

The Impact of Regional Green Finance Development Level on Green Total Factor Productivity of Enterprises: An Empirical Study Based on A-Share Listed Companies

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Abstract. This paper uses the data of Chinese A-share listed companies from 2009 to 2021 to explore the impact of green finance development on the green total factor productivity performance of enterprises. The research finds that the regional green finance development level improves the green total factor productivity of enterprises by guiding them to enhance their green technological progress. The above results have conditional heterogeneity, and the administrative regulation level and market regulation level of regional governments have different moderating effects on the improvement of enterprise green total factor productivity. The mechanism analysis shows that regional green finance development affects the green total factor productivity level of enterprises by promoting their green technological progress. The impact of green finance on enterprises with different characteristics varies. Enterprises located in the eastern region are more likely to be affected by regional green finance development. Labor-intensive and technology-intensive enterprises are both significantly affected. Private and foreign-funded enterprises are more significantly affected than state-owned enterprises. Further inter-group difference analysis reveals that labor-intensive enterprises and private enterprises are more likely to be affected by green finance development. The policy implications of the research conclusions of this paper are as follows: It is necessary to further improve the green credit policy system, pay attention to the impact of government behavior on the implementation effect of policies, and strengthen the amplification effect of market-based regulations mainly based on environmental taxes. At the same time, it is necessary to focus on cultivating the internal environmental governance awareness of enterprises, promote the green coordinated development of different types of enterprises, improve resource allocation in both stock and flow aspects, promote the transformation and upgrading of enterprises, and the green coordinated development of society.

Keywords: Regional Green Financial Development Level; Enterprise Green Total Factor Productivity; Enterprise Innovation; Administrative Regulation; Market Regulation.

1. Introduction and Literature Review

The modern economy is a market economy, and at its core, a market economy is a highly developed monetary credit economy or financial economy. Finance is the heart of the modern economy and plays a crucial role in its development. On the one hand, high-quality financial development can better serve the real economy, providing enterprises with high-quality, high-efficiency, and safer financial services and stimulating new growth drivers for the real economy. On the other hand, high-quality financial development helps optimize the allocation of financial resources, improve the efficiency of their use, and ensure that financial resources flow more rationally to efficient sectors. Moreover, high-quality financial development helps prevent and defuse financial risks, ensuring the safe and stable operation of the financial system and providing a stable financial environment for high-quality economic development. Therefore, how to guide financial institutions and enterprises to assume more environmental and social responsibilities through institutional innovation while promoting economic development is a key issue in balancing resource allocation efficiency and achieving high-quality development through green business operations.

The essence of financial resources promoting the green development of enterprises lies in whether market mechanisms can be used to guide funds towards green and low-carbon sectors, optimize resource allocation, and encourage enterprises to carry out green technological innovation and

industrial transformation and upgrading. Under the traditional financial framework, enterprises' efforts to reduce pollution emissions often conflict with maximizing profits. Green finance, as economic activities that support environmental improvement, address climate change and promote the efficient and sustainable use of resources, can more effectively address the externalities of environmental projects, internalize the positive externalities of enterprises' assumption of green development responsibilities, and vice versa. This, in turn, incentivizes financial institutions and enterprises to assume more social responsibilities and pursue green and high-quality development. Therefore, exploring whether green finance can have a practical impact on enterprise behavior, analyzing the regulatory effect of government actions on green finance policies, and clarifying the specific channels through which green finance influences the high-quality development of enterprises are the main contents of assessing the micro-effects of green finance and also important evidence for examining the impact of macro-resource allocation on enterprise behavior.

Based on the research questions, two pieces of literature are closely related to this paper's research. The first literature studies the micro-effects of green credit from different subjects' perspectives [1]. For financial institutions dominated by banks, green credit represents green financial policies, which can help break through the dilemma zone of the environmental Kuznets curve. Green credit policies can enhance banks' profitability and intermediary business level to improve innovation efficiency, reputation value, and competition in the banking industry, all of which show a significant positive regulatory effect [2]. For enterprises, green finance guides "high-energy-consuming and high-pollution" enterprises to exit the market and encourages incumbent enterprises to reduce pollution emissions, improve investment efficiency, and choose innovative development strategies [3]. The second literature analyzes and examines the primary mechanisms by which green credit affects enterprise behavior. The first type of mechanism focuses on the resource allocation channels of green finance, which can be divided explicitly into financing constraints and investment penalty effects [4]. That is, green credit can simultaneously increase the financing costs of heavily polluting enterprises and reduce their investment levels. By increasing the direct costs of enterprises, enterprises force enterprises to carry out green innovation and improve production efficiency. The second type of mechanism is the "information effect." Under the condition of the same capital price, green credit promotes investment in green projects by establishing identification standards and guides enterprises to green development by increasing the opportunity cost of enterprises.

The existing literature has laid a good foundation for studying the micro-effects of green credit policies. However, there are still several shortcomings: 1) In terms of research perspectives, existing studies mainly focus on the impact of green financial development on macroeconomic development from a macro perspective, such as the impact of green financial development on GDP. 2) The analysis of the effect of government policies is insufficient. The moderating effect, which is not used frequently in existing literature, reflects the effect differences of different policy means. 3) The heterogeneity analysis is not deep enough. Most literature analyzes whether the explanatory variables are significant under different conditions without conducting inter-group difference analysis.

In conclusion, the possible marginal contributions of this paper mainly lie in: 1) From the perspective of enterprises, studying the impact of green finance on economic development, enriching the research perspective of the micro-effects of green financial policies, and increasing the mechanism channels for enterprises to undertake environmental responsibility governance, social responsibility governance, and corporate governance. 2) This paper analyzes and uses the moderating effect to analyze the impact of administrative and market regulation on the effectiveness of green financial policies. 3) Analyzing the differences in the implementation effects of green financial policies from the perspectives of enterprise ownership, the proportion of enterprise production factors, and geographical location, which is conducive to providing appropriate high-quality development suggestions for different types of enterprises and further improving the green financial system.

2. Theoretical Analysis and Research Hypotheses

2.1 The Level of Regional Green Finance Development and Enterprise Green Total Factor Productivity

Green finance provides financial support for green technological innovation, encouraging enterprises to increase their R&D efforts and introduce more advanced production technologies and processes. This not only enhances the production efficiency of enterprises but also reduces resource consumption and environmental pollution, thereby improving the green total factor productivity of enterprises. Technological innovation is an important driving force for the high-quality development of enterprises, and green finance is a powerful guarantee for this driving force; green finance policies guide financial institutions to invest funds in green industries and environmental protection projects, reducing the financing difficulty and costs of related enterprises and projects. This resource allocation optimization enables funds to flow more efficiently to high-potential and high-efficiency enterprises, promoting these enterprises to expand production scale and improve technical levels, thereby enhancing green total factor productivity [1]. At the same time, green finance also promotes the transfer of resources from inefficient and highly polluting enterprises to high-efficiency and low-polluting enterprises through market mechanisms and policy guidance [5]; green finance policies often come with strict environmental regulatory measures, exerting pressure on polluting enterprises and forcing them to improve production processes and reduce emissions. This external pressure can be transformed into an internal driving force for enterprises to improve technology and enhance efficiency. At the same time, green finance also encourages enterprises to adopt more environmentally friendly production methods through policy incentives, such as tax exemptions and subsidies, to improve resource utilization efficiency and thereby enhance green total factor productivity; the development of green finance helps to promote the optimization and upgrading of regional industrial structures. With the in-depth implementation of green finance policies, those traditional industries with high pollution and high energy consumption will gradually be restricted and eliminated, while green, environmentally friendly, and efficient emerging industries will have more development opportunities. This process of industrial upgrading and transformation will be accompanied by the improvement of green total factor productivity of enterprises; enterprises actively participating in green finance activities can often establish a good environmental image, enhancing the trust of consumers and investors. This positive image helps enhance enterprises' market competitiveness, attracting more high-quality customers and partners. At the same time, green finance policies encourage enterprises to disclose environmental information and improve transparency, which also helps enterprises strengthen internal management and enhance operational efficiency. Thus, this paper proposes:

Hypothesis 1: The green total factor productivity of enterprises will increase as the level of green finance development improves.

2.2 The Regulatory Mechanism of Green Finance on the Green Total Factor Productivity of Enterprises

China has been actively promoting the "dual carbon" initiative in recent years, and green finance has witnessed vigorous development. However, specific problems in China's policy system and market environment affect the initiative and enthusiasm of various market entities to participate in green finance activities, thereby influencing the effectiveness of green finance policies. The government, through formulating green finance policies, guides financial institutions to invest funds in green industries and projects, thereby promoting enterprises' green transformation and improving green total factor productivity. At the same time, the government can also use environmental regulations and other means to restrain and punish polluting enterprises, forcing them to carry out technological innovation and green upgrading. These policy regulatory means have played an important regulatory role in the development of green finance [6]. Environmental tax and other environmental regulatory means are important to promote economic green transformation, and their

regulatory effect on the impact of environmental tax on the green total factor productivity of enterprises deserves in-depth discussion. Environmental tax and other environmental regulatory means indirectly promote the development of green finance and the improvement of green total factor productivity of enterprises by increasing the costs of polluting enterprises and forcing them to reduce pollution emissions and carry out green upgrading [7]. "Porter's Hypothesis" (Porter, 1991; Porter & Van der Linde, 1995) holds that if appropriately designed, environmental regulations (predominantly market-based tools) can achieve "innovation compensation." Market-based regulatory tools, such as emission taxes, tradable quotas, or performance standards, are more conducive to innovation than technical standards, mainly because these regulatory tools are more flexible, leaving more space for companies to solve technical problems, which helps to reduce the compliance costs of enterprises. Secondly, environmental regulations reduce the uncertainty of the value of environmental investment for enterprises and affect their expectations, driving enterprises to innovate in the environmental field [6]. At the same time, environmental tax can provide green fiscal revenue for the government to support the development of green industries and projects. These environmental regulatory means have played an important regulatory role in the development of green finance. **Hypothesis 2: The effect of green finance on the green total factor productivity of enterprises exhibits a threshold effect related to administrative regulations and environmental regulations.**

2.3 The Mediating Mechanism of Green Finance on the Impact of Green Total Factor Productivity of Enterprises

Under the background of the carbon neutrality strategy, how green finance can assist enterprises in green innovation and promote social transformation has become a key issue. Li Rong and Liu Lucheng believe that green finance can promote enterprise green innovation by increasing the proportion of long-term loans and improving the debt structure of enterprises [8].

Furthermore, green finance can also provide diversified financing channels and preferential conditions for enterprises' green technological innovation through a series of policies and services, such as green credit, green bonds, and green funds. These policies and services not only reduce the financing costs of enterprises but also improve the efficiency of fund utilization, enabling enterprises to focus more on the research and application of green technologies. Zhang Xueying et al. believe that after a company issues green bonds, its green innovation ability significantly improves. Green bonds can enhance the company's green innovation ability by alleviating financing constraints and improving information transparency [9]. With the continuous progress and application of green technologies, the production processes of enterprises will become more efficient and environmentally friendly, and the efficiency of resource utilization will also be significantly improved. This will be directly reflected in the improvement of enterprises' green total factor productivity, manifested as reduced resource consumption per unit output, lower environmental pollution, and the realization of dual growth in economic and social benefits. This process not only contributes to the sustainable development of enterprises but also helps to promote the green transformation and high-quality development of the entire economy. Thus, Hypothesis 3 is proposed.

Hypothesis 3: The development of green finance can enhance the overall productivity of enterprises by promoting the technological progress of green technologies within them.

3. Research Design

3.1 Data Sources and Data Processing

This paper takes A-share listed companies from 2006 to 2020 as the research sample. The data sources mainly include the following parts: 1) Data of listed companies. Basic information, financial statements, and profit forecasts of all listed companies were obtained from the China Research Data Service Platform (CNRDS), and relevant indicators such as control variables were calculated. The listed company data were processed as follows: enterprises with ST, PT, or *ST status during the sample period were excluded; data of financial and real estate enterprises were excluded; data of

companies with an asset-liability ratio greater than 1 were excluded; and data with severe missingness in financial data or other indicators were excluded. To avoid the influence of outliers, bilateral truncation was performed on all control variables at the 1st and 99th percentiles. Other data mainly came from the China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, China Labor Statistical Yearbook, provincial statistical yearbooks, and the China Insurance Yearbook.

Green Total Factor Productivity (GTFP): This paper refers to the method of scholars Yin Zibiao et al. [17], using 2014 as the base period, and adopting the non-radial and non-angular SBM model. **Green Finance (GI):** This paper draws on the methods of scholars Guo Xiyu [12], Shi Daimin, and Shi Xiaoyan [16] to construct the method for green finance indicators in 30 provinces of China (excluding the Tibet Autonomous Region, Hong Kong, Macao, and Taiwan regions), and calculates them using the entropy method.

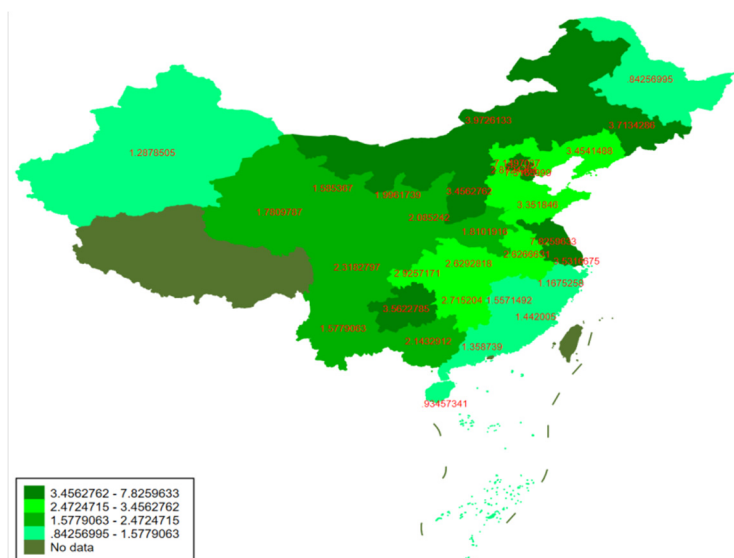


Fig 1. Spatial Difference Map of Regional Green Total Factor Productivity

The above figure shows the spatial differences in the development level of regional green total factor productivity in China in 2020. From the figure, it can be seen that the regional green total factor productivity indicators of national central cities such as Beijing and Shanghai have reached above 7, and a spatial driving trend like a contour line is formed around these two cities. Yao Lu believes that generally speaking, "local" financial agglomeration can promote the flow of funds, talents and technologies to the "adjacent areas", thereby promoting the improvement of green total factor productivity in the surrounding adjacent regions [7]. The green total factor productivity development level of coastal cities along the Bohai Sea is generally high. This may be because, on the one hand, technological progress advantages: the main source of growth in the green total factor productivity of coastal areas is technological progress [15]. These regions have developed economies and high R&D investment, which is conducive to promoting environmental technological progress and the growth of high-tech industries. On the other hand, there are industrial advantages: coastal areas have advantages over inland areas that are incomparable in terms of national trade, FDI (foreign direct investment), and intangible technologies with technological spillover effects. This also helps to improve the green total factor productivity. In addition, coastal areas have stronger environmental regulations, which to a certain extent prompts enterprises to strengthen technological innovation and management innovation to improve the green total factor productivity and adapt to environmental protection requirements.

3.2 Model Construction

In order to conduct a comprehensive exploration of the mechanism by which green finance affects the green total factor productivity of enterprises, a multiple regression model is constructed:

$$GTFP_{it} = \beta_0 + \beta_1 GI_{it} + \beta_2 X_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Here, $GTFP_{it}$ represents the enterprise's green total factor productivity, GI_{it} represents the regional green financial development level, and X_{it} represents the control variables (including $lohc$ human capital level, urbanization rate, Size of the enterprise, Roe net profit margin, Growth of the company, perear earnings per share, Ratlia debt-to-equity ratio, Bookmar book-to-market ratio, Top1 shareholding ratio of the largest shareholder), λ_i is the individual fixed effect, λ_t is the time fixed effect, and ε_{it} is the random error term.

To explore the internal transmission mechanism of "green finance - enterprise green total factor productivity", the following recursive equation system is constructed to investigate the interaction mechanism between the two:

$$GTFR_{it} = \beta_0 + \beta_1 GI_{it} + \beta_2 X_{it} + \lambda_i + \lambda_t + \varepsilon_{1it} \quad (2)$$

$$GTP_{it} = \alpha_0 + \alpha_1 GI_{it} + \alpha_2 X_{it} + \gamma_i + \gamma_t + \varepsilon_{2it} \quad (3)$$

$$GTFR_{it} = \eta_0 + \eta_1 GI_{it} + \eta_2 GTP_{it} + \eta_3 X_{it} + \theta_i + \theta_t + \varepsilon_{3it} \quad (4)$$

Here, GTP represents the index of enterprise green technology progress change. If the green finance coefficient and the green technology progress coefficient in Equations (3) and (4) are significant, it indicates that there is a mediating effect between the explanatory variables and the explained variable.

Table 1 presents the descriptive statistics of the model variables mentioned above.

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
GTFP	24,302	0.9793	0.0992	0.7813	1.1430
GI	24,302	0.3973	0.1022	0.1099	0.6115
Lohc	24,302	0.0316	0.0306	0.0006	0.1249
Urban	24,302	0.7415	0.1595	0.3466	1.0000
Size	24,302	22.0662	1.2156	19.5655	25.6293
Roe	24,302	0.0520	0.1644	-0.9341	0.3830
Growth	24,302	0.1646	0.4402	-0.6292	2.8679
Perear	24,302	0.3375	0.5921	-1.6864	2.7687
Ratlia	24,302	0.4290	0.2057	0.0535	0.9203
Bookmar	24,302	0.5885	0.2467	0.1010	1.1572
TOP1	24,302	32.8053	14.2242	8.3400	70.7600

4. Analysis of Empirical Results

4.1 Model Selection Test

Table 2. Model Selection

Existence		
Factors	YES	NO
Individual factors	Present	
Time factors	Present	
Individual factors and time factors	The factor of time is present.	Individual factors do not exist.

Through F-test to examine whether there are individual factors, the statistical value of the F-test is 26.93, and $P > F = 0.0000$ indicates the existence of individual factors.

Through F-test to examine whether there are individual factors, the statistical value of the F-test is 77615.35, and $P > F = 0.0000$ indicates the existence of individual factors. After adding time dummy

variables for F-test, it is found that there are no individual factors, and the statistical value of the F-test is 1.04, $P > F = 0.1077$, indicating the absence of individual factors. After adding individual dummy variables for the test, it is found that there is time factors present, and the statistical value of the F-test is 16385.21, $P > F = 0.0000$. Considering individual factors and time factors, it is concluded that the two-factor model should be selected.

From the LM test, $\text{chibar2} = 5768.68$, $P > \text{chibar2} = 0$, indicating that the random effects model is more suitable than the mixed effects model. The robust Hausman test (overidentification test) shows that there is a significant difference between fixed effects and random effects, that is, the random effects are not unbiased estimates. Therefore, the fixed effects model is selected.

4.2 Correlation Analysis

Table 3. Coefficient Table of Correlation

	GTFP	GI	Size	Roe	Growth	Perear	Ratlia	Bookmar	TOP1	Lohc	Urban
GTFP	1.0000										
GI	0.383***	1.0000									
Size	0.186***	0.032***	1.0000								
Roe	0.094***	0.022***	0.120***	1.0000							
Growth	0.068***	0.033***	0.086***	0.044***	1.0000						
Gerear	-0.0100	-0.0090	0.254***	0.727***	0.032***	1.0000					
Ratlia	0.033***	0.056***	0.414***	0.247***	0.038***	0.163***	1.0000				
Bookmar	0.073***	0.024***	0.554***	0.060***	0.144***	0.030***	0.308***	1.0000			
TOP1	0.144***	0.053***	0.176***	0.149***	0.0070	0.171***	0.019***	0.141***	1.0000		
Lohc	-0.012*	0.105***	0.041***	0.012*	-0.0020	0.0090	0.044***	0.028***	0.024***	1.0000	
Urban	0.237***	0.567***	0.053***	0.0050	-0.0080	0.0080	0.036***	0.018***	0.019***	0.134***	1.0000

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

From the above correlation coefficient table, it can be seen that the correlation coefficients are basically below 0.6. This indicates that the correlations among the variables are relatively low and the problem of multicollinearity is not serious. Only the correlation coefficient between the return on net assets and earnings per share is relatively large, but this is also in line with the basic content of finance. Further judgment on the problem of multicollinearity needs to be made in combination with other testing methods

Visualizing the correlation coefficients in Table 3 by drawing a heatmap of the correlation coefficient matrix. This can more clearly and precisely display the correlation coefficients among the explained variable, the core explanatory variable, and the control variable.

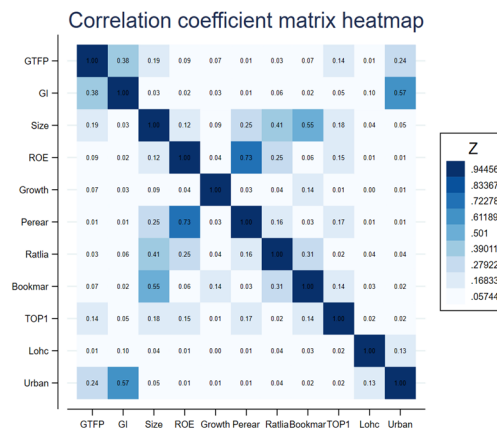


Fig 2. Heat map of correlation coefficient matrix

As shown in Chart 4, after conducting the variance inflation factor (VIF) test, the result is $VIF = 1.57$. Since VIF is less than 10, it indicates no problem with multicollinearity. The design of the model variables is reasonable.

Table 4. Test for Multicollinearity

Variable	VIF	1/VIF
Pear	2.340	0.427
Roe	2.210	0.453
Size	1.930	0.518
Urban	1.570	0.636
GI	1.570	0.638
Bookmar	1.550	0.645
Ratlia	1.380	0.723
Lohc	1.070	0.932
TOP1	1.070	0.937
Growth	1.020	0.976
Mean	VIF	1.570

4.3 Basic Regression Analysis

Table 5(1)(2)(3)(4) represent the total effect model. The difference lies in whether control variables and fixed effects are included. The green finance coefficients in all three groups of models are significant, and the green finance coefficients in models (1), (3), and (4) have passed the test at the 1% significance level. The adjusted R^2 in all models is higher than 0.98, indicating that the model results have a linear relationship. The green finance coefficient is positive and has passed the 1% significance level, which strongly confirms the significant positive effect of green finance on promoting high-quality economic development. Specifically, when the level of green finance development increases by one percentage point, it is expected to drive the economic high-quality development level to rise by approximately 0.795 percentage points. This finding further confirms Hypothesis 1: Green finance can promote high-quality economic development. Models (5) and (6) respectively represent the regression of the core explanatory variable GI (regional green finance development level) on the two decomposition indicators of the explained variable GTFP, GTE (green technology efficiency change index), and GTP (green technology progress change index). From model 5, it can be seen that the green finance coefficient is insignificant, and the sign is negative, opposite to that of the basic model (4). This indicates that regional green finance mainly promotes technological progress to achieve high-quality development. Ma Yahong, taking industrial enterprises as an example, believes that the impact of green finance development on industrial technological progress is positive and significant.

Table 5. Basic Regression

VARIABLES	(1) GTFP	(2) GTFP	(3) GTFP	(4) GTFP	(5) GTE	(6) GTP
GI	0.00798*** (0.00237)	0.00136* (0.000680)	1.80925*** (0.028686)	0.00795*** (0.00249)	-0.00413 (0.00326)	0.0126** (0.00448)
Constant	0.975*** (0.000949)	0.979*** (0.000304)	0.260*** (0.011646)	0.980*** (0.00465)	0.984*** (0.00416)	0.998*** (0.00743)
Control variable	NO	NO	NO	YES	YES	YES
Fixed time	YES	YES	NO	YES	YES	YES
Individual fixation	YES	NO	YES	YES	YES	YES
Observations	24,129	24,302	24,129	24,129	24,129	24,129
R-squared	0.982	0.980	0.982	0.982	0.983	0.104

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In contrast, the impact on industrial technological efficiency is negative and significant [10]. Green finance development can also promote technological progress through risk dispersion mechanisms. Technological progress involves significant risks, which are contradictory to the demands of banks

for safety and stability. It makes it difficult for enterprises to complete technological progress solely through bank financing. However, the development of green finance provides investors and enterprises with risk assessment and risk management means, which can help enterprises better cope with the uncertainties brought by green technological innovation and enable green investment to receive reasonable returns, motivating more enterprises to engage in green, low-carbon transformation.

4.4 Test of Mediating Effect

$$GTFP_{it} = \beta_0 + \beta_1 GI_{it} + \beta_2 X_{it} + \lambda_i + \lambda_t + \varepsilon_{1it} \quad (5)$$

$$GTP_{it} = \alpha_0 + \alpha_1 GI_{it} + \alpha_2 X_{it} + \eta_i + \eta_t + \varepsilon_{2it} \quad (6)$$

$$GTFP_{it} = \eta_0 + \eta_1 GI_{it} + \eta_2 GTP_{it} + \eta_3 X_{it} + \theta_i + \theta_t + \varepsilon_{3it} \quad (7)$$

As shown in Table 6, Model (1) represents the direct effect of the regional green finance development level on the enterprise's green total factor productivity. The results indicate that green finance has a positive promoting effect on the high-quality economic development of enterprises and has been verified at the 1% significance level. As shown in Model (2) of Table 6, the indirect effect model demonstrates the role of the green technological progress change index as a mediating variable.

The results show that green finance positively promotes green technological progress and has been verified at the 5% significance level. (3) The total effect analysis reveals that green technological progress significantly positively affects high-quality economic development. Under the premise of introducing green technological progress as a mediating variable, the promoting effect of green finance on high-quality economic development has been empirically supported. Specifically, green finance effectively promotes the transformation of the economy towards high-quality development through the key link of enhancing the ability of green technological innovation [16]. After rigorous calculation and in-depth analysis, it is known that the mediating effect of technological innovation accounts for approximately 77.58% of the overall effect. This indicates that approximately 77.58% of the driving force of green finance on high-quality economic development is indirectly generated by stimulating and promoting technological innovation activities. In summary, in guiding the economy towards high-quality development by green finance, technological innovation plays an indispensable mediating bridge role. Thus, Hypothesis 3 is verified.

Table 6. Test of Mediating Effect

VARIABLES	(1) GTFP	(2) GTP	(3) GTFP
GI	0.00795*** (0.00249)	0.0126** (0.00448)	0.00178 (0.00228)
GTP			0.490*** (0.00196)
Sobel Test	0.006171*** (Z=2.807)		
Mediating effect coefficient	0.001783*** (Z=0.780896)		
Direct effect coefficient	0.007955*** (Z=3.19502)		
Total effect coefficient	0.980*** 0.998*** 0.491***		
Mediating effect ratio	0.77583098		
Constant	0.980*** 0.998*** 0.491***		
	(0.00465)	(0.00743)	(0.00302)
Control variable	Control	Control	Control
Observations	24,129	24,129	24,129
R-squared	0.982	0.104	0.991

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

4.5 Heterogeneity Analysis

4.5.1 Heterogeneity Regression Analysis

The differences in the industries to which enterprises belong and the ownership structure of enterprises often lead to variations in the opportunities for obtaining financing and the impetus for enhancing enterprise competitiveness. To further investigate whether the positive promoting effect of green finance on enterprise competitiveness varies due to the differences in the industries to which enterprises belong and the types of ownership of enterprises, this paper uses samples of labor-intensive, capital-intensive, technology-intensive enterprises and non-state-owned enterprises. It conducts group regression analysis using static panel data models. The regression results are shown in Table 7.

From Model (1) to Model (3) in Table 7, the positive promoting effect of green finance on the high-quality development of enterprises varies due to the differences in the industries to which enterprises belong. The coefficient of green finance for labor-intensive industries is 0.0227, which is the maximum among the three groups of regression coefficients, and it shows a positive promoting effect, being significant at the 5% level. From Model (2), it can be obtained that the development of regional green finance has an inhibitory effect on the high-quality development of enterprises in capital-intensive industries, and the coefficient is insignificant. This may be due to the following reasons: 1) The financing threshold has increased: Green finance often comes with higher environmental standards and stricter financing conditions. Some high-pollution and high-energy-consuming enterprises in capital-intensive industries may be unable to meet these standards, thus facing financing difficulties [11]. This may limit the access to funds for these enterprises, thereby affecting their technological innovation and industrial upgrading and thus having an inhibitory effect on high-quality development. 2) Cost increase: To meet the requirements of green finance, capital-intensive industries may need to invest more resources in environmental governance and pollution reduction, increasing enterprises' operating costs. In the short term, these additional costs may squeeze the funds available for research and innovation of enterprises, adversely impacting high-quality development. 3) Inconsistency between investment cycle and return: Capital-intensive industries usually have longer investment cycles and payback periods, while green finance tends to support projects that can generate environmental benefits in the short term. This Inconsistency between the investment cycle and return may cause capital-intensive industries to face difficulties seeking green finance support, thereby affecting their high-quality development. From Model (3), it can be obtained that green finance development has a specific promoting effect on the high-quality development of enterprises in technology-intensive industries, with a green finance coefficient of 0.00548. Compared with the green finance coefficient of labor-intensive enterprises, it has decreased somewhat, and the coefficient is significant at the 10% level.

From Model (4), Model (5), and Model (6), it can be concluded that the different ownership structures of enterprises lead to different impacts of green finance on the high-quality development of enterprises. The high-quality development of state-owned enterprises is not significantly affected by green finance. In contrast, the green total factor productivity of private and foreign-owned enterprises is significantly promoted by green finance. This is consistent with the conclusion drawn by Zhang Yongliang et al. that the implementation of green finance policies has a significant inhibitory effect on the total factor productivity of heavily polluting enterprises; compared with non-state-owned enterprises, the inhibitory effect of the implementation of green finance policies on state-owned enterprises is more significant [12]. The green finance coefficient in Model (5) is significant at the 5% level, and the green finance coefficient in Model (5) is at the 10% level. This may be due to the following reasons: 1) Different policy burdens and decision-making mechanisms: The decision-making mechanism of state-owned enterprises is relatively complex, and it may be difficult for them to quickly adapt to the market changes brought about by green finance policies. 2) Differences in financing convenience and costs: Although state-owned enterprises enjoy government credit endorsement in financing and have higher credit convenience, this may also decrease their sensitivity

to green finance policies and a lack of sufficient motivation for green transformation. At the same time, due to the large scale of state-owned enterprises, the transformation cost is relatively high, and the promotion effect of green finance policies on their total factor productivity may be relatively limited. In contrast, the reasons for the significant performance of private and foreign-owned enterprises are as follows: 1) Large financing demand and high flexibility: Private enterprises and foreign-owned enterprises usually have more muscular financing demands and higher flexibility and can adapt to the market changes brought about by green finance policies more quickly. 2) Intense market competition and improved incentive mechanisms: Private and foreign-owned enterprises face more significant pressure in the market competition, making them more likely to enhance their competitiveness by improving their green total factor productivity. Green finance policies give these enterprises more green financing channels and investment opportunities, encouraging them to carry out green transformation and technological innovation.

The visualization analysis of Figure 3 reveals that the standard error intervals of the regression coefficients of labor-intensive enterprises are relatively large, indicating that the differences in the green finance coefficients among individual enterprises of the same type in the data may be significant. This only indicates that, on average, the green finance coefficient of foreign-owned enterprises (0.0362) is greater than that of private enterprises (0.00598). At the same time, it should be noted that the significance of the green finance coefficient in Model (6) is significant at the 10% level, which is lower than the significance at the 5% level in Model (5).

Table 7. Grouped Regression for Heterogeneity Analysis

VARIABLES	(1) Labor- intensive GTFP	(2) Capital- intensive GTFP	(3) Technology- intensive GTFP	(4) state-owned enterprise GTFP	(5) Private enterprise GTFP	(6) Foreign capital GTFP
GI	0.0227** (0.00938)	-0.00565 (0.00588)	0.00548* (0.00157)	0.00308 (0.00462)	0.00598** (0.00274)	0.0362* (0.0172)
Controls	Control	Control	Control	Control	Control	Control
Code, year	Control	Control	Control	Control	Control	Control
Constant	0.946*** (0.0117)	0.988*** (0.00511)	0.995*** (0.00057)	0.975*** (0.00654)	0.986*** (0.00598)	0.889*** (0.0329)
Observations	5,974	5,770	11,006	8,853	13,290	628
R-squared	0.984	0.983	0.982	0.984	0.981	0.983

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

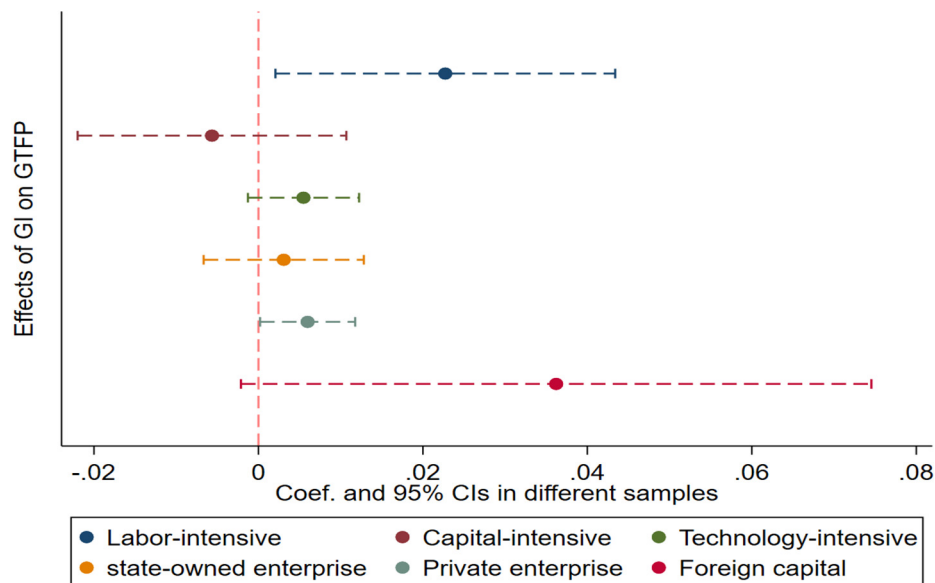


Fig 3. Heterogeneous Group Regression

4.5.2 Analysis of Variance between Groups

Table 8. Inter-group Difference Test

Differences test between labor-intensive and technology-intensive groups		
Without relevant tests	3.21	2.49
Chi-square statistic	Prob > chi2 = 0.0730*	Prob > chi2 = 0.1145
Fisher combination	0.017	-0.030
Test for coefficient differences	Prob = 0.054*	Prob = 0.272

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

From Table 8, the coefficient of the seemingly unrelated test is 3.21, and the chi-square statistic is 0.073. At the 10% level, it is significant, which can indicate that there are indeed differences between labor-intensive and technology-intensive types. Although the green financial coefficients of both Model (1) and Model (3) in Table 6 are significant, the green total factor productivity of labor-intensive and technology-intensive types is affected differently by the level of green financial development.

4.5.3 Heterogeneity Test of Virtual Variables for the Three Regions (East, Central, and West)

Table 9. Cross-product Terms of the Three Regions (East, Central and Western)

VARIABLES	(1) GTFP	(2) GTFP	(3) GTFP
GI	0.00962*** (0.00230)	0.00585* (0.00306)	0.00594** (0.00255)
ec_center	-0.00209*** (0.000691)	0.000190 (0.00112)	
ec_west	-0.00187* (0.000989)		0.000155 (0.000966)
ec_east		0.00263** (0.00104)	0.00256*** (0.000614)
Constant	0.981*** (0.00473)	0.980*** (0.00461)	0.980*** (0.00469)
Observations	24,129	24,129	24,129
R-squared	0.982	0.982	0.982

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In Table 9, Model (1) incorporates the interaction terms of the central dummy variable and the core explanatory variable, as well as the interaction terms of the western dummy variable and the core explanatory variable; Model (2) incorporates the interaction terms of the eastern dummy variable and the core explanatory variable, and the interaction terms of the central dummy variable and the core explanatory variable; Model (3) incorporates the interaction terms of the eastern dummy variable and the core explanatory variable, and the interaction terms of the western dummy variable and the core explanatory variable. From Models (2) and (3), it can be concluded that the interaction terms of the eastern dummy variable and the core explanatory variable are significant. In contrast, the interaction terms of the central dummy and core explanatory variables are insignificant in Model (2). The interaction terms of the western dummy variable and the core explanatory variable are insignificant in Model (3). This indicates that the interaction terms of the eastern region with the core explanatory variable have a strong substitution effect on the interaction terms of the central and western regions; that is, there are differences in the development level of green finance in China. The interaction terms of the regional green finance development level in the eastern region have a promoting effect on the high-quality development of enterprises, while in the central and western regions, as shown in Model

(1), it can even be concluded that the interaction terms of the regional green finance development level have an inhibitory effect on the high-quality development of enterprises. Lili Zhang et al. believe that green finance's development level and efficiency in some provinces and regions, both at the static and dynamic levels, show an uncoordinated feature. The reason is that although green finance investment is increased, these financial resources are not effectively utilized, while some provinces and regions show insufficient green finance resource investment [14].

4.6 Robustness Test

Table 10. Robustness Test

	(1)	(2)	(3)	(4)	(5)
	Robustness test of the lag period			95% of the tail is retracted	Delete major events
VARIABLES	GTFP	GTFP	GTFP	GTFP	GTFP
GI	0.00795*** (0.00249)			0.00528** (0.00250)	0.00720** (0.00274)
L.GI		-0.00164 (0.00238)			
L2.GI			-0.00656** (0.00288)		
L3.GI					
Controls	Control	Control	Control	Control	Control
Code,year	Control	Control	Control	Control	Control
Constant	0.980*** (0.00465)	0.996*** (0.00621)	1.000*** (0.00714)	0.979*** (0.00427)	0.947*** (0.00582)
Observations	24,129	21,032	18,459	23397	
R-squared	0.982	0.980	0.975	0.983	

Note: The values in parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

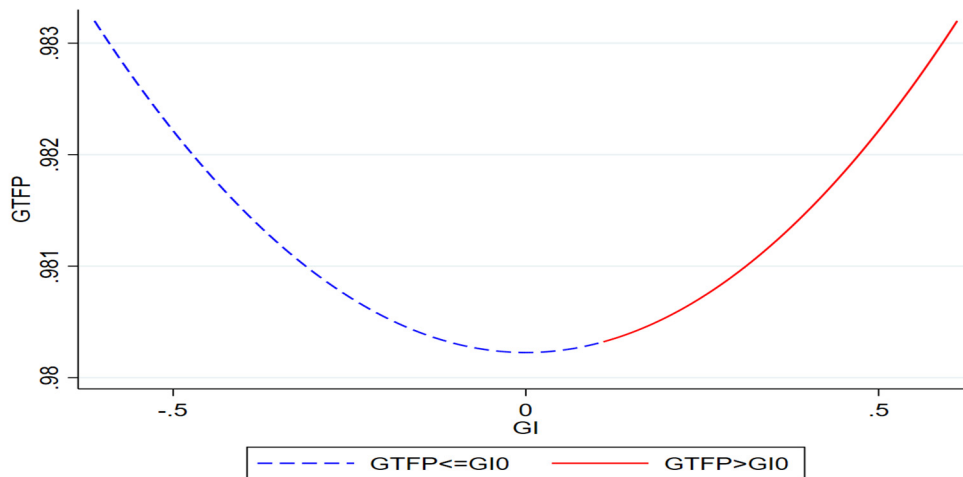


Fig 4. The U-shaped Curve of Green Finance Coefficient

Table 10 Models (1), (2), and (3) are the lag period robustness tests. From Model (3), it can be concluded that the model with a lag of 2 periods is still significant, while the green finance coefficient with a lag of 1 period is no longer significant. This is likely related to the U-shaped relationship between the regional green finance development level and the enterprise's green total factor productivity. The lag period's green finance coefficient is negative [17]. Model (4) changes the tailing level of the basic regression from 99% to 95% tailing level to remove the influence of more extreme values. It can be concluded that the green finance coefficient is 0.00528, which is still significant at

the 5% level. Model (5) avoids the impact of the 2019 COVID-19 epidemic on the enterprise's green total factor productivity. It deletes the data of 2020 and 2021 and then conducts the basic regression (1). The green finance coefficient is 0.00720, which is significant at 95%. The above robustness tests indicate that the model is very robust.

4.7 The Threshold Effect

As an important institutional arrangement for coordinating the objective functions of environmental protection and economic development, the economic effects of environmental tax policies represented by pollution discharge fees have always been a hot topic in the academic circle. Yang Cuo believes that the general characteristics of the environmental tax policies' influence on enterprises' green investment behavior present a nonlinear trend. The green investment amount of enterprises will show a "U-shaped" feature of increasing first and then decreasing as the collection intensity increases [13]. Therefore, it is of great significance to discuss whether the causal relationship between regional green finance development and enterprises' green total factor productivity is nonlinear, and it is necessary to clarify whether it will also be affected by the regulatory role of environmental regulations. Based on the "counterfactual" framework, the analysis results show that the green investment incentive effects generated by the environmental "tax system" and "fee system" are slightly different. Therefore, under the pressure of the dual carbon goals, the administrative regulation guided by government policies may also have a different regulatory effect on improving enterprises' green total factor productivity compared with market-based environmental regulations [13]. To test the above issues, the following adopts the panel threshold regression model proposed by Hansen (1999) to test the above nonlinear relationship. "Threshold regression" is a nonlinear econometric model. Its essence is to find the threshold variable in the variables reflecting the causal relationship, and the threshold value is estimated based on sample data and tested to see if the parameters of the sample groups divided according to the threshold value are significantly different (Che, 2013). For the econometric model of this paper, the following is the panel threshold regression model set for testing:

$$GTFP = \alpha_0 + \alpha_1 GI \cdot 1(\text{paiwufe} \leq \gamma_1) + \alpha_2 GI \cdot 1(\gamma_1 < \text{paiwufe} \leq \gamma_2) + \alpha_3 GI \cdot 1(\gamma_2 < \text{paiwufe}) + \alpha_4 X + \mu_1 \quad (8)$$

$$GTFP = \Phi_0 + \Phi_1 GI \cdot 1(\text{xingzheng} \leq \delta_1) + \Phi_2 GI \cdot 1(\delta_1 < \text{xingzheng} \leq \delta_2) + \Phi_3 GI \cdot 1(\delta_2 < \text{xingzheng}) + \alpha_5 X + \mu_2 \quad (9)$$

Among them, $1(\cdot)$ represents an indicator function. When the expression within the parentheses is false, its value is 0; otherwise, it is 1. Based on whether the market-based regulatory variable *paiwufe* and administrative regulation variable *xingzheng* exceed the threshold values γ and δ , this function can be divided into two regions, and the two regions are distinguished by the slope values, respectively. X represents control variables, including company size, return on equity *Roe*, company growth, earnings per share *perearn*, debt-to-asset ratio, book-to-market ratio *bookmark*, the proportion of the largest shareholder's equity *TOP1*, human capital level *loch*, and urbanization level *urban*.

Table 11. Panel Threshold Regression Results

Regulatory type	Number of thresholds	F value	P-value	10% critical value level	5% critical value level	1% critical value level
Market-based regulation	A threshold	287.75	0.0000	36.5585	41.9192	57.9707
	Two-barrier threshold	327.63	0.0000	40.6960	46.4735	59.1918
Administrative Regulation	A threshold	37.20	0.0000	15.5307	17.9969	22.2052
	Two-barrier threshold	66.78	0.0000	16.1677	18.6474	22.7554

Note: The P-value is the probability value obtained by repeatedly sampling 1000 times using the bootstrap method, and this value is used to determine at what significance level the F-statistic passes the threshold effect test.

As shown in Table 11, when *paiwufe* or *xing zheng* are threshold variables, the following conclusions can be drawn: The F-statistic is significant at least at the 1% level in either one-threshold

or two-threshold models; that is, the P-values are all less than 0.01. Therefore, the model has two threshold values. Table 12 presents the estimated results of the threshold values.

Table 12. Threshold Estimation Values and Confidence Intervals

Regulatory type	Threshold value	95% confidence interval		Regulatory type	Threshold value	95% confidence interval	
Market-based regulation	65731	65411	71211	Administrative Regulation	0.7284	0.7267	0.7512
	95414	94477	96006		0.7409	0.7211	0.7416

Corresponding to the above table, according to the principle of the threshold model, the threshold estimates are the γ and δ values corresponding to the situation where the likelihood ratio statistic LR approaches 0. The following figure shows the likelihood ratio function graph of the two thresholds, 65731 and 95414, in the 95% confidence interval. The second figure is the likelihood ratio function graph of administrative regulation's two threshold estimates, 0.7284 and 0.7409. The lowest point of the LR statistic is the corresponding actual threshold value. The dotted line represents the critical value. Since the critical value is significantly larger than the threshold value, it can be concluded that the above threshold values are genuinely valid.

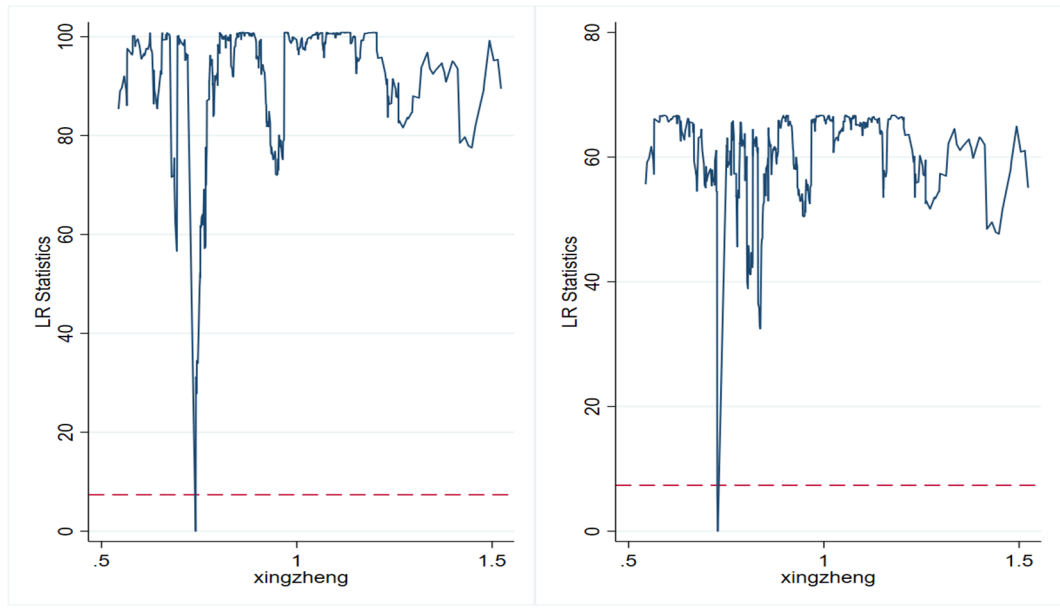


Fig 5. The Double Threshold of Administrative Regulation

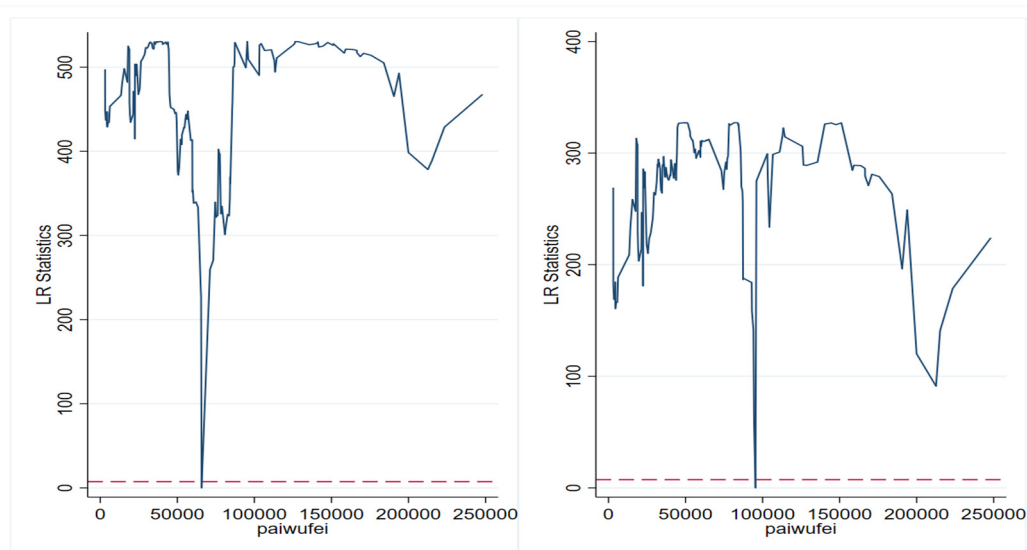


Fig 6. Market-based Regulatory Double Thresholds

While obtaining the threshold regression results of market-based and administrative-based regulations, the panel threshold regression results are presented in Table 13. Specifically, the results of the market-based regulations regression are as follows. As can be seen from the table, the core explanatory variable GI of different regional regulations is adjusted by the threshold variable. It is higher than the coefficient of the basic regression and has the same sign. This indicates that market-based environmental regulations positively regulate the impact of regional green financial development levels on enterprises' green total factor productivity. Different *paiwufei* values significantly differ in the impact on regional green financial development levels. When market-based environmental regulations are relatively loose ($\text{paiwufei} \leq 65731$), the green financial impact coefficient is 1.000; when the intensity of market-based environmental regulations increases ($65731 < \text{paiwufei} \leq 95414$), the green financial impact coefficient is 0.930; when the intensity of market-based environmental regulations further increases ($\text{paiwufei} > 95414$), the green financial impact coefficient is 1.036. From this, it can be concluded that when market-based environmental regulations change from loose to firm, there will be certain policy compliance costs. Enterprises have to carry out green innovation or reallocate resources, which will impact enterprise productivity. As the intensity of market-based environmental regulations increases, the incentive mechanism effect of market-based regulations becomes apparent; that is, the penalty cost for high-pollution production further increases, while the benefit of green production is improved due to reducing the penalty cost.

Table 13. Threshold Regression

Variable (market-based regulation)	Regression coefficient	t-value	Variable (Administrative Regulation)	Regression coefficient	t-value
Size	0.0415***	37.60	Size	0.0418***	36.77
Roe	-0.0186***	-3.46	Roe	-0.0200***	-3.63
Growth	0.00305***	3.03	Growth	0.00274***	2.64
Perearn	-0.00260	-1.59	Perearn	-0.00218	-1.29
Ratlia	-0.0424***	-9.30	Ratlia	-0.0380***	-8.12
Bookmar	-0.00698***	-2.75	Bookmar	0.00610**	2.40
TOP1	-0.000980***	-13.13	TOP1	-0.00110***	-14.32
Lohc	-0.465***	-7.38	Lohc	0.480***	-7.42
Urban	0.315***	27.97	Urban	0.286***	24.76
$\text{Paiwufei} \cdot 1(\text{Paiwufei} \leq 65731)$	1.000***	71.00	$\text{xingzheng} \cdot 1(\text{xingzheng} \leq 0.7284)$	1.069***	71.39
$\text{Paiwufei} \cdot 1(65731 < \text{Paiwufei} \leq 95414)$	0.930***	62.75	$\text{xingzheng} \cdot 1(0.7284 < \text{xingzheng} \leq 0.7409)$	1.020***	69.69
$\text{Paiwufei} \cdot 1(\text{Paiwufei} > 95414)$	1.036***	70.57	$\text{xingzheng} \cdot 1(\text{xingzheng} > 0.7409)$	1.076***	73.90

Second, the results of the regression analysis of administrative regulation. As can be seen from the table, the core explanatory variable GI of different regional systems, under the regulation of threshold variables, is higher than the coefficient of the basic regression and has the same sign. This indicates that administrative environmental regulation positively regulates the impact of regional green finance development level on enterprises' green total factor productivity. This is because the more emphasis on green development in government policy reports, the higher the law enforcement intensity of governments at all levels will be. Different *paiwufei* values significantly differ in the impact on regional green finance development level. When administrative environmental regulation is relatively loose ($\text{xingzheng} \leq 0.7284$), the green finance impact coefficient is 1.069; when the intensity of administrative environmental regulation increases ($0.7284 < \text{xingzheng} \leq 0.7409$), the green finance impact coefficient is 1.020; when the intensity of administrative environmental regulation further increases ($\text{xingzheng} > 0.7409$), the green finance impact coefficient is 1.076. From this, it can be concluded that when administrative environmental regulation changes from loose to firm, there will be certain policy implementation costs. Past production that does not meet green standards will face higher administrative penalties, even shutdowns. This will have a particular impact on enterprises. With the further increase in the intensity of market-based environmental regulation, enterprises will make the following changes: 1) Facing policy pressure and compliance requirements: In order to comply with these policy regulations and avoid penalties such as fines and production suspension and

rectification, enterprises have to carry out green production transformation to reduce the negative impact on the environment. 2) Catering to market demand and consumer preferences: With the enhancement of consumers' environmental awareness, more and more consumers tend to choose environmentally friendly products and services with green labels. To meet the market's demands and enhance brand image, enterprises will actively carry out green production to satisfy consumers' demand for environmentally friendly products. 3) Pursuing technological innovation and cost savings: In the long-term production process, enterprises find that by adopting advanced energy-saving technologies and equipment and optimizing production processes, they can efficiently utilize energy and resources, significantly reducing production costs. Green production helps enterprises save resources, reduce waste disposal costs, open new market fields through technological innovation, and realize differentiated competition. 4) Seeking policy support and preferential treatment: To encourage enterprises to carry out green production, the government usually introduces a series of policies, such as tax incentives, subsidies and rewards, and green credits. These policy supports can reduce the cost of green transformation for enterprises and enhance their enthusiasm. Enterprises will actively carry out green production transformation to obtain these policy preferences. 5) Building harmonious relationships between enterprises and society and creating a good brand image: As society members, enterprises protect our typical home. Through green production, enterprises can actively fulfill environmental protection responsibilities, reduce pollution and environmental damage, and build harmonious relationships between enterprises and society. Under the market economy, this helps to enhance the social reputation and image of enterprises, stabilize stock prices, and lay a good foundation for their long-term development. These aspects will promote green production by enterprises and achieve high-quality economic development. Thus, hypothesis 2 verified that the effect of green finance on enterprises' total factor productivity shows a threshold effect related to administrative and environmental regulation.

5. Conclusion and Policy Considerations

Chapters Two, Three, and Four establish the basic hypotheses and econometric models, conduct empirical analysis on the impact of green finance on enterprises' green total factor productivity, analyze the transmission mechanism of this process and the regulatory role of different types of regulations therein, as well as conduct heterogeneity analysis of enterprises from various perspectives, and draw a series of important conclusions. Based on this, this chapter comprehensively summarizes the relevant findings. Finally, it puts forward policy recommendations based on the main conclusions for reference and decision-making by government departments, market supervision departments, and enterprise entities.

5.1 Further Strengthen the Strategy of Promoting Innovation-driven Development

From the analysis of the mediating effect, we can see that green technological progress plays a decisive mediating role in enhancing enterprises' green total factor productivity. This indicates that the government should attach great importance to guiding enterprises to carry out green innovation to achieve high-quality economic development at the enterprise and even national levels. Currently, the world is undergoing a significant transformation unseen in a century. The global competitive landscape is undergoing new changes and new directions. Technological innovation has become a key variable in the competition among major powers. It is the only way and the necessary path for enterprises to achieve high-quality development and promote technological innovation. China needs to strengthen top-level design. It is essential to promptly formulate the action outline for building a strong country in science and technology, improve and perfect the institutional mechanisms for scientific and technological innovation, deepen the reform of the science and technology management system, improve the evaluation system for scientific and technological innovation, optimize the incentive and restraint mechanism for scientific and technological innovation, strengthen the protection of intellectual property rights, the mechanism for benefit distribution, the incentive

mechanism, and the construction of the rule of law, deepen international cooperation in scientific and technological innovation, explore the establishment of a global cooperation fund for scientific and technological innovation, take the lead or jointly take the lead in conducting international cooperation and exchanges in scientific and technological innovation, formulate major research plans and projects, and improve the institutional mechanisms for scientific and technological innovation services, in order to create a favorable institutional environment for enterprises' innovation.

5.2 Different Types of Environmental Regulations are Working Together with Full Force.

From the analysis of the threshold effect, we can also observe that both types of environmental regulations can, to a certain extent, improve the basic regression coefficient of green finance to a certain extent. This indicates that the government needs to combine different environmental regulations to promote the high-quality economic development of enterprises. To promote the improvement of enterprises' total green factor productivity through green finance, the government needs to combine market-based and administrative regulations to encourage the organic development of the enterprise economy. To ensure that green finance can effectively promote the improvement of green total factor productivity of enterprises and achieve high-quality economic growth, the government needs to intervene by combining market-based regulations and administrative regulations:

Market-based regulations: The government can guide market capital to flow to green industries and projects by establishing a green finance policy system and providing green finance incentive measures. For example, through tax incentives, subsidy policies, etc., enterprises can be encouraged to adopt green technologies and carry out environmental protection renovations, thereby improving green total factor productivity. In addition, the government can strengthen the supervision of the green finance market to ensure the rational allocation and effective use of financial resources.

Administrative regulations: The government can formulate and implement strict environmental protection regulations and standards to restrict the development of high-pollution and high-energy-consuming industries while encouraging and supporting the development of green industries. In addition, the government can also enable enterprises to carry out environmental protection, technological innovation, and industrial upgrading through administrative means, thereby improving green total factor productivity. Combining market-based and administrative regulations organically can promote the improvement of green total factor productivity of enterprises and high-quality economic development. On the one hand, market-based regulations can play a decisive role in resource allocation and guide capital to flow to green industries and projects; on the other hand, administrative regulations can make up for the market failure and deficiencies, ensure the effective implementation of environmental protection regulations, and promote enterprises to carry out ecological protection technological innovation and industrial upgrading.

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