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Research on the Impact of Fintech on Green Innovation of Enterprises

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Abstract

The study constructed regional fintech development level indicators based on the Baidu search index of fintech keywords in each province, and conducted an empirical analysis using relevant data of A-share listed companies from 2012 to 2021. It is found that the development of fintech significantly promotes corporate green innovation. This finding remains robust after changing the sample interval and the measurement regression, verifying the important role of fintech in promoting corporate green innovation. Meanwhile, the heterogeneity analysis finds that FinTech plays a more significant role in promoting corporate green innovation in the eastern region. Its development not only brings new opportunities for the financial industry in the east, but also provides a steady stream of innovation vitality for the real economy in the east. Continuously promoting the development of fintech and reshaping the ecological pattern of the financial industry is of great significance in stimulating the innovation vitality of the real economy and promoting the construction of an innovative country.

Keywords: Fintech, green innovation, high quality development

1. Introduction

1.1 Research Background and Research Questions

The report of the twentieth Party Congress emphasizes that, in order to promote green development, it is necessary to comprehensively optimize the fiscal, taxation, financial, investment and pricing policy frameworks and standard systems to strengthen support. At the same time, it is necessary to vigorously develop green and low-carbon industries, establish and improve the market-oriented allocation mechanism of resources and environmental factors, accelerate the pace of research and development of energy-saving and carbon-reducing cutting-edge technologies, and widely disseminate the results of their application. In addition, we should actively advocate the concept of green consumption, stimulate the participation of all sectors of society, and jointly promote the construction of a green low-carbon as the core of the production model and lifestyle, and promote the overall green transformation of the economy and society. At a time when China's economic development is facing the gradual loss of the traditional competitive advantages of the manufacturing industry and the dual challenges posed by the ecological environment and climate change, the Outline of the Fourteenth Five-Year Plan and Vision 2035 for National Economic and Social Development of the People's Republic of China explicitly regards the improvement of environmental quality as a crucial task, and emphasizes the construction of a green, low-carbon, and recycling-based economic system through green technological innovation. This strategic choice deeply recognizes that the choice of technological innovation path has a decisive impact on the future direction of the economy, society and ecological environment. If innovation resources can be concentrated and allocated to green technologies, and if the economy can be transformed into a green technology path, it will not only enhance production efficiency and bring significant economic benefits, but also effectively reduce harmful emissions and enhance the overall well-being of society.

The key point of high-quality development, as the core task of comprehensively building a modern socialist country, lies in the high-quality development of enterprises as microeconomic subjects. In this context, enterprise green technology innovation becomes a bridge connecting technology innovation and green development, which is crucial. It not only strengthens the competitiveness of enterprises in the market, but also promotes their positive actions in the field of environmental protection, adding bricks and mortar to reach the goals of "carbon peak" and "carbon neutrality". This win-win strategy is an indispensable driving force for China's economy to move towards green transformation and high-quality development.

In recent years, the government has accelerated the construction and implementation of relevant policy systems to promote enterprise green technology innovation. Among them, the introduction of policies such as the

Implementation Plan on Further Improving the Market-Oriented Green Technology Innovation System (2023-2025) not only draws a clear blueprint and goal for green technology innovation, but also profoundly embodies the central position of the market in resource allocation, and stimulates the enthusiasm of enterprises to increase their investment in green technology research and development by means of market mechanisms. These policies not only point out the direction for enterprises, but also encourage them to prioritize the allocation of resources to green technology with clear signals and expectations, and jointly drive the transformation of the economy to a green technology-driven growth model. In order to realize the goal of "dual carbon" and the vision of building a beautiful China, the green development path has become an inevitable choice. Fintech is a key driving force, and the green transformation of enterprises is the core element of their sustainable development. Exploring the role of fintech in promoting green innovation of enterprises in China has far-reaching theoretical and practical value for accelerating the comprehensive green transformation of the economy and society.

With the rapid development of FinTech and the growing demand for green innovation, it is of great theoretical and practical significance to explore the relationship between the two. This study focuses on the following two core issues:

(1) What are the implications of fintech developments for green innovation in business?

(2) Are there regional differences in the impact of fintech on green innovation?

First, fintech is reshaping the supply of traditional financial services through technological innovation and model change, but its specific mechanism of action on green innovation has not yet been fully explored. Green innovation, as an important way to achieve sustainable development, often faces challenges such as financing constraints and information asymmetry, while FinTech may provide support for corporate green innovation by lowering the financing threshold, optimizing resource allocation and enhancing information transparency. However, whether this impact is universal and the path of action behind it still needs to be studied in depth.

Second, given the significant differences in the level of economic development, financial infrastructure and policy environment across China's regions, the impact of fintech on green innovation may vary from region to region. In regions where FinTech development is more mature, its facilitating effect on corporate green innovation may be more significant; while in less economically developed regions, the role of FinTech may be constrained by other factors. Therefore, exploring regional differences in the impact of fintech on green innovation will not only help to understand the complexity of the relationship between the two, but also provide a basis for the development of differentiated regional policies.

The possible marginal contributions of this paper are: (i) Incorporating FinTech into the analytical framework of corporate innovation expands the understanding of the influencing factors of corporate innovation at the macro level and enriches the existing research on corporate innovation. (ii) Using the panel data of Chinese A-share listed companies from 2012 to 2021, the paper analyzes the impact of fintech on corporate green innovation from the perspectives of financing constraints and corporate profits, and takes into account the impact of policies in the robustness test, which clarifies the internal logic and actual performance of fintech's impact on green technological innovation. (iii) This paper explores the heterogeneous impact of FinTech on corporate green innovation from the regional level, providing insights on how to better use FinTech to optimize the green financial system.

1.2 Literature Review

Currently, academic exploration of the field of corporate green innovation has presented a multi-dimensional and deep-level situation, with the core focus on the far-reaching impact of the three dimensions of corporate intrinsic characteristics, macro external environment and national policy orientation on corporate green innovation activities. At the level of corporate attributes, the study shows that executives with backgrounds in science and engineering, agriculture, and medicine are more inclined to engage in green innovation research and development than their counterparts with backgrounds in liberal arts, business, and law, and that their technological expert attributes have a significant positive driving effect on the promotion of the green innovation process and its efficiency enhancement. In addition, the integration of those with experience in environmental protection into the senior management team can further enhance the catalytic effect of financial technology on green innovation. At the national policy level, Guo et al. show that green credit policies that do not adequately tolerate short-term innovation failures may not only fail to incentivize polluting firms to increase green innovation, but also inhibit their incentives to innovate. At the external environment level, scholars such as Wang J. analyzed the mechanism of environmental regulatory strategy interaction on green innovation, pointed out the existence of market-based and command-based environmental regulatory strategy interaction and its different paths of influence on corporate green innovation, including the phenomenon of bottom-by-bottom and top-by-top competition, and explored the heterogeneity of these influences in different dimensions.

1.3 Theoretical Mechanisms and Hypotheses

In recent years, fintech has made unprecedented leaps in China, relying on the booming platform economy. Emerging Internet financial products based on advanced mobile communication technology, such as Balance, WeChat Wallet, Ant Credit, and Jingdong White Bar, have not only realized the in-depth integration of diversified financial services, such as efficient matching of funds, innovation of the payment system, intelligent monitoring of the credit system, personalized wealth management recommendations, accurate asset allocation and risk management, but also fundamentally reshaped the ecological pattern and business model of the financial industry, leading to a profound financial transformation. Fintech has led a profound financial transformation. As a product of the in-depth integration of big data, cloud computing and other cutting-edge technologies, financial technology has demonstrated excellent data mining capabilities and unprecedented information processing efficiency. Compared with traditional financial technology, it relies more on in-depth analysis of data and accurate prediction of future trends, providing solid data support and forward-looking insights for financing decisions.

1. Mitigating information asymmetries and improving financing conditions

Fintech reduces the information asymmetry between financial institutions and enterprises by analyzing their financial data, operating conditions and market performance in real time. While traditional financial institutions often rely on static financial indicators and limited operational information when assessing corporate credit risk, FinTech is able to dynamically collect and analyze multi-dimensional data, including a company's environmental performance, technological innovation capability, and market outlook. Through intelligent risk control models and credit scoring systems, financial institutions can more accurately assess an enterprise's green innovation potential, thereby reducing credit risk. This improved information transparency not only reduces the concerns of financial institutions, but also significantly lowers the cost of financing for enterprises, shortens the financing approval cycle, and provides more abundant and timely financial support for enterprises' green innovation.

2. Optimizing the allocation of resources and lowering financing thresholds

Green innovation projects are usually characterized by large-scale investment, long payback cycles and high technological risks, which makes traditional financial institutions often cautious in providing financing support. Fintech provides professional technology assessment and risk analysis services to financial institutions through the establishment of a science and technology expert pool. The science and technology expert pool consists of industry experts, technical consultants and scientific research institutions, which can comprehensively assess the technological innovation ability, market prospects and environmental impact of enterprises, and provide a scientific basis for the credit decision-making of financial institutions. This specialized service model not only improves the recognition of green innovation projects by financial institutions, but also lowers the financing threshold of enterprises and incentivizes them to increase their investment in green technology research and development.

The role of financial technology in promoting green innovation and enterprise innovation has received widespread attention. Tan Changchun et al. showed that fintech improves the allocation efficiency of green credit and promotes the supply of green credit "ex ante", and improves the efficiency of green investment through supervision "ex post". Yin Hongying studied the effect of smart manufacturing on the innovation behavior of enterprises and its mechanism. It is found that the promotion of intelligent manufacturing significantly improves the innovation level of enterprises through three paths: information channel, human capital channel and capital channel, and provides new power for the high-quality development of enterprises. Based on the modernization and development needs of industrial chain and supply chain, Wuwei et al. examined the policy effect of government procurement to support the innovation of "specialized, special and new" small and medium-sized enterprises (SMEs). It is found that government procurement can significantly promote the substantive and strategic innovation of "specialized, special and new" SMEs, and the policy mechanism is mainly manifested in enhancing the efficiency of expansion and development and reducing the risk of non-compliance. Moreover, participation in e-commerce platforms also significantly improves the innovation level of manufacturing enterprises.

The role of fintech in promoting green innovation may also vary by region. The role of fintech in promoting green innovation is more significant in the eastern region, mainly due to the advantages of the eastern region in terms of the level of development of fintech, the demand of enterprises, policy support, financial ecological environment and technology spillover effect. First of all, the eastern region has a more complete financial infrastructure and higher digitalization level, which provides good conditions for the application of fintech; secondly, enterprises in the eastern region have a more urgent demand for green innovation, and fintech can better satisfy their financial needs through efficient financing and accurate risk assessment; in addition, local governments in the eastern region have stronger policy support, and green financial pilot projects and Special policies provide a guarantee for the

combination of fintech and green innovation; at the same time, the mature financial ecosystem and diversified capital market in the eastern region further promote the application of fintech in green innovation; finally, the eastern region, as a scientific and technological innovation highland, has a significant technological spillover effect, and fintech has accelerated the research and development and popularization of green technology through the cooperation with high-tech enterprises and scientific research institutions. Therefore, FinTech can more effectively promote enterprise green innovation in the eastern region.

Based on the above theoretical analysis, this paper proposes the following research hypotheses:

H1: Fintech can promote green innovation in business.

H2: Fintech's contribution to green innovation is more pronounced in the East.

2. Data, Models and Variables

This paper uses the Baidu search index of fintech keywords in each province, classifies them and then assigns weights to the keyword search index by entropy value method to construct the regional fintech development level index. The use of Baidu search index to construct the fintech index is mainly based on its real-time, wide coverage and public perception representation. By selecting keywords from the four dimensions of technology, capital payment, intermediary service model and direct address, and combining the entropy value method for objective weighting, it can comprehensively and dynamically reflect the development level and trend of regional fintech. The Baidu Search Index not only captures public attention and market demand for FinTech, but also provides segmented data at the regional level, providing a scientific basis for studying regional differences in FinTech development. And the empirical analysis of the impact of FinTech on green innovation was conducted by using the relevant data of A-share listed companies from 2012 to 2021. And the impact of fintech on green innovation of enterprises is further verified by changing the sample interval and conducting robustness test by econometric regression. Heterogeneity is also analyzed in terms of the district to which the enterprises belong. These studies provide certain reference significance for improving the green financial system, stimulating the vitality of green innovation of enterprises, helping to achieve the "double carbon" goal and promoting high-quality development.

2.1 Data Sources and Data Processing

This study focuses on the financial performance and green innovation of A-share listed companies during the period from 2012 to 2021, and the research sample set was constructed through a systematic data collection and screening process. In the sample screening stage, firstly, listed companies labeled ST and *ST during this period were excluded to ensure the financial robustness of the sample; secondly, company records with missing or obviously abnormal financial data were excluded to safeguard the validity and reliability of the data. After the above rigorous screening, a sample dataset containing 14,940 observations was finalized.

The financial data of listed enterprises adopted in this study are mainly derived from economic and financial databases - CSMAR database and WIND database. In addition, in order to explore in-depth the green innovation capability of listed companies, this study additionally obtains green patent data from the CNRDS database, which provides an important basis for analyzing the environmental technology innovation activities of companies.

2.2 Model Construction

In order to examine the impact of FinTech on corporate green innovation, this paper constructs the following model with reference to the research of Li Chuntao (2020) and others:

$$\mathrm{Grein}_{i,t} = \alpha + \beta \mathrm{Fin}_{m,t} + \gamma X + \delta_i + \theta_{t,j} + \varepsilon_{i,t}$$

where $\mathrm{Grein}_{i,t}$ denotes the green innovation level of firm i in year t, $\mathrm{Fin}_{m,t}$ denotes the FinTech index of city m in year t, X denotes the firm's individual characteristic control variables, δ_i denotes the firm-level individual fixed effects, $\theta_{t,j}$ denotes the firm-level time fixed effects, and $\varepsilon_{i,t}$ denotes the random error term.

2.3 Key Variable Metrics

(1) Level of green innovation in enterprises.

The existing literature mainly measures innovation from the perspectives of innovation inputs, patent outputs and new product sales revenues. In terms of green innovation, the existing literature mainly adopts the number of green patent applications to measure. Therefore, this paper uses the number of green patent applications to measure the level of green innovation. Considering that the annual value of green patents of enterprises is zero and there is a right-skewed distribution, this paper takes the natural logarithm of the number of green patent applications after adding 1 to get the level of green innovation of enterprises. In order to explore the role of financial technology on different types of green innovation, this paper divides green patents into green invention patents and green utility

model patents, and takes the natural logarithm of the number of green patent applications after adding 1 to get the innovation level of green invention patents and green utility model patents, respectively. The patents under the name of each company and the patents under the name of its subsidiaries are combined and counted as the patents of the head office in the year.

(2) Level of Development of Financial Technology.

This paper compiles the Baidu search index of FinTech-related keywords in each province from 2012 to 2021 and summarizes it into FinTech index. The construction method of fintech level index refers to the construction method of Sheng Tianxiang, Fan never. First, several major categories of keywords closely related to the field of fintech are clarified. From the perspective of technology, the keywords include "big data", "cloud computing", "artificial intelligence", "blockchain" and "biotechnology". In terms of technology, the keywords include "big data", "cloud computing", "artificial intelligence", "blockchain" and "biometrics"; in the dimension of capital payment, they include "online payment", "mobile payment" and "third-party payment"; and "third-party payment". In the dimension of fund payment, it includes "online payment", "mobile payment" and "third-party payment"; in the intermediary service model of fintech, the keywords are "online loan", "online financing", "network financing ", "online microfinance", "online loan", "Internet banking", "Internet banking ", "e-banking", "online banking", "open banking", "internet banking "Internet banking", "Internet banking", "e-banking", "online banking", "open banking", "Internet banking" and "direct marketing banking"; finally, the terms that directly refer to fintech are "Internet finance" and "fintech". The search index data for all of the above keywords were then comprehensively collected through the Baidu search platform. After the collection, the search indexes were categorized and summarized according to four different perspectives: technology, capital payment, intermediary service model and direct address. In order to comprehensively assess the overall heat and attention in the field of financial technology, the entropy value method, an objective assignment method, will be used to assign weights to the keyword search index under each perspective. The entropy value method can effectively deal with the uncertainty in the data and determine the weight of each index according to the amount of information it provides, thus avoiding the bias caused by subjective judgment. Ultimately, the weights calculated by the entropy value method will be weighted to synthesize the search indexes under different perspectives into a comprehensive index. This composite index will comprehensively reflect the overall development status and trend of the FinTech field in terms of technology, capital payment, intermediary service model and public perception.

2.4 Other Control Variables

(1) Company Size

Firm size is an important factor influencing innovation. Larger firms usually have stronger product production capacity and higher reputation, and they are more inclined to make long-term investments for the sake of sustainable development of their firms and to improve their risk management capabilities through innovation and other means. In this paper, the logarithm of total assets is chosen to be used as a measure of firm size.

(2) Gearing Ratio

The gearing ratio reflects the capital structure and solvency of an enterprise, reflecting its ability to raise debt to operate. When firms have lower leverage, they are able to invest more securely and continuously in research and development, and are thus more capable of expanding their knowledge base through mergers and acquisitions, etc., and therefore exhibit greater innovative capacity. In this paper, the ratio of year-end liabilities to year-end total assets is used to measure gearing.

(3) Business Growth Capacity

Firm growth has a significant impact on innovation behavior. In general, firms with higher growth have greater growth potential, which allows them to cope with the risks associated with their innovation projects when they are challenged by the market and still have good market expectations. However, fast-growing firms also tend to face greater financial pressures, which may prevent them from advancing risky innovation projects with longer investment cycles. Therefore, the impact of firm growth on its innovation capability is not static. In this paper, we adopt the growth rate of operating income as an indicator of firm growth.

(4) Fixed Assets Ratio

The higher the proportion of fixed assets, the better the technical conditions of production and the stronger the profitability of the enterprise. At the same time, fixed assets can also be used as collateral to improve the enterprise's financing ability, providing more abundant funds for the enterprise's innovation projects. Therefore, the more fixed assets an enterprise has, the stronger its innovation ability is. This paper uses total fixed assets over total assets at the end of the year to measure the fixed asset ratio.

(5) Independence of the Board of Directors

As an important supervisory force in corporate governance, independent directors are able to make more independent judgments on matters such as corporate innovation when it comes to major decisions of the company, and are better able to express neutral opinions that are in line with the interests of small and medium-sized shareholders while playing an important internal governance role. Therefore, the higher the independence of the board of directors, the stronger the innovation ability of the enterprise. In this paper, we use the ratio of the number of independent directors to the total number of board members to measure board independence.

(6) Corporate Cash Flow

As the blood of an enterprise's operation, enterprise cash flow plays a crucial role in supporting innovation activities. Sufficient operating cash flow can provide a stable resource base for enterprises, enabling them to make decisions and execute more freely in innovation areas such as R&D investment, technology upgrading and market exploration, thus promoting the continuous improvement of innovation capability. The health of operating cash flow not only guarantees the smooth implementation of innovation projects, but also indirectly promotes the innovation vitality and long-term competitiveness of enterprises by reducing financing pressure and enhancing market adaptability. In this paper, we use the ratio of operating cash flow value to total assets to measure corporate cash flow.

(7) Corporate Profitability

Enterprises with high profitability have more abundant capital reserves and stronger financial resilience, which can not only provide stable financial support for R&D activities and reduce the risk of interruption due to shortage of funds, but also inspire enterprises to increase investment in technological innovation and product upgrading. High profitability means that enterprises are better able to withstand market fluctuations and bear the uncertainty brought by innovation, thus daring to try more forward-looking and disruptive innovation projects. Therefore, the more profitable a firm is, the more innovative it tends to be. In this paper, we use the ratio of year-end net profit to total assets to express corporate profitability.

2.5 Descriptive Statistics

Table 1 shows the descriptive statistics of the main variables of this study. The number of observations is 14940.The mean value of the level of fintech development is 0.331, the minimum value is 0.002, the maximum value is 0.842, and the standard deviation is 0.194. It shows that the level of fintech development is currently high but with obvious variability across China. The mean value of enterprise green invention-based innovation is 0.548, the standard deviation is 0.966, and the range of variation is from 0 to 7.781, showing the popularity and differences of green innovation among enterprises in different regions. The mean value of firms' green utility model innovation is 0.542, with a minimum value of 0 and a maximum value of 6.387. Again, this suggests that there are significant differences in green innovation capabilities among listed firms in China. Subsequent columns of the table briefly summarize other relevant statistics such as firm size, firm age, board independence, etc., which comprehensively reflect the multiple dimensions and characteristics of regional finance.

Table 1. Descriptive statistics for key variables

Stats	Mean	SD	Min	Max.	median
Green Inventive Innovation for Businesses	0.548	0.966	0	7.781	0
Green Utility Model Innovation for Businesses	0.542	0.923	0	6.387	0
Regional level of fintech development	0.331	0.194	0.00202	0.842	0.321
Enterprise size	22.48	1.478	14.94	31.04	22.28
Corporate gearing	0.474	1.522	0.00797	178.3	0.444
Corporate profitability	0.0186	0.457	-30.69	7.445	0.0295
Enterprise growth capacity	2.686	92.43	-48.42	9291	0.127
Corporate cash flow	0.0445	0.0821	-1.686	0.92	0.045
Enterprise fixed assets ratio	0.226	0.174	0	0.937	0.192
Board independence	37.48	5.69	16.67	80	33.33

3. Analysis of Empirical Results

3.1 Benchmark Regression Results

Considering that firms' individual differences and time differences affect firms' green innovation, this section uses a fixed-effects model, controlling for firms' individual effects and time fixed effects, to study the direct impact of FinTech on firms' green innovation in order to verify the theoretical hypotheses. Table 2 shows the regression results, in which the coefficient of fintech development level is always positive and statistically significant. This supports hypothesis H1, which states that fintech can promote corporate green innovation.

According to the idea of stepwise regression, column (1) in Table 2 is the regression result of enterprise green inventive innovation not included in the control variables, and from the empirical analysis results, it can be seen that the coefficient of the impact of fintech on the enterprise green inventive innovation is 0.729, and the regression coefficient is significant at the level of 1%, which indicates that for every one unit of increase in the level of regional development of fintech, the level of the enterprise green inventive innovation will increase by 0.729 unit. Interpreted from the perspective of credit constraint theory: adopting big data technology, fintech can effectively improve the regulatory efficiency of financial institutions and enhance the transparency of market information, thereby reducing the enterprise financing constraints and the cost of credit supply, which in turn enhances the enterprise's green innovation ability. The development of fintech can also help financial institutions manage their loan assets more effectively. In this context, fintech can enhance the capital leverage of financial institutions, thus indirectly promoting the financing of corporate green innovation. In addition, FinTech can help shorten the credit application process and effectively enhance the financing efficiency, thus improving the financing environment for green innovation. Therefore, FinTech can effectively improve the financing environment of enterprise green inventive innovation, thus promoting the development of green innovation.

The effects of control variables such as enterprise size, enterprise years of establishment, enterprise gearing ratio, and enterprise profitability on the green innovation capacity of enterprises are then taken into account. In order to make the results more scientific, the control variables are included in column (3), and the results show that after the inclusion of control variables, the coefficient of fintech on the green innovation ability of enterprises is 0.539, and it is significant at 1% level, which indicates that after the inclusion of control variables, fintech can still promote the enhancement of the green innovation ability of enterprises. From the regression coefficients of control variables, enterprise size has a significant positive effect on the green innovation ability of enterprises, which is because the larger the size of the enterprise, the enterprise will have a stronger green innovation capital, including human capital, physical capital and information capital, which will provide funds, talents and technology to the enterprise's green innovation. In addition, large enterprises have more business management experience and can better grasp the opportunities of green innovation, thus better realizing green innovation.

Meanwhile, Column (2) is analyzed by using enterprise green practical innovation to express enterprise green innovation capacity index, from the empirical analysis results, the coefficient of the impact of financial technology on enterprise green practical innovation is 0.392, and the regression coefficient is significant at 1% level. After adding control variables, the result is column (4), the coefficient of the influence of financial technology on enterprise green practical innovation is 0.229 and significant at 1% level, which indicates that financial technology can still promote the improvement of enterprise green innovation ability after including control variables.

Comparing the results of regression coefficients in columns (1) and (3), it is found that after adding control variables, the promotion effect of financial science and technology on the green innovation ability of enterprises is reduced by 0.19 units, which indicates that the selected control variables are reasonable and have empirical significance, and therefore the benchmark regression results of this study should be based on model (3). In conclusion, from the results of regression coefficients of model (1) and model (3), Fintech has a significant promotion effect on the enhancement of enterprise green innovation, which indicates that the development of Fintech can effectively improve the green innovation ability of enterprises, so the theory should be accepted.

Table 2. Benchmark Regression Results

	(1)	(2)	(3)	(4)
VARIABLES	Green Inventive Innovation for Businesses	Level of green and practical innovation in enterprises	Green Inventive Innovation for Businesses	Green Utility Model Innovation for Businesses
Regional level of fintech	0.729***	0.392***	0.539***	0.229***

development				
Enterprise size			0.204***	0.163***
Corporate gearing			-0.002	-0.001
Corporate profitability			0.003	0.014
Enterprise growth capacity			-0.000	-0.000
Corporate cash flow			-0.068	-0.019
Enterprise fixed assets ratio			0.076	0.155**
Board independence			0.000	0.001
Constant			-4.227***	-3.287***
Observations	14,940	14,740	14,899	14,899
R-squared	0.708	0.686	0.715	0.690
Year fixed effects	be	be	be	be
individual fixed effect	be	be	be	be

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.2 Robustness Tests

(1) Changing the Sample Interval

The time period chosen for the above study is 2012-2021. In 2012, the China Banking Regulatory Commission (CBRC) issued the Green Credit Guidelines, which, as the core of China's green credit policy system, significantly influenced enterprises' green innovation behavior through a series of institutional arrangements. Meanwhile, the implementation of the Green Credit Guidelines has improved the level of corporate environmental information disclosure and reduced information asymmetry, which in turn has enhanced the quality of corporate green innovation. Although there are differences in the impact of the Guidelines on the green innovation of different types of enterprises in the process of implementation, overall, it provides strong policy support and market incentives for enterprises' green innovation, promotes the formation of green and low-carbon production methods and lifestyles, and contributes to the high-quality development of China's economy. However, the policy effect of the Green Credit Guidelines is not immediate, and it takes a certain amount of time to be fully realized. This is because the implementation of the green credit policy involves a number of processes, including the publicity and popularization of the policy, the internal system adjustment of banking institutions, the screening and evaluation of green projects by enterprises, and the issuance and recovery of credit funds, all of which take time to complete. In addition, the construction and operation of green projects tends to have a long cycle, and the realization of their environmental and economic benefits also takes some time to accumulate.

Therefore, the impact of the Green Credit Guidelines in promoting the green transformation of enterprises and facilitating green technological innovation tends to appear gradually within a few years after the implementation of the policy, and gradually strengthens with the passage of time. In summary, taking into account the impact of the Green Credit Guidelines on corporate green innovation and its lag effect, this paper selects the 2013-2021 sample to re-regress, in addition, the level of corporate green innovation will also be affected by the development of the city's economy, for this reason, this paper adds the level of financial development measured by the output value of the financial sector divided by the end of the year GDP to the regression at the city level. And considering that there is a certain correlation between the gender share of management and corporate innovation, the male share of management is also regressed as a control variable. The results are summarized in the table below. It can be seen that the level of regional fintech development in both columns is significantly positive at the 1% level, indicating the reliability of the benchmark regression results.

Table 3. Regression results for changing sample intervals

	(1)	(2)
VARIABLES	Green Inventive Innovation for Businesses	Green Utility Model Innovation for Businesses
Level of regional fintech development	0.445***	0.363***
Enterprise size	0.203***	0.168***
Corporate gearing	-0.003	-0.003
Corporate profitability	0.005	0.013
Enterprise growth capacity	-0.000	-0.000
Corporate cash flow	-0.065	-0.021
Enterprise fixed assets ratio	0.067	0.099
Board independence	0.001	0.002
Percentage of men in management	0.004***	0.004***
Financial sector output GDP	1.100**	-0.822*
Constant	-4.617***	-3.790***
Observations	13,417	13,417
R-squared	0.730	0.701

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(2) Change in Measurement Regression

In order to ensure the robustness of the findings and to avoid bias in the results due to differences in the estimation methods of the different regression models, robustness tests are used in this section. Specifically, the previous findings are verified by changing the measurement regression. Given that the number of patent applications for green technology innovation is discrete non-negative integer-type data, this paper adopts a Poisson distribution model to test the previous conclusions.

The Poisson regression model is particularly well suited to deal with count-type data and can better capture the characteristics of patent filings for green technology innovations. In the model, the impact of FinTech on corporate green innovation is again verified. Through this model, we find that the regression coefficient of the level of regional FinTech development is still significantly positive at the 1% significance level, with a coefficient of 0.640, indicating that the development of FinTech still has a significant positive driving effect on the green invention-based innovation of enterprises.

This result further demonstrates that the role of fintech in driving green innovation remains solid despite the change in the regression, and the positive impact of fintech does not change depending on the model, showing the robustness and consistency of the results.

3.3 Heterogeneity Analysis

In order to test hypothesis H2, this paper analyzes the heterogeneity from the location of the firms' affiliation to further explore the impact of FinTech on firms' green innovation.

In order to explore the impact of different levels of regional economic development, according to China's geographic location, natural conditions, economic foundation, social development level and national development policies and other factors to be considered in a comprehensive manner, with reference to the National Bureau of Statistics division, the creation of provincial and municipal location of the dummy variable: the eastern provinces (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan) assigned to the value of 1. The central provinces (Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan) are assigned a value of 2, the western provinces (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang) are assigned a value of 3, and the northeastern provinces (Liaoning, Jilin, and Heilongjiang) are assigned a value of 4. The results of the heterogeneity regression are presented in Table 4.

Table 4. Heterogeneity Regression Results

	(1)	(2)	(3)	(4)
VARIABLES	Green Inventive Innovation for Businesses	Green Inventive Innovation for Businesses	Green Inventive Innovation for Businesses	Green Inventive Innovation for Businesses
	Eastern provinces	Central provinces	Western provinces	Northeastern provinces
Regional level of fintech development	0.640***	-0.225	0.516**	1.144
Enterprise size	0.194***	0.287***	0.098***	0.147**
Corporate gearing	-0.003	-0.184	0.057**	0.140
Corporate profitability	0.034	-0.178	-0.004	-0.040
Enterprise growth capacity	-0.000**	0.000	0.000	-0.000
Corporate cash flow	-0.112	-0.043	0.045	-0.149
Enterprise fixed assets ratio	0.055	0.362***	-0.065	-0.440*
Board independence	0.001	0.004	0.002	-0.010
Observations	10,142	2,244	2,138	375
R-squared	0.733	0.697	0.699	0.375

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

It can be seen that the level of regional fintech development is significantly positive at the 1% level only in the eastern region, and significantly positive at the 5% level in the western region. This shows that the eastern region has obvious location advantages, strong economic strength, more developed science and technology education, more rapid flow of information, adequate enterprise resources, and the government policy is more encouraging of green innovation, so fintech provides more financing channels and technical support for enterprises, which is conducive to the rapid development of fintech.

The level of FinTech development in the western region also plays a more significant role in corporate green innovation, mainly due to the advantages of FinTech in enhancing resource allocation efficiency, optimizing risk management and promoting green technological innovation. Although the western region is relatively lagging behind in economic development, the state has strongly supported the development of the western region in recent years, and the western region has most of the country's land area, rich in ecological resources, which provides a rich application scenario and experimental field for green innovation. At the same time, the state has implemented a series of ecological protection and governance measures in the western region in recent years, promoting the continuous improvement of the ecological environment, providing a good ecological environment for green innovation. In addition, as an important node of the "Belt and Road" construction, the western region's advantage of openness and cooperation also provides a broad space for international cooperation in green innovation. Empowered by fintech, the western region can better integrate green resources, promote the R&D and application of green technology, and realize the coordinated development of economy and ecology. In the central and northeastern regions, despite the improvement in the level of fintech development, the green innovation of enterprises in these regions may be constrained by imperfections in resources, market demand and policy support, resulting in a less significant impact of fintech.

The positive effect of firm size on green innovation across regions, especially in the central and western regions, can be explained by the fact that large firms have more resources to bear the costs and risks of green technology development, while small and medium-sized enterprises (SMEs) face financial and technological constraints. In addition, the positive effect of firms' gearing ratio on green innovation in the western region suggests that firms with higher debt may be able to obtain policy support or reduce environmental risks by introducing green technologies. In contrast, the negative effect of fixed asset weight in the Northeast region may stem from the fact that excessive fixed asset weight restricts the liquidity of firms and the flexibility of innovation investment, which hinders the development of green innovation. These results reflect the differences in the economic environment, firm characteristics and policy support in promoting green innovation among firms in different regions.

4. Conclusions and Recommendations

4.1 Conclusion

Promoting the greening and decarbonization of economic and social development is a key part of achieving high-quality development, improving the fiscal, taxation, financial, investment and pricing policies and standard systems that support green development, and developing green and low-carbon industries. Fintech is a new financial development model relying on the deep integration and development of emerging technologies such as big data, blockchain, artificial intelligence and cloud computing with the financial industry, the development of fintech not only promotes the improvement of the efficiency of financial services, but also changes the consumer behavior, provides the market with better quality of financial services and the efficiency of the allocation of financial resources, and the development of fintech will inevitably have a big impact on the production activities of the enterprise and the The development of FinTech will inevitably have a big impact on the production activities of enterprises and green innovation activities, especially in the context of the national policy of vigorously developing the green economy. Based on the new perspective of financial technology and green innovation, this study discusses the research on the impact mechanism of financial technology on enterprises' green innovation.

The research object is to select the data related to A-share listed enterprises from 2012 to 2021, collect the keywords related to financial technology, and use the entropy value method to assign weights to the keyword search index, weighted and synthesized into a comprehensive index, so as to measure the financial technology development index. In addition, the data related to listed enterprises were matched with green innovation and enterprise-related data, and finally a research sample of 14,940 listed companies was obtained. Using the fixed effect model, the impact and mechanism of fintech on the green innovation of the company are explored, and based on the perspective of the differences in the environment where the enterprises are located, the promotion effect of fintech on the green innovation of the enterprises is discussed from the perspective of the heterogeneity of the location to which the enterprises belong, and the following conclusions are mainly drawn. First, FinTech has a significant positive promotion effect on the green innovation ability of enterprises, and the conclusion still holds after the robustness test. Second, in the heterogeneity test, the effect of fintech on enterprise green innovation is more significant in enterprises in the eastern region, indicating that China pays more attention to economically developed regions and key industries, and fintech is better able to play its enabling role. Fintech significantly improves the performance of enterprises in green innovation by alleviating credit constraints, enhancing corporate social responsibility, and optimizing equity check and balance mechanisms. The optimization of these mechanisms not only provides enterprises with more financial support, but also incentivizes their investment in environmental protection and sustainable development, thus promoting the progress of green innovation.

4.2 Recommendations

In order to better highlight the supportive role of financial science and technology on enterprise green innovation, promote the green transformation of China's enterprises, and ultimately realize the green and low-carbon development of China, this paper puts forward the following suggestions:

First, from the government level, at present, the development of financial technology in China is in a period of rapid growth, while there are gaps in relevant guiding policies and a lack of specific guidelines for financial technology to support green finance. A relevant legal normative system matching the development process of realizing green transformation of the economy should be established and improved, focusing on key areas without neglecting other industries, guiding the orderly development of the FinTech system, and providing a solid foundation for empowering green finance. In addition, legislators should be actively encouraged to cooperate effectively with relevant law enforcement and regulatory authorities to establish a legal mechanism for "multi-party collaborative governance".

Secondly, at the enterprise level, the realization of economic benefits from green transformation and development and the social benefits of assuming responsibility for environmental protection should be regarded as the potential driving force for the ultimate profitability of enterprises. Financial institutions represented by banks can fully utilize technologies such as big data, cloud computing and artificial intelligence to reduce difficulties in the green credit review process and ease corporate financing constraints. Large enterprises should play a leading role in green transformation, leading the upstream and downstream of the industrial chain to utilize financial and technological means to carry out green innovation and realize the green transformation of enterprises. Enterprise managers, as the main responsible persons for enterprise green transformation, should learn and develop new thinking and new concepts adapted to the new environment and new needs, create a green enterprise culture, and at the same time cultivate capable cross-field talents with high skills and professional qualities.

Furthermore, at the academic level, an expert group on green low-carbon international standards and a group of high-tech talents should be cultivated on the basis of the requirements of international technical conventions and regulations, so as to promote the synchronization of China's work related to green low-carbon transformation with international standards, achieve the goal of sustainable development based on green innovation, and gradually eliminate the green barriers of developed countries.

Finally, from the regulatory level, it is necessary to create an inclusive and prudent regulatory mechanism for fintech innovation and build a healthy ecology for fintech application. On the one hand, the regulatory rules as the core, standardize the development path of fintech and clarify its enabling position. Timely introduction of targeted regulatory rules to prevent the risk of regulatory arbitrage brought about by the derivation and generalization of fintech. On the other hand, on the basis of risk prevention, we should balance the relationship between safety and efficiency, tolerate orderly and reasonable innovation of fintech, create a favorable environment for the development of fintech, and ultimately form a "fintech regulatory framework that meets China's national conditions with innovative regulatory tools, regulatory rules as the core, and digital regulation as the means".

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