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Fin-Tech and Corporate Innovation: Evidence from China

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ABSTRACT
Can Fin-Tech improve corporate innovation? Using the data of Chinese listed companies, this paper studies the impact and mechanism of financial technology on corporate innovation. The empirical results show that the development of financial technology has significantly improved the innovation performance of corporations. This paper obtains a consistent conclusion by taking the development level of regional financial science and technology as a variable. The conclusion is consistent when using multiple regression models, which reflects its robustness. Mechanism analysis shows that Fin-Tech can alleviate the financing difficulties of corporations and improve tax returns, which is more obvious in the economically developed eastern region and high-tech industries. According to the analysis results, this paper also puts forward specific measures to promote the development of financial technology and improve the innovation performance of corporations.

Keywords: *Fintech, Innovation, financial technology.*

1. INTRODUCTION

In recent years, particularly the last decade, corporate innovation has become an increasingly important issue and has gained significant attention in enterprises, governments, and research institutions. This is mainly due to the fact that corporate innovation has become one of the major driving forces not only for the development and growth of corporations but for the industry in general and even countries as a whole. It can be said that corporate innovation is one of the major determinants of whether or not a corporation can sustain high growth and remain competitive and profitable in its industry. However, for various factors, many of these corporations often lack the funding to bring their innovations to fruition. Some of these salient factors include the asymmetric information between investors and corporations, the reliance of corporations on capital for innovation, the inherently higher risk associated with growth firms, and the inability of new or small corporations to acquire security ratings.

In recent years, with the rapid global development of science and technology, accelerated especially in China, the financial market has received strong external assistance. Financial technology (Fin-Tech) has ushered in explosive growth, driven by new technologies such as distributed computing technology led by cloud computing and block-chain, the Internet of things and mobile Internet, security technology led by biometric and digital encryption technology, big data, and artificial intelligence. CB Insights, an internationally renowned venture capital consulting and research institution, pointed out in a 2016 report that the global financial technology industry received US $12.7 billion in investments. The US $4.6 billion was invested in Chinese Fin-Tech corporations. Through cutting-edge digital technology, financial technology can obtain more information about borrowers, engendering a new financial service model [1], expanding the coverage of financial services, and broadening the financing channels for corporations. All of this may effectively increase the efficiency of the liquidity of funds available for innovation, thus improving corporations' innovation ability. Therefore, identifying the impact of Fin-Tech on the development of corporate innovation and its effective mechanism has important practical significance for driving China's high-quality economic development and for improving the function of financial services to the real economy.

Since becoming driven by financial technology, the financial industry has gradually evolved with a distributed and networked structure, represented by lower transaction costs and more diverse participants. Unfortunately, due to the absence of appropriate financial

technology performance indicators, existing publications mainly discuss the development characteristics of financial technology and the relevant regulatory approach [2, 3] but fail to examine how financial technology affects corporate innovation [4, 5]. As pointed out above, innovations and breakthroughs can create decisive advantages within a competitive market and have become the main driving forces promoting sustainable economic growth [6]. Exploring the impact of financial technology on corporate innovation will help evaluate the social and economic benefits of financial technology development and deepen the understanding of the driving factors of corporate innovation. The construction of financial, technical indicators is the key to investigating the impact of financial technology development on micro-enterprise behavior. Shi Bing Zhan and Jin Xiang Yi used Baidu search data to compile an attention index of domestic residents in different countries [7]. Using annual data, Shi and Jin were able to obtain the number of relevant articles regarding Fin-Tech visited by people residing in specific regions in China. This reflects the differences in Fin-Tech not just in terms of development but also across different regions. As for the impact of science and technology on finance, Chong et al. [8], Zhang Jie et al., and Zhang Xuan et al. all selected the average value of neighboring cities' financial technology development level as the instrument variable [9, 10]. In addition, Fin-Tech has not only greatly broadened the scope of the services provided by existing financial institutions but has also spawned a number of new credit intermediaries, such as diversified financial loans for small and micro enterprises. This inclusive nature enables more small and micro enterprises to enjoy convenient and safe financial products and services. Small and micro enterprises have achieved substantial profits in the development of financial technology.

The impact of Fin-Tech on corporate innovation is as follows:

- Fin-Tech can reduce the information asymmetry between the parties associated with the demand and supply of funds to solve the financing dilemmas faced by corporations and promote corporate innovation. In researching this issue, Huan et al. used Alibaba's data and found that Ant Financial uses many non-financial forms of information, such as sales information, that are not part of the traditional loan approval process, to assist in determining loan approval [11]. This has been found to reduce the information asymmetry and improve the overall quality of financial services, stimulating innovation and the development of the real economy. Lin et al. found that the borrower's social network-related information can be used for credit review by using the data on Prosper.com, an online lending platform, to improve the probability of loan success and reduce both the financing cost and the risk of subsequent default [12]. This shows that Fin-Tech plays an important role in mining more comprehensive user information and alleviating information asymmetry.

- Fin-Tech can accelerate the speed of credit approval, thereby easing corporate financing constraints and reducing financing costs. In their research on this problem, Fuster et al. used the U.S. housing credit data [13]. After controlling a series of factors that can affect the mortgage loan approval process, they found that financial technology increased loan approval speed by 20% and that this rapid approval did not increase the default risk of loans. Huang et al. [14], using the microfinance data of Ant Financial Services, found that Ant Financial services reduced the traditional bank loan approval and issuance time from up to several months to 3 seconds by relying on financial technology. This loan approval method based on big data and artificial intelligence also reduces human intervention and the rent-seeking space in the loan approval process, thus decreasing the financing cost.

- Fin-Tech can make external financing inclusive and reduce the financing threshold of the financial market. Under the traditional financial service model, banks and other financial institutions pay more attention to the assets that can be mortgaged by corporations and ignore the technology and innovation ability, which makes it difficult for corporations with fewer assets but impressive growth potential to obtain financing, thus hindering corporate innovation [15]. Fin-Tech comprehensively combs and analyzes various financial service subjects through advanced technologies such as big data, artificial intelligence, and block-chain, forms an ecological map of science and technology industries [16], expands the coverage of financial services, and reduces the threshold of the credit market. Buchak et al. [1] found that borrowers from Fin-Tech shadow banks have lower personal credit scores and loan value ratios by using data from the American housing mortgage market. This means that those groups which find it difficult to obtain loans from traditional banks are more likely to obtain the required funds from Fin-Tech shadow banks. Therefore, the deep integration of Finance and technology is bound to better serve the real economy, further enrich the funds available for corporations, encourage corporations to use more funds for productive activities, and help stimulate the innovative vitality of Chinese corporations.

2. DATA AND METHODS

2.1. Data

The data on patents used in this paper is compiled from the database on baiten.cn; the data of the regional financial development level are from the branch data of commercial banks, published by China Banking and Insurance Regulatory Commission; the financial data, as well as data on the board of directors and the R&D data of the listed companies, are from the CSMAR database

and the WIND database; and the relevant data on the characteristics of the city which the enterprise belongs to are from China City Statistical Yearbook. To make the sample data more representative, it will be processed as follows: ① exclude the samples of listed companies in the financial service sector, such as banks and corporations whose main operations concern securities and insurance; ② exclude the samples lacking the main data variables; ③ exclude the sample of companies with negative owner's equity value; ④ to eliminate the interference of outliers on the results of this paper, a bilateral 3% tail reduction (Winsor), is performed on continuous variables. After the above processing, the final sample involves the annual observation values of 23,558 companies from 2012 to 2016.

2.2. Model

The model constructed in this paper is as follows:

$$Y_{i,t} = \alpha + \beta * X_{m,t} + \gamma * Z + \delta_i + \theta_{j,t} + \epsilon_{i,t}$$

In this model, the dependent variable is $Y_{i,t}$, which represents company i's innovation output in year t, where the number of patent applications measures the innovation output. Independent variable $X_{m,t}$ represents the Fin-Tech development for city m, where company i is located, in year t; Z represents other control variables of enterprise-specific characteristics and city-level characteristics, including enterprise size, Debt ratio (Lev), enterprise growth, capital expenditure ratio (Capex), fixed assets ratio (PPE), board independence (Indep), urban GDP, urban population, etc.; δ_i refers to the company's individual fixed effect. Since the company's individual fixed effect will absorb the regional fixed effect, this paper essentially also controls the regional fixed effect; $\theta_{j,t}$ represents unobservable factors, where the subscript t represents year, and j represents industry; ϵit represents the random error term. Key independent variable $X_{m,t}$ coefficient β indicates the impact of financial technology development on corporate innovation. According to the research hypothesis of this paper, this coefficient β is expected to be positive and statistically significant.

2.3. Variable Description

(1) Corporate innovation ($Y_{i,t}$). The measurement of corporate innovation can be divided into innovation input measurement and output measurement. The innovation input includes R&D personnel and R&D funds, and the innovation output is mainly the number of patents applied [16, 17], authorized or cited by the enterprise [9, 18]. Because the enterprise R&D expenditure is a trade secret and the data is difficult to obtain, this paper uses the number of patents applied as an indicator to measure innovation. It uses the proportion of total R&D expenditure to sales revenue (R&D / Sales) to test the robustness. The company's number of patents reflects the utilization efficiency of innovation investment and can better reflect the influence of technological innovation [19]. This paper uses natural pairs to measure the innovation of corporations. The number of patent applications of some corporations in the sample may be 0 within a year, and there is an obvious thick tail phenomenon in the distribution of the number of patent applications. Therefore, to avoid the situation where the independent variable of the logarithmic function is 0, this paper uses the method of taking the natural logarithm after adding 1 to the number of patents to measure corporate innovation. According to the detailed rules for implementing China's patent law, enterprise patents can be divided into invention patents, utility model patents, and design patents. An invention patent is the innovation of products and methods, reflects the core competitiveness of corporations, and has the highest technical content. Utility model patents only protect products, mainly for their shape and structure, and as the technical content is relatively low compared with invention patents, they are called "small patents". Design patents focus on the design of product appearance. They do not involve the product's technical performance, so the technical content is the lowest of the three. Therefore, to investigate the impact of the development of financial technology on different types of patents, this paper uses the natural logarithm of enterprise invention patents to measure the innovation of enterprise invention patents (patent1) and uses the natural logarithm of the sum of utility model patents and design patents to measure the innovation of enterprise non-invention patents (patent2).

This paper takes listed companies as the research object. The reasons for choosing listed companies are mainly based on the following considerations: a. there are more than 3,000 listed companies, which are widely distributed in all provinces and cities across the country, covering areas with different levels of financial technology development; b. the financial data is highly reliable after being externally audited; c. its patent application data can be obtained through the announcement of listed companies. This paper collects the enterprise patent information published by baiteng.com, matches it with the list of listed companies, and obtains the application data of various patents from listed companies over the years. For any company renamed during the sample period, the patents under the name of the original company and the patents under the name of its wholly-owned subsidiary are incorporated into the patents of the company in the current year after the rename, but the subsidiaries established across regions are not included in the scope of consolidation.

(2) Fin-Tech ($X_{m,t}$): According to "the 13th Five Year Plan for Science and Technology Innovation of the People's Republic of China", "Big Data Industry Development Plan (2016-2020)", "China Financial Technology Operation Report (2018)" and relevant

important news and conferences, this paper extracts keywords related to financial technology, including big data, third-party payment, cloud computing, Internet finance, block-chain, artificial intelligence, Internet of things, and virtual reality Keywords such as mobile Internet, mobile payment, intelligent investment adviser, etc. These keywords are matched with all prefecture-level cities or municipalities directly under the central government in China to get the total search volume $X_{m,t}$. Due to the significant right deviation of this index distribution, this paper makes a logarithmic transformation on this index to measure the financial science and technology development level of the prefecture-level city or municipality directly under the central government to be used as $X_{m,t}$ indicators.

(3) Firm size (size): enterprise size is an important factor affecting innovation [20]. The larger the scale, the stronger the product production capacity and the higher the reputation usually is. Sustainable development of the enterprise requires it to be more inclined to commit to long-term investment and improve the risk management ability of the enterprise through innovation. This paper selects the logarithm of total assets to measure the size of the company.

(4) Debt ratio (LEV): the asset liability ratio represents the capital structure and solvency of an enterprise and reflects the ability of an enterprise to raise debt. When the leverage faced by corporations is low, continuous R&D investment is more guaranteed to expand the knowledge base through mergers and acquisitions [21], so the innovation ability is stronger. This paper uses the ratio of year-end liabilities to year-end total assets to measure LEV.

(5) Company Growth (Growth): enterprise growth has an important impact on innovation behavior. Corporations with stronger growth usually have greater growth potential. When the investment outlook for innovation projects is not promising, an accurate grasp of market expectations will help mitigate the relevant risks. However, faster-growing corporations are also facing greater financial pressure. This capital pressure is not conducive to funding innovative projects with high risk and long investment cycles. Therefore, the impact of growth on corporate innovation ability cannot be completely determined [22]. This paper uses the growth rate of total assets at the end of the year to measure the growth of corporations.

(6) Capital Expenditure Ratio (Capex): Capex is a concept of increment, usually referring to all expenses that can increase the value of fixed assets. Since fixed assets can reflect corporations' production and technical conditions to a certain extent, the larger the proportion of capital expenditure, the better the production and technical conditions of corporations, and the higher the innovation enthusiasm of corporations. However, the increase in the proportion of capital expenditure improves the existing technology and production conditions of corporations and reduces the demand for new technologies by prolonging the life cycle of existing technologies, contributing to the "inertia" of corporate innovation [23]. Therefore, the impact of the capital expenditure ratio on corporate innovation cannot be completely determined. This paper uses the ratio of the total cash paid for the purchase and construction of fixed assets, intangible assets, and other long-term assets to the enterprise's total assets at the end of the year to measure the proportion of capital expenditure.

(7) Fixed Assets Ratio (PPE): the higher the proportion of fixed assets is, the better the enterprise's production technical conditions and profitability are. At the same time, fixed assets can be used as collateral to improve the financing capacity of corporations and provide more abundant funds for corporate innovation projects [24]. Therefore, the more fixed assets are, the stronger the innovation ability is. This paper uses the ratio of total fixed assets to total assets at the end of the year to measure the ratio of fixed assets.

(8) Independence of the board of directors (Indep): as an important regulatory force in corporate governance, independent directors can make more independent judgments on the company's innovation and other matters when it comes to the company's major decisions. While playing an important role in internal governance, they can better express opinions in line with the interests of small and medium-sized shareholders [25]. Therefore, the higher the independence of the board of directors is, the stronger the innovation ability of the enterprise is. This paper uses the proportion of the number of independent directors to the total number of directors to measure the board of directors' independence.

In addition, the innovation output of corporations is not only the result of unilateral R&D resource investment, but is also closely related to the cities the corporations are based in. Cities with a high economic development level and large population often have rich economic resources and a large number of talented workers. So the conditions for corporate innovation are more abundant. Therefore, this paper also adds the urban level GDP and population to the control variables to control the urban level factors.

3. EMPIRICAL ANALYSIS

3.1. Descriptive statistics

The basic statistical characteristics of the main variables are shown in Table 1. For Patents_R, the median is 0, indicating that most corporations have not applied for patents. The average (Mean) annual number of patent applications is only 3.19, indicating that the company's overall innovation is not strong. This reflects the lack of innovation of most Chinese corporations. The average of the total number of patents is much larger than the median, indicating that patent applications have obvious right

deviation characteristics. Therefore, the method used to calculate the corporate innovation index patent is reasonable for making the logarithmic transformation (Patent = ln(1+Patent_R)). The statistical characteristics of the financial technology measurement index (x)_ R are shown in Table 1. The mean value of X_R is 5303, which is much larger than the median 99, indicating that X_R also has serious right deviation characteristics. Therefore, the method used to calculate financial science and technology development index is also reasonable for X_R.

Table 1. Statistical characteristics of variables

VarName	Obs	Min	Median	Max	Mean	SD
Patent1	23558	0.000	0.000	5.489	0.363	0.701
Patent2	23558	0.000	0.000	5.288	0.519	0.876
Patent	23558	0.000	0.000	6.084	0.705	1.023
Patent_R	23558	0.000	0.000	438.000	3.194	9.189
X	23558	0.000	4.605	15.776	4.546	1.297
X_R	23558	0.000	99.000	7.10e+06	5303.249	1.91e+05
Size	23558	15.452	18.107	21.101	18.107	1.190
LEV	23558	0.033	0.419	0.950	0.425	0.218
Growth	23558	-5.689	0.148	0.856	0.079	0.725
CapEx	23558	0.001	0.164	0.759	0.212	0.186
PPE	23558	0.001	0.113	0.664	0.164	0.159
Indep	23558	0.000	0.000	0.429	0.019	0.080
GDP	23558	15.733	18.338	19.457	18.181	0.977
Population	23558	4.731	6.581	8.120	6.527	0.646

The trend of Fin-Tech development (x) by year and region is shown in Table 2. The results show that with the development of new-generation information technology such as big data, cloud computing, and artificial intelligence, financial technology's development level is increasing year by year. Through the horizontal comparison of different regions at the same time, it can be seen that corporations are more distributed in the eastern region during the sample period. The eastern region has a developed economy and rapid scientific and technological progress, and its financial science and technology development levels are higher than those of the western regions, which are in turn more developed than the central regions, and Guiyang, the "capital of big data", plays a decisive role. The State Council proposed developing strategic emerging industries such as electronics and new generation information technology in Guizhou in 2012. The first national data center was established in Guizhou in 2015. This has greatly improved the overall development level of financial science and technology in the western region.

Table 2. Trends in Fin-Tech

		Year					
Region		2011	2012	2013	2014	2015	2016
East Area	Size	573	581	1625	4072	5330	5330
	Mean	3.627	3.771	3.801	4.309	4.931	5.497
Middle Area	Size	113	110	384	968	1243	1243
	Mean	2.268	3.038	2.789	3.329	3.974	4.280
Western Area	Size	61	60	180	471	607	607
	Mean	3.020	3.244	3.136	3.698	4.451	4.916

3.2. Benchmark regression and instrumental variable regression

The regression results of financial technology development on enterprise invention and non-invention innovation and the total innovation are shown in Table 3. Control variables at the enterprise and city levels are added to each column of regression. The development level of financial technology varies from city to city, and the correlation between corporations in the same city is high. Therefore, we use the urban clustering effect to correct the standard error in the regression model.

Table 3 shows that the coefficient of Fin-Tech is significantly positive in the three regressions, indicating that the Fin-Tech development index constructed in this paper demonstrates a significant positive correlation with the innovation output of the listed companies. In the economic sense, taking column (1) as an example, the average value of Patent_R without logarithm is 3.19; that is, for every 1% increase in the city's financial technology development level, the average number of patent applications of local corporations will increase by about 0.17 (3.19 × 0.0543=0.17). This is because the development of financial technology uses big data technology to reduce the information asymmetry between banks and corporations, improve the speed of credit approval, enable financial services to be accurately located in corporations lacking collateral but possessing innovation potential, and alleviate the shortage of innovation funds. The relationship between the control variables and corporate innovation behavior in the regression results has basically reached the theoretical expectation: the coefficient of enterprise size is positive and reaches the significance level of 1%, indicating that

larger corporations have stronger innovation ability; the coefficient of asset-liability ratio (Lev) is significantly negative at the level of 1%, indicating that debt operation is not conducive to corporate innovation; the two coefficients of board independence (Indep) are significantly positive, indicating that better corporate governance can promote corporate innovation.

As a variable, the development level of regional financial technology is less affected by the innovation behavior of a single enterprise. However, the results will still deviate due to the measurement error of financial technology. This paper uses the instrumental variable method to alleviate this problem. Referring to the methods of [8-10], this paper uses the mean value of the financial technology development level of all neighboring cities in the same year as the instrumental variable. The instrumental variables meet the two constraints of correlation and exogenous: on the one hand, the economic development level of adjacent cities is similar, and the development degree of financial science and technology is similar; on the other hand, due to the regional nature of credit financing, the development level of financial technology in adjacent areas struggles to affect the innovation of local corporations through financing channels. The regression results of instrumental variables are shown in Table 4. After considering the possible problems between Fin-Tech and corporate innovation, the coefficient of Fin-Tech is still positive, indicating that the development of Fin-Tech can significantly promote corporate innovation output, which is completely consistent with the previous results.

Table 3. Benchmark regression

	(1) Patent1	(2) Patent2	(3) Patent
X	0.016*	0.051***	0.054***
	(1.810)	(3.294)	(3.461)
LEV	-0.112***	-0.209***	-0.261***
	(-3.966)	(-5.110)	(-5.473)
Growth	-0.011	-0.001	-0.007
	(-1.565)	(-0.144)	(-0.776)
Size	0.083***	0.079***	0.121***
	(4.198)	(2.735)	(3.308)
Indep	0.188	0.366**	0.448**
	(1.436)	(2.327)	(2.541)
Population	0.001	-0.142	-0.108
	(0.006)	(-0.298)	(-0.231)
CapEx	-0.132	-0.091	-0.127
	(-1.646)	(-1.050)	(-1.318)
PPE	0.222**	0.136	0.272*
	(1.985)	(0.976)	(1.754)
GDP	0.107	0.194	0.218
	(0.666)	(1.187)	(0.838)
_cons	-3.525	-3.561	-5.068
	(-1.117)	(-0.934)	(-0.972)
Year*Industry	Yes	Yes	Yes
N	23558	23558	23558
r2_w	0.074	0.080	0.104

Table 4. Instrumental variable regression

	(1) Patent1	(2) Patent2	(3) Patent
Fin-Tech	0.633**	0.270	0.658*
	(2.108)	(0.790)	(1.668)
Size	0.066***	0.067***	0.099***
	(4.019)	(2.580)	(3.112)
LEV	-0.015	-0.054	-0.058
	(-1.042)	(-1.607)	(-1.603)
Growth	-0.001*	-0.000	-0.001
	(-1.742)	(-1.115)	(-1.603)
CapEx	-0.148	-0.078	-0.131
	(-1.501)	(-0.888)	(-1.181)
PPE	0.247*	0.104	0.264
	(1.946)	(0.757)	(1.597)
Indep	0.193	0.365**	0.458***
	(1.628)	(2.350)	(2.725)
GDP	-0.075	0.165	0.077
	(-0.221)	(0.680)	(0.181)
Population	-0.660	-0.383	-0.749

	(-1.438)	(-0.692)	(-1.178)
Year*Industry	Yes	Yes	Yes
N	23484	23484	23484

3.3. Robustness check

3.3.1. Excluding Corporations That Have Not Applied For Patents

Given that some corporations that have never applied for a patent in the sample period may affect the regression results of this paper, this paper excludes companies with zero patent applications in the sample period to eliminate this interference and to enhance the credibility of these results. The regression results are shown in Table 5. After excluding the corporations that have never applied for patents, the development of financial technology still plays a significant role in promoting the innovation output of corporations. This is consistent with the previous results.

3.3.2. Consider the level of financial development

The regional financial development level will influence the channels for corporations to obtain external financing [26]. The rising level of financial development will increase the number of formal financial institutions, broaden the financing channels of corporations, and alleviate any financing obstacles. In cities with relatively developed financial development, the cost of supervision and approval for corporations to obtain financing is low, which has played a positive role in promoting innovation [27]. Therefore, there is a possibility that the increase of corporate innovation is brought on by an improvement in the regional financial development level, rather than driven by the development of financial technology. In view of this situation, this paper adds the regional financial development level to the control variables and performs a further regression. Factoring in the establishment and cancellation records of bank branches, this paper calculates the number of commercial bank branches in each prefecture-level city each year. It measures the regional financial development level (Branch) with the number of local corporations. The regression results are shown in Table 6. After considering the impact of the regional financial development level, the development of financial science and technology still plays a significant role in promoting the innovation output of corporations, which confirms the reliability of the benchmark regression results mentioned above.

3.3.3. R&D expenditure as the dependent variable

The number of patents applied for by corporations reflects the innovation output level of corporations. However, the effect of financial technology should influence that innovation output by affecting the innovation input of corporations. To further test the innovation effect of financial technology, this paper uses the proportion of total R&D expenditure in sales revenue to replace the measurement index of corporate innovation [28]. The regression results are shown in Table 7. Although many companies do not disclose R&D expenditure data, resulting in a significant reduction in the number of samples, enough data remains available to show that financial technology still has a significant positive impact on corporate innovation. The development of financial technology increases the R&D investment of corporations and subsequently promotes the innovation behavior of corporations. This is consistent with the previous conclusion.

3.3.4. Different Regression Models

Since the number of patents of the listed companies is zero, this paper uses the Tobit model to further test the impact of financial technology development on corporate innovation. To investigate the innovation intention of corporations, this paper constructs a virtual variable according to whether the number of patent applications is zero and uses the logit model to test for robustness. This paper also uses the Poisson model to reinforce the robustness tests. The results of the three regression models are shown in the first three columns of Table 8. After using different regression models, Fin-Tech development is still shown to significantly promote corporate innovation, which is completely consistent with the benchmark regression results.

Since innovation input is also an important factor affecting patent output, this paper adds a corporate innovation input index (measured by the ratio of total R&D expenditure to sales revenue) to the control variable. This paper uses the innovation input index with one lag period because the impact of innovation input on innovation output experiences time lag. The regression results are reported in Table 8. The results show that after excluding the impact of innovation input on patent output, the coefficient of Fin-Tech development is still significantly positive, demonstrating the robustness of the previous results.

Table 5. Robustness test excluding corporations that have never applied for patents

	(1) Patent1	(2) Patent2	(3) Patent
X	0.022*	0.068***	0.073***
	(1.895)	(3.734)	(3.916)
Size	0.162***	0.157***	0.240***
	(5.545)	(3.516)	(4.474)
LEV	-0.216***	-0.404***	-0.503***
	(-4.387)	(-6.208)	(-6.637)
Growth	-0.005	0.002	0.000
	(-0.743)	(0.338)	(0.061)
CapEx	-0.172	-0.072	-0.108
	(-1.198)	(-0.447)	(-0.612)
PPE	0.301	0.146	0.321
	(1.625)	(0.631)	(1.299)
Indep	0.120	0.295	0.337
	(0.638)	(1.437)	(1.411)
GDP	0.195	0.259	0.323
	(0.881)	(1.148)	(0.887)
Population	-0.068	-0.240	-0.246
	(-0.283)	(-0.405)	(-0.455)
Year*Industry	Yes	Yes	Yes
N	15393	15393	15393
r2_w	0.096	0.104	0.137

Table 6. Robustness test considering financial development level

	(1) Patent1	(2) Patent2	(3) Patent
X	0.016*	0.051***	0.054***
	(1.785)	(3.331)	(3.472)
Branch	0.002	0.003	0.003
	(1.036)	(1.325)	(1.177)
Size	0.076***	0.073***	0.111***
	(4.177)	(2.610)	(3.196)
LEV	-0.104***	-0.197***	-0.245***
	(-3.756)	(-5.028)	(-5.329)
Growth	-0.005	0.001	-0.001
	(-1.120)	(0.273)	(-0.219)
CapEx	-0.137*	-0.092	-0.133
	(-1.697)	(-1.071)	(-1.382)
PPE	0.228**	0.135	0.276*
	(2.041)	(0.968)	(1.777)
Indep	0.217	0.388**	0.487**
	(1.517)	(2.377)	(2.584)
GDP	0.126	0.200	0.238
	(0.800)	(1.239)	(0.931)
Population	-0.003	-0.150	-0.117
	(-0.015)	(-0.321)	(-0.256)
Year*Industry	Yes	Yes	Yes
N	23558	23558	23558
r2_w	0.074	0.080	0.104

Table 7. Robustness test considering R&D expenditure

	(1) RD/Sales	(2) RD/Sales	(3) RD/Sales
X	0.831***	0.680**	0.329***
	(3.216)	(2.292)	(3.606)
Size	-2.276***	-1.305**	-2.128***
	(-8.897)	(-2.296)	(-3.422)
LEV	-9.256***	3.959**	5.075**
	(-9.565)	(2.543)	(2.360)
Growth	-2.970***	-2.098***	-1.652***
	(-5.548)	(-4.074)	(-3.551)
CapEx	26.310***	6.086*	4.530
	(11.768)	(1.919)	(1.138)
PPE	-29.962***	-1.235	1.560
	(-10.078)	(-0.369)	(0.387)

Indep	3.118*	0.703	0.718
	(1.670)	(0.624)	(0.654)
GDP	0.680**	8.804***	0.912
	(2.060)	(3.359)	(0.400)
Population	-0.370	1.516	-2.749
	(-1.005)	(0.223)	(-0.397)
Year*Industry	No	No	Yes
N	13977	13977	11666
r2_a	0.141	0.037	0.056
r2_w		0.038	0.061

Table 8. Robustness test based on multiple models

	(1) Logit	(2) Tobit	(3) Poisson
X	0.096***	0.936***	0.107***
	(2.608)	(3.274)	(3.573)
Size	0.385***	3.538***	0.401***
	(22.518)	(13.693)	(11.585)
LEV	-0.762***	-5.308***	-0.428***
	(-7.988)	(-6.166)	(-3.594)
Growth	0.030**	0.359***	0.074**
	(2.029)	(2.980)	(2.573)
CapEx	0.239	1.292	-0.054
	(1.090)	(0.572)	(-0.146)
PPE	0.054	-0.279	-0.054
	(0.231)	(-0.116)	(-0.128)
Indep	1.325***	9.896***	0.598**
	(4.879)	(3.952)	(2.130)
GDP	0.033	3.086	0.688
	(0.040)	(0.625)	(1.354)
Population	-0.053	-0.959	0.014
	(-0.096)	(-0.197)	(0.020)
/:			
var(e.Patent_R)		246.577***	
		(8.013)	
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
city	Yes	Yes	Yes
N	23501	23558	23558
r2_p	0.182	0.054	0.222

3.4. Mechanism Analysis

The previous research shows that the development of financial technology promotes the innovation of corporations, which is reflected in an increase in the number of patent applications and R&D investment. To further explore the mechanism of the impact of financial technology on corporate innovation, this paper examines external financing as a research point, mainly from the two aspects of alleviating financing and improving the use efficiency of external funds.

For most corporations, it is difficult to bridge the financing gap between the cost of R&D activities and the typical limitations of internal funding. Ensuring continuous R&D investment through external financing has thus become an important source of R&D funds [29]. Therefore, when the financing source of corporations is unstable, they tend to limit their investment in new product R&D, which restricts the innovation activities of corporations. Research shows that the more developed the financial market is, the more financing channels can be provided to ease the financing difficulties faced by corporations, allowing corporate innovation to be increased [30]. Financial technology has expanded the coverage of financial services through technical means, increased and improved the external capital supply, and provided more convenient and diversified financing channels for corporations, which all help to promote their innovation output. To investigate whether Fin-Tech has alleviated the inhibitory effects of financing difficulties on corporate innovation, and referring to the indicators adopted in [31], this paper selects six indicators to construct the enterprise financing scoring index: cash ratio, enterprise scale, enterprise life, repayment ratio, net value ratio of fixed assets, and accounts receivable. The steps are as follows: ① according to the values of the above sub-indicators, divide the sample into five equal parts and assign values from high to low; That is, the greater the value of each sub-indicator, the smaller the score given. The higher the score of each sub-index, the worse the financing ability of the enterprise and the higher the degree of financing. ② After calculating the scores of the six sub-indicators of the enterprise, the financing constraint index FC is constructed and standardized.

The research shows that the development of financial technology significantly reduces the degree of financing constraints corporations face. Corporations with high financing constraints often face greater capital constraints for innovation, so innovation output is less. At the same time, the development of financial technology has indeed alleviated the inhibitory effect of financing on corporate innovation output. Through advanced technical means, Fin-Tech has provided diversified financing channels for corporations, thus alleviating the financing difficulties of corporations and further promoting the increase of R&D investment and innovation expenditure.

The existence of information asymmetry makes it challenging for government departments to obtain relevant information about enterprise R&D, so it is difficult to evaluate the advantages and disadvantages of innovation projects [8]. At the same time, government subsidies and tax returns to corporations have an obvious tendency, and corporations that can create a large number of high-tech employment opportunities find it easier to obtain government subsidies [32]. However, the government has limited information when deciding which corporations to grant subsidies and tax returns to, so it is difficult for a large number of corporations with innovation potential to obtain policy preference. Through in-depth mining and analysis of big data, combined with artificial intelligence algorithms, Fin-Tech can quickly generate "portraits" of user behavior characteristics [2] to provide government departments with more information about enterprise operation status and credit risk and effectively identify corporations that both need innovation funds and have more innovation potential, allowing them to funnel more resources to these companies, increase the possibility for corporations to obtain R&D financial support from government departments, and improve overall innovation output.

To further investigate the impact mechanism of financial technology on corporate innovation, this paper divides the funds obtained by corporations from government departments into government subsidies and tax returns. The results show that there is no statistically significant coefficient for the interaction between government subsidies and financial technology. This is mainly because the subsidies provided by the government to corporations may be an inefficient rent-seeking activity between officials and corporations [33], which weakens the efficiency of resource allocation and improves enterprise performance and promotes technological progress. Therefore, Fin-Tech has not played a role in promoting the transformation of government subsidies into innovative output. In areas with high development levels of financial science and technology, the positive impact of government tax returns on corporate innovation is more obvious. The development level of financial science and technology improves the innovation effect of tax returns, which can help the government better identify corporations with innovation ability and provide corresponding policy support.

4. CONCLUSIONS

Using the data of Chinese listed companies, this paper has studied the impact of financial technology development on corporate innovation. The results show that the development of financial technology significantly improves the innovation output of corporations. After the robustness test, this conclusion is still valid. Further research found that the development of financial technology can alleviate the inhibitory effect of financing dilemma on corporate innovation and enhance the innovative effect of the tax return. In addition, the impact of financial technology development on corporate innovation is more obvious in the eastern region and high-tech industry.

The research conclusions of this paper provide the following policy enlightenment for promoting the development of financial technology and accelerating the construction of innovative corporations:

1. The development of financial science and technology has an obvious positive effect on promoting corporate innovation and promoting the sustainable development of the real economy. In the special period when China's economy is changing from extensive rapid growth to high-quality development, we should actively comply with the rapid development of financial science and technology, give sufficient policy support to corporations, and encourage the integration of science and technology and finance. In terms of policies, the government should build diversified financial service formats, realize the accurate connection between finance and corporations, reduce the threshold of enterprise financing services, and give full play to the role of the development of financial technology in improving the efficiency of economic growth and leading the release of new driving forces of economic growth.

2. Traditional financial institutions should actively embrace emerging technology means, efficiently screen corporations, reduce credit risk, and improve the utilization efficiency of funds. Specifically, in the design of financial products, carry out intelligent investment advisory business: in terms of credit management, blockchain technology is used to optimize risk management and increase transaction transparency; in terms of user experience, it provides diversified and high-quality financing channels for corporations.

3. Improve the ability to screen corporate innovation levels. Simply increasing government subsidies and tax rebates will sometimes lead to corporations' "rent-seeking" behavior but inhibit the enthusiasm of enterprise technological innovation. Identifying innovative corporations and helping them better obtain the support of government funds and policies is an important means

for financial technology to promote corporate innovation. Only by actively promoting the development of financial science and technology, improving the efficiency of resource allocation, promoting the high-quality and rapid development of corporations, and stimulating the innovation vitality of corporations can we build a good "ecological environment" for innovation.

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