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The Impact of Green Finance Pilot Cities on Enterprises' Green Innovation Performance: An Empirical Study in China

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Abstract: Effectively leveraging green finance policies is essential to promoting urban green technology innovation, achieving sustainable development, and addressing global environmental challenges. This paper investigates the impact of the Green Finance Pilot City Policy (GFPP) on corporate green innovation performance by analyzing data from China's A-share listed companies from 2012 to 2022. Using a difference-in-differences methodology, mediation effect analysis, and panel data techniques, the findings reveal that the GFPP significantly enhances corporate green innovation performance, with particularly strong effects in designated pilot zones compared to other cities. Key mechanisms identified include reductions in financing and agency costs, which facilitate innovation. Furthermore, the impact of the GFPP is heterogeneous, varying by region, the nature of firms' property rights, and specific industry characteristics. The promotional effect of the GFPP on firms' green innovation performance will, to some extent, also contribute to green sustainable development in the wider environment within the region, and the feasibility of the pilot policy will also drive the promotion and development of the policy on a wider scale in China.

Keywords: green innovation performance; financing cost; agency cost; green finance policies; sustainable development

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Academic Editor: Paulo Santos

Received: 24 December 2024
Revised: 17 January 2025
Accepted: 22 January 2025
Published: 24 January 2025

Citation: Liu, S.; Qian, J.; Wen, H.; Wang, Y. The Impact of Green Finance Pilot Cities on Enterprises' Green Innovation Performance: An Empirical Study in China. *Sustainability* **2025**, *17*, 948. https://doi.org/10.3390/su17030948

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1. Introduction

China is a nation that places significant emphasis on balanced and sustainable development. China pays attention to the economic development balance between developed and less developed regions and ensures common development between regions. For example, a series of public support policies, such as the development of the western region, the revitalization of the northeast region, and the promotion of the central region, ensure the economic development of the less developed regions. China also pays attention to and contributes to the sustainable development of the overall environment internationally [1–3]. Since the 1960s, the ecological crisis and resource dilemma characterized by global warming, land desertification, resource depletion, and environmental degradation have become an urgent global challenge [4–7]. In order to find ways to meet this challenge, many countries have begun to explore new development paths, and a low-carbon economy has now become a sustainable development strategy that is recognized in the current global environment [8,9]. Therefore, helping the country and the world find a suitable path to achieving low-carbon economic development has become key. As the world's largest developing country and

the second largest economy, China's rapid economic development has brought about a substantial increase in energy consumption and environmental damage. According to statistics, China's total energy consumption has increased by 6.4% per year on average from 2001 to 2021 [10,11]. It can be seen that ecological damage caused by rapid economic growth, especially the increase in energy consumption and pollution, is currently a major challenge that China and a large number of developing countries urgently need to solve in the low-carbon context [12,13].

The added value of China's annual industrial output accounts for more than 30% of its GDP. The swift economic growth observed in developing nations is largely fueled by the expansion of conventional sectors, particularly manufacturing and services, which heavily rely on the extensive consumption of fossil fuels like coal, crude oil, and natural gas [14]. In this context, given the rapid growth of China's energy consumption [15], traditional industrial production is still a key factor affecting the economic development trajectory of China and most developing countries [16–18]. At a time when China is in a phase of rapid development and is transitioning to high-quality development centered on dual-carbon goals (carbon peaking and carbon neutrality), decisions such as closing high-emitting enterprises or cutting the production of energy-intensive products could have a significant impact on the current steady trend of economic growth. Nonetheless, uncontrolled ecological deterioration represents a considerable threat to sustainable development, jeopardizing the green and low-carbon initiatives championed by the United Nations. The deterioration of the ecological environment, which is regarded as a crucial foundation for industrial progress, significantly obstructs industrial expansion and technological advancements, ultimately stalling the comprehensive development of the industrial economy. Consequently, addressing the conflict between industrial economic development and environmental sustainability has emerged as a pivotal theme in global scholarly research [8,19–22].

In this context, global attempts at green innovation provide valuable lessons for building a green financial system [23]. Business green innovation is also recognized as a key and viable way to facilitate a comprehensive transition to a sustainable green economy [24,25]. This approach is characterized by its inherent complexity and the integration of advanced, cutting-edge technologies and practices that not only improve environmental sustainability but also drive economic growth. The multi-faceted nature of green innovation covers all aspects, including the development of environmentally friendly products, the implementation of sustainable processes, and the adoption of circular economy principles [26–28].

In addition, the importance of green innovation has led to its incorporation into national policy design considerations, reflecting governments' increasing commitment to promoting sustainable development and reducing environmental impact [29,30]. These policies are designed to incentivize businesses to invest in innovative solutions that meet environmental objectives, which is an approach that establishes a collaborative structure that integrates both the public and private sectors. Such a strategic partnership is vital for effectively navigating the challenges associated with transitioning to a green economy, thereby promoting a more sustainable future for society as a whole.

In pursuit of this goal, the Chinese government has implemented a range of environmental initiatives aimed at encouraging businesses to realize energy efficiency and reduce emissions via innovative green practices. Nonetheless, certain administrative measures fail to generate the anticipated "innovation offset" outcome, as posited by Porter, instead unintentionally hindering innovation as a result of their coercive characteristics [31–33]. Furthermore, evidence suggests that the majority of market-oriented policies fail to offer adequate motivation for companies to engage in green innovation [34].

In essence, green innovation projects are riskier and have lower success rates than traditional innovation projects. They tend to require more extended research and development cycles and higher costs and, therefore, require external financial support [35,36]. To address this challenge, since 2007, the Chinese government has complemented traditional environmental policies with a series of green finance initiatives, including green bonds and green credit. In 2017, China officially launched a comprehensive and influential pilot green finance policy. The government has appointed eight cities within four provinces and one autonomous region as pilot areas for the Green Finance Reform and Innovation Program (GFPP). These regions are encouraged to cultivate a comprehensive green technology innovation framework by refining and critically assessing existing green finance mechanisms [37]. The specific implementation cities are shown in Table 1.

Table 1. Cities implementing the 2017 Green Pilot Policy.

Implementation of Urban	Province Located
Quzhou Huzhou	Zhejiang Province
Ganjiang New District	Jiangxi Province
GUI 'an New District	Guizhou Province
Changji Prefecture Karamay City Hami City	Xinjiang Uygur Autonomous Region
Guangzhou City	Guangdong Province

In theory, The GFPP can guide financial resources to environmentally friendly enterprises by establishing environmental thresholds that affect their external financing and green innovation strategies [38,39]. Nonetheless, fundamental inquiries persist: Does it genuinely motivate businesses to develop innovations in environmentally friendly technologies? Is it capable of generating authentic ecological value for both enterprises and society at large? Our comprehension of these matters continues to be inadequate.

In order to verify this problem, this study selects Chinese A-share listed enterprises from 2012 to 2022 as the research object and adopts the differences-in-differences method (DID) to study whether green city pilot policies can promote the development of green innovation performance of enterprises.

The marginal contributions of this paper are as follows: (1) This study explores how green finance pilot city policies affect enterprises' green technology innovation through agency costs and financing costs. (2) At the enterprise level, it is divided into heavily polluting enterprises and non-heavily polluting enterprises according to the pollution degree standard. The green technology innovation achievements of heavily polluting enterprises and non-heavily polluting enterprises under the influence of policies are analyzed respectively. (3) Green financial policies, to a certain extent, will encourage enterprises to carry out green technological innovation. These green financial policies are more effective in economically developed regions with low levels of pollution emissions from enterprises. The results of this study on the implementation of green reform policies provide a reference for other countries, and China's successful practice provides valuable experience for the practice of sustainable development in other developing countries. The framework diagram of this experiment is shown in Figure 1.

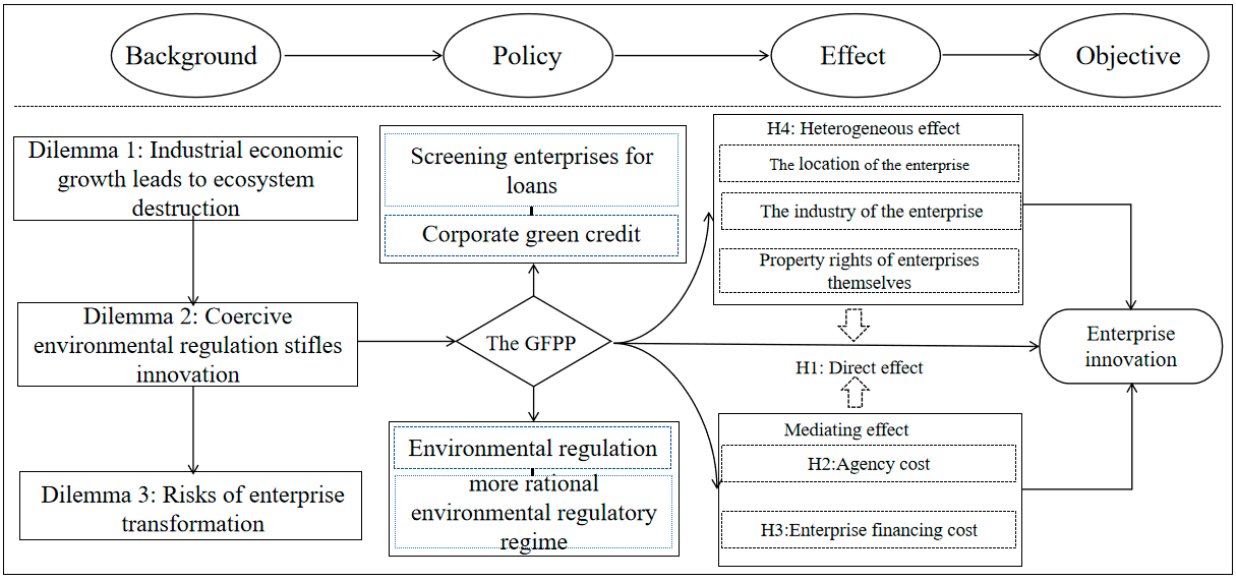

Figure 1. Framework diagram of the impact of green finance pilot cities on firms' innovation performance.

The rest of the paper is organized as follows: the second part of the literature review provides an in-depth analysis of the intrinsic mechanism of the GFPP affecting firms' innovation performance; the third part describes the empirical methodology, variables, and related data analysis the fourth part analyzes the results of the heterogeneity analysis; and the last section presents the conclusions, as well as policy recommendations.

2. Policy Background and Theoretical Analysis

2.1. Policy Background

The development of green finance in China started relatively late, and its earliest exploration can be traced back to 1995, when the People's Bank of China (PBC) issued the Notice on Issues Related to Implementing Credit Policies and Strengthening Environmental Protection Work. The circular made it clear that financial institutions at all levels should not grant loans to projects and enterprises that are prohibited by the state or do not comply with environmental protection regulations, and they should withdraw loans already granted. This initial attempt to promote environmental protection through credit policies did not have a significant social impact at the time.

With the passage of time, since the concept of "ecological civilization" was put forward at the Central Population, Resources and Environment Work Symposium in 2005, environmental protection and sustainable development have gradually gained widespread attention from the government and society. At the same time, the 17th National Congress of the Communist Party of China regarded the building of ecological civilization as an important goal to achieve all-round social prosperity.

In the face of increasingly serious environmental pollution problems, in 2007, the Ministry of Environmental Protection, the China Banking Regulatory Commission (CBRC), and the People's Bank of China jointly adopted a series of measures and collectively issued the Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks. The guideline encourages financial institutions to actively carry out green credit business, marking the formal establishment of China's green credit system. Since then, the CBRC and other relevant departments have successively issued a series of policy documents to promote the development of green finance, covering green credit, green bonds, green insurance, and green funds.

In March 2016, the adoption of the Outline of the 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China once again emphasized the importance of "establishing a green financial system, cultivating green credit and green bonds, and creating green development funds". However, due to the relative novelty of the concept of green finance, these policy documents lack effective evaluation and assessment mechanisms in actual implementation, and practical experience is still very limited. Therefore, it is imperative to further promote the development model of green finance and explore a "bottom-up" green finance development path. The purpose of this exploration is to accumulate practical experience that can be replicated and generalized in order to promote it within institutional mechanisms.

On 14 June 2017, at the State Council executive meeting, it was decided to set up pilot zones for green financial reform and innovation in four provinces and one autonomous region: Zhejiang, Jiangxi, Guangdong, Guizhou, and Xinjiang. These pilot zones are designed according to the unique characteristics and priorities of each location. Subsequently, on June 23, the People's Bank of China, together with seven other ministries, issued the Master Plan for the Construction of the Green Finance Reform and Innovation Pilot Zone, providing the necessary direction and guidance for the implementation of the initiative. Since then, joint meetings have been held among ministries, industry associations, and pilot zones to exchange effective practices, accumulating valuable experience for reform and innovation nationwide.

In summary, the research background of the development of green finance pilot cities not only involves the evolution and implementation of policies but also reflects China's institutional innovation and practical exploration in addressing environmental challenges.

2.2. Theoretical Analysis

The GFPP represents a significant reform and innovation in green financial instruments, focusing on the establishment of a comprehensive green technological innovation system. This is achieved by enhancing the related green financial frameworks. The GFPP fundamentally operates as a cohesive framework that integrates financial strategies with environmental regulatory policies. The primary objective is to optimize the management of financial resource allocation between firms committed to environmental sustainability and those with elevated pollution levels, utilizing environmental disclosure data as a vital reference point. By streamlining these processes, the GFPP aims to promote sustainable economic development while holding companies accountable for their environmental impact. This initiative not only encourages investment in green technologies but also fosters a more transparent and responsible approach to environmental management within the financial sector.

From the perspective of technological output, the GFPP primarily employs two mechanisms—"incentives" and "penalties"—to encourage enterprises to pursue green technological innovation. Firstly, as a financial instrument, the GFPP enhances financing opportunities for enterprises through instruments such as green credit, dedicated funds, and insurance products. This approach effectively lowers the financing costs for green enterprises, allowing them to allocate more resources toward green technology investments [21]. Furthermore, the GFPP offers a spectrum of financing alternatives that, while supplying various funding avenues, also entail differing levels of risk connected to advancements in green technology [40,41]. In order to strengthen these initiatives, the policy promotes the establishment of dedicated departments within financial institutions that prioritize sustainability. These departments are tasked with providing tailored services to enterprises, thereby streamlining business processes and enhancing access to financing specifically for green technology initiatives. By fostering a supportive environment for innovation, the

GFPP stimulates the creation of new capital-driven incentives for enterprises, ultimately promoting robust advancements in green technology.

Secondly, the GFPP serves as a regulatory framework aimed at encouraging businesses to engage in green innovation through a variety of incentives and mechanisms. Traditional economic theory posits that environmental regulations encourage investments in environmental management by raising the costs associated with corporate emissions, thereby enhancing social welfare. However, this viewpoint often overlooks the potential compensatory benefits stemming from green innovation.

Porter's Hypothesis challenges this conventional perspective, suggesting that flexible environmental regulations can actually incentivize firms to engage in green innovation activities rather than merely imposing additional costs [42]. By adopting a more holistic approach, the GFPP encourages enterprises to view environmental compliance not just as an obligation but as an opportunity for innovation and improvement. This approach fosters a culture of proactive adaptation and encourages firms to invest in sustainable practices that not only meet regulatory requirements but also enhance their competitiveness. Ultimately, the GFPP aims to create a regulatory environment that supports and accelerates the development of green technologies, benefiting both the economy and the environment.

The GFPP strengthens the requirements for industrial firms to record and disclose environmental information, compelling financial institutions to establish environmental eligibility criteria for access to financing. By imposing restrictions on external funding for polluting firms, the GFPP creates a more stringent regulatory environment that incentivizes these firms to engage in green innovation as a means of achieving a sustainable transition.

This policy framework exerts a strong binding effect on the emissions behaviors of polluting enterprises, effectively pushing them toward adopting green innovation strategies. Through these innovations, companies not only mitigate their environmental costs but also leverage technological advancements to achieve energy savings and reduce emissions. As a result, these firms can lift restrictions on their access to external financing and secure green funding support.

In summary, the GFPP encourages polluting enterprises to adapt to stringent environmental regulations by investing in green technologies, ultimately fostering a more sustainable and competitive business model that aligns with both regulatory expectations and market demands. In addition, the GFPP promotes green innovation through consumption incentives. A notable example of this is the establishment of green consumption loans paired with regulated interest rates, which not only incentivizes individuals to acquire environmentally friendly products but also serves to nurture a gradual shift toward sustainable preferences within the community [43]. In light of the escalating demand for sustainable consumption, businesses are progressively embracing eco-friendly technological innovations to fulfill market requirements, motivated by significant profit opportunities.

Thus, the GFPP is designed to accomplish two key objectives: it not only curtails the activities of polluting enterprises through punitive measures but also promotes green innovation via incentive mechanisms. This balanced approach enables businesses to simultaneously pursue environmental protection and economic development.

Hypothesis 1. *The GFPP can incentivize internal enterprises to carry out green technological innovation.*

This study examines the financing costs in relation to the unique framework of incentives and penalties established by the GFPP. While it may initially be challenging for enterprises to secure funding due to regulatory constraints, long-term trends indicate a decline in financing costs [44]. The GFPP supports projects related to the circular economy, environmental protection, energy conservation, and the transformation of emission reduc-

tion technologies within the city. It also mandates banks to limit financing to "two high" (high pollution, high energy consumption) enterprises.

When an enterprise applies for long-term loans from a bank, the bank conducts a thorough review, assessing the enterprise's financial status, creditworthiness, profit stability, and development prospects. Under the green credit policy, banks are increasingly attentive to the environmental impact of enterprises, taking into account both their own interests and social responsibility. Consequently, they tend to restrict loans to polluting enterprises, making it more difficult for "two high" enterprises to obtain new bank financing [45,46].

In this challenging financing landscape, enterprises often resort to alternative financing options such as commercial financing methods to address short-term capital shortages. This shift can lead to increased financing costs for heavily polluting enterprises in the short term [47–49]. However, in the long run, these financing costs are expected to decrease.

For non-heavily polluting industries, the characteristics of their operations typically result in lower financing costs, enabling them to continue innovating and developing green technologies. In contrast, heavily polluting industries are subject to stringent state regulations regarding pollution. Although their financing costs may decrease as they undergo green transformations, the impact of technological innovation in green practices may not be as pronounced.

Hypothesis 2a. *The GFPP for non-heavily polluting enterprises will reduce their financing costs and promote enterprises' green technological innovation.*

Hypothesis 2b. *The GFPP will reduce the financing cost for heavily polluting enterprises in the long run, but the effect of green technology innovation is not significant.*

From the perspective of corporate innovation risk, developing green technologies often presents considerable challenges, primarily due to the relatively low success rates and high capital investment requirements. Consequently, many rational business managers may find themselves in a dilemma; when the costs associated with environmental regulations are lower than the benefits of traditional development methods, they may be more inclined to utilize less expensive end-of-pipe technologies rather than actively investing in green technologies and undergoing transformation.

However, the implementation of stringent environmental regulations under the GFPP has significantly raised the costs of environmental compliance for firms. In some instances, these compliance costs can even exceed the benefits associated with conventional development practices. In this scenario, shareholders, as the principals, have a heightened incentive to encourage corporate managers to actively pursue green innovation. This shift is fundamentally driven by the need to mitigate risks linked to potential environmental violations and their associated penalties.

As a result, the increased regulatory pressure compels firms to prioritize green innovation as a strategic response, aligning corporate objectives with environmental sustainability while reducing the likelihood of incurring substantial fines or reputational harm. By fostering a culture of innovation that emphasizes environmental responsibility, companies can navigate compliance complexities and position themselves for long-term success in an increasingly sustainability-focused market.

The tenets of agency theory emphasize that discrepancies in objectives within an agency relationship can generate actions that do not necessarily correspond to the optimal interests of all stakeholders involved [50]. Frequently, members of an organization exhibit a tendency to emphasize short-term benefits at the expense of the firm's broader sustainability objectives, potentially undermining the company's dedication to investing in green innovations [51,52]. Moreover, individuals tend to be risk-averse, concerned

that taking on too much risk might jeopardize their reputation and future funding opportunities. This caution often leads them to avoid high-risk approaches, especially in the context of significant technological advancements, thereby favoring more conservative project choices [53,54]. Thus, without suitable interventions, changes in agency costs stemming from the environmental regulatory policies of the GFPP may hinder firms' green innovation pursuits.

In summary, the Green Finance Pilot City Policy, through its robust monitoring function, not only assists firms in mitigating environmental and social risks but also promotes proactive measures for R&D in green technology and environmental transformation. As environmental regulations continue to strengthen, the GFPP will likely enhance its capacity to drive green technology innovation in enterprises, offering solid financial support and guarantees for sustainable development and social responsibility. Based on this framework, this paper proposes its third hypothesis:

Hypothesis 3. *The GFPP can reduce the agency cost of raising pilot city enterprises to promote green financial innovation.*

2.3. Heterogeneous Promotion of Enterprise Innovation

In the context of green finance, the implementation of the GFPP necessitates the support of relevant environmental policies, as well as applicable laws and regulations. The impact of the GFPP on various enterprises differs across regions due to their distinct regional environments. In particular, the east, west, and central regions exhibit varying economic strengths, leading to different rates of business response to policy implementation [55,56]. Consequently, the pace of green transformation varies from one region to another.

Within the same region, state-owned enterprises (SOEs) tend to be slower in adapting to policy changes compared to non-state-owned enterprises (non-SOEs). Additionally, under the influence of financial sectors, such as banking and bond markets, heavy polluters experience a significant reduction in financing options compared to the period prior to policy implementation, resulting in increased financing costs. As a result, these enterprises are compelled to pursue their own green transformation initiatives [57–59]. Thus, this paper proposes the following hypothesis:

Hypothesis 4. *The GFPP will have different responses to the green transformation of enterprises in their regions depending on the region, and in the same environment, it will also have different responses to the green transformation due to the enterprise's own property rights or industry.*

3. Research Design

3.1. Sample Selection and Data Sources

In order to further exclude the interference of the rest of the policy, taking into account China's green credit policy enacted in 2012, this paper selects the data after 2012 to conduct the experiment, in addition to considering the availability of experimental data, Due to the difficulty in collecting relevant indicators for small- and medium-sized enterprises, and because most current listed companies in China choose A-share and H-share, the number of samples of enterprises and the standardization of the collection of indicators is ensured. This paper takes all A-share-listed companies during the period of 2012~2022 as the research object and selects the sample according to the following criteria: (1) Listed companies in the financial, insurance, and real estate industries are excluded. (2) Listed companies with abnormal gearing ratios are excluded. (3) Listed companies with abnormal trading (including ST, ST*, and PT) are excluded. (4) Companies listed after 2017 and companies with missing indicators of strictly heavily polluting listed companies are excluded. (5) To

ensure that the regression results are not affected by outliers, all continuous variables are shrink-tailed at the 1% and 99% levels. The data on the number of green patents held by enterprises are sourced from the China Research Service Platform (CNRDS) database, and other enterprise-level data are from the Cathay Pacific database.

3.2. Model Setup and Variable Definitions

This study is based on the quasi-natural experiment of the green financial reform and innovation pilot zones established in China. This research employs a differences-in-differences methodology to construct a fixed-effects econometric model that is specifically designed to assess the influence of pilot zone establishment on the green technological innovation capacities of enterprises. In order to exclude the possible bias of the original data, this paper adopts the propensity score matching method and selects the cities not covered by the GFPP as the experimental control group for treatment.

$$GFPP_{i,t} = Treat_i \times Post_t \tag{1}$$

$$innavation_{i,t} = \beta_0 + \beta_1 GFPP_{i,t} + \theta X_{i,t} + \mu_t + \delta_t + \lambda_j + v_r + \varepsilon_{i,t} \tag{2}$$

Model (1) constructs a core interaction variable $GFPP_{i,t}$, which is the intersection of $Treat_i$ and $Post_t$. Model (2) is the main model of this paper, where the explanatory variable $innavation_{i,t}$ is the level of green technological innovation of enterprise i in year t, which is divided into two aspects: quantity and quality. The classification of green patents is based on the World Intellectual Property Organisation (WIPO) system, which classifies green patents in accordance with the United Nations Framework Convention on Climate Change. This study uses the total number of green patent applications as an indicator to measure the quantity of green technological innovation of enterprises (*lntotal*). The number of patent applications can better reflect the innovation capacity at the current stage and is less affected by external factors than the number of patents granted.

The quality of green technological innovation of enterprises is measured by the number of green invention patent applications (*lnlnva*). Here, i, j, r, and t denote the company, region, industry, and year, respectively. $GFPP_{i,t}$ is the core explanatory variable of this study. μ_t, δ_i, λ_j, and v_r represent the time-fixed effects, individual fixed effects, regional fixed effects, and industry-fixed effects, respectively. $X_{i,t}$ denotes a series of control variables, and $\varepsilon_{i,t}$ denotes the random perturbation term. This study focuses on β_1, and β_0 is a constant term in the equation. β_1 measures the average difference between firms' innovation performance before and after regional policies. If the coefficient of β_1 is greater than 0, this suggests that the policy actively encourages the advancement of sustainable technological innovations among enterprises.

To further ensure the scientific rigor of the experiment, this study selects the age of the business (*lnage*), enterprise size (*lnsize*), return on equity (*lnroe*), return on assets (*lnroa*), Tobin Q (*lntobinq*), and price-to-book ratio (*Lnpb*) as control variables. The control variable will affect, to a certain extent, the financial investment in innovation for the enterprise, and with the change in policy, there will be some changes. In order to ensure that the results of the experiment are scientific, this change will be used as a control variable to ensure that the results of the experiment are scientific. Key variables are defined and described in Table 2.

Table 2. Definitions and descriptions of key variables.

Variable Type	Variable Name	Variable Symbol	Variable Definition
Explained variable	Total patent applications of enterprises	*lntotal*	The logarithm of the total number of green patents granted to the company, i.e., the sum of the number of green invention patents and green utility model patents granted, reflects the amount of company innovation.
	Total number of patent invention applications of enterprises	*lnlnva*	The logarithm of the number of patent applications for green inventions is an indicator of the quality of corporate innovation with more substantial innovations with independent intellectual property rights.
explanatory variable	Green finance policy Implementation	*DID*	Whether the region where the enterprise is located is part of the pilot region in the current year is 1; otherwise, it is 0.
Control variable	Age of business	*lnage*	Difference between the year in which the statistics were compiled and the year in which the enterprise was established
	Enterprise size	*lnsize*	The logarithm of the firm's assets
	Financial gearing ratios	*lnlev*	The logarithm of a firm's financial leverage
	Return on assets	*lnroa*	Return on assets = Net profit after tax/total assets
	Tobin Q	*lntobinq*	The ratio of a company's market value to the replacement cost of its assets
	Return on equity	*lnroe*	The logarithm of the number of patent applications for green inventions is an indicator of the quality of corporate innovation with more substantial innovations with independent intellectual property rights.
	Price-to-Book Ratio	*Lnpb*	The ratio of stock price per share to net asset value per share
Mechanism variable	TAC	*TAC*	Loss due to agency problems
	Cost	*cost*	Loss due to financing problems

4. Empirical Results and Analysis

4.1. Descriptive Statistical Analysis

Table 3 illustrates the results of the descriptive statistical analysis, revealing that this study comprised a total of 9801 participants, with the majority of standard deviations remaining notably low.

Table 3. Descriptive statistical analysis of 9801 listed companies.

Variable	(1) Mean.	(2) S.D.	(3) Min.	(4) Max.
lntotal	0.504	0.926	0	4.094
lnlnva	0.356	0.798	0	6.594
lnsize	22.76	1.289	20.37	26.55
lnlev	0.361	0.133	0.0703	0.618
lnroa	0.0390	0.0504	−0.147	0.198
lntobinq	1.036	0.319	0.608	2.113
lnroe	1.404	0.0249	1.293	1.476
lnpb	0.481	0.169	0.115	0.809
TAC	15.42	10.90	1.590	63.68
cost	0.0103	0.0278	−0.126	0.0586

4.2. Analysis of Baseline Results

According to Model (2), the corresponding data from the baseline regression can be derived, resulting in Table 4. Table 4 displays the regression analysis concerning the influence of the green finance pilot program on corporate green innovation. *CityFE* is the city non-time effect, which controls for the impact of city-level factors that do not vary over time on firms' green innovation performance, and *YearFE* is the year non-linear effect, which removes the impact of macro time trends on firms' green innovation performance. The results in Column (1) pertain to total green patent applications, whereas Column (2) focuses specifically on applications for green invention patents. It is observed that both exhibit a significantly positive relationship at the 1% level when controlling for region and year. Column (3) and Column (4) are regression results of control variables, and it can be seen that the results are still significant under the condition of no control variables. This provides evidence for Hypothesis 1, indicating that the policy framework of the green finance pilot zone plays a significant role in facilitating the progress of green technological innovation in enterprises.

Table 4. Benchmark regression.

Variables	(1) lntotal	(2) lnlnva	(3) lntotal	(4) lnlnva
GFPP	0.121 ***	0.107 ***	0.129 ***	0.112 ***
	(4.69)	(4.86)	(4.67)	(4.79)
control	YES	YES	NO	NO
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	−2.176 **	−0.799 *	0.488 ***	0.333 ***
	(−2.49)	(−2.02)	(141.54)	(114.34)
N	9801	9801	9801	9801
Adj. R^2	0.697	0.683	0.697	0.683

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3. Robustness Tests

4.3.1. Parallel Trend Test

This study identifies the year 2017, when the green finance city pilot policy was implemented, as the baseline year. It performs a parallel trend analysis on the overall quantity of green patent applications and the total count of green invention patent applications, with findings presented in Figures 2 and 3. The analysis of dynamic effects demonstrates that subsequent to 2017, the execution of the green finance city pilot policy has significantly contributed to augmenting the technical impact, as evidenced by the total number of green patent applications. In contrast, 2016 witnessed a significant increase in the number of green invention patent applications. This upsurge can be largely ascribed to the introduction of the green credit policy in 2012, coupled with a phenomenon of policy pre-activation that encouraged enterprises to enhance their submissions of green invention patents. It can be seen in the table that although the overall stability is relatively stable after 2017, there is a downward trend in 2019 and 2021, mainly because of the following reasons: First, the policy received the impact of environmental changes at that time, and the enterprise could not adjust in a short period of time, such as the impact of the epidemic in 2019. Second, the policy environment of the enterprise has not changed for a long time, and it needs the stimulus of new policies to help the enterprise carry out further reform.

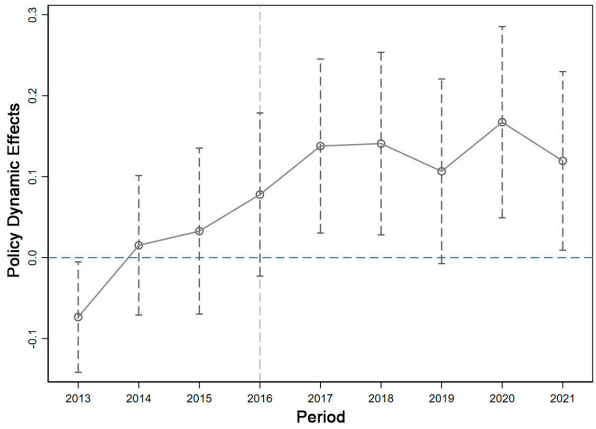

Figure 2. Parallel trend test for total green applications.

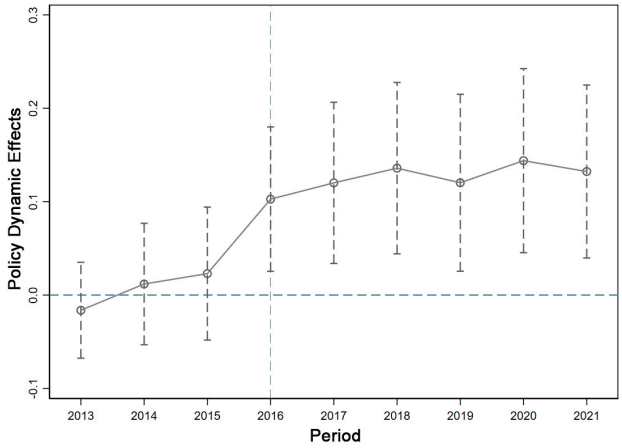

Figure 3. Parallel trend test for green invention patent applications.

4.3.2. Lagged One Period

In order to avoid errors and ensure the scientificity of the empirical results, this paper processes empirical results with a lag of one period according to Model (2) and obtains Table 5. According to Columns (1), (2), (3), and (4), it can be seen that after a lag of one period, the green finance pilot zone policy has a significant positive effect on the total number of green patent applications and the number of green invention patent applications at the level of 5%, which further confirms the establishment of H1.

Table 5. One-phase lag treatment.

Variables	(1) lntotal	(2) lnlnva	(3) lntotal	(4) lnlnva
L.GFPP	0.095 **	0.085 **	0.096 **	0.088 **
	(2.69)	(3.17)	(2.49)	(2.99)
Control	YES	YES	NO	NO
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	−1.755	−0.819	0.507 ***	0.349 ***
	(−1.26)	(−1.00)	(114.19)	(103.48)
N	8910	8910	9801	9801
Adj. R^2	0.712	0.700	0.711	0.700

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

4.3.3. Placebo Test

The placebo test can further determine whether the results are produced by the influence of green finance pilot city policies, excluding the influence of other policies or random factors on the experimental results. This method is mainly carried out by constructing a virtual experimental group and performing DID regression on the virtual experimental group. This method has been widely used in DID studies [45,60]. In this paper, by randomly selecting provinces and policy implementation time, according to Model (2), a placebo test with 500 randomly selected times was conducted, and Figures 4 and 5 were obtained. From Figures 4 and 5, It is evident that the baseline regression coefficients significantly differ from the other estimated coefficients, indicating that the baseline regression is a low-probability event. Additionally, the passage of the placebo test further confirms the stability of the baseline regression results.

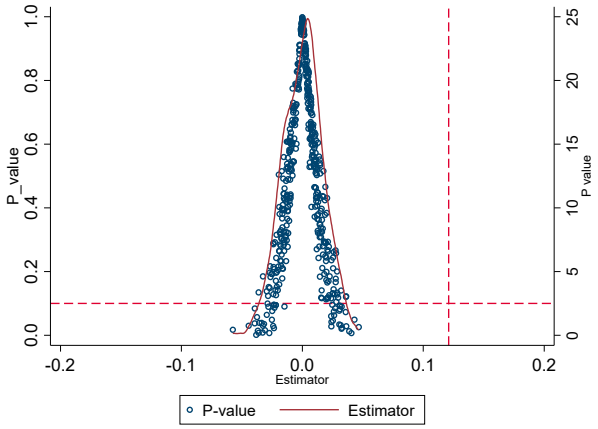

Figure 4. Placebo test for total green applications.

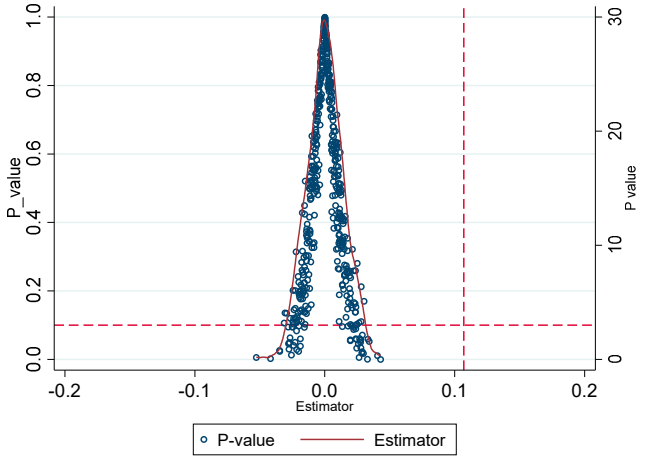

Figure 5. Placebo test for green invention patent applications.

4.3.4. Propensity Score Matching (PSM-DID)

To enhance the methodological rigor and scientific integrity of Model (2), this study adopts the propensity score matching technique, specifically implementing the nearest-neighbor matching strategy to appropriately align the samples; the results are shown in Table 6. As can be seen in Table 6, Columns (1) and (2) are the regression results of the total number of green patent applications and the number of green invention patent applications after matching, while Columns (3) and (4) are those without adding control variables. It can be seen that after the propensity matching score, the total number of green

patent applications and the number of green invention patent applications are significantly positive at the 1% level, which further proves the robustness of the baseline regression.

Table 6. Results of regression of propensity score matching.

	(1)	(2)	(3)	(4)
Variables	**lntotal**	**lnlnva**	**lntotal**	**lnlnva**
GFPP	0.121 ***	0.107 ***	0.129 ***	0.112 ***
	(4.69)	(4.86)	(4.67)	(4.79)
Control	YES	YES	NO	NO
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	−2.176 **	−0.799 *	0.488 ***	0.333 ***
	(−2.49)	(−2.02)	(141.54)	(114.34)
N	9801	9801	9801	9801
Adj. R^2	0.697	0.683	0.697	0.683

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4. Mechanism Test

On the basis of the literature review and theoretical analysis, this study hypothesizes that the GFPP can promote the development of green technology innovation by reducing financing and agency costs. The GFPP can reduce the agency and financing costs of enterprises, promote the improvement of enterprise income, reduce the risk and cost of enterprise transformation, and expand the investment capital of enterprises. The mechanism by which the GFPP promotes innovation performance is shown in Figure 6.

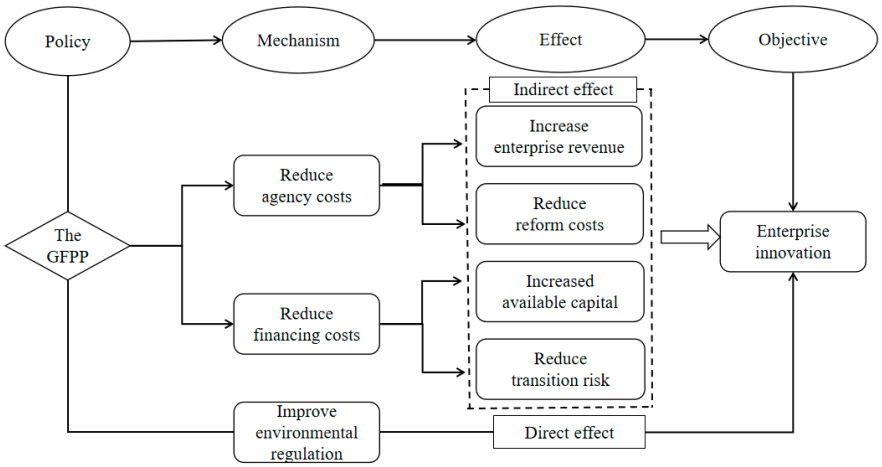

Figure 6. Mechanisms of GFPP to promote green innovation performance of firms.

We will start with a specific analysis of financing and enterprise agency costs.

First, in order to verify H1, we will construct the following model to analyze the impact of green finance pilot zones on financing cost and financing scale:

$$Cost_{i,t} = \partial_0 + \partial_1 GFPP_{i,t} + \partial_3 X_{i,t} + \mu_t + \delta_t + \lambda_j + v_r + \varepsilon_{i,t} \quad (3)$$

In Model (3), the explanatory variable is $Cost_{i,t}$, and the cost of debt financing is used as a measure of its financing cost. The remaining indicators have the same meaning as the variables in Model (2).

Second, in order to verify H3, we construct the following model to analyze the impact of green finance pilot zones on agency costs:

$$TAc_{i,t} = \eta_0 + \eta_1 GFPP_{i,t} + \eta_2 X_{i,t} + \mu_t + \delta_t + \lambda_j + v_r + \varepsilon_{i,t} \quad (4)$$

In Model (4), the explanatory variable is $TAc_{i,t}$. The agency cost *TAc* is adopted as a measure. The remaining indicators have the same meaning as the variables in Model (2). Referring to the existing literature practice, we adopt the management expense ratio to measure the total agency cost (*TAc* = management expense/total operating revenue); the larger the value, the more serious the agency problem. The management expense ratio mainly reflects the actual costs incurred because of agency behavior, mainly the waste caused by managers' overspending. Using Model (2) and Model (3), Table 7 is obtained.

Table 7. Regression of policy agency and financing costs in green finance pilot cities.

Variables	(1) TAC	(2) TAC	(3) Cost	(4) Cost
GFPP	−0.013 **	−0.015 **	−0.003 **	−0.110 ***
	(−2.42)	(−2.86)	(−2.90)	(−6.13)
Control	YES	NO	YES	NO
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	0.570 *	0.156 ***	−0.338 **	−22.744 ***
	(2.00)	(240.19)	(−2.77)	(−10,084.56)
N	9801	9801	9801	9801
Adj. R^2	0.762	0.728	0.999	0.941

Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, the *GFPP* and the two mediating variables are placed in the regression equation simultaneously.

$$innavation_{i,t} = \alpha + \beta GFPP_{i,t} + \phi \mathrm{Cost}_{i,t} + \sigma TAc_{i,t} + \theta X_{i,t} + \mu_t + \delta_t + \lambda_j + v_r + \varepsilon_{i,t} \quad (5)$$

Using Model (5), Table 8 is obtained to observe the impact of financing and agency costs on enterprises' green technological innovation. The variables in Model (5) have the same meanings as those in Model (1), except for the addition of two mediating variables, $Cost_{i,t}$ and $Ac_{i,t}$. In the current literature analyzing the impact of financing costs on Chinese enterprises, enterprises are classified into two categories, including those with heavy pollution emissions and non-heavy pollution emissions, according to the Guidelines for Environmental Information Disclosure of Listed Companies issued by China's State Ministry of Environmental Protection (MEP) in 2010 [61,62]. Therefore, this paper analyzes the impacts of the mechanism variable concerning financing costs on enterprises' green innovation performance. The relevant enterprises are classified into heavily polluting and non-heavily polluting enterprises when we analyze the impact of the financing cost mechanism variable on enterprises' green innovation performance.

As illustrated in Column (1) and Column (2) of Table 7, TAc exhibits a significant negative correlation at the 5% significance level, indicating a trend of declining agency cost changes over time among firms situated in the city where the policy has been implemented. In addition, regarding financing expenses, the data presented in Column (3) and Column (4) of Table 7 indicate a significant negative correlation at the 10% significance level, suggesting that financing costs tend to decline over time. Furthermore, the findings from Columns (1) and (2) of Table 8 reveal that both green quantity innovations and green quality innovations exhibit a significant negative correlation at the 5% significance level. From the results in Columns (1) and (2), it can be seen that the number of green quantity innovation and green quality innovation inventions are both negatively correlated at the 5% level, and Hypothesis H3 is valid. According to Table 8, Columns (3) and (5), it can be seen that heavily polluting firms are irrelevant in terms of green patent quantity and quality. According to Table 8, Columns (4) and (6), it can be seen that non-heavily polluting

firms are significantly correlated and negatively correlated at the 1% level for both the green patent quantity and quality indicators, i.e., financing costs are also decreasing over time. Because they are significantly and negatively correlated, the decline in financing costs will promote the development of green patents; thus, Hypotheses H2a and H2b are valid.

Table 8. Effect of financing and agency costs on the number of green patents.

Variables	(1) TAC lntotal	(2) TAC lnlnva	(3) Heavy Pollution lntotal	(4) Non-Heavy Pollution lntotal	(5) Heavy Pollution lnlnva	(6) Non-Heavy Pollution lnlnva
TAC	−0.583 **	−0.331 **				
	(−2.23)	(−2.38)				
Cost			−0.052	−0.298 ***	−0.026	−0.204 ***
			(−0.89)	(−6.08)	(−0.80)	(−5.06)
Control	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Constant	−0.415	−4.307 ***	−0.773	−6.805 ***	−0.286	−4.684 ***
	(−1.62)	(−6.55)	(−0.51)	(−5.79)	(−0.32)	(−4.83)
N	2255	2255	500	1754	500	1754
Adj. R^2	0.712	0.687	0.529	0.740	0.505	0.702

Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

4.5. Heterogeneity Analysis

The regression analysis and robustness tests conducted in the previous section indicate that the GFPP effectively promotes enterprises in their green transformation and advances their green technology development. Building on these findings, we proceed to test Hypothesis 4 by conducting a heterogeneity analysis.

4.5.1. Regional Heterogeneity

According to Model (2), the following regression results can be obtained by dividing the region into three subregions: east, west, and central. It can be seen that because of the different policies, as well as economic levels around the world, the performance of the Green Finance Pilot City Policy in each region is not the same. From Columns (1) and (4) of Table 9, it can be observed that in the eastern region, the policy shows a positive significance at the 1% level for both green patent applications and green invention patent applications. Although Column (6) is also significant, it is only significant at the 10 percent level, and the effect is not significant. Consequently, it is not significant in the less economically developed central and western regions, which aligns with the experimental prediction.

Table 9. Regression results of policy in different regions.

Variables	(1) East lntotal	(2) West lntotal	(3) Middle lntotal	(4) East lnlnva	(5) West lnlnva	(6) Middle lnlnva
GFPP	0.120 ***	0.058	0.051	0.097 ***	0.106	0.108 *
	(4.53)	(0.59)	(0.83)	(4.88)	(1.13)	(1.83)
Control	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Constant	−5.033 ***	4.278 *	1.145	−2.195 *	3.697 *	−0.100
	(−3.31)	(1.90)	(0.44)	(−2.09)	(1.95)	(−0.06)
N	6023	1525	1772	6023	1525	1772
Adj. R^2	0.710	0.629	0.725	0.688	0.636	0.727

Robust t-statistics in parentheses *** $p < 0.01$, * $p < 0.1$.

4.5.2. Heterogeneity of Business Ownership

According to Model (2), by dividing the nature of enterprise property rights into two types of enterprises, SOEs and non-SOEs, the following regression results can be obtained: It can be seen that because of the special nature of the SOEs themselves, the SOEs are not particularly responsive to the green transition; thus, the Green Finance Pilot City Policy takes effect more rapidly on non-SOEs. From Columns (2) and (4) of Table 10, it can be seen that the policy is positively significantly correlated with the green patent application and the green invention patent application of non-SOEs at the 1% level. Additionally, based on the results in Columns (1) and (3), it can be seen that this factor is not significant in the case of SOE specialization, which is consistent with the experimental prediction.

Table 10. Regression results of different property rights properties on policy.

Variables	(1) State-Owned lntotal	(2) Non-State-Owned lntotal	(3) State-Owned lnlnva	(4) Non-State-Owned lnlnva
GFPP	0.039	0.198 ***	0.037	0.175 ***
	(1.48)	(4.62)	(1.42)	(5.73)
Control	YES	YES	YES	YES
FirmFE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	0.052	−4.735 ***	−0.353	−1.654 *
	(0.04)	(−5.44)	(−0.36)	(−1.93)
N	4930	4871	4930	4871
Adj. R^2	0.749	0.706	0.734	0.692

Robust t-statistics in parentheses *** $p < 0.01$, * $p < 0.1$.

4.5.3. Heavy Polluter Status

Based on Model (2) and in accordance with the "Guidelines for Disclosure of Environmental Information of Listed Companies" (draft for public comment) issued by the Ministry of Environmental Protection of the People's Republic of China in 2010, which clearly identifies 16 industries, including thermal power, iron and steel, cement, aluminum electrolysis, coal, metallurgy, chemical, petrochemical, building materials, papermaking, brewing, pharmaceuticals, fermentation, textiles, tanning, and mining, as heavily polluting industries, enterprises can be categorized into two types: heavily polluting and non-heavily polluting. The following regression results can be obtained by dividing enterprises into two types, namely, heavily polluting and non-heavily polluting. It can be seen that because of the industry specificity of heavily polluting enterprises, the industries themselves are highly polluting; therefore, it is more difficult to observe the green transformations of heavily polluting enterprises to a certain extent. In Columns (2) and (4) in Table 11, it can be seen that the green patent and green invention patent application policies for non-heavily polluting enterprises are positively significant at the 1% level. Additionally, according to Columns (1) and (3), it can be seen that this factor is not significant for heavily polluting enterprises, which are inherently industry-specific; this is in alignment with the experimental prediction.

In summary, under the influence of the Green Finance Pilot City Policy, although enterprises will actively promote their own green transformation and promote the innovation of green technology, they will still be influenced by various factors such as the region, the nature of property rights, and the industry; thus, Hypothesis H4 is valid.

Table 11. Regression results of different industries on policy.

Variables	(1) Heavy Pollution lntotal	(2) Non-Heavy Pollution lntotal	(3) Heavy Pollution lnlnva	(4) Non-Heavy Pollution lnlnva
GFPP	0.020	0.128 ***	0.042	0.109 ***
	(0.40)	(3.76)	(1.35)	(4.15)
Control	YES	YES	YES	YES
FirmFE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	−1.026	−3.065 **	−1.191	−0.845
	(−0.80)	(−2.78)	(−1.36)	(−1.62)
N	2918	6876	2918	6876
Adj. R^2	0.599	0.756	0.545	0.745

Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

5. Conclusions and Policy Implications

5.1. Conclusions

Using the announcement by the Chinese government regarding the establishment of a pilot zone for green financial reform and innovation in 2017 as an event, this paper constructs a quasi-natural experiment and utilizes the DID methodology to assess the policy effect of the GFPP on firms' green innovation performance. The following conclusions can be drawn: First, these findings enhance our understanding of the impact of the GFPP in China. Specifically, the establishment of the pilot zone in 2017 significantly contributed to the development of firms' green innovation performance, which is in line with the findings of previous research in this area [63]. These results are supported by several robustness tests, such as the PSM-DID analysis of the nearest-neighbor matching method with a placebo test. Secondly, although previous studies have examined this kind of problem, most of the research mechanisms favor the environment and other macro aspects [64] and do not take into account the influence of the enterprise itself. Therefore, this paper discusses the enterprises' own financing and agency costs [62] and finds that the agency and financing costs tend to decrease under the influence of the GFPP, thereby promoting the performance of enterprises' green technology innovation. In addition, the impact of the GFPP on the innovation performance of enterprises is affected by the geographical location of the city, the nature of the enterprises' own property rights, and the characteristics of the enterprises' own industries. In the economically underdeveloped regions of China, the impact of enterprises that are heavy polluters themselves and those whose property rights are owned by the state is not significant.

5.2. Policy Implications

According to the results of this study, it can be seen that the implementation of the GFPP is conducive to improvement in the green innovation performance of enterprises, which is conducive to the alleviation of the current environmental pollution problems. However, the effect of the GFPP is mainly influenced by the region and other aspects, so this paper offers the following suggestions: First, the selection of regions should be broadened to promote the further implementation of the policy, with economically developed regions mainly chosen as the pilot sites. Second, the government should target policies to drive the development of and promote the economic growth of underdeveloped regions [65] to ensure that the GFPP will work well throughout China. Finally, the state should appropriately relax its control over state-owned enterprises, strengthen its supervision of the transformation of heavily polluting enterprises into clean energy-based enterprises, and

strengthen the flow of information to ensure the smooth progress of bank financing and avoid the emergence of financing difficulties.

5.3. Limitations and Future Research

The current study still has some limitations. Firstly, this paper only explores the impact of the GFPP on enterprise innovation performance from a micro perspective and does not consider the impact on society or cities from a macro perspective. Future research can consider the impact of urban green policies and the overall employment situation. Secondly, this study only includes listed large-scale enterprises and does not consider small- and medium-sized enterprises (SMEs); future research can consider SMEs. Finally, the reality of enterprise green transition involves a variety of factors. This paper only offers a preliminary exploration of GFPP policy, and future studies can further expand this field of research.

Author Contributions: Conceptualization, S.L.; Methodology, J.Q. and H.W.; Software, Y.W.; Formal analysis, J.Q.; Data curation, Y.W.; Writing – original draft, J.Q. and Y.W.; Writing—review & editing, S.L., J.Q. and H.W.; Supervision, S.L. and H.W. All authors have read and agreed to the published version of the manuscript.

Funding: Project of 2024 Think Tank Research of Jiangxi Province, China (No. 24ZK09).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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