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# The Impact of Climate Transition Pressure on Innovation Participation of Small Enterprises in China: The Moderating Role of Digital Finance

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**Abstract:** This paper examines the impact of climate transition risks on innovation participation of micro and small enterprises (SMEs) in China and explores whether digital finance can mitigate these impacts. Using firm-level data from the 2014 China SME Survey, combined with provincial digital finance inclusion index data, the study employs a Probit model to analyze firm innovation participation and uses an OLS framework to examine the impact of financing constraints. To capture the heterogeneity of transition pressures, the study categorizes firms based on the transition pressures of their respective industries. The results show that digital finance significantly increases the likelihood of SMEs participating in innovation and alleviates their financing constraints. While climate transition risks themselves do not have a significant direct impact on innovation participation, the interaction between digital finance and high transition risk is positive and statistically significant, indicating that digital finance has a stronger innovation-promoting effect on firms in high-risk industries. Mechanism analysis shows that digital finance primarily supports innovation by alleviating overall financing frictions faced by SMEs. These findings highlight the complementary role of digital finance in supporting firms' innovation in response to climate transition pressures and provide policy implications for promoting financial inclusion and facilitating a smooth low-carbon transition in emerging economies.

**Keywords:** Climate transition risk; Digital finance; Innovation participation; Small and micro enterprises; Financing constraints

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## 1. Introduction

Climate change is no longer just regarded as an environmental issue, but has become an urgent financial issue. The potential impact of climate change on the financial system is mainly reflected in two aspects: physical risk and transition risk. This paper focuses on the climate transition risk related to regulatory, legal and market changes associated with the global transition to low carbon emissions. As the world's largest developing economy and

a major carbon emitter, China set an ambitious "dual carbon" target in 2010, which significantly accelerated industrial transformation. According to the latest evidence from the International Monetary Fund (IMF) Financial Sector Assessment Project, China's transition risk has a significant and uneven impact on different industries and regions, with high-emission industries facing greater threats and vulnerabilities in the process of low-carbon transition [1].

Existing research indicates that environmental pressures and carbon risks can influence corporate innovation behavior to some extent. Aghion *et al.* based on Porter's hypothesis, pointed out that climate-related policies, such as rising fuel prices including taxes, can guide companies to innovate towards cleaner technologies [2]. Another article found similar findings, which indicates that there is a significant positive correlation between carbon risk and corporate green transition. Companies can optimize their internal production structure by increasing investment in environmental innovation [3]. However, their research also revealed significant heterogeneity: this positive innovation response is concentrated in large companies with relatively low financial constraints, less financing pressure, and more resources.

Therefore, it is unclear whether this mechanism applies to small companies. SMEs play a crucial role in employment and innovation diffusion in China, but they often face severe financing constraints and low risk tolerance. For these companies, climate transition pressures may increase compliance costs and uncertainty, thereby inhibiting rather than promoting their participation in innovation. This paradox suggests that financial conditions may have a key impact on how companies cope with transition risks.

Whether such mechanisms apply to small firms remains unclear. SMEs play a vital role in employment and innovation diffusion in China, but they often face severe financing constraints and limited risk tolerance. For these businesses, climate transition pressures may increase compliance costs and uncertainty, thereby inhibiting rather than promoting innovation participation. This paradox suggests that financial conditions can have a key impact on how businesses cope with transition risks.

The rapid development of digital finance may provide an important channel for the innovation of SMEs. Existing research shows that fintech can reduce information asymmetry and provide funding for the development of high-quality SMEs by expanding the credit coverage of borrowers with low credit scores, thereby supporting enterprise innovation [4]. Meanwhile, under the limited credit function of traditional banks, fintech can help improve the risk resistance of SMEs [5]. Hence, the core question of this paper is as follows: In the face of climate transition risks, can digital finance help SMEs maintain their innovative participation?

This paper utilizes matched enterprise-level data from the China Micro and Small Enterprise Survey (CMES) and the Peking University Digital Finance Inclusion Index (PKU-DFIIC) to study the impact of climate transition risks on the development and innovation of Chinese SMEs, and explores whether fintech plays a moderating role in this relationship. This paper enriches the literature on climate transition risks, SME innovation and R&D, and digital finance from a micro perspective.

## 2. Theoretical framework and hypotheses

With the advancement of low-carbon transformation, increasingly stringent environmental regulations and constantly changing external market demands, many studies have shown that climate transition risk is gradually becoming an important factor affecting corporate decision-making [2,3,6]. Compared with traditional large enterprises or listed companies, SMEs have limited risk tolerance and financial flexibility. Meanwhile, innovation activities

usually require long-term investment and have uncertain returns, making them particularly sensitive to the impact of transformation [1]. For SMEs, when financing constraints intensify and future earnings expectations become more uncertain, the increased risk of transformation may inhibit their participation in innovation. However, innovation itself is also an important way for enterprises to cope with structural transformation, which helps to improve efficiency and maintain competitive advantage [7]. Therefore, whether enterprises can continue to innovate under the pressure of transformation largely depends on their ability to obtain external financing.

Existing evidence suggests that digital finance can reduce information asymmetry, expand financial inclusion, alleviate financing constraints, and promote innovation, especially among small businesses and capital-constrained enterprises [4]. In the context of climate transition, traditional financial institutions tend to adopt more cautious credit strategies for transition-related industries due to concerns about regulatory uncertainty and potential risks, thereby exacerbating the financing pressure on enterprises [6]. Therefore, digital finance provides key support for small businesses to continue their innovative activities under the pressure of transition by providing diversified financing channels and improving the credit availability of enterprises.

The role of digital finance in promoting innovation is expected to vary depending on the level of transition risk faced by businesses. For industries with higher transition risk, uncertainty and cost pressures related to climate policies are more likely to exacerbate financing constraints, thereby increasing the marginal value of digital finance in supporting innovation activities. In contrast, industries with lower transition risk face fewer transition-related financing frictions, implying a smaller marginal impact of digital finance on innovation participation. Therefore, based on the above theoretical arguments, this study proposes the following testable hypotheses:

H1: Digital finance is positively correlated with the likelihood of small businesses participating in innovation;

H2: All other things being equal, companies in industries with higher transformation risk are less likely to participate in innovation;

H3: The positive impact of digital finance on innovation participation is more significant in companies in industries with higher transformation risk than in companies in industries with lower transformation risk.

## 3. Data, empirical strategy, and model specification

This study uses firm-level data from the 2014 wave of the China Micro and Small Enterprise Survey (CMES), a nationally representative survey conducted by the Chinese Academy of Social Sciences. The CMES provides detailed information on firms' innovation activities, financing conditions, owner characteristics, and operational features. After excluding observations with missing values for key variables, the final sample consists of 5,500 micro and small enterprises across 24 provinces. The geographic distribution of firms is broadly consistent with the regional concentration of small enterprises in China, supporting the representativeness of the sample.

To measure digital financial development, the analysis employs the provincial Digital Financial Inclusion Index compiled by Peking University (PKU-DFIIC). Constructed using transaction-level data from Ant Financial Services Group, the index captures cross-provincial variation in the breadth, depth, and digitalization of financial services. Provincial index values are matched to firms based on their registered location, providing an external measure of the local digital finance environment faced by each firm.

The dependent variable is a binary indicator of innovation participation, equal to one if the firm reports engaging in innovation activities and zero otherwise. The key explanatory variable is the aggregate digital finance index. To capture heterogeneity in climate transition pressure, firms are classified into high- and low-transition-

exposure groups according to their industry affiliation, with a binary indicator equal to one for firms operating in transition-exposed industries. The analysis controls for a standard set of firm characteristics, including assets, firm age, high-tech status, CEO age, education level, number of employees, and owner gender. Provincial GDP is included to control for regional economic development, while industry and region fixed effects account for unobserved heterogeneity across sectors and locations.

Given the binary nature of the innovation outcome, the empirical analysis employs a probit model to estimate the probability of innovation participation. To examine whether the effect of digital finance varies with transition exposure, an interaction term between the digital finance index and the transition exposure indicator is included. The baseline specification is given by:

$$\Pr(Y_{i,p} = 1) = \Phi(\beta_1 FinTech_p + \beta_2 TranExpo_i + \beta_3 (FinTech_p \times TranExpo_i) + \gamma X_{i,p} + \delta_i + \delta_p)$$

In this model, $Y_{i,p}$ denotes the innovation participation of firm $i$ in province $p$. $FinTech_p$ captures the level of digital financial development at the provincial level, while $TranExpo_i$ indicates whether the firm is exposed to high climate transition risk. The interaction term identifies the differential effect of digital finance on innovation for firms with high transition exposure. $X_{i,p}$ represents a set of firm-level control variables, including firm size, age, technological intensity, managerial characteristics, and local economic conditions, $\delta_i$ and $\delta_P$ denote unobserved firm- and province-specific factors. The coefficient on the interaction term is of primary interest, as it captures whether digital finance mitigates the adverse effects of transition exposure on firms' innovation participation.

# 4. Empirical results

## 4.1. Baseline results: Innovation participation

The baseline probit results reveal a clear and economically meaningful relationship between digital finance and firms' innovation participation (**Table 1**). Specifically, enterprises located in provinces with higher levels of digital finance development are significantly more likely to participate in innovation activities ($p < 0.05$). This result is consistent with the conclusions of existing studies, namely that financial technology provides strong support for enterprise innovation by expanding the channels for SMEs to obtain external financing and reducing transaction costs and information asymmetry [8].

When enterprises are grouped according to their climate transition risk exposure, the results show obvious heterogeneity. Although the transition risk exposure itself does not have a significant impact on enterprise innovation participation, the interaction coefficient between digital finance and high transition risk exposure is positive and statistically significant. This indicates that, compared with industries with lower transition risk, the promoting effect of digital finance on enterprise innovation participation is more prominent in industries with higher transition risk exposure. In other words, digital finance plays a compensatory role to a certain extent, providing support for the innovation activities of enterprises in high-risk industries by alleviating transition-related pressures [2].

This result shows that digital finance does not simply improve the level of enterprise innovation participation in general, but helps enterprises better cope with structural transformation by alleviating the constraints faced by transition-intensive industries. In these industries, companies typically face higher regulatory uncertainty and adjustment costs, making external financing support particularly crucial for sustaining their innovation investments.

## 4.2. Financial constraints as a mechanism

To examine whether financing constraints constitute an important mechanism of the above relationship, this paper further analyzes the relationship using corporate loan satisfaction as a proxy variable for financing constraints (**Table 1**). The regression results show that the higher the level of digital finance development, the significantly lower the degree of financing constraints faced by enterprises, indicating that digital finance plays a positive role in improving the credit accessibility of micro and small enterprises [9].

Further examination of the interaction term reveals that the interaction coefficient between digital finance and transformation risk exposure is negative, but not statistically significant. This means that although digital finance helps alleviate financing constraints overall, its marginal mitigation effect on enterprises with high transformation risk exposure is not significantly stronger than that on other enterprises.

This result indicates that digital finance mainly plays a role by generally reducing financing friction and improving the overall financing environment, rather than by providing significantly differentiated financing support to enterprises with different transformation risk exposures. In summary, the empirical results support the following explanation: digital finance promotes innovation participation by alleviating the financing constraints generally faced by micro and small enterprises; at the same time, its role in promoting innovation is more prominent in industries with greater climate transition pressure [6].

**Table 1.** Effects of digital finance on innovation and financing constraint

| Variables | Innovation participation | Financing constraints |
|---|---|---|
| FinTech | 0.0041*** (0.0006) | -0.0030** (0.0009) |
| Transition exposure (TranExpo = 1) | −0.1033 (0.1882) | 0.1954 (0.1195) |
| FinTech × TranExpo | 0.0022** (0.0009) | -0.0009 (0.0006) |
| Firm controls | Yes | Yes |
| Industry fixed effects | Yes | Yes |
| Region fixed effects | Yes | Yes |
| Observations | 4,121 | 790 |
| Pseudo $R^2$ | 0.137 | 0.102 |

Notes: Column (1) presents marginal effects from a Probit model in which the dependent variable is a binary indicator of whether a firm participates in innovation activities. Column (2) reports results from an OLS regression using firms' financing constraints as the dependent variable, where higher values indicate more severe credit constraints. FinTech refers to the provincial-level Digital Financial Inclusion Index, and TranExpo is a dummy variable equal to one for firms operating in industries with high climate transition exposure. Firm-level control variables include total assets, firm age, high-tech firm status, CEO age, owner education level, provincial GDP per capita, number of employees, and owner gender. All regressions control for industry and region fixed effects. Robust standard errors clustered at the firm level are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

# 5. Discussion

This study systematically and empirically analyzes the impact of digital finance development on firm behavior under climate transition pressures. Based on firm-level data and a Probit-OLS model, the results show that fintech development significantly enhances firms' innovation participation while effectively alleviating financing constraints. More importantly, this impact exhibits significant heterogeneity across different industries: the

interaction between fintech and transition risk has a significantly positive effect on innovation participation, but a significantly negative effect on financing constraints, indicating that fintech has a stronger impact on SMEs facing higher climate transition risks.

These findings enrich the literature in the field of sustainable finance by highlighting the complementary mechanism between fintech and climate transition. SMEs operating in industries with higher transition risks often face higher uncertainty, stricter regulatory pressures, and greater financing frictions, factors that inhibit innovation investment. Empirical results show that fintech alleviates these constraints by increasing information transparency, reducing transaction costs, and expanding external financing channels. Therefore, SMEs are better able to participate in innovation activities, thereby promoting technological upgrading and low-carbon transition. This model supports the view that digital finance can serve as an effective market tool to support the real economy during structural transformation.

From a policy perspective, the results of this study offer important insights. For instance, promoting fintech development can reduce the adjustment costs for SMEs, thereby improving the effectiveness of climate transition policies. Moreover, the interaction effect shows that fintech can not only stimulate innovation overall but also precisely allocate financial resources to industries facing the greatest transition pressure, supporting a smooth low-carbon economic transition [10].

However, this study still has certain limitations as follows:

(1) The measurement of transition risk relies on industry-level classification, which may not fully reflect the specific risks faced by enterprises;

(2) Even with the introduction of rich control variables and fixed effects, potential endogeneity issues (such as reverse causation) between fintech development and enterprise innovation cannot be completely ruled out;

(3) This study focuses on the degree of innovation participation rather than innovation output or quality, which may underestimate long-term effects.

Future research can be expanded in several ways as outlined:

(1) By introducing climate transition risk indicators at the firm or asset level to improve identification accuracy;

(2) By employing causal inference methods such as policy shocks or instrumental variables to strengthen causal explanatory power;

(3) By focusing on the quality and direction of innovation, such as green patents or carbon reduction technologies, to more comprehensively assess the role of fintech in supporting sustainable technological change;

(4) By examining the heterogeneous impacts across different ownership structures or regions to deepen the understanding of the role of digital finance in climate transition.

## 6. Conclusion

In summary, this study demonstrates that fintech not only promotes corporate innovation and alleviates financing constraints but also plays a crucial moderating role for firms facing climate transition risks. By reducing financing frictions and supporting innovation under pressure, fintech helps build a more resilient and adaptable real economy.s For emerging markets that are advancing digital transformation and achieving carbon neutrality goals,

building an inclusive and well-regulated fintech ecosystem is an effective strategy for promoting high-quality, sustainable economic development.

## Disclosure statement

The author declares no conflict of interest.

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