from commercial banks. Conversely, in Columns (3), (5), and (7), the coefficient of *FinTech* is significant and positive, while that of *Loan* is markedly negative. This implies that expanding financing channels acts as a mediating factor in how FinTech enhances a company's innovative capabilities. On the one hand, FinTech has introduced innovative financing models such as P2P lending, crowdfunding, token issuance, and supply-chain financing, offering enterprises sources of capital beyond those available from the traditional banking system (Abbasi et al., 2021). On the other hand, digital and automated processes have significantly streamlined the financing workflow, reducing the time and costs associated with manual processing and conventional transactions (Gabor & Brooks, 2017). In particular, the use of technologies such as blockchain has made cross-border transactions more efficient and transparent, facilitating cross-regional financing for businesses and further broadening financing channels (Bollaert et al., 2021). Overall, FinTech has effectively incentivized business innovation by expanding financing channels and proactively providing funds from the supply side.

5.4. Heterogeneity analysis

5.4.1. Differences in FinTech development structure

Lee et al. (2021) suggest that different categories of FinTech companies differentially impact bank efficiency, which in turn may affect firms' innovation activities through credit conditions. Therefore, based on Lee et al. (2021), this study categorizes FinTech companies into

five categories to explore the impact on firms' innovation activities: (1) credit, deposit, and capital-raising (Credit); (2) payment, clearing, and settlement (Payment); (3) investment management (Investment); (4) market support (Market); and (5) other services (Others). Panels A, B, and C of Table 7 summarize the corresponding results for total-, invention-, and utility-patent applications, respectively. The results still support a beneficial effect of FinTech on corporate innovation, which suggests that our previous findings are robust to categories of FinTech applications. Among these applications, we find that the influence of FinTech credit on innovation activities is more prominent. This finding further confirms that FinTech incentivizes firms to innovate by funding them primarily through the supply side. Previous studies have shown that SMEs and private enterprises have difficulties in obtaining bank loans due to their poor creditworthiness; however, FinTech-lending companies have advantages in reducing the cost of borrower screening and monitoring the operations of innovative projects by using the technology of the Internet and big data to provide financing for such projects (Acs & Audretsch, 1987).

We also utilized the Bank for International Settlements (2018) classification of FinTech, categorizing FinTech companies into four groups: payments and settlements (Settlements); deposits, loans, and capital mobilization (Deposits); investment management; and market infrastructure (Infrastructure). For the sake of brevity, these estimates are not shown but the results show that the regression coefficients of *Deposits* are the highest, demonstrating that FinTech primarily enhances corporate-innovation capability by providing financing for companies.

Table 7. Heterogeneity analysis: FinTech company types

Panel A: *FinTech company types and total patent*					
Variable	(1)	(2)	(3)	(4)	(5)
	$Patent_{t+1}$	$Patent_{t+1}$	$Patent_{t+1}$	$Patent_{t+1}$	$Patent_{t+1}$
Credit	0.105***				
	(0.025)				
Payment		0.096***			
		(0.035)			
Investment			0.087***		
			(0.027)		
Market				0.089***	
				(0.025)	
Others					0.081***
					(0.027)
Controls	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES
Adj. R^2	0.244	0.241	0.242	0.243	0.242
Observations	12,169	12,169	12,169	12,169	12,169

End of Table 7

Panel B: *FinTech company types and invention patent*					
Variable	(1)	(2)	(3)	(4)	(5)
	$Invention_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$	$Invention_{t+1}$
Credit	0.097***				
	(0.021)				
Payment		0.087***			
		(0.029)			
Investment			0.079***		
			(0.023)		
Market				0.080***	
				(0.021)	
Others					0.075***
					(0.023)
Controls	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES
Adj. R^2	0.242	0.238	0.239	0.240	0.239
Observations	12,169	12,169	12,169	12,169	12,169
Panel C: *FinTech company types and utility patent*					
Variable	(1)	(2)	(3)	(4)	(5)
	$Utility_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$	$Utility_{t+1}$
Credit	0.080***				
	(0.021)				
Payment		0.068**			
		(0.031)			
Investment			0.062**		
			(0.024)		
Market				0.068***	
				(0.021)	
Others					0.061***
					(0.023)
Controls	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES
Adj. R^2	0.183	0.180	0.181	0.182	0.181
Observations	12,169	12,169	12,169	12,169	12,169

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.4.2. Differences in enterprise property rights

Chinese SOEs enjoy a unique advantage in the credit market, while private firms tend to encounter problems of inadequate financial supply (Lin & Tan, 1999). This also results in differences in the innovation capabilities of firms with different property rights attributes, and thus the impact of FinTech on the innovation of the two types of firms may be different. In this paper we divide the sample into SOEs and private enterprises according to the property rights attributes and assess the impact of FinTech on the innovation ability of different enterprises.

The estimation results for different property rights attributes are given in Panel A of Table 8. Although FinTech has a facilitating effect on firms' innovation capability, the intensity is different. The coefficient of *FinTech* in the private enterprise group is higher than that for SOEs, indicating that FinTech has a stronger role in promoting innovation in private enterprises. SOEs commonly achieve adequate, or even excessive, financing levels in traditional financial markets due to the clout of their national prominence. In contrast, private firms often experience financial exclusion in the financing market (Zhang et al., 2019). Functioning as an essential complement to conventional financial avenues, FinTech optimizes funding scenarios, leading to a pronounced surge in the marginal output of innovation (Ding et al., 2022). Consequently, FinTech's efficacy in propelling innovation among private entities becomes distinctly pronounced.

Table 8. Heterogeneity analysis: property rights and different business sizes

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
Panel A: *Property rights*						
	Private enterprises			State-owned enterprises		
FinTech	0.133***	0.118***	0.104***	0.055*	0.056**	0.032
	(0.022)	(0.018)	(0.016)	(0.030)	(0.026)	(0.028)
Controls	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES
Adj. R^2	0.215	0.217	0.161	0.290	0.289	0.230
Observations	6,743	6,743	6,743	5,426	5,426	5,426
Panel B: *Enterprise size*						
	Small-scale enterprises			Large-scale enterprises		
FinTech	0.101***	0.094***	0.084***	0.089***	0.075***	0.068***
	(0.028)	(0.024)	(0.026)	(0.020)	(0.016)	(0.019)
Controls	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES
Adj. R^2	0.273	0.262	0.196	0.229	0.210	0.151
Observations	4,434	4,434	4,434	7,735	7,735	7,735

End of Table 8

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
Panel C: *Company's age*						
	Young enterprise			Mature companies		
FinTech	0.104***	0.090***	0.084***	0.091***	0.084***	0.073***
	(0.027)	(0.022)	(0.023)	(0.025)	(0.022)	(0.025)
Controls	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES
Adj. R^2	0.209	0.214	0.147	0.270	0.264	0.202
Observations	4,810	4,810	4,810	7,359	7,359	7,359

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.4.3. Size differences

Differences in market power, degree of entry barriers, and industry size variability among firms of different sizes lead to differences in innovation advantages (Acs & Audretsch, 1987). At the same time, SMEs are prone to information asymmetry under the traditional financial system due to unsound financial information and weak collateral capacity; thus, financial institutions are not inclined to provide funds to them. Conversely, large-scale enterprises are financially sound themselves and have lower constraints on their own financing. Therefore, FinTech may have different impacts on the innovation ability of different size enterprises. To examine such differences, we divide the sample into large-scale enterprises and small-scale enterprises based on their median size.

Panel B of Table 8 estimates the impact of FinTech on the innovation of firms of different sizes. We find that while *FinTech* has a significant contribution to innovation for all firms, it has a stronger contribution to innovation for small-scale firms. FinTech can transform raw data into useful information, directly shaping decision-making through technological mechanisms. This capacity is particularly effective in the sophisticated analysis of financial data and the accurate risk assessment of private SMEs. By reducing the information asymmetry between banks and these businesses, FinTech helps facilitate increased credit support for them (Yadi et al., 2019).

5.4.4. Firm age

In today's business environment, a company's creditworthiness plays a critical role (Chang et al., 2019). A robust credit record indicates consistent operational performance, trustworthiness, and the ability to repay debts. Conventional financial institutions tend to cater to the requirements of these enterprises, providing them with increased flexibility and greater prospects for research and innovation. Conversely, startups or entities lacking a sound credit history or substantial fixed assets often encounter challenges when seeking external financing (Ryan et al., 2014; Wang et al., 2022). Consequently, firms with different credit histories may be differentially affected by FinTech in their ability to innovate. To examine this effect, we used

the median duration of company establishment to divide the sample into two sub-samples: young and mature companies. Generally, younger firms have poorer credit histories than established ones.

The results in Table 8, Panel C demonstrate the impact of FinTech on companies' innovation capabilities across different durations of their existence. While FinTech appears to bolster innovation across all company-age brackets, its impact is notably more profound for younger companies. This can be attributed to the departure of FinTech from age-old financing paradigms. Financial entities, leveraging cutting-edge digital technologies, can seamlessly interface with a company's financial systems and management platforms. By juxtaposing real-time transactional data with industry-growth projections, they can offer a more nuanced assessment of a company's credit profile. Moreover, given their innate drive for profitability and market dominance, startups exhibit an amplified zest for innovation (Abbasi et al., 2021; Bollaert et al., 2021). As a result, FinTech offers an advantage when targeting the financial supply of young firms to be better able to support their innovative capacity.

5.4.5. Differences in collateral capacity

Firms often need to provide sufficient assets as collateral for bank credit financing, and most financial institutions such as banks usually prefer to accept fixed assets such as houses or land as collateral (Chen et al., 2015). On the one hand, collateral is seen by banks as a tool to ensure good behavior of borrowers and can be used to mitigate adverse selection problems. On the other hand, the size of collateral also serves as a signaling function; i.e., high-quality lenders tend to provide sufficiently good collateral to secure lending financing transactions. However, FinTech's integration and processing of data, such as corporate profitability and financial information through big data and AI technologies, help to obtain detailed information that cannot be described by traditional finance, making it easier to screen a firm's credit quality (Bollaert et al., 2021), rather than having to measure its credit quality using collateral values such as fixed assets. Under the above logic FinTech may have different impacts on firm innovation with different collateral quality. Therefore, this paper uses the median fixed asset ratio to divide the sample into high and low fixed asset ratio firms to assess the influence of FinTech on innovation across firms.

Panel A of Table 9 illustrates the effect of FinTech development on the innovative abilities of companies with varying fixed asset ratios. A comparative analysis reveals that FinTech profoundly enhances the innovation output of companies with lower fixed asset ratios, with a markedly positive impact on their innovation capabilities. Amid the rapid advancement of financial technology, FinTech lending entities and commercial intermediaries effectively utilize advanced technologies. This strategy allows for comprehensive collection of enterprise information, leading to accurately targeted financing for innovation (Norden et al., 2014). In contrast, companies with substantial fixed assets typically possess strong credit standings in traditional financing markets, resulting in sufficient financing capabilities (Voulgaris et al., 2004; Yu et al., 2022). However, companies with fewer fixed assets are often sidelined in traditional financing channels due to their limited collateral financing abilities and less stable financial positions. Should their financing situations improve, a significant rise in marginal innovation output is expected (Ding et al., 2022). Therefore, FinTech's role in driving innovation is particularly prominent among companies with lower concentrations of fixed assets.

Table 9. Heterogeneity analysis: collateral capacity and financial regulation

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
Panel A: *Collateral capacity*						
	Low fixed assets enterprises			High fixed assets enterprises		
FinTech	0.099***	0.089***	0.073***	0.080***	0.075***	0.069**
	(0.024)	(0.020)	(0.019)	(0.029)	(0.026)	(0.030)
Controls	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES
Adj. R^2	0.281	0.282	0.207	0.225	0.219	0.175
Observations	6,352	6,352	6,352	5,816	5,816	5,816
Panel B: *Regions with strict financial regulation vs. Regions with relaxed financial regulation*						
	Strict financial regulation			Relaxed financial regulation		
FinTech	0.085***	0.087***	0.073***	0.102***	0.087***	0.076***
	(0.026)	(0.020)	(0.023)	(0.023)	(0.021)	(0.023)
Controls	YES	YES	YES	YES	YES	YES
FEs	YES	YES	YES	YES	YES	YES
Adj. R^2	0.250	0.244	0.188	0.235	0.236	0.176
Observations	5,007	5,007	5,007	7,162	7,162	7,162
Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.						

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

5.4.6. Differences in financial regulation intensity

Effective financial regulation can rationally regulate the behavior of the financial sector in the economic system and direct financial resources to those micro-productive behaviors that are conducive to quality economic development. By nature, finance is a public good that aims to maintain financial stability and prevent economic shocks caused by the dysfunction of the financial system through the regulation of investment and financing activities. Hua and Huang (2021) point out that one of the reasons for the breakthrough development of FinTech is the relaxed attitude of financial regulators towards its development. The relaxed financial regulatory environment fosters the growth of FinTech, thereby bolstering regions' financial supply capacity. However, FinTech also entails risks such as data breaches, financial fraud, and targeted cyberattacks, each of which significantly impacts regulatory frameworks and can extend to the broader financial system (Chen et al., 2022; Li et al., 2020; Yao et al., 2021). Thus, firms may make different financing choices under varying regulatory environments, which in turn may have separate impacts on firm innovation. In this paper we use provincial financial regulatory expenditures as a proxy variable for financial regulation (financial regulatory intensity). We use the median of financial regulatory intensity as the dividing line to analyze the driving effect of FinTech on corporate innovation under different financial regulatory intensity.

In Panel B of Table 9, it is evident that FinTech significantly propels corporate innovation, with its role becoming particularly pronounced in areas characterized by less stringent financial regulation. It is possible that this phenomenon is precisely due to the lax attitude of the financial sector towards FinTech development (Hua & Huang, 2021). By comparing the FinTech development index with strict financial supervision area and tolerant financial supervision area, we find that the average values of the FinTech development index of the former and of the latter are 2.570 and 4.295, respectively that is, the stronger the financial regulation is, the lower is the number of FinTech companies registered in the region, and the lower is the likelihood that companies will receive innovation funding from FinTech companies. In contrast, in regions with weaker financial regulation intensity, the number of registered FinTech firms is higher, and the likelihood that firms will obtain innovation funding from FinTech firms is substantially greater, significantly boosting innovation output.

6. Further analysis

As shown in Section 2.2, the impact of the interaction between banking deregulation and FinTech on firm innovation remains unclear. We refer to Chen's et al. (2023) study to examine this role using Opinions on Market Access and Model (2). Table 10 illustrates how increased competition among urban banks, following policy shifts, impacts FinTech innovation. The positive coefficient of FinTech further indicates that the results of the benchmark regression in this paper are robust. Conversely, the *Exposure* variable demonstrates a negative coefficient, although it lacks statistical significance. This observation suggests that a heightened market concentration among the top five major SOCBs may potentially pose a hindrance to firm-level innovation.

The coefficient of *Exposure* × *Post* × *FinTech* is significantly negative, supporting **H2b**, that bank deregulation crowds out the positive effect of FinTech on firm innovation. Increased bank competition drives firm innovation through better regulation of loan programs and a deeper understanding of firms' financial and operational information. FinTech still faces risks such as data leakage and financial fraud due to the lax attitude of the government and financial regulators towards FinTech development, while banks have regulatory soundness and complete industry guidelines to effectively protect corporate information and interests. Therefore, when banks improve financial supply, they will squeeze out FinTech financial supply.

Finally, we conducted parallel trend test and placebo test on the policy of relaxing bank supervision. For the sake of brevity, these tests are not shown, but are available from the authors upon request. The unreported results of parallel trend test confirm that the parallel trend assumption is satisfied. The results of placebo test also indicate the positive effect of FinTech was not due to random chance, but the real effect caused by policy implementation.

Table 10. Bank competition, FinTech development, and corporate innovation

Variable	(1)	(2)	(3)
	$Patent_{t+1}$	$Invention_{t+1}$	$Utility_{t+1}$
FinTech	0.134***	0.119***	0.110***
	(0.023)	(0.018)	(0.022)
Exposure	–0.299	–0.397	–0.207
	(0.385)	(0.323)	(0.311)
Exposure × Post	0.320	0.285	0.466
	(0.345)	(0.321)	(0.304)
Exposure × Post × FinTech	–0.082***	–0.064**	–0.092***
	(0.033)	(0.030)	(0.024)
Controls	YES	YES	YES
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Adj. R^2	0.242	0.237	0.183
Observations	12,169	12,169	12,169

Notes: The robust standard errors clustered by city are shown in parentheses. *p < 0.1, **p < 0.05, and ***p < 0.01.

7. Conclusions

In developing countries, imbalances in the traditional financial sector, along with strict government controls on financial risk, have severely reduced the supply of finance from banks and other financial institutions. This reduction is further exacerbated by prudent risk assessment frameworks and differences in the credit and collateralization capacities of firms, which hinder the development of business innovation. However, the rise of digital technologies offers tangible solutions that enhance the financial sector's supply of finance and spark business innovation. When financial institutions utilize digital technology to gather company information and leverage these data for modeling and assessing a company's creditworthiness and predicting its future development prospects, they address the limitations of traditional financial institutions in evaluating credit based on non-financial information and fixed assets. Online platforms such as P2P not only streamline the company-information verification process but also offer tailored financial products to companies, providing financing options for innovative projects.

By constructing city-level FinTech indicators in China from 2003 to 2017 and utilizing innovation data from listed companies, we have found that FinTech is able to improve financial supply and incentivize firms to innovate. Such enhancements are particularly notable among private firms, small firms, emerging firms, firms with limited fixed assets, and firms operating in regions with lax financial regulations. Interestingly, we use Opinions on Market Access to find that government easing of banking regulations tends to dampen the positive impact of the new regulations. However, due to the absence of detailed company-loan data, we could not assess how FinTech assisted financial institutions in overcoming geographical limitations

and offering cross-regional financing for companies. lead to an underestimation of the impact of FinTech on corporate innovation. We look forward to future research addressing this constraint.

Our findings bear significant policy implications. First, FinTech has the potential to mitigate financing constraints, lower borrowing costs, and diversify funding sources, thereby fueling corporate innovation. Governments should advocate for the extensive integration of digital technology within banking operations to broaden financial accessibility and stimulate innovative endeavors. Second, the lending sector within FinTech plays a pivotal role in driving business innovation, underscoring the importance of FinTech in boosting financial provisions. This encourages enterprises to pursue diverse, multifaceted, fundraising strategies. Third, while loosening bank regulations appears to undermine FinTech's contributions to business innovation, a moderated easing of financial oversight can indeed stimulate competitive prowess among financial entities and foster adeptness in digital-technology adoption. Moving forward, striking a balance between these aspects and enhancing financial supply remains a critical topic for both scholars and policymakers.

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APPENDIX

Table A1. Variable definitions

Variable	Name	Definition
Innovation variables		
Patent	Total innovation output	Ln(1 + aggregate applications of three types of patents)
Invention	Invention innovation output	Ln(1 + invention patents)
Utility	Utility model innovation output	Ln(1 + utility model patents)
FinTech		
FinTech	FinTech development indicators	Ln(1 + number of FinTech companies)
Enterprise-level control variables		
Age	Firm age	Ln (firm age)
Size	Total assets	Ln (total assets)
Debt	Debt ratio	Total debt/Total assets
Roa	Return on assets	Ratio of net profits relative to assets
TQ	Tobin's Q	Tobin's Q
Dual	Dual positions in one	One person holds the two positions of chairman and general manager
Top1	Ownership concentration	The largest shareholder's shareholding ratio
Gs	Government subsidy	Total government subsidies/Total assets
HHI	Herfindahl-Hirschman index	Calculated based on operating income (the first three digits in the industry code)
Area-level control variables		
GDP	GDP growth rate	Gross regional product growth
IS	Industry structure	Value added of secondary industry/regional GDP
EI	Scientific research and education investment	(Science and technology expenditure + education expenditure)/public finance expenditure

End of Table A1

Variable	Name	Definition
Intermediate variables		
FC	Financing constraints	Natural logarithm of the absolute value of the financing constraint SA
ASY	Information asymmetry	Average of the sum of the absolute values of manipulability accruals over the past three years
Financial_rate	Financial expense ratio	Ratio of finance costs to operating income
Loan	Bank loan	(Short-term borrowings + long-term borrowings + non-current liabilities due within one year)/total assets
Other variables		
FinTech_capital	FinTech development indicators	Ln(1 + FinTech company registered capital)
FinTech_index	FinTech development indicators	Peking University Digital Inclusive Finance Index
R&D	R&D expense	R&D expense/Total assets
IE	Innovation efficiency	Follows Hirshleifer et al. (2012)

Table A2. Descriptive statistics for variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Patent	21,926	1.193	1.645	0.000	6.227
Invention	21,926	0.928	1.378	0.000	5.521
Utility	21,926	0.754	1.271	0.000	5.226
FinTech	21,926	3.013	2.399	0.000	7.963
Age	21,837	2.547	0.468	1.099	3.332
Debt	21,841	0.472	0.219	0.053	1.099
Roa	21,575	0.061	0.133	–0.731	0.355
Size	21,878	21.897	1.288	19.237	25.823
Dual	18,785	0.219	0.414	0.000	1.000
Top1	21,845	36.743	15.568	8.940	76.440
TQ	21,056	1.922	1.197	0.934	7.835
Gs	16,726	0.011	0.015	0.000	0.095
HHI	21,047	0.102	0.087	0.017	0.505
GDP	19,711	11.292	3.196	4.300	19.200
IS	19,721	0.465	0.103	0.197	0.675
EI	21,543	0.194	0.042	0.101	0.290