Can Technology-Finance Policies Promote Collaborative Innovation in Enterprises?

-- Evidence from Pilot Policies on the Integration of Technology and Finance

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Abstract

This study examines the impact of the "Promoting Technology-Finance Integration" pilot policies, implemented in 2011 and 2016, on collaborative innovation in enterprises. Utilizing a multi-period difference-in-differences (DID) model and a dataset of listed companies from 2003 to 2023, the study identifies the causal effects of these policies. The findings indicate that the pilot policies significantly enhance collaborative innovation, primarily through two mechanisms: alleviating financing constraints and reducing risk exposure. These results underscore the crucial role of technology-finance policies in fostering corporate innovation and provide empirical evidence to support policy optimization aimed at strengthening enterprise competitiveness and innovation capacity.

Keywords

Technology-finance, collaborative innovation, pilot policy, difference-in-differences (DID).

1. Introduction

On March 20, 2024, General Secretary Xi Jinping emphasized at the symposium on the promotion of central China's rise in the new era: "We must strengthen the role of enterprises as innovation entities, build closely integrated innovation consortia along the upstream and downstream, promote the integration of industry, academia, and research, and accelerate the transformation of scientific and technological achievements into productive forces." Today, enterprise-led innovation consortia are vital platforms for achieving significant breakthroughs in national technological development. As an effective path for enterprise innovation, collaborative innovation involves collaboration between enterprises, universities, research institutes, and other innovation entities to integrate external resources, reduce costs, and diversify risks, thus ensuring the smooth progression of innovation activities in enterprises[1]. However, financing constraints, high risks, and information asymmetry have long been obstacles to enterprise innovation. As the leading pillar of China's "Five Major Articles of Finance," technology finance supports corporate collaborative innovation by strengthening the integration of technological and financial resources[2].

In 2011 and 2016, the Ministry of Science and Technology, the People's Bank of China, and other departments launched the "Promotion of Technology and Finance Integration" pilot policies, jointly supporting technological innovation development. These policies have played a key role in breaking through financing bottlenecks, promoting the transformation of technological achievements, and nurturing strategic emerging industries. Under the support of these policies, did technology finance promote collaborative innovation among enterprises in the pilot regions?

If so, to what extent? This paper aims to investigate the effects of the pilot policies on corporate collaborative innovation and identify the internal link between technology finance policies and corporate collaborative innovation.

The concept of corporate collaborative innovation was proposed relatively recently but has garnered widespread attention from scholars, with numerous related studies emerging. Existing research has mainly focused on two aspects: internally, Persaud (2005)[3] used multiple regression and factor analysis to reveal that the innovative capacity of laboratories is significantly influenced by factors such as laboratory autonomy, internal organizational socialization, and the effectiveness of face-to-face communication between headquarters and laboratories. Externally, Xiao Dingding and Zhu Guilong (2013)[4] employed a stochastic frontier model to analyze how external technological dependence and government funding positively impact collaborative innovation. Tang Houxing and Liang Wei (2019)[5] constructed an optimization model to evaluate the impact of market factors on inter-enterprise collaborative innovation. With the integration of technological innovation and finance, technology finance has become an important factor influencing corporate collaborative innovation, yet limited literature has explored this relationship. Furthermore, most existing studies focus on the promotion of overall enterprise innovation by technology finance, often based on data from listed companies. These studies find that technology finance helps facilitate corporate digital transformation, alleviate financing pressure, and improve corporate governance, thus enhancing the scale and efficiency of innovation[6]. However, few studies have used the DID approach to investigate the impact of technology finance on corporate collaborative innovation.

Given this, the marginal contributions of this paper are twofold: first, it links technology finance with corporate collaborative innovation, exploring the causal relationship between the two using the external shock of the "Promotion of Technology and Finance Integration" pilot policies; second, the paper analyzes the mechanisms of technology finance's impact on corporate collaborative innovation through financing constraints and risk-taking, thereby enriching the literature on government policies influencing collaborative innovation; third, it employs a multi-period difference-in-differences (DID) model to identify the effects of technology finance on corporate collaborative innovation and uses a mediation model to verify the two mechanisms, providing empirical evidence for further promoting technology finance integration in pilot cities.

2. Policy Background and Mechanism Analysis

2.1. Policy Background

In 2011, the "12th Five-Year Plan for National Science and Technology Development" (hereafter referred to as the "Development Plan") proposed strengthening the integration of technology and finance. This not only helps leverage the support role of science and technology in economic and social development but also promotes financial innovation and the sustainable development of finance. This plan laid the foundation for the development of technology finance and guided future policy direction. To implement the Development Plan, China launched the "Promotion of Technology and Finance Integration" pilot policies in two batches. In January 2011, 16 regions, including Wuhan and Changsha, became the first batch of pilot cities[7]. In June 2016, 9 cities, including Xiamen and Nanchang, were included in the second batch of pilot cities[8]. Over the course of these pilot policies, China gradually built a diversified and multi-tiered technology finance service structure that includes capital market financing and risk-bearing dimensions, with policies and market forces working together to provide comprehensive financial support for corporate collaborative innovation. It is expected that companies in pilot areas will significantly improve their technology finance capabilities, thereby promoting collaborative innovation.

2.2. Mechanism Analysis

(1) The Role Mechanism of Sci-tech Finance in Promoting Enterprise Collaborative Innovation

This article analyzes the pilot policies of combining science and technology with finance from the perspective of the functions of sci-tech finance. From a macro perspective, sci-tech finance, as an important component of the national innovation system, can effectively promote collaboration among multiple stakeholders such as enterprises, research institutions, and governments by optimizing the allocation of financial resources, reducing innovation risks, and facilitating the flow of knowledge and technology. This collaborative effect is not only reflected in the technological research and development but also extends to industrial chain integration, market expansion, and other dimensions, thereby significantly improving overall innovation efficiency. In the context of the global economic transformation and upgrading, sci-tech finance accelerates the economic shift from traditional factor-driven to innovation-driven growth by supporting the development of high-tech industries and emerging strategic industries, providing significant support for collaborative innovation. Furthermore, sci-tech finance also supports enterprises in conducting cross-border and cross-disciplinary collaborative innovation, which enhances their position in the global value chain and strengthens their international competitiveness.

From a micro-mechanism perspective, sci-tech finance provides financial support and risk management guarantees for enterprise collaborative innovation through two core paths: financing constraints and risk-bearing mechanisms, thus creating favorable conditions for the smooth progress of enterprise innovation activities.

1) Financing Constraint Mechanism

Innovation activities in enterprises require substantial financial investment in areas such as R&D, production, and market promotion, which are characterized by long cycles and high costs. In collaborative innovation, enterprises often need to cooperate across industries, fields, and regions, which requires even more financial investment, especially for start-ups and growing companies. Relying solely on self-capital accumulation makes it difficult for these enterprises to achieve collaborative innovation. The financing constraint mechanism, as an important path for sci-tech finance to promote enterprise collaborative innovation, alleviates the financing difficulties in innovation activities. From a theoretical perspective, the information asymmetry theory [9] reveals the financing dilemmas in enterprise innovation activities, and sci-tech finance mitigates the problem of information asymmetry by introducing professional financial institutions and intermediary platforms, thus lowering the financing threshold. The financing preference theory [10] suggests that the diversified financing tools provided by sci-tech finance optimize the capital structure of enterprises and reduce financing costs. From a practical perspective, methods such as angel investment, venture capital funds, and technology transaction contract financing provide diversified financing constraints throughout the lifecycle of enterprise technological innovation [11]. Meanwhile, scholars such as Zhou Kaiguo et al. point out that increasing financial support for high-tech enterprises can effectively alleviate the financing constraints faced by enterprises, significantly enhancing R&D investment levels, and subsequently increasing resource allocation in collaborative R&D activities [12]. Therefore, sci-tech finance pilot policies, as policies that support scientific and technological enterprise innovation, can guide and promote various capital flows into tech enterprises, providing financing constraints for collaborative innovation activities.

2) Risk-Bearing Mechanism

Collaborative innovation is a complex activity in which enterprises jointly cope with uncertainties in technology, market, management, and other areas during cooperation. It requires enterprises to coordinate various risks across multiple dimensions of collaboration. In traditional financing and innovation models, enterprises often face multiple risks from social systems, technological systems, and project management, which make the innovation process highly uncertain [13]. These risks not only challenge the innovation capacity of enterprises but also affect trust and long-term cooperation among partners, even leading to the breakdown of collaboration or failure of innovation projects. In this context, sci-tech finance can effectively help enterprises identify, share, and manage various risks in the innovation process through venture capital institutions, banking systems, and government support [14][15][16]. On the one hand, according to the risk diversification theory [17], sci-tech finance introduces multiple stakeholders, which can spread innovation risks across a broader range of participants. This not only reduces the risk pressure on a single enterprise but also fosters trust and long-term collaboration among the cooperating entities. On the other hand, the principal-agent theory [18] suggests that sci-tech finance can alleviate the principal-agent problem by designing reasonable risk-bearing mechanisms, effectively reducing conflicts of interest between enterprises and their partners, and motivating all parties to actively participate in innovation activities. Therefore, sci-tech finance provides a more robust risk management framework for enterprise collaborative innovation, facilitating cooperation between different entities, enhancing the success rate of innovation projects, and helping enterprises achieve innovation goals in complex and ever-changing market environments.

Based on the above analysis, the following research hypotheses are proposed:

- Hypothesis 1: Sci-tech finance can significantly enhance the level of enterprise collaborative innovation.
- Hypothesis 2a: Sci-tech finance can effectively enhance enterprise collaborative innovation by alleviating financing constraints.
- Hypothesis 2b: Sci-tech finance can effectively enhance enterprise collaborative innovation by improving risk-bearing capacity.

(2) The Heterogeneity of Sci-tech Finance in Promoting Enterprise Collaborative Innovation

There are significant differences in the demand and capacity for technological innovation at different stages of the enterprise lifecycle, which profoundly affect the implementation effectiveness of sci-tech finance policies. Enterprises in the growth stage are typically in the critical phase of market expansion and technological accumulation. Facing significant market competition pressures, growth-stage enterprises need to improve product competitiveness and market share through technological innovation to gain a foothold in the market. Sci-tech finance policies provide these enterprises with multi-dimensional resources such as funding, technology, and talent, helping them break through technological bottlenecks and enhance collaborative innovation capabilities. In contrast, mature enterprises have relatively rich technological accumulation and market position, with a stable market share and a well-established technological system. Sci-tech finance policies can drive the upgrading and improvement of existing technologies in mature enterprises, thus achieving incremental collaborative innovation. However, for enterprises in the decline stage, the promotion effect of sci-tech finance policies is relatively weak. Declining enterprises often face issues such as shrinking market share and insufficient motivation for technological renewal. Their resources are more focused on maintaining existing operations rather than on technological innovation. Due to uncertain market prospects, enterprises may lack sufficient motivation and resources to make large-scale R&D investments, leading to a further decline in technological innovation capabilities. Furthermore, the technological foundation and market outlook of declining enterprises may limit their potential for collaborative innovation with other enterprises or research institutions. Therefore, this article proposes Hypothesis 3: Sci-tech finance pilot policies have a significant positive effect on the collaborative innovation capabilities of growth-stage and mature enterprises, while their effect on declining enterprises is relatively weak.

3. Research Design

3.1. Model Design

This article views sci-tech finance as a "quasi-natural experiment" policy that influences external enterprise research behavior, aiming to explore its impact on enterprise innovation activities. Given that China's pilot policies promoting the combination of science and technology with finance were implemented in two phases, in 2011 and 2016, this study adopts a difference-in-differences (DID) model to analyze the impact of the sci-tech finance policy implementation on enterprise green innovation. The model is constructed as follows:

$$Pat_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 X_{it} + \lambda_i + \mu_t + \epsilon_{it} \tag{1}$$

In equation (1), $\mathbf{Pat}_{it}$ represents the number of joint patents applied by enterprise i in year t ,which reflects the level of enterprise collaborative innovation. $\mathbf{DID}_{it}$ is the main explanatory variable, and this paper focuses on the coefficient α_1 , which represents the net impact of the pilot policy on enterprise collaborative innovation. $\mathbf{X}_{it}$ is the matrix of control variables that affect enterprise collaborative innovation. λ_i is the enterprise fixed effect, μ_t is the time fixed effect, and ϵ_{it} represents the random disturbance term.

3.2. Variable Selection

(1) Dependent Variables

In order to more accurately measure the changes in enterprise collaborative innovation under the influence of sci-tech finance, we have classified the number of joint patent applications (Pat) into three categories: joint invention patents (JIP), joint utility model patents (JUMP), and joint design patents (JDP), in accordance with the Patent Law of the People's Republic of China.

- Joint Invention Patents (JIP) typically represent innovative breakthroughs in core technology areas, with higher technological content and innovation difficulty.
- Joint Utility Model Patents (JUMP) focus on practical new technical solutions proposed for the shape, structure, or combination of products, which have important practical value.
- Joint Design Patents (JDP) focus on the unique design aesthetic and innovation exhibited in the overall or partial appearance of a product.

If the pilot policy significantly increases the number of joint patent applications by enterprises, it indicates that sci-tech finance has effectively promoted the collaborative innovation capabilities of enterprises.

(2) Core Explanatory Variable

The core explanatory variable in this study is the difference-in-differences (DID) term for the two sets of "promoting the combination of science and finance" pilot policies implemented in 2011 and 2016. The estimated coefficient reflects the effect of the pilot policies. The first batch of pilot policies involved 16 regions, including Beijing and Nanjing. Since these regions consist of provinces, cities, and economic zones, this study adopts the approach from Haiyun et al.and refines the first batch of pilot cities into 41 corresponding cities, including Wuhan and Changsha.

- The first batch of pilot cities in 2011 includes: Beijing, Tianjin, Shanghai, Nanjing, Wuxi, Xuzhou, Changzhou, Suzhou, Nantong, Lianyungang, Huai'an, Yangzhou, Zhenjiang, Taizhou, Suqian, Hangzhou, Wenzhou, Huzhou, Hefei, Bengbu, Wuhu, Wuhan, Changsha, Guangzhou, Foshan, Dongguan, Chongqing, Chengdu, Mianyang, Xi'an, Baoji, Tianshui, Weinan, Tongchuan, Shangluo, Qingyang, Pingliang, Longnan, Dalian, Qingdao, and Shenzhen.

- The second batch of pilot cities in 2016 includes: Zhengzhou, Xiamen, Ningbo, Jinan, Nanchang, Guiyang, Yinchuan, Baotou, and Shenyang.

The term DID_{it} is defined as $Treat_{it} \times POST_{it}$,where $Treat_{it}$ is a dummy variable indicating whether the city of the enterprise is one of the pilot cities for combining science and finance.The variable takes the value of 1 if the city is a pilot city,and 0 otherwise. $POST_{it}$ is a time dummy variable, which takes the value of 0 before the policy implementation and 1 after.

(3) Control Variables

Table 1. Definitions and Calculation Methods of Key Variables

	variable	definition
variable being explained	Number of joint invention patent applications(JIP)	Ln(1 + Number of joint invention patent applications)
	Number of joint utility model patent applications(JUMP)	Ln(1 + Number of joint utility model patent applications)
	Number of joint design patent applications(JDP)	Ln(1 + Number of joint design patent applications)
control variable	Enterprise Size(Size)	Ln(Total assets of the enterprise at the end of the year)
	Leverage Ratio(Lev)	Total liabilities/total assets
	Return on Assets(ROA)	Total liabilities/total assets
	Asset Turnover(ATO)	Operating income/Average assets
	Cash Flow Ratio(Cashflow)	Net cash flows from operating activities/total assets
	Revenue Growth Rate(Growth)	(Current year's operating income/previous year's operating income) -1
	Proportion of Independent Directors(Indep)	Number of independent directors/Total number of board members
	Dual Role(Dual)	If the chairman and the general manager are the same person, the value is 1, otherwise it is 0
	Largest Shareholder's Ownership(Top1)	Number of shares held by the largest shareholder/total number of shares
	Firm Age	Ln(Year of establishment)
	Ownership Type(SOE)	If the enterprise is a state-owned enterprise, the value is 1; otherwise, it is 0

To enhance the reliability of the research results, this study controls for the following variables:

1) Enterprise Size (Size): Represented by the natural logarithm of total assets at the end of the year.
2) Leverage Ratio (Lev): The ratio of total liabilities to total assets.
3) Return on Assets (ROA): The ratio of net profit to total assets.
4) Asset Turnover (ATO): The ratio of operating income to average total assets.
5) Cash Flow Ratio (Cashflow): The ratio of net cash flow from operating activities to total assets.
6) Revenue Growth Rate (Growth): The ratio of this year's revenue to last year's revenue minus 1.
7) Proportion of Independent Directors (Indep): The ratio of the number of independent directors to the total number of board members.

8) Dual Role (Dual): Takes the value of 1 if the CEO and chairman are the same person, otherwise 0.
9) Largest Shareholder's Ownership (Top1): The ratio of the largest shareholder's shares to the total shares.
10) Firm Age (Firm Age): The natural logarithm of the number of years since the enterprise was founded.
11) Ownership Type (SOE): Takes the value of 1 if the enterprise is a state-owned enterprise (SOE), otherwise 0.

By controlling for the above variables, this study minimizes potential omitted variable bias, thus enhancing the reliability and robustness of the research results.

3.3. Data Sources and Processing

This study selects Chinese listed companies from 2003 to 2023 as the research sample, covering the entire process of pilot policy implementation. The dataset mainly includes patent and financial data from listed companies. Patent data are sourced from the China Research Data Service Platform (CNRDS), and financial data are sourced from the Guotai An (CSMAR) Database.Following common practices in existing literature, this study excludes companies with a leverage ratio less than 0 or greater than 1, non-tech companies such as those in the financial industry, companies with missing data, and firms with financial risks (ST, PT, and *ST companies). To avoid the influence of extreme values, the study uses the Winsorize method to perform 1% two-sided trimming on continuous variables. Ultimately, the final sample consists of 51,664 observations.

4. Empirical Results and Analysis

4.1. Descriptive Statistics

Table 2 shows the statistical distribution of various variables. Notably, there is a significant difference in the number of joint patent applications across different categories, particularly between joint invention patents (JIP) and joint utility model patents (JUMP). Although joint design patents (JDP) are relatively low in value, there is a notable spread between the minimum value of 0 and the maximum value of 6.860, with a standard deviation of 0.364, indicating significant variability between firms. This indicates considerable differences in firms' involvement in joint patent applications. Additionally, variables like Lev, Growth, ROA, ATO, and Cashflow show higher volatility.

Table 2. Descriptive Statistics

variable	sample size	mean value	p50	standard deviation	least value	maximum value
JIP	51,664	0.345	0	0.855	0	8.846
JUMP	51,664	0.241	0	0.751	0	8.333
JDP	51,664	0.055	0	0.364	0	6.860
DID	51,664	0.469	0	0.499	0	1
Size	51,664	22.068	21.869	1.293	19.333	26.440
FirmAge	51,664	2.835	2.890	0.406	1.099	3.638
Lev	51,664	0.425	0.420	0.206	0.027	0.990
ROA	51,664	0.040	0.039	0.066	-0.375	0.254
ATO	51,664	0.655	0.554	0.449	0.055	3.138
Cashflow	51,664	0.048	0.047	0.071	-0.232	0.283
Growth	51,664	0.163	0.107	0.391	-0.737	3.808
Indep	51,664	37.252	33.330	5.445	0	60
Dual	51,664	0.274	0	0.446	0	1
Top1	51,664	0.348	0.325	0.151	0.076	0.758
SOE	51,664	0.388	0	0.487	0	1

4.2. Benchmark Regression Analysis

Table 3. Benchmark Regression Results

variable	(1)	(2)	(3)	(4)	(5)	(6)
	JIP	JUMP	JDP	JIP	JUMP	JDP
DID	0.106***	0.066***	0.021***	0.136***	0.077***	0.031***
	(0.008)	(0.007)	(0.003)	(0.009)	(0.008)	(0.004)
Size	0.219***	0.171***	0.042***	0.228***	0.174***	0.048***
	(0.005)	(0.005)	(0.002)	(0.005)	(0.005)	(0.003)
Firm Age	-0.031***	-0.049***	-0.019***	-0.000	-0.010	0.011*
	(0.009)	(0.008)	(0.004)	(0.012)	(0.011)	(0.006)
Lev	-0.322***	-0.134***	-0.059***	-0.154***	-0.071***	-0.052***
	(0.021)	(0.018)	(0.009)	(0.022)	(0.019)	(0.010)
ROA	0.212***	0.174***	0.082***	0.295***	0.153***	0.077***
	(0.063)	(0.054)	(0.028)	(0.063)	(0.054)	(0.029)
ATO	0.075***	0.053***	0.025***	0.050***	0.044***	0.017***
	(0.008)	(0.007)	(0.004)	(0.009)	(0.008)	(0.004)
Cashflow	0.101**	0.106**	0.062***	0.027	0.131***	0.079***
	(0.048)	(0.043)	(0.022)	(0.049)	(0.043)	(0.023)
Growth	-0.062***	-0.049***	-0.019***	-0.061***	-0.055***	-0.021***
	(0.008)	(0.007)	(0.003)	(0.008)	(0.007)	(0.003)
Indep	0.002**	0.002***	0.001*	0.001*	0.002***	0.001**
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
Dual	0.035***	0.015**	0.028***	0.010	0.000	0.026***
	(0.008)	(0.007)	(0.004)	(0.008)	(0.007)	(0.004)
Top1	-0.199***	-0.101***	-0.051***	-0.110***	-0.071***	-0.035***
	(0.028)	(0.024)	(0.012)	(0.027)	(0.024)	(0.012)
SOE	-0.015*	-0.025***	-0.022***	0.032***	-0.002	-0.019***
	(0.008)	(0.007)	(0.004)	(0.008)	(0.007)	(0.004)
Constant	-4.369***	-3.463***	-0.821***	-4.752***	-3.660***	-1.059***
	(0.105)	(0.097)	(0.048)	(0.121)	(0.110)	(0.062)
Observations	51,664	51,664	51,664	51,664	51,664	51,664
R-squared	0.101	0.080	0.022	0.148	0.127	0.034
λ_i	NO	NO	NO	YES	YES	YES
μ_t	NO	NO	NO	YES	YES	YES

Based on the theoretical analysis of the relationship between technological finance and corporate collaborative innovation, this study first estimates the benchmark regression using econometric model (1). The results are shown in Table 3.

In Table 3, columns (1)–(3) display the results of regressions with only the core explanatory variable DID included, for different types of joint patent applications. At the 1% significance level, the regression coefficients for all types of patent applications are significantly positive. Columns (4)–(6) add a series of control variables. Even after controlling for these variables, the positive impact of DID on all types of joint patent applications remains robust and significant. Therefore, Hypothesis 1 is validated, indicating that the technological finance pilot policy significantly enhances corporate collaborative innovation.

4.3. Parallel Trend Test and Dynamic Effects

The parallel trend assumption is a prerequisite for using the multi-period DID method. Specifically, prior to the policy shock, the trends in the experimental and control groups should generally be consistent. As the pilot process is divided into two batches, different time dummy variables need to be set. The model is specified as follows:

$$\text{Pat}_{it} = \beta_0 + \sum_{s=1}^{4} \gamma_{-is}\, \text{DID}_{-is} + \gamma_0 \text{DID}_0 + \sum_{s=1}^{5} \gamma_{is}\, \text{DID}_{is} \tag{2}$$

In equation (2), DID_{-is}, DID_0 , and DID_{is} represent the interaction terms of the years before the pilot, the start of the pilot, and post-pilot years with the policy. The coefficients α_0, γ_0 , and γ_{is} correspond to the respective terms, and the other symbols are consistent with those in equation (1). The observation period of this study is from 2003 to 2023 . The year before the policy was implemented is taken as the baseline, and because some pilot regions do not have data prior to year -4, time periods before -4 are combined into the -4 period.

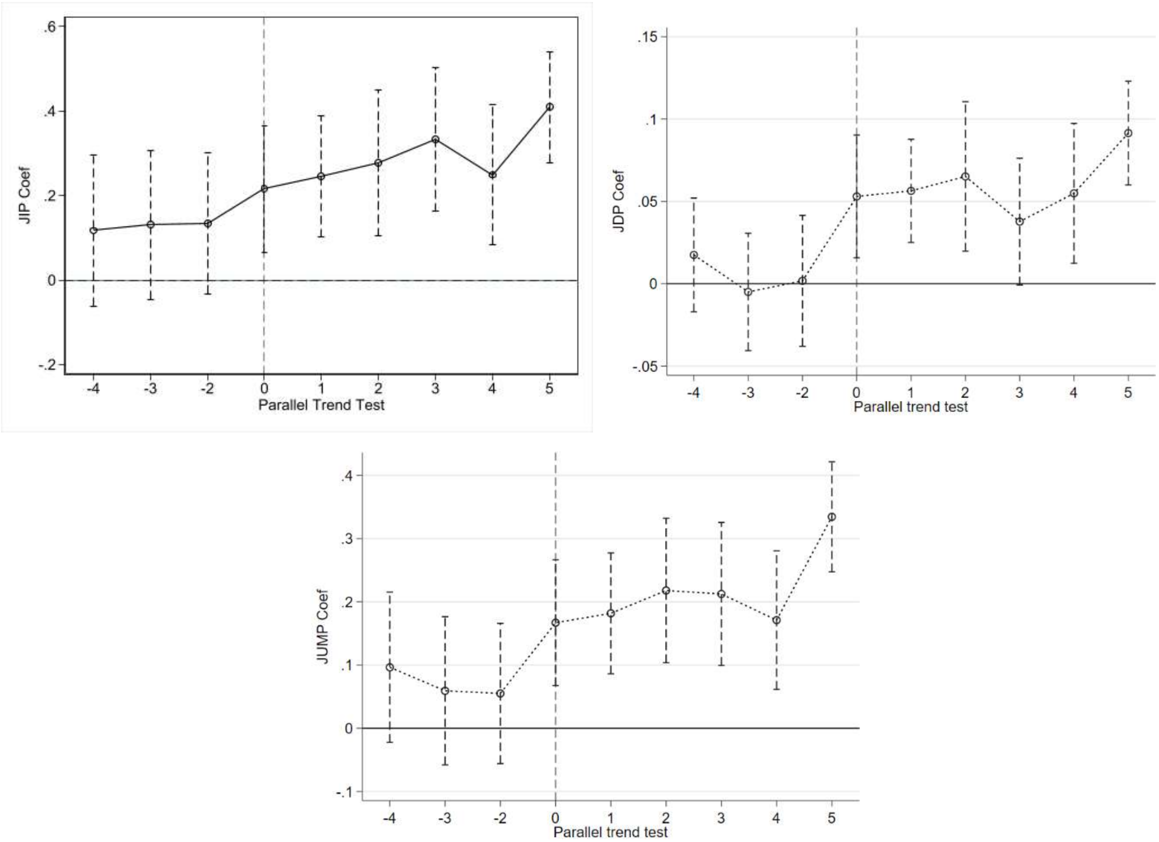

Figure 1. Parallel Trend Test for Technological Finance Pilot Policy

From the results, it can be observed that prior to the implementation of the pilot policy, the DID coefficient estimates are generally insignificant, which satisfies the parallel trend assumption. After the implementation of the policy, the regression coefficients are significantly positive at the 1% level and show an upward trend. The results of the parallel trend test suggest that the trends of the treatment group and the control group are consistent, and there are no significant systematic differences between them. Additionally, the coefficient estimates after the pilot policy are all significantly positive, indicating that the technological finance pilot policy has a persistent positive impact on corporate collaborative innovation.

4.4. Robustness Tests

Since the ideal scenario for using the progressive DID method is random selection of the experimental and control groups, a series of methods were employed in this study to address sample selection bias and endogeneity issues, ensuring the applicability and effectiveness of the progressive DID model.

Placebo Test

Following the approach of Hu Jie et al., this study conducts a placebo test. To exclude the influence of non-observable factors on the policy evaluation results, 500 random samplings were performed to construct a "pseudo-policy dummy variable" and re-estimate the model (1). The distribution of coefficients and p-values is shown in Figure 2. The results display a normal distribution, with the mean coefficient close to 0, significantly smaller than the true estimated coefficient, and most p-values exceed 0.1. This confirms the robustness of the baseline regression results and further proves that the impact of the technological finance pilot policy on corporate collaborative innovation is not due to random factors, thus validating the accuracy of the conclusions.

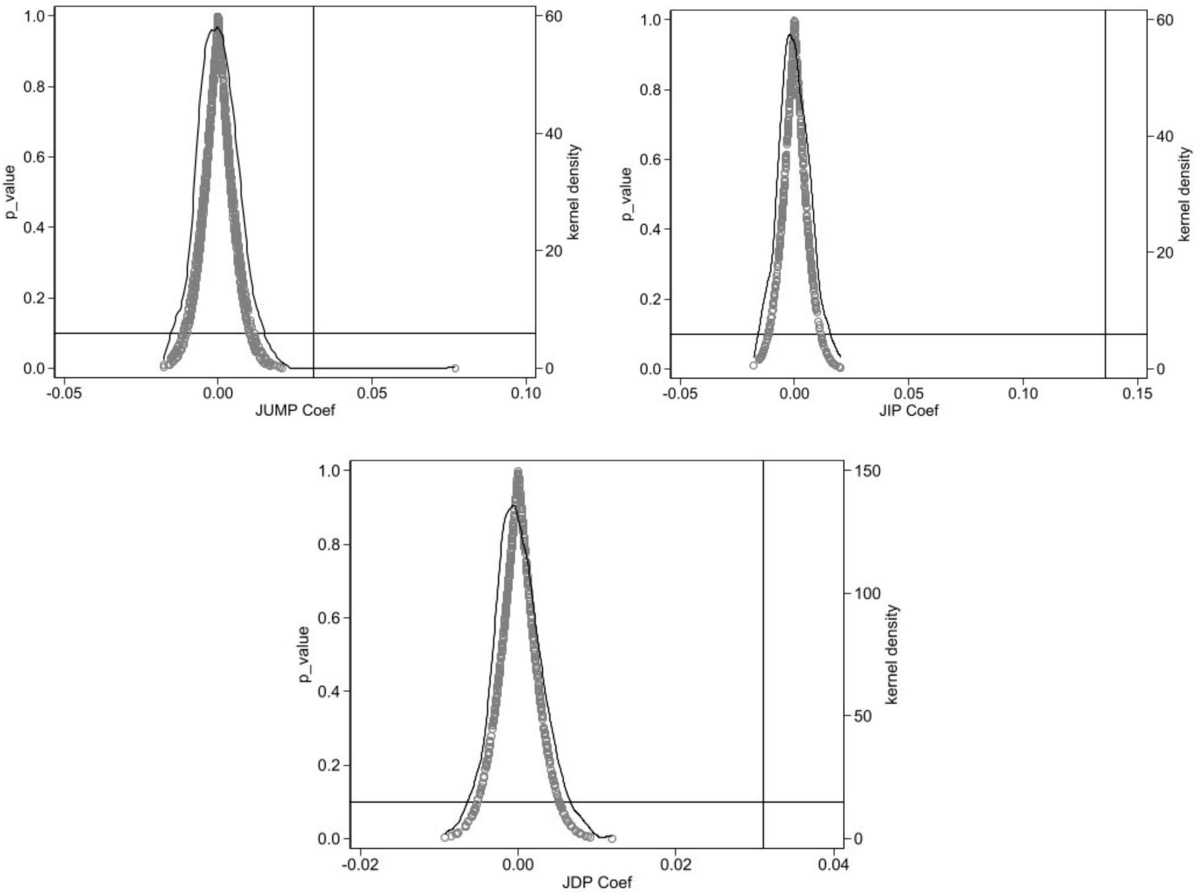

Figure 2. Placebo Test

5. Mechanism Tests

5.1. Testing the Mechanisms

Based on the previous theoretical analysis, to examine the mechanisms through which the pilot policy affects corporate innovation collaboration, the following mediation model is constructed:

$$y_{it} = \beta_0 + \beta_1 \mathrm{DID}_{it} + \beta_2 X_{it} + \lambda_i + \mu_t + \epsilon_{it} \tag{3}$$

$$\mathrm{Pat}_{it} = \alpha + \theta \mathrm{DID}_{it} + \phi y_{it} + \eta X_{it} + \lambda_i + \mu_t + \epsilon_{it} \tag{4}$$

Where y represents the mediator variables reflecting the mechanisms of financing constraints and risk-taking. Other variables are consistent with those in the previous sections. If both β_1

and ϕ are significant, it indicates the presence of a mediation effect. If θ is significant and its sign aligns with $\beta_1 \times \phi$, it suggests the presence of a partial mediation effect. The selection and handling of mediating variables are as follows:

Financing Constraints Mechanism: Following the work of Ju Xiaosheng et al. , this study uses the SA index as a proxy for financing constraints. The SA index, proposed by Hadlock and Pierce in 2010, more accurately measures the degree of financing constraints faced by firms. The larger the absolute value of the SA index (which is negative, meaning smaller SA values indicate greater constraints), the more severe the financing constraints.

Risk-Taking Mechanism: Based on the study of Pan Weihua and Luo Yongheng, the Risk index is used as a proxy for risk-taking. This is calculated as the adjusted standard deviation of earnings before interest and taxes (EBIT) to total assets at year-end. If the technological finance policy improves a firm's risk-taking ability, the risk index should decline.

Table 4. Mechanism Test Regression Results

	Financing Constraints Mechanism				Risk-Taking Mechanism			
variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SA	JIP	JUMP	JDP	Risk	JIP	JUMP	JDP
DID	-0.011***	0.130***	0.073***	0.031***	-0.002***	0.160***	0.097***	0.034***
	(0.002)	(0.008)	(0.008)	(0.004)	(0.000)	(0.010)	(0.009)	(0.005)
SA		-0.546***	-0.423***	-0.033***				
		(0.043)	(0.040)	(0.010)				
Risk						-0.414***	-0.303***	-0.075*
						(0.093)	(0.083)	(0.041)
Constant	0.084***	-4.906***	-3.904***	-1.149***	2.501***	-3.387***	-2.602***	-0.977***
	(0.005)	(0.152)	(0.141)	(0.080)	(0.027)	(0.117)	(0.107)	(0.045)
Observations	51,664	51,664	51,664	51,664	35,120	35,120	35,120	35,120
R-squared	0.717	0.158	0.135	0.035	0.130	0.144	0.128	0.035
λ_i	YES	YES	YES	YES	YES	YES	YES	YES
μ_t	YES	YES	YES	YES	YES	YES	YES	YES

Table 4 presents the regression results for the mediation tests. In terms of the financing constraints mechanism, in column (1), the "Pilot Policy" under technological finance significantly alleviates financing constraints at the 1% level. In columns (2), (3), and (4), the effect of financing constraints on joint invention patents, joint utility model patents, and joint design patents is significantly positive at the 1% level, indicating that alleviating financing constraints promotes the application for various types of joint patents. This supports Hypothesis 2a.

Regarding the risk-taking mechanism, in column (5), the technological finance "pilot policy" significantly reduces the level of risk-taking at the 1% level. In columns (6), (7), and (8), the effect of risk-taking on joint invention patents, joint utility model patents, and joint design patents is significantly negative at least at the 10% level, indicating that a reduction in risk-taking enhances corporate collaborative innovation. This supports Hypothesis 2b.

Overall, the analysis shows that the technological finance pilot policy can effectively alleviate financing constraints, reduce risk-taking, and subsequently promote corporate collaborative innovation. The policy has a positive impact on various types of patent applications, highlighting the importance of strengthening the financial support system for enterprises to foster innovation.

6. Conclusion and Policy Implications

This study constructs a multi-period difference-in-differences (DID) model, using data from Chinese listed companies between 2003 and 2023, to empirically test the impact of the Sci-tech Finance Pilot Policy on enterprise collaborative innovation. The research findings are as follows:

Impact of the Sci-tech Finance Pilot Policy: The pilot policy "Promoting the Integration of Science and Finance" significantly enhances the level of enterprise collaborative innovation. This conclusion remains robust even after conducting parallel trend tests, multi-period propensity score matching DID (PSM-DID), placebo tests, and various robustness checks.

Mechanisms of Sci-tech Finance: Sci-tech finance promotes enterprise collaborative innovation primarily through two mechanisms: alleviating financing constraints and enhancing risk-taking capabilities.

Impact of Firm Life Cycle: The effect of the Sci-tech finance pilot policy on enterprise collaborative innovation is influenced by the firm's life cycle stage.

Based on these conclusions, the following policy recommendations are made:

Strengthen Policy Support and Financial Assistance: The government should increase support for the Sci-tech Finance Pilot Policy, especially in terms of financial investment and expanding financing channels. Providing more extensive financial services to enterprises should be prioritized. In addition, efforts should be made to encourage financial institutions, venture capital firms, banks, and other diversified financing bodies to participate in the financing of technology-based enterprises. During this process, policy guidance and financial subsidies should be used to reduce the financing costs for financial institutions and investors, thus incentivizing more capital to flow into the technology innovation sector.

Improve Risk-Taking Mechanisms: A well-structured risk-taking mechanism is crucial to reducing the risks of innovation and stimulating innovation activities. It is recommended to encourage venture capital institutions and banks to actively engage in the innovation projects of enterprises. For venture capital institutions, policies such as tax incentives and risk compensation should be adopted to encourage them to increase investment in tech enterprises. For banks, collaboration with enterprises could be encouraged to establish risk-sharing funds, alleviating the financial pressure on banks and boosting their confidence in lending to technology firms. Additionally, a technology insurance system could be explored to provide relevant insurance products that cover the risks faced by enterprises in R&D, production, and other processes, further diversifying the innovation risks for companies.

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