Membrane Technology
ISSN (online): 1873-4049

Driving Impact of Sci-Tech Finance on Companies' Green Productivity: An Empirical Analysis Using High-Dimensional Fixed Effects and Difference-in-Differences Models

Bowen Li[1], Tingting Zhuge[1], Junxian Zhang[1], Lehui Lin[2,*]

[1]*School of International Business, Zhejiang Yuexiu University, Shaoxing, Zhejiang, China*
[2]*School of Economics, Dongbei University of Finance and Economics, Dalian, Liaoning, China*
** Corresponding Author.*

Abstract:
Achieving high-quality economic performance and cultivating new quality productive forces are important goals of the Chinese government currently. Green development serves as a foundation for high-quality economic performance, where new quality productive forces are essentially green productivity. Sci-tech finance refers to a financing framework aimed at fostering technological innovation and advancing the commercialization of R&D achievements. To investigate how the development of Sci-tech finance influences companies' green productivity, this research utilizes panel data from listed companies in Zhejiang Province from 2007 to 2021, using high-dimensional fixed effects model and difference-in-differences model. The findings reveal that Sci-tech finance plays a crucial role in boosting companies' green total factor productivity, encouraging green patent applications, and driving the cultivation and growth of green productivity. Heterogeneity analysis shows that the impact of sci-tech finance is particularly significant in high-income regions, private companies, small and medium-sized enterprises, and firms not audited by the Big Four accounting firms. Furthermore, by constructing a quasi-natural experiment, it is verified that the "Pilot policy for synergizing technology and finance" considerably boosts the green productivity of companies in pilot cities. Finally, the research makes policy proposals for the growth of green productivity in companies, such as strengthening Sci-tech finance policy support, promoting regional coordinated development, and providing more financing channels for small and medium-sized companies.

Keywords: Sci-Tech finance development, green productivity, new quality productive forces, listed companies, Zhejiang province in China.

INTRODUCTION

Zhejiang Province is a major economic region in southeastern coastal China. According to data from the relevant agencies, Zhejiang's GDP is estimated at 1.18 trillion US dollars in 2023, accounting for 6.59% of China's total GDP. Zhejiang has a per capita disposable income of approximately 9,100 USD, ranking just below Beijing and Shanghai. Despite its strong economic performance, Zhejiang is constrained by a comparatively poor per capita natural resource endowment. Therefore, Zhejiang is confronted with the dual challenges of sustainable use of resources and high-quality economic growth. The significant assertion that "Clear rivers and green mountains are treasures on par with gold and silver." was proposed as early as August 2005. This thesis served as the theoretical foundation and practical guide for Zhejiang's green development. With the promotion of the idea of green development, Zhejiang companies are pursuing low-carbon development and green transformation, focusing on green, digital, and intelligent practices. Green development underpins high-quality development, and new quality productive forces are green productivity. Since September 2023, the key idea of "New quality productive forces" has been frequently referenced. As a major force of sustainable economic growth, green and eco-friendly productivity is currently not only setting the standard for modern productivity but also ushering in a new era of growth for companies. This signifies not just the quickening of the shift to a greener industrial structure but also the emergence of green technology as the primary engine of companies' green productivity.

The advancement of green technology is the primary determinant of the growth and development of green productivity in Zhejiang companies. Financial support is essential for green technology innovation and R&D investment. In October 2023, at the central financial work conference, Sci-tech finance was prioritized as the foremost among the "Five Key Financial Tasks." Sci-tech finance is an innovative approach that integrates technological innovation, financial tools, services, and regulations to support research and development and uncover new green technology's potential. It has played a significant part in the green transformation of Zhejiang's economy and the green development of businesses. By supporting green innovative technologies and environmental protection initiatives, it assists Zhejiang companies in creating a green credit system, encouraging the expansion of the green industrial chain, enhancing information transparency, and providing the required funding support. Private companies and small and medium-sized companies abound in Zhejiang. In the face of intense market competition and financing constraints, Sci-tech finance can help companies overcome financing bottlenecks, improve capital utilization efficiency, and lower financing thresholds and costs by introducing diversified financing modes and advanced credit risk assessment techniques.

As early as 2011, five ministries and commissions of the Chinese government issued a notice on “Printing and distributing the pilot program for promoting the combination of science and technology and finance,” designating four cities in Zhejiang Province as the first batch of policy pilot cities. This provided policy support for the improvement of green productivity among Zhejiang companies. The purpose of this article is to examine whether Zhejiang companies’ green productivity has increased as a result of the growth of Sci-tech finance.

The literature closely related to this paper can be divided into two main categories. The first category of literature concerns research on company green productivity. On the one hand, some theoretical research focuses on creating new quality productive forces in science, technology, and industry. They propose that sci-tech innovation is a crucial driver of new quality productive forces, emphasizing its importance in promoting green and low-carbon development [1,2]. On the other hand, the empirical study concentrates on the effect of both internal and external factors on companies’ green productivity. Some studies examined the factors influencing company green productivity through spatial spillover effects, noting that the spillover effect of technological progress was not significant [3]. Research has also demonstrated that, from the standpoint of green finance, appropriate pilot programs can support the development of green technology and GTFP [4].

The second category of literature primarily examines the economic impacts of financial and technological advancement at the regional or corporate level. Current studies mainly focus on regional development [5], industrial structure transformation [6], and scientific and technological innovation [1]. Among these, some studies have highlighted that the strategy significantly benefits smaller urban centers, areas with limited innovation capacity, or non-Yangtze River Economic Belt regions when innovative technology and digitization serve as intermediaries [7]. Existing research at the company level has concentrated on corporate green sustainability investment [8], corporate total factor productivity [9], corporate digital transformation [1,10], and green technology innovation [11,12]. According to Wang et al., financial policies based on science and technology can significantly enhance the financial ecosystem [5].

The article contributes to the existing literature in three main sides: First, the research examines the influence of Sci-tech finance on regional green transformation and addresses the theoretical meaning of new quality productive forces and green productivity. This work extends the research perspective by empirically examining the connection between companies’ green productivity and the growth of Sci-tech finance, focusing on the micro-innovation of companies. Second, the study examines the impact of the “Pilot policy for synergizing technology and finance” on the development of regions and companies and their green transformation. The role of Sci-tech finance in fostering green productivity in companies is empirically studied in this article, which constructs indicators from the input and output dimensions. Additionally, the impact of pilot policies is analysed using quasi-natural experimental techniques. Third, the private sector and small and medium-sized companies predominate in Zhejiang. Despite their tremendous innovative vigour, many companies face challenges in funding and complying with environmental regulations. The sample of listed companies in Zhejiang Province selected for empirical analysis and heterogeneity tests demonstrates how various companies supported by Sci-tech finance differ in their green productivity.

The remaining component of this study is organized as follows: Section 2 presents the theoretical mechanism derived from existing literature. The model setup, variable selection, and data sources are presented in Section 3. Section 4 introduces the findings of the benchmark regression, robustness tests, and heterogeneity analysis. Section 5, the policy impacts of the "Pilot policy for synergizing technology and finance" are reported, and the relevant policy implications are discussed at the end.

THEORETICAL ANALYSIS

There are two dimensions to the growth of Sci-tech finance: science and technology, as well as finance. To overcome technological challenges and foster sustainable production, companies are encouraged to support and advance research and technology. Simultaneously, Sci-tech finance products provide financial assurance for companies’ sustainable growth. Figure 1 illustrates the interrelation between government-driven technology and finance, while the “technology-government-finance” synergy promotes companies to enhance their sustainable output.

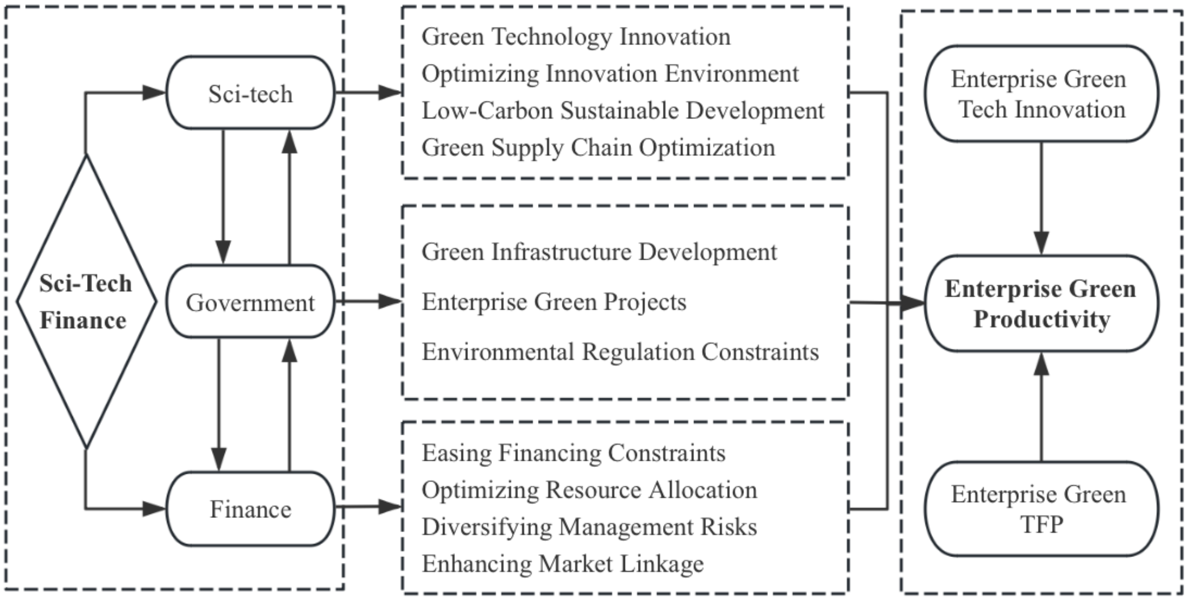

Figure 1. The theoretical mechanism of Sci-tech finance to cultivate companies' green productivity

Function of Science and Technology

First, one of the most significant ways in which science and technology can support corporate innovation is through the progress of green technologies. Sci-tech finance is effective in assisting companies to overcome the challenges associated with innovation heterogeneity and encouraging them to increase R&D investment. This assistance enables companies, especially SMEs and non-state-owned companies in eastern China, to overcome the challenges of innovation and development, including the high costs of adopting new technologies. Through technical assistance, Sci-tech Finance has effectively supported these companies in addressing most of their challenges. Second, a critical component of companies' R&D adjustment is the optimization of the soft environment for innovation. Companies can obtain more thorough and accurate information regarding technology trends and industry dynamics through science and technology platforms. This knowledge assists companies in avoiding impulsive investments, enhancing resource utilization efficiency, and promptly reorienting R&D efforts. Third, technological empowerment is significantly influenced by low-carbon sustainable development. To accomplish a win-win situation that benefits both the economy and the environment, Zhejiang companies consistently implement green transformations by employing modern energy-saving and clean production technologies in alignment with green development policies. The assistance provided by Sci-tech finance can facilitate the adaptation of non-state-owned companies and small and medium-sized companies—which experience heightened pressure to change—to new environmental protection regulations and technical specifications, thereby accelerating their transition to a green economy. Fourth, the optimization of green supply chain management plays a significant role. Zhejiang companies are effective in reducing resource waste and environmental contamination by implementing intelligent logistics technology and streamlining their supply chain management. This approach also ensures that all components of the supply chain adhere to environmental protection regulations. Consequently, Zhejiang companies are better equipped to achieve efficient cost control and resource utilization due to enhanced flexibility within their supply chains.

Function of Financial Support

First, financial innovation services constitute a critical component of financial support. The financing barriers for green technology innovation projects are effectively reduced by Sci-tech finance through the provision of various financial instruments, such as risk compensation, guaranteed loans, and performance guarantee insurance. Financing constraints are greatly alleviated, and the challenges faced by companies in starting and growing due to insufficient funds are addressed. By lowering the financing barriers for non-state-owned companies and SMEs in Zhejiang, funding bottlenecks are overcome, and the innovation and application of green technology are fostered. Second, resource allocation is effectively optimized by Sci-tech finance. Capital utilization efficiency is enhanced, capital mismatch is reduced, and market capital is logically directed toward green innovation. Furthermore, information asymmetry between companies and investors is reduced by establishing sci-tech finance service platforms and improving credit evaluation systems. SMEs and non-state-owned companies in high-income areas of Zhejiang are effectively assisted in better accessing the financial market and obtaining necessary financial support. Third, a significant role in decentralized risk management is played by Sci-tech finance. Investment risks are distributed among multiple investors using tools such as venture capital and technology insurance; risks for individual investors are reduced, and more Zhejiang companies are incentivized to engage in green technology innovation. Market risks for these companies are collectively reduced by these factors. Fourth, by enhancing market connections, essential funding for green technology innovation initiatives is provided by Sci-tech finance, and the competitiveness of companies involved in green innovation is boosted, assisting Zhejiang companies in increasing their GTFP.

Role of Government Connectivity

First, necessary support measures are implemented by the government through promoting green infrastructure development. This not only supports the objectives of sustainable development and green innovation but also enhances the effectiveness of its own Sci-tech finance initiatives. By facilitating easier access to financial services and streamlining financial transaction processes, the costs associated with green innovation for SMEs and non-state-owned companies are reduced. Second, the development of corporate green projects is also crucial. The government encourages companies to pursue green technology innovation through legislative initiatives like green finance, tax breaks, and subsidies. These regulations not only encourage the development of green initiatives but also lower the barriers for companies to conduct research and development on green technologies. This approach effectively alleviates the burden of internal resource shortages for these companies, including those in high-income districts of Zhejiang, which may struggle to afford the costs of green transformation independently. Third, environmental regulatory policies serve as significant support for development. By creating and enforcing stringent environmental regulations, the government requires companies to enhance their GTFP and encourages them to adopt environmental protection and green technologies in their manufacturing processes through incentive programs and regulatory measures. For companies under greater pressure to transform, these regulatory measures facilitate the adoption of cleaner production methods and support sustainable development.

In conclusion, interactions occur among the financial support provided by Sci-tech finance, technological empowerment, and government initiatives such as the development of green infrastructure, companies' green projects, and environmental regulation policies. Driven by financing constraints and the need for green technology innovation, the green technologies of most private companies, small and medium-sized companies, and companies in high-income areas of Zhejiang have emerged and evolved. Additionally, the companies' GTFP has been improved, further enhancing their overall green productivity.

METHODOLOGY

Models

To verify the impact of Sci-tech finance on Zhejiang companies' green productivity, a high-dimensional fixed effects model is employed to construct the benchmark model as follows:

$$GTFP_{it}/GINO_{it} = \alpha_0 + \alpha_1 TechF_{it} + \sum_n \alpha_n X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \tag{1}$$

In the formula, i and t denote the companies and years. $GTFP_{it}$ and $GINO_{it}$ represent green TFP and green technological innovation, respectively, and are used to evaluate the green productivity of Zhejiang companies. $TechF_{it}$ captures the advancement of Sci-tech finance in the company's location. X_{it} represents a set of control variables, while γ_i and δ_t are industry and year fixed effects, respectively. The term ε_{it} accounts for random errors. The coefficient α_1, which is the primary parameter of interest, indicates whether a robust Sci-tech finance environment significantly boosts the green productivity of listed firms if it shows a positive and significant value.

Variable Definition

Dependent variable: companies' green productivity

The concept of companies' green productivity lacks a standardized assessment index in academia currently. A closely related notion, namely companies' GTFP, is the primary focus of current research. Some studies also utilize companies' green technological innovation as a proxy measure for green productivity. Building on prior research, companies' green productivity is also evaluated in this paper based on these two factors.

Following the approach of Liu et al. [4], companies' environmental pollution is incorporated into the evaluation system, and the non-radial SBM-ML index method is employed to calculate GTFP. The input indicators for companies' GTFP include labour, capital, energy, and other factors, while the output indicators consist of expected operating income and undesirable pollutant emissions. By including environmental pollutants as undesirable outputs, this efficiency evaluation method overcomes the limitations of the conventional Data Envelopment Analysis (DEA) model. This method allows for the collection of data samples from listed companies across various industries.

Referring to the methodology of Li et al. [13], an organization's green technological innovation (GINO) is assessed by counting the number of patents filed in the green technology sector. Relevant green patent data are sourced from the CNRDS database and categorized according to the WIPO green patent classification. Subsequently, the number of patent applications in alternative energy production, transportation, energy conservation, waste management, agriculture and forestry management, regulatory design, and nuclear power is extracted annually to evaluate companies' green technological innovation comprehensively and accurately.

Independent variable: Sci-Tech finance

An index system is developed to assess the development level of Sci-tech finance from two dimensions: input and output. From the input dimension, the percentage of fiscal appropriations for science and technology expenditure is used as a proxy variable. This demonstrates the extent of investment in Sci-tech finance across various cities, as indicated by the support of urban special financial capital for green innovation activities. The investment in the Sci-tech finance environment encompasses both the talent environment and the R&D environment, which are assessed by the proportion of scientific and technical personnel within the regional population and the amount of urban R&D institutions, respectively. According to the output dimension, the number of regional patent applications and authorizations directly reflects the influence of Sci-tech finance on green technological innovation and the improvement of companies' GTFP. Lastly, with all indicators being positive, the entropy weight method can be utilized to reduce dimensionality, thereby producing the core explanatory variable for the development of Sci-tech finance (TechF).

Control variables

This study adopts existing research methods and selects control variables at the company level from multiple perspectives to avoid omitting important explanatory variables that may lead to biased regression results [14]. The selected control variables include company size (Size), leverage ratio (Lev), ownership concentration (Top1), return on equity (ROE), financial cost rate (Ffee), management cost rate (Mfee), R&D intensity (Rdstr), and the number of directors and supervisors (Igov). Descriptions and details of the variables are included in Table 1.

Table 1. Variable declaration

Classification	Variable	Name	Variable Description
Explained variable	GTFP	Green Total Factor Productivity	Non-radial SBM-ML index method is used to calculate.
	GINO	Green Innovation	The logarithm of the number of green patents
Explanatory variables	TechF	Sci-tech finance	Using the entropy weight method for calculation
Control variable	Size	Companies scale	Logarithm of total assets
	Lev	Leverage ratio	Total liabilities / Total assets
	Top1	Major shareholder ownership	The proportion of tradable shares controlled by the largest shareholder.
	Roe	Return on shareholders' equity	The proportion of net income to total equity.
	Ffee	Financial cost rate	Financial expenses / operating income
	Mfee	Management fee rate	Management expenses / Operating income
	Rdstr	Companies R&D strength	R&D spending / operating income
	Igov	The number of directors and supervisors high	The number of directors, supervisors and seniors takes logarithm

Data sources

The research sample was constructed using relevant data from listed companies in Zhejiang province and related city information from 2007 to 2021. The sample selection commences in 2007, primarily because listed companies were required to provide mandatory information in their annual reports following the release of China's new accounting standards in January of that year. The content of environmental information disclosure has gradually shifted towards quantitative indicators, thereby improving the accuracy of the relevant data. The data for the listed companies analysed were gained from the Wind, CSMAR, and CNIPA databases, while city-level data were obtained from the China City Statistical Yearbook. Following common practices in existing research, samples with ST, *ST, or missing financial data were excluded, along with samples from the financial industry and those newly listed in the current year. To eliminate heteroscedasticity, the natural logarithm is applied to all continuous variables, and they are winsorized at the 1% and 99% levels [13]. In the end, a balanced panel dataset comprising 1,235 observations was obtained.

EMPIRICAL RESULTS

Benchmark Regression

Results from the baseline regression can be found in Table 2. The univariate regression results in columns (1) and (3) include industry and year dummies. The regression coefficients for Sci-tech finance development (TechF) concerning GTFP and green innovation (GINO) are 0.133 and 0.222, respectively, both of which achieve significance at the 1% level. Columns (2) and (4) include company-level control variables. The coefficients for Sci-tech finance in the regression fall to 0.096 and 0.099, yet they are still positive and statistically significant at the 1% level. This points to the conclusion that improving Sci-tech finance has a significant effect on enhancing companies' GTFP. They also promote green patent applications and green technological innovation, driving Zhejiang companies to foster and develop green productivity.

Table 2. Results of the benchmark regression

	(1)	(2)	(3)	(4)
	GTFP	*GTFP*	*GINO*	*GINO*
TechF	0.133***	0.096***	0.222***	0.099***
	(31.942)	(23.641)	(10.840)	(4.670)
Size		1.083***		3.939***
		(17.624)		(12.20)
Lev		-0.096***		-0.252***
		(-5.360)		(-2.67)
Top1		-0.047***		-0.068
		(-5.276)		(-1.460)
Roe		-0.070***		-0.101
		(-4.085)		(-1.120)
Ffee		-0.004**		0.030***
		(-2.036)		(2.660)
Mfee		-0.004		-0.024
		(-0.837)		(-1.080)
Rdstr		0.017***		0.089***
		(6.504)		(6.700)
Igov		-0.086***		-0.079
		(-5.423)		(-0.950)
Cons	-0.458***	4.395***	-0.2120***	16.138***
	(-37.471)	(15.958)	(-3.530)	(11.150)
Industry dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Observation	1235	1235	1235	1235
Adjusted R-squared	0.473	0.609	0.2404	0.3593

Note: The t-value is enclosed in parentheses, and the symbols ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively. The subsequent table reflects the same information.

Robustness Test

The indicator for the degree of Sci-tech finance growth in the baseline regression is calculated using the entropy weight method for dimensionality reduction, involving various indicators from both input and output dimensions. To mitigate potential bias in research conclusions stemming from insufficient rigor in indicator generation, an alternative indicator is constructed based on the underlying logic of high-level Sci-tech finance services. This research selects three metrics from the "Peking University Digital Inclusive Finance Index": the amount of internet users per 100 people (FI), the proportion of personnel in computer services and software (DI), and the amount of mobile phone users per 100 individuals (FIP).

According to the regression results in columns (1) through (3) of Table 3, the coefficients for FI, DI, and FIP show significant positive values at the 1% level, which suggests an agglomeration effect of digital and technological factors in the region. This effect enhances the greening, digitalization, and upgrading development of companies, thereby promoting the cultivation of green productivity.

Table 3. Results of the robustness test

	(1)	(2)	(3)	(4)	(5)	(6)
TechF				0.072***	0.080***	0.059***
				(12.843)	(14.425)	(11.258)
FI	0.001***					
	(59.821)					
DI		1.985***				
		(57.000)				
FIP			0.566***			
			(37.481)			
Cons	0.878***	0.841***	0.836***	-0.527***	-0.438***	-0.443***
	(4.733)	(4.347)	(3.122)	(-21.940)	(-38.620)	(-93.760)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observation	1091	1091	1091	1235	1235	1235
Adjusted R-squared	0.869	0.859	0.754	0.540	0.561	0.775

According to econometric principles, omitting important variables can result in biased and inconsistent outcomes. The baseline regression has already controlled for company characteristics, industry, and year dummies. However, operational relevance within industrial and supply chains across industries and regions, as well as among companies, makes them susceptible to interference from common factors. Therefore, the assumption regarding independent and identically distributed random disturbances is relaxed, and clustered standard errors are applied to confirm the robustness of the research findings. The regression results shown in columns (4) to (6) of Table 3 reveal that while the regression coefficient for TechF gradually decreases, it continues to be significantly positive at the 1% level, further affirming the strong positive correlation between Sci-tech finance development and green productivity among companies in Zhejiang.

Regional Heterogeneity Analysis

Table 4. Results of regional heterogeneity

TechF	(1)	(2)	(3)	(4)	(5)	(6)
	Northern region	Southern region	Add interaction	Middle & low-income regions	High-income regions	Add interaction
	0.132***	0.135***	0.136***	0.109***	0.058***	0.036***
	(28.502)	(14.046)	(14.434)	(14.400)	(14.957)	(7.928)
TechF×Northern region			-0.004			
			(-0.390)			
TechF×High income regions						0.042***
						(20.325)
Cons	-0.461***	-0.440***	-0.458***	3.270***	1.588***	3.047***
	(-33.494)	(-16.403)	(-37.453)	(9.112)	(5.352)	(12.347)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observation	989	246	1235	547	678	1235
Adjusted R-squared	0.593	0.790	0.609	0.731	0.446	0.709

In the regional heterogeneity analysis section, Zhejiang is divided into northern and southern regions. The northern Zhejiang region is primarily characterized by a flat landscape, encompassing the cities of Hangzhou, Shaoxing, Ningbo, Zhoushan, Jiaxing, and Huzhou. Historically, this region has maintained closer economic and cultural ties with the present-day Jiangsu and Shanghai. The southern Zhejiang region includes the cities of Jinhua, Wenzhou, Taizhou, Lishui, and Quzhou, which are characterized by mountainous and hilly terrain. This terrain raises transportation costs for local companies but also provides valuable green forest resources and a thriving county-level economy. The sub-sample findings for northern and southern Zhejiang are presented in columns (1) and (2) of Table 4, respectively, with column (3) introducing the interaction items between Sci-tech finance development and the northern Zhejiang region. A vital positive coefficient for TechF at the 1% level reveals that the development of Sci-tech finance contributes to the increase of green productivity among enterprises in both northern and southern Zhejiang.

Secondly, according to the definition provided by the NBSC, regions with a per capita GDP below 80,000 yuan are classified as middle & low-income regions. Those above this threshold are classified as high-income regions. Columns (4) and (5) of Table 4 present the sub-sample results for middle-low and high-income regions, respectively. The TechF coefficient maintains its sign and significance, indicating that Sci-tech finance developing significantly and positively affects the green productivity of companies in both income segments. Column (6) further introduces the interaction term between Sci-tech finance development and the high-income regions. The TechF coefficient retains its sign and significance, while the interaction term's coefficient shows a significant positive value at the 1% level. This suggests that Sci-tech finance development has a more significant impact on promoting green productivity in companies located in high-income regions than in those in middle & low-income areas.

Company Heterogeneity Analysis

Within the company heterogeneity analysis section, companies in the sample were first classified as private or non-private based on ownership. In columns (1) and (2) of Table 5, the coefficient of TechF for private enterprises is significantly positive at the 1% level, while the coefficient of TechF for non-private companies is not significant. This may be attributed to the fact that private companies in Zhejiang are more market-oriented and innovation-driven. The development of Sci-tech finance has provided them with greater financial support, significantly enhancing their green productivity.

Secondly, the sample companies were categorized into large companies and SMEs based on the average company size. The consequences presented in columns (3) and (4) indicate that SMEs have a significantly positive regression coefficient for Sci-tech finance's impact on GTFP, whereas the coefficient for large companies is positive yet not significant. This implies that SMEs are more reliant on Sci-tech finance to enhance their green productivity, possibly due to their more limited capital and resources. This necessitates greater reliance on external financial support. In contrast, large companies possess more diversified funding sources, resulting in a relatively weaker marginal effect of Sci-tech finance.

Finally, the sample companies were categorized into external and internal audit groups based on whether they were audited by one of the Big Four accounting companies. The regression results detailed in columns (5) and (6) demonstrate that, for companies audited by the Big Four, the Sci-tech finance coefficient does not achieve statistical significance, whereas the regression coefficient is significantly positive for companies audited by other companies. This may be due to the fact that listed companies in Zhejiang are primarily private companies, often lacking standardized internal controls and adequate cash flow. Such companies may face higher operational uncertainty and insufficient financial stability. Sci-tech finance support has significantly promoted their green technology R&D and innovation, thereby enhancing their green productivity.

Table 5. Results of company heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
	Non-private companies	Private company	Large company	Small and medium-sized company	External audit company	Non-external audit company
TechF	-0.002	0.098***	0.040	0.083***	0.014	0.097***
	(-0.376)	(19.228)	(0.081)	(14.419)	(0.728)	(23.479)
Cons	-0.171	3.309***	-0.163	7.726***	11.747***	4.340***
	(-1.631)	(10.112)	(-1.636)	(14.997)	(7.526)	(15.521)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observation	485	750	637	598	229	1006
Adjusted R-squared	0.489	0.638	0.488	0.661	0.433	0.607

FURTHER DISCUSSION

In the previous section, we discussed in detail how the development of Sci-tech finance can support the cultivation of companies' green productivity. By opting for the "Pilot policy for synergizing technology and finance", this section develops a quasi-natural experiment to examine its effects and the actual role of this policy in enhancing the green productivity of Zhejiang companies is examined. The purpose of this investigation is twofold: First, by constructing a quasi-natural experiment according to some exogenous policies, concerns regarding the scientific validity of the Sci-tech finance indicators used throughout this paper are alleviated, and the endogeneity problem is mitigated. Furthermore, this approach ensures the robustness of the previous analysis results. Second, by comprehensively verifying the promotional effects of the existing relevant policy on companies' green productivity, a solid scientific basis is provided for the adjustment, implementation, and expansion of similar policies in the future.

Difference-in-Differences Model

In this section, a quasi-natural experiment is constructed using the "Pilot policy for synergizing technology and finance" implemented by the Chinese government in 2011. To assess the policy impacts, a difference-in-differences (DID) model is utilized, focusing on two groups of pilot cities within Zhejiang. By comparing data changes before and after the policy implementation, alongside the differences between the pilot cities and their counterparts, the actual effects of the relevant policy are evaluated. The detailed model specification is outlined below:

$$GTFP_{it} = \beta_0 + \beta_1 Treat_{it} \times Post_t + \beta_2 Treat_{it} + \beta_3 Post_t + \sum_n \beta_n X_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

The core explanatory variable in the model is $Treat_{it} \times Post_t$, where $Post_t$ represents the time when the policy takes effect and $Treat_{it}$ indicates whether a company is in the treatment group. As previously mentioned, the Sci-tech finance pilot policy was implemented in two batches, covering a total of 50 selected cities nationwide, including 4 cities in Zhejiang. The first batch of pilot cities was announced in 2011, comprising 41 cities across the country, including the cities of Hangzhou, Wenzhou, Huzhou, and Ningbo in Zhejiang. The second batch was announced in 2016 and included nine cities, with Ningbo again being part of this group. Thus, 2011 is set as the benchmark year for assessing the policy's impact. The listed companies in Hangzhou, Wenzhou, Huzhou, and Ningbo are classified as the treatment group, while the listed companies in the other seven cities in Zhejiang are designated as the control group. Apart from the core explanatory variable, the other components of the model specification remain consistent with the baseline regression.

Estimated Results of the Pilot Policy

Leveraging the "Pilot policy for synergizing technology and finance" as a pseudo-experimental framework and applying the DID model introduced earlier to evaluate the policy's effect on companies' GTFP. In Table 6, column (1) excludes control variables, while column (2) depicts the benchmark regression model after controlling for company characteristics. The data show that, by employing high-dimensional fixed-effects models to control for sectoral and temporal fixed effects, the Treat × Post coefficient relative to GTFP shows statistical significance at the 1% level, independent of the inclusion of firm-specific characteristics. This finding suggests that, after the policy implementation, the GTFP of companies in the pilot cities is significantly greater than that of companies in other regions of Zhejiang. Thus, additional support is provided for Hypothesis 1. Regarding economic significance, an increase of approximately 14.0% in GTFP among companies is observed as a result of the policy, as shown in column (2).

Table 6. Results of difference-in-differences model

	(1)	(2)
	GTFP	GTFP
Treat×Post	0.201***	0.140***
	(15.731)	(13.499)
Cons	-0.108***	5.892***
	(-28.409)	(19.877)
Control variable	No	Yes
Industry dummy	Yes	Yes
Year dummy	Yes	Yes
Observation	1235	1235
Adjusted R-squared	0.196	0.502

To ensure the robustness of the difference-in-differences (DID) analysis, it is imperative that both the treatment and control groups satisfy the parallel trends assumption. This means that, in the absence of the pilot policy, the time trends of GTFP among companies should not exhibit systematic differences. Figure 2 examines the parallel trends of the structural characteristics of

GTFP for Zhejiang companies from 2008 to 2016. An upward trend in the GTFP of the sample companies was observed before the implementation of the pilot policy; however, the 95% confidence interval of the estimated values included zero, indicating that the requirement for parallel trends was essentially met. Post-policy implementation in 2011, the regression coefficient exhibited a statistically significant positive value within the 95% confidence interval, and the general trend showed a continuous upward trajectory. Thus, the parallel trend test confirms that the DID model is appropriate, and the conclusion that the policy positively impacts the GTFP of Zhejiang companies is robust.

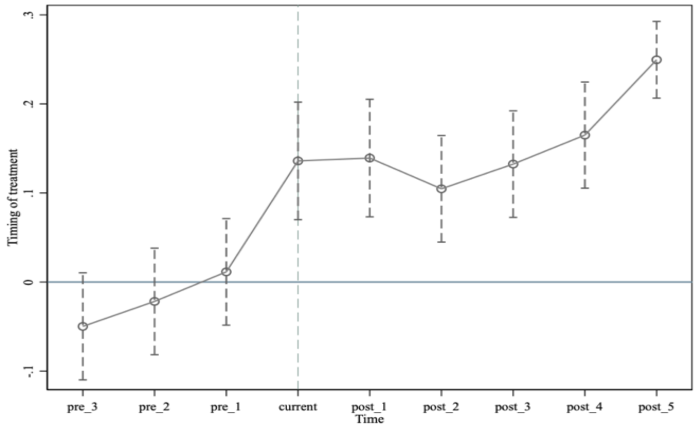

Figure 2. Parallel trend test

CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper utilizes micro-level data of listed companies in Zhejiang Province of China from 2007 to 2021 and employs high-dimensional fixed effects model and difference-in-differences model to examine the effect of Sci-tech finance development on the cultivation of companies' green productivity. It is found that the development of Sci-tech finance effectively promotes the enhancement of green total factor productivity and the advancement of green technological innovation in companies through two pathways: optimizing the supply of financial resources and accelerating the aggregation of low-carbon technological elements. The significant promoting effect of Sci-tech finance on companies' green productivity exists in both southern and northern regions of Zhejiang and across areas with different income levels, and is particularly prominent in high-income regions. Moreover, this promoting effect is more significant for small and medium-sized companies, private companies, and non-audited companies. Based on a quasi-natural experiment using the "Pilot policy for synergizing technology and finance." the pilot policy is also found to have a notable beneficial impact on the green productivity of companies in relevant pilot cities.

In light of these findings, this report advances a series of strategic suggestions: First, policy support for Sci-tech finance should be continuously strengthened by the Zhejiang government, financial resource allocation should be optimized, and funds should be ensured to flow to the most promising green innovation projects. Second, differentiated Sci-Tech financial policies tailored to the characteristics of different regions should be formulated by the Zhejiang government, experience sharing and technology transfer should be promoted, and regional coordinated development should be driven. For high-income regions, the role of Sci-tech finance should be further strengthened; for middle- and low-income regions, policy support should be increased to narrow regional development disparities. Third, more financing channels should be provided for small and medium-sized companies in Zhejiang, especially start-ups, to alleviate their financial pressures and support R&D investment. By building a diversified financial product system and providing customized financial solutions for different companies, companies can be promoted to enhance their innovation capabilities and improve the level of GTFP. Fourth, a multi-level capital market should be developed in Zhejiang, more direct financing channels should be provided, the Sci-Tech credit system should be innovated, and risks should be diversified. By building a Sci-tech finance ecosystem and promoting cooperation among financial institutions, companies, and research institutions, the support of Sci-tech finance for companies' green productivity can be enhanced, further promoting regional green economic development.

ACKNOWLEDGMENTS

Shaoxing city philosophy and social science planning project (No. 145425); scientific research fund of Zhejiang provincial education department (No. Y202455099).

REFERENCES

[1] Chen, H., Hu, S., Cai, Y. (2024) Driving Effect of Fintech on Firm Green Innovation in China's Strategic Emerging Industries: The Mediating Role of Digital Transformation. International Review of Economics & Finance, 96, 103613.

[2] Wang, J., Qiao, L., Zhu, G., Di, K., Zhang, X. (2025) Research on the Driving Factors and Impact Mechanisms of Green New Quality Productive Forces in High-Tech Retail Enterprises under China's Dual Carbon Goals. Journal of Retailing and Consumer Services, 82, 104092.

[3] Tao, F., Zhang, H., Hu, Y., Duncan, A.A. (2017) Growth of Green Total Factor Productivity and Its Determinants of Cities in China: A Spatial Econometric Approach. Emerging Markets Finance and Trade, 53, 2123–2140.

[4] Liu, Y., Peng, Y., Wang, W., Liu, S., Yin, Q. (2024) Does the Pilot Zone for Green Finance Reform and Innovation Policy Improve Urban Green Total Factor Productivity? The Role of Digitization and Technological Innovation. Journal of Cleaner Production, 471, 143365.

[5] Wang, L., Li, M., Wang, W., Gong, Y., Xiong, Y. (2023) Green Innovation Output in the Supply Chain Network with Environmental Information Disclosure: An Empirical Analysis of Chinese Listed Firms. International Journal of Production Economics, 256, 108745.

[6] Wang, W., Dong, Y. (2024) Spatial-Temporal Coupling and Interactive Effects of Digital Finance and Green Technology Innovation: Empirical Evidence from China. Journal of Cleaner Production, 470, 143354.

[7] Fan, M., Zhou, Y., Lu, Z., Gao, S. (2024) Fintech's Impact on Green Productivity in China: Role of Fossil Fuel Energy Structure, Environmental Regulations, Government Expenditure, and R&D Investment. Resources Policy, 91, 104857.

[8] Akhtar, S., Tian, H., Alsedrah, I.T., Anwar, A., Bashir, S. (2024) Green Mining in China: Fintech's Contribution to Enhancing Innovation Performance Aimed at Sustainable and Digital Transformation in the Mining Sector. Resources Policy, 92, 104968.

[9] Zhong, Y., Jin, X. (2024) How Does Technology Finance Promote the High-Quality Development of Firms? Evidence from China. Finance Research Letters, 69, 106186.

[10] Wei, R., Xia, Y. (2024) Digital Transformation and Corporate Green Total Factor Productivity: Based on Double/Debiased Machine Learning Robustness Estimation. Economic Analysis and Policy, 84, 808–827.

[11] Wu, Y., Shi, F., Wang, Y. (2024) Driving Impact of Digital Transformation on Total Factor Productivity of Corporations: The Mediating Effect of Green Technology Innovation. Emerging Markets Finance and Trade, 60, 950–966.

[12] Xue, Q., Bai, C., Xiao, W. (2022) Fintech and Corporate Green Technology Innovation: Impacts and Mechanisms. Managerial and Decision Economics, 43, 3898–3914.

[13] Li, B., Zhang, Z., Zhang, Z. (2024) The Impact of the Belt and Road Initiative on Green Innovation and Innovation Modes: Empirical Evidence from Chinese Listed Enterprises. Frontiers in Environmental Science, 11, 1323888.

[14] Crane, A.D., Koch, A., Michenaud, S. (2019) Institutional Investor Cliques and Governance. Journal of Financial Economics, 133, 175–197.