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The Role of Urban Forest Policies in Driving Green Innovation: Evidence from Chinese Cities

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Abstract: Urban forest policies have garnered increasing global attention for their critical role in providing key ecosystem services such as carbon sequestration, air pollution control, microclimate regulation, and biodiversity enhancement, as well as their potential to drive green innovation and sustainable urban development. This study utilized panel data from 273 Chinese cities between 2000 and 2022, employing a quasi-natural experiment and a difference-in-differences (DID) model to systematically evaluate the impact of the National Forest City Policy (NFCP) on urban green innovation. The results indicate that NFCP significantly enhances urban green innovation, with these findings remaining robust across a series of validation tests. Mechanism analysis revealed that the policy fosters green innovation by increasing environmental attention, facilitating talent aggregation, and reducing carbon emissions. Furthermore, heterogeneity analysis showed that the policy's effects are more pronounced in small- and medium-sized cities, non-transportation hub cities, and economically developed regions. Based on these findings, this paper offers recommendations for optimizing policy implementation across different city types to further promote sustainable urban green economic development. This study broadens the research perspective on the relationship between urban policies and green innovation, providing more precise decision-making guidance for policymakers while also highlighting the important role urban forests play in enhancing ecosystem services and driving sustainable urban growth.

Keywords: urban forest policy; sustainable urban development; ecosystem services; green innovation; environmental attention

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1. Introduction

As global climate change and environmental degradation intensify, countries around the world are implementing policies to address environmental challenges and promote sustainable development. Urban forests and green spaces, as integral components of urban ecosystems, provide essential ecosystem services such as carbon sequestration [1], air pollution control [2], microclimate regulation [3], and biodiversity enhancement [4]. These services are crucial for improving urban quality of life and driving sustainable urban development. China, as the largest developing country, faces increasing environmental pressures and resource consumption challenges while striving for economic growth. In recent years, the Chinese government has implemented the National Forest City Policy (NFCP) to enhance urban greening, improve urban ecosystems, reduce carbon emissions, and promote green innovation and sustainable development. In developing countries like China, balancing rapid economic growth with environmental protection presents unique sociopolitical challenges. Firstly, these countries often experience resource depletion and environmental degradation in their pursuit of economic expansion, where short-sighted decisions can undermine long-term sustainability. Secondly, the capacity for effective policy implementation is often hindered by limited resources and weak governance structures, which may lead to insufficient enforcement of environmental regulations. In contrast, developed countries have more established institutional frameworks which enable better integration of environmental considerations into economic policies. Therefore, developing countries require tailored approaches to address their specific socioeconomic contexts while promoting sustainable development. Therefore, examining the impact of the NFCP on urban green innovation is not only essential for understanding how this policy improves ecological quality but also provides valuable insights into achieving a balanced approach to economic and environmental development.

The implementation of the NFCP aims to enhance urban environmental quality and improve residents' living standards through urban greening and ecological development. Unlike traditional industrial development policies, this policy prioritizes ecological considerations, striving for a balanced integration of economic, social, and environmental benefits. Green innovation, as a crucial means to promote resource efficiency and environmental protection, has become increasingly important under the framework of this policy. By advancing the NFCP, green technological innovation and the development of green industries not only reduce pollutant emissions and improve energy efficiency but also facilitate economic restructuring and upgrading. However, while the theoretical mechanisms of the NFCP have been extensively discussed, its actual impact on urban green innovation has yet to receive sufficient empirical support, particularly in developing countries like China, where the effects of such policies remain a subject of debate. This lack of empirical evidence can be attributed to two main reasons. First, specific data on green innovation, such as the number of green patent applications and corporate innovation activities, are often scarce, especially at a prefecture's city level. Many cities may not have collected or made this relevant data publicly available in a timely manner. Second, environmental policies typically require time to manifest their effects. In the early stages of policy implementation, significant increases in green innovation may not be immediately observable, leading to inaccurate preliminary assessments of policy effectiveness.

The literature closely related to this study can be divided into two main strands. The first focuses on the impact of urban policies on green innovation, while the second explores evaluations of the NFCP. Regarding the effects of urban policies on green innovation, numerous studies have shown that appropriate urban policies can promote the development of environmental products and green innovation [5]. For instance, recent research has highlighted the role of outdoor thermal comfort conditions in historical urban plazas and their influence on tourist satisfaction, emphasizing how microclimatic factors can affect visitor experiences in urban settings [6]. In terms of policy themes, scholars have examined the influence of various urban policies, such as those related to the digital economy [7], innovative cities [8], low-carbon cities [9,10], smart cities [11], and green finance [12], on green innovation. In terms of policy mechanisms, researchers have explored factors such as industrial structure [13], financial constraints [14], environmental regulations [15], marketization [16], and technological innovation [8] as mediating elements in how urban policies impact green innovation. Concerning the heterogeneity of policy effects, scholars have analyzed the differing impacts of urban policies on green innovation across various city sizes [17] and regions [18]. Methodologically, researchers have employed diverse approaches, including case studies [19], difference-in-differences (DID) models [20], and theoretical frameworks [21], to investigate the green innovation effects of urban policies.

Research on the evaluation of the NFCP primarily focuses on qualitative studies and urban environmental ecology. For instance, Liao et al. used a DID model to investigate the impact of the policy on carbon emissions, concluding that green spaces and green development models are key mechanisms for achieving carbon reduction [22]. Studies by Zhang et al. and Xu et al. found that the NFCP improves urban living environments and air quality [23,24]. Moser et al. and Koh et al. conducted case studies on foreign-funded forest city projects in Malaysia, highlighting potential negative effects on local urban ecosystems [25,26]. Additionally, Mauro Ramon et al., from a nature-based solutions (NBS) perspective, conducted a case study on forest city projects in Brazil, finding that such policies effectively reduce vehicular emissions and improve urban air quality [2]. Other scholars have explored the policy's impact on green total factor productivity and urban environmental welfare [27,28].

Existing research has provided a solid foundation and valuable insights for this study, but several gaps remain. First, from a research perspective, although previous studies have explored the impact of various urban policies on green innovation and discussed the ecological effects of the NFCP, few have examined the policy's green innovation effects from this perspective, particularly at the urban level with empirical analysis. Second, regarding policy mechanisms, existing research lacks detailed analysis of how the policy promotes green innovation, particularly in terms of multiple mechanisms such as environmental attention, talent aggregation, and carbon reduction. Environmental attention reflects the degree of awareness among the public, enterprises, and governments toward environmental issues, and an increase in this attention may be a key driver for green innovation. Additionally, limited research exists on how talent aggregation fosters green innovation in the context of the NFCP. Improvements in the urban ecological environment following policy implementation may attract high-quality talent, thereby fostering innovation activities. Lastly, controlling carbon emissions is a critical measure of the policy's effectiveness. Carbon reduction not only directly improves the environment but also indirectly stimulates green innovation. However, this mechanism has not been fully explored in existing studies. Furthermore, discussions on the heterogeneity of policy effects, such as differences in transportation infrastructure, city size, and economic geography, are not sufficiently in-depth. Therefore, it is necessary to conduct a more detailed investigation at the urban level using real-world data to thoroughly assess the green innovation effects of the NFCP.

Based on this, this paper constructs a quasi-natural experiment centered on the NFCP, using the difference-in-differences (DID) method and panel data from 273 Chinese cities between 2000 and 2022 to systematically empirically evaluate the policy's effects on green innovation. The use of the DID method is justified as it allows for the estimation of causal effects by comparing changes in outcomes over time between a treatment group (cities implementing the NFCP) and a control group (cities not implementing the NFCP). This approach effectively accounts for unobserved confounding factors which may influence both the policy implementation and the outcome, thus enhancing the validity of the findings. To ensure the robustness and reliability of the results, this study conducts a series of robustness checks, including propensity score matching difference-in-differences (PSM-DID) models, parallel trend tests, placebo tests, winsorization, the addition of omitted variables, and the control of fixed effects. These additional tests help confirm the consistency of the results and mitigate potential biases, thereby providing a more comprehensive evaluation of the NFCP's impact on green innovation.

Compared with existing research, the potential marginal contributions of this paper are as follows. ① From a research perspective, this study is the first to evaluate the green innovation effects of the NFCP through a quasi-natural experiment. This not only enriches the literature on the impact of urban policies on green innovation but also expands the research framework for evaluating the NFCP. ② Regarding the mechanisms of policy impact, this paper introduces the concepts of environmental attention, talent aggregation, and carbon emissions, expanding the theoretical framework for how the policy influences green innovation. It also provides new explanations for the pathways through which the policy affects green innovation. ③ In terms of analyzing the heterogeneity of policy effects, this paper examines the differences in the policy's impact across various dimensions, such as urban transportation conditions, city size, and economic geographic regions. This analysis reveals the differentiated effects of the policy in different regions and city types, thereby extending the perspective of policy heterogeneity analysis and offering more precise tools for policymakers to design effective strategies.

The remainder of this paper is structured as follows. Section 2 presents the theoretical analysis and research hypotheses, exploring the mechanisms through which the NFCP influences green innovation and proposing relevant hypotheses. Section 3 details the research design, including data sources, variable construction, and model specification.

Section 4 conducts an empirical analysis, presenting the regression results of the policy's impact on green innovation along with robustness tests. Section 5 examines the mechanisms of the policy's effects. Section 6 analyzes the heterogeneity of the policy's impact. Finally, Section 7 provides conclusions and policy recommendations, offering suggestions for optimizing the policy based on the empirical findings.

2. Theoretical Analysis and Research Hypotheses

2.1. Policy Background

As global climate change and environmental challenges intensify, the Chinese government has placed great emphasis on the construction of an ecological civilization, implementing a series of policies to promote green development. The NFCP, as a key initiative in realizing the concept of ecological civilization, was first introduced in 2004 and has since been widely promoted. This policy aims to enhance urban greening and increase forest coverage, thereby improving the quality of urban ecosystems and livability and laying the foundation for green innovation and sustainable development. In 2007, the State Forestry Administration issued the "National Forest City Evaluation Index System", which established a comprehensive set of criteria for evaluating urban forests across four dimensions—urban forest networks, urban forest economy, urban ecological culture, and urban forest management—providing a foundational guide for the construction and evaluation of national forest cities.

In 2016, the State Forestry Administration released the "Guiding Opinions on Promoting Forest City Construction", which further clarified specific tasks and development goals for forest city construction. The document emphasized that forest city construction not only enhances urban greening levels but also improves urban ecosystem functions, with the ultimate goal of achieving harmony between humans and nature. This policy supports increasing urban green space, improving air quality, and providing richer ecological services and recreational spaces for residents, significantly boosting urban livability. In 2018, the State Forestry Administration issued the "National Forest City Development Plan (2018–2025)", outlining the overall layout and key tasks for forest city construction nationwide. The document set a target of building 300 national forest cities by 2025 and proposed the creation of forest city clusters and ecological corridors to further optimize urban ecological spatial planning. The policy also introduced initiatives such as "Forests in Cities", "Forest Surrounding Cities", and "Forests Benefiting the People", aimed at advancing urban greening and ecological restoration, to improve the overall quality of urban environments.

Since 2004, over 200 cities and regions in China have implemented the NFCP. However, despite more than a decade of implementation, there remains a lack of systematic evaluation of the policy's specific impact on urban green innovation and its underlying mechanisms. As green innovation is a critical driver for balancing environmental protection and economic growth, whether the NFCP can foster green technological innovation and development through environmental improvements remains the core question of this study. Therefore, this paper aims to empirically analyze the impact of the NFCP on green innovation, offering a new perspective for evaluating the policy's effectiveness and providing insights for future policy formulation and optimization.

2.2. Mechanisms of the Green Innovation Effects of the NFCP

As a crucial component of China's green development policies, the NFCP improves urban ecological environments, directly enhancing cities' sustainable development capabilities while indirectly driving green technological innovation. This study proposes analyzing the mechanisms through which the policy influences green innovation, focusing on three key areas: environmental attention, talent aggregation, and carbon emissions.

Implementation of the NFCP improves urban environmental quality, which in turn raises awareness of environmental issues among the public, businesses, and the government. Environmental attention refers to the increased focus of various societal stakeholders on environmental protection and ecological improvement, which can be transformed into a demand for and investment in green innovation [29]. In this process, the environmental attention mechanism serves as a key driver of green innovation for several reasons [30].

First, the environmental attention mechanism enhances public awareness of environmental issues, prompting more individuals and organizations to pay attention to sustainable development. This awareness manifests not only in consumer choices but also in support for and promotion of policies, thus creating strong demand for green innovation.

Second, as environmental attention increases, businesses face greater social pressure to adopt sustainable practices in order to maintain their reputation and competitiveness in the market. Consequently, companies are more inclined to invest in green technologies to meet consumer expectations and comply with environmental regulations, thereby driving technological innovation.

Third, when the public and businesses are highly aware of environmental issues, governments are more likely to implement and strengthen environmental policies [31]. This policy support includes not only financial subsidies and incentives but also regulatory measures which promote green technologies, creating a more favorable external environment for green innovation by firms [32].

Fourth, the environmental attention mechanism can also facilitate cooperation among various stakeholders. By enhancing the collective focus on environmental issues, different sectors of society, including businesses, government, non-governmental organizations, and the public, can form a consensus on green technological innovation, promoting resource sharing and technology transfer.

Therefore, by raising awareness of environmental issues among the public and businesses, the NFCP helps stimulate demand for green technological innovation and sustainable development. While the policy promotes urban greening and improves air quality, it also subtly boosts the overall demand for and investment in green technological innovation in cities. Based on this, we propose the following hypothesis:

Hypothesis 1. *The NFCP promotes green innovation by strengthening environmental attention.*

The implementation of the NFCP may also improve urban ecological environments, enhancing urban livability and thereby increasing the city's attractiveness to high-quality talent [33]. Talent aggregation [34] is a key driver of technological innovation, particularly in green technology. The competitiveness of modern cities largely depends on their ability to attract and retain highly skilled technical professionals, whose concentration provides the necessary intellectual and technical support for green innovation. A high-quality ecological environment often coincides with a high standard of living, attracting more innovative talents who are inclined to work and live in cities where the policy is implemented [35]. This is especially true for professionals in green technology and environmental science, for whom a superior ecological environment plays a significant role in career decisions.

By increasing urban forest coverage, improving air quality, and reducing pollution, the NFCP not only enhances urban ecological livability but also boosts the city's ability to attract innovation-driven talent. As high-quality talent flows into these cities, their capacity for innovation, particularly in green technologies, is greatly enhanced. Additionally, the aggregation of talent fosters knowledge spillovers [34], accelerating the development and application of green technologies across the city. The talent aggregation mechanism promotes the research and application of green technologies by facilitating the concentration of skilled professionals. In urban areas, the gathering of high-quality talent allows for the sharing of knowledge, experience, and resources, creating a strong innovation network. This density of talent enhances the city's capacity for innovation in green technologies, making it more capable of developing and implementing sustainable solutions. In cities with favorable ecological environments, talent is often more focused on sustainable development and environmental protection, actively participating in the research and promotion of green technologies. These cities typically provide better resource support, such as funding, infrastructure, and favorable policy environments, further facilitating green innovation. Conversely, in cities with poorer ecological conditions, despite the presence of talent aggregation, there may be greater environmental challenges and resource constraints. This can diminish the motivation and capacity for innovation among talent, ultimately affecting the effectiveness of green innovation. Based on this, we propose the following hypothesis:

Hypothesis 2. *The NFCP promotes green innovation by enhancing talent aggregation.*

The NFCP directly curbs carbon emissions by increasing green space and reducing pollution [36]. Carbon reduction is not only a key goal for improving the ecological environment but also a critical factor in driving green technological innovation [37]. By increasing urban forest coverage, the policy enhances a city's carbon sequestration capacity, effectively reducing greenhouse gas emissions. At the same time, in pursuit of further carbon reduction goals, businesses and governments are likely to intensify their research, development, and application of low-carbon and green technologies [38]. This transition to a low-carbon economy not only reduces pollution but also creates favorable conditions for the development of a green economy in cities.

Moreover, the pressure to reduce carbon emissions accelerates the pace at which companies develop and adopt green technologies to comply with increasingly stringent environmental regulations [39]. The implementation of the NFCP, while improving urban ecological environments, forces enterprises to adapt more quickly to the demands of a low-carbon economy, thereby promoting the advancement of green technologies and environmental innovation. Consequently, carbon reduction, as a direct result of policy implementation, indirectly fosters the development of green innovation. Based on this, we propose the following hypothesis:

Hypothesis 3. *The NFCP promotes green innovation by facilitating carbon reduction.*

2.3. Heterogeneity of the Green Innovation Effects of the NFCP

While the NFCP has a generally positive impact on green innovation, the actual effects may vary significantly across different types of cities due to the diverse resource endowments, economic development levels, transportation conditions, and geographic locations in China. This section explores the heterogeneity of the policy's effects in three key dimensions: city size, transportation conditions, and economic-geographical regions.

From the perspective of city size, differences in scale may significantly influence the policy's impact on green innovation [40]. Large cities typically have more advanced technological infrastructure, stronger innovation capacities, and richer resource allocation, which give them a comparative advantage in green technology innovation. Large cities benefit from stronger technological spillover and agglomeration effects, allowing them to better translate the policy's benefits into actual technological innovation outcomes. With a higher concentration of skilled talent, technological facilities, and financial resources, the NFCP is likely to have a more pronounced effect in large cities.

However, while large cities possess more robust innovation resources, smaller cities with weaker infrastructure may experience greater marginal benefits from policy intervention. These cities, with relatively underdeveloped innovation foundations, could see the policy fill gaps in green technology and resource management. The improvement in ecological environments in smaller cities may be more substantial and the demand for green technological innovation more urgent, leading to a potentially larger marginal effect of the policy in these cities. Based on this, we propose the following hypotheses:

Hypothesis 4-1a. *The NFCP has a more significant positive effect on green innovation in large cities compared with small cities.*

Hypothesis 4-1b. *The NFCP has a more significant positive effect on green innovation in small cities compared with large cities.*

From the perspective of transportation conditions, transportation infrastructure plays a critical role in facilitating the flow of resources and the diffusion of technology in cities [41,42]. Transportation hub cities, with their well-developed transportation networks and capacity for resource aggregation, can more quickly absorb external innovation resources such as capital, talent, and technology, thereby effectively driving the dissemination and application of green technologies. The openness and market potential of transportation hubs enable them to convert green technologies into economic growth more rapidly during implementation of the policy. Therefore, the green innovation effects of the NFCP are expected to be more significant in transportation hub cities.

In contrast, while non-hub cities may face challenges due to underdeveloped transportation infrastructure, implementation of the policy could help these cities overcome their infrastructural disadvantages by improving the ecological environment. This improvement may in turn enhance their capacity for green innovation. As non-hub cities tend to rely more on the exploitation and use of local resources for economic development, the ecological improvements from the policy may trigger a more urgent demand for green technologies. Thus, the marginal effects of the policy's promotion of green innovation may be more pronounced in these cities. Based on this, we propose the following hypotheses:

Hypothesis 4-2a. *The NFCP promotes green innovation more significantly in transportation hub cities compared with non-hub cities.*

Hypothesis 4-2b. *The NFCP promotes green innovation more significantly in non-hub cities compared with transportation hub cities.*

From the perspective of economic-geographical heterogeneity, China's regional economic development is highly uneven [43], with significant differences in economic foundations, innovation capacities, and resource endowments across regions [44], particularly between the northern and southern areas divided by the Hu Line. Economically developed cities, such as those in the southern regions, typically possess more advanced green technology systems and stronger economic foundations. These cities are better equipped to leverage the NFCP and drive green innovation. With their higher levels of technological reserves and marketization, these cities are more capable of integrating market forces and policy interventions to promote the application of green technologies. Therefore, the policy's impact on promoting innovation is likely to be more pronounced in these regions.

On the other hand, cities in less developed economic-geographical regions, such as those in the northern areas, may experience greater marginal benefits from policy intervention despite their lower levels of economic development. Compared with the developed eastern regions, these less developed areas face more acute ecological challenges, and their potential for green innovation has not yet been fully realized. Implementation of the NFCP can significantly improve the ecological quality in these cities, which in turn may stimulate demand for green technologies and innovation. Consequently, the policy's green innovation effects could be more pronounced in less developed regions. Based on this, we propose the following hypotheses:

Hypothesis 4-3a. *The NFCP promotes green innovation more significantly in economically developed regions compared with less developed regions.*

Hypothesis 4-3b. *The NFCP promotes green innovation more significantly in less developed regions compared with economically developed regions.*

In summary, this paper presents a theoretical analytical framework regarding the impact of the NFCP on green innovation, as illustrated in Figure 1. As shown, the NFCP influences green innovation by strengthening environmental attention, enhancing talent aggregation, and facilitating carbon reduction. The impact of the NFCP on green innovation varies under different contexts of city size, transportation hub, and city region.

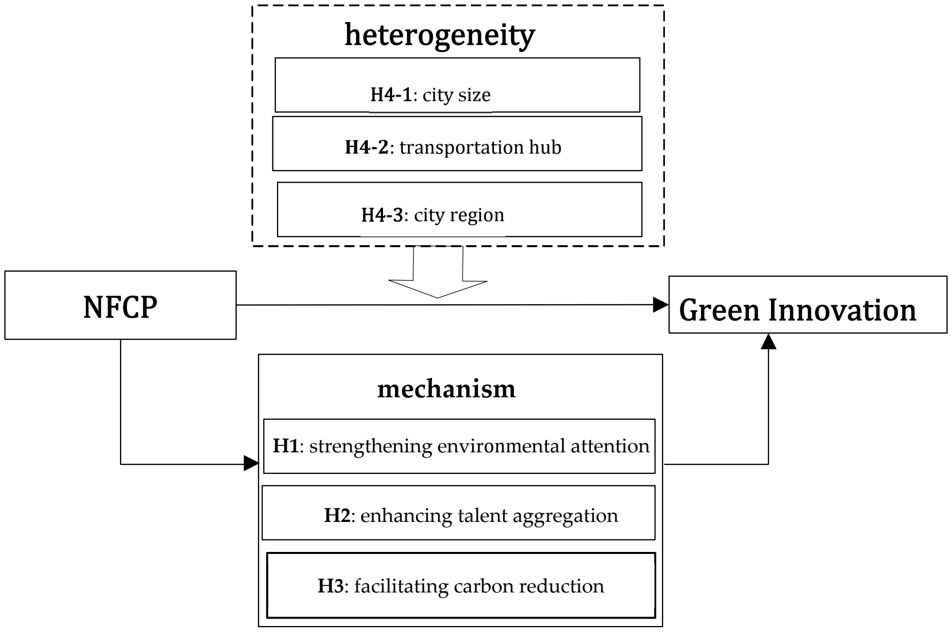

Figure 1. Theoretical analytical framework diagram of the impact of the NFCP on green innovation.

3. Research Design

3.1. Model Construction

The difference-in-differences (DID) method is an econometric approach used to evaluate the effects of policies or interventions [45]. The core idea is to compare the changes in outcomes between a treatment group and a control group before and after the intervention, thereby eliminating the influence of time trends and inherent differences between groups and identifying the causal effect of the policy. Since the NFCP was implemented in multiple phases, this study adopts a multi-period DID approach to assess the impact of the policy on green innovation. To effectively control for time and city fixed effects and reduce potential endogeneity issues, the model is specified as follows:

$$lngreenapply_{it} = \alpha_0 + \alpha_1 treatNFC_{it} + \alpha_2 controls + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In the above equation, $lngreenapply_{it}$ represents the logarithm of the number of green patent applications in city i at time t, used as a proxy for the level of green innovation; $treatNFC_{it}$ is the treatment variable indicating the implementation of the NFCP, which takes the value of one if the policy was implemented in city i at time t and is zero otherwise; controls represents a set of control variables to account for other factors affecting green innovation; μ_i denotes city fixed effects, controlling for unobserved city-specific characteristics; γ_t denotes time fixed effects, controlling for time trends which may affect all cities; and ε_{it} is the error term. This model set-up allows for identification of the causal effect of the NFCP on green innovation while controlling for both the time-invariant characteristics of cities and macro-level time trends.

3.2. Variable Design

The key variables in this study are categorized as follows:

Dependent Variable: Green innovation (*lngreenapply*) is the dependent variable, measured by the logarithm of the number of green patent applications in a city. It serves as an indicator of the city's level of green innovation [46,47].

Independent Variable: The primary independent variable is the effect of the NFCP (*treatNFC*), which indicates whether a city has implemented the policy. If a city implemented the policy in year t, then the variable takes a value of one for that year and subsequent years; otherwise, it is zero.

Control Variables: To account for other factors which may influence green innovation, the following control variables are introduced. ① The economic development level (*lnpgdp*) is the logarithm of the per capita GDP and reflects the economic conditions of a city. ② The financial development level (*lnfinance*) is the logarithm of the total loan and deposit balances of financial institutions in the city, representing a city's financial development. ③ The population density (*popdensity*) is the number of permanent residents per square kilometer, indicating the population density in a city. ④ Foreign direct investment (*lnfdi*) is the logarithm of actual utilized foreign direct investment in a given year, used as a measure of a city's openness to external investment. ⑤ Government intervention (*lngovinterv*) is the logarithm of the total fiscal expenditure by a city's government, which is used to measure the degree of government intervention. ⑥ The infrastructure level (*lninfrustru*) is the logarithm of the road mileage and public transport route mileage, representing the level of urban infrastructure development. ⑦ The information technology level (*lninformation*) is the logarithm of the total postal and telecommunications business volume, reflecting the level of a city's information technology development.

The meanings and descriptions of the relevant variables in this paper can be found in Table 1.

Table 1. Variable definitions and explanations.

Variable Name	Variable Symbol	Measurement	Explanations
Green innovation	*lngreenapply*	Logarithm of the number of green patent applications	Measures the level of urban green innovation
NFCP	*treatNFC*	A dummy variable taking values of 0 or 1	Measuring whether a city has implemented the NFCP
Economic development level	*lnpgdp*	Logarithm of per capita GDP	Controlling for urban economic characteristics
Financial development level	*lnfinance*	Logarithm of the total loan and deposit balances of financial institutions	Controlling for urban financial characteristics
Population density	*popdensity*	The number of permanent residents per square kilometer	Controlling for urban demographic characteristics
Foreign direct investment	*lnfdi*	Logarithm of actual utilized foreign direct investment in a given year	Controlling for urban foreign investment characteristics
Government intervention	*lngovinterv*	Logarithm of total fiscal expenditure by the city government	Controlling for urban government intervention characteristics
Infrastructure level	*lninfrustru*	Logarithm of road mileage and public transport route mileage	Controlling for urban infrastructure characteristics
Information technology level	*lninformation*	Logarithm of total postal and telecommunications business volume	Controlling for urban information technology characteristics

3.3. Data Sources

This study utilizes panel data from 273 prefecture-level cities in China, covering the period from 2000 to 2022. The data sources were as follows. ① Green innovation data measure the level of green innovation in cities with the number of green patent applications. These data were obtained from the patent database of the China National Intellectual Property Administration (CNIPA). ② Economic and environmental data are data on economic development, population density, foreign direct investment, urban science and technology expenditures, infrastructure levels, and information technology levels sourced from several publications, including the *China Urban Statistical Yearbook*, the *China Urban Environmental Statistical Yearbook*, the *China Urban Construction Statistical Yearbook*, and various statistical bulletins released by local governments. These data were used to control for city-specific characteristics. ③ Policy implementation data are information on the cities which implemented the NFCP and the corresponding years of implementation, which comes from policy documents and official announcements issued by the National Forestry and Grassland Administration. In cases where certain data points were missing, interpolation methods were used to fill in the gaps. Descriptive statistics for the key variables in this study are provided in Table 2.

Table 2. Descriptive statistics.

	(1)	(2)	(3)	(4)	(5)
Variables	**Observations**	**Mean**	**sd**	**Min**	**Max**
lngreenapply	6279	3.7214	2.0473	0.0000	9.9278
lnpgdp	6279	10.1446	0.9610	4.5951	13.0557
lnfinance	6279	16.6813	1.3581	13.2638	21.4117
lnfdi	6279	9.1656	2.3492	0.0000	14.5605
lninfrustru	6279	9.3532	0.6903	6.5539	10.7239
lninformation	6279	12.2651	1.1301	8.8478	16.5035
lnenvregul	6279	10.0000	1.3492	0.6931	13.1151
lngovinterv	6279	14.0110	1.2644	9.7050	17.7270
popdensity	6279	418.8869	317.0201	5.0000	2712.0000

4. Empirical Analysis

4.1. Baseline Regression Model

In the baseline regression model, several city-level factors were controlled for, including economic development level, financial development level, population density, foreign direct investment, government intervention, infrastructure construction, environmental regulation, and information technology levels.

Table 3 presents the regression results for the impact of the NFCP on green innovation. Column (1) reports the results without controlling for any variables. Column (2) introduces control variables but does not account for city or year fixed effects. Column (3) incorporates control variables, city fixed effects, and year fixed effects. Finally, column (4) presents results from an optimized model.

Table 3. Baseline regression results.

	(1)	(2)	(3)	(4)
Variables	***lngreenapply***	***lngreenapply***	***lngreenapply***	***lngreenapply***
treatNFC	2.6580 ***	0.2845 ***	0.2015 ***	0.1665 ***
	(0.0487)	(0.0241)	(0.0221)	(0.0210)
constant	3.1613 ***	−18.5753 ***	3.6789 ***	−11.7207 ***
	(0.0255)	(0.2264)	(0.0080)	(1.1986)
controls	NO	YES	NO	YES
city fixed	NO	NO	YES	YES
year fixed	NO	NO	YES	YES
observations	6279	6279	6279	6279
R squared	0.280	0.899	0.940	0.945

Notes: *** denotes $p < 0.01$.

The results show that the coefficient for the NFCP (*treatNFC*) was positive and statistically significant at the 1% level across all models, indicating that the policy significantly promotes green innovation in cities. Specifically, in model (1), the policy effect coefficient was 2.6580, demonstrating a significant positive impact on green innovation even without controlling for any other variables. In model (2), after introducing control variables, the policy effect coefficient dropped to 0.2845 but remained significant, suggesting that the policy continues to have a positive impact on green innovation even when economic, population, and other city-level factors are considered. In models (3) and (4), after accounting for city and year fixed effects, the policy effect coefficients were 0.2015 and 0.1665, respectively, indicating that the policy's positive influence on green innovation remained robust.

In summary, implementation of the NFCP significantly enhanced cities' green innovation capabilities. Whether or not control variables are included, and after accounting for city and year fixed effects, the policy showed a consistently significant positive impact. This suggests that the NFCP not only directly benefits the urban environment but also stimulates demand for green innovation, driving research and development in green technologies.

4.2. Parallel Trend Test

The parallel trend assumption is a crucial prerequisite for ensuring the validity of the estimated policy effects. This assumption requires that prior to the implementation of the policy, the trends in green innovation for both the treatment group (cities which implemented the NFCP) and the control group (cities which did not implement the policy) should be consistent, meaning there should be no significant difference in the trajectory of green innovation between the two groups. To validate this assumption, this paper employs a placebo test.

The core idea of the placebo test is to assume that the policy was "implemented earlier" at a hypothetical point in time before the actual policy implementation and examine whether there is a false policy effect. If no significant difference is found between the treatment and control groups during the placebo period, then this indicates that there was no spurious policy effect, confirming that the trends in green innovation were consistent between the two groups before the policy's implementation and thus validating the parallel trend assumption.

For this purpose, we defined placebo policy variables—*F.treatNFC*, *F2.treatNFC*, and *F3.treatNFC*—which represent the policy being hypothetically implemented 1 year, 2 years, and 3 years earlier, respectively. We then tested the significance of the policy effect coefficients. The regression results are shown in Table 4. It can be observed that regardless of whether the policy was assumed to have been implemented 1 year, 2 years, or 3 years earlier, the policy effect coefficients were not significant. This indicates that prior to the actual implementation of the NFCP, there was no significant difference in the level of green innovation between the two groups. Therefore, the parallel trend assumption is satisfied in this study.

Table 4. Parallel trend test results.

Variables	***lngreenapply***
F.treatNFC	−0.0231
	(0.0509)
F2.treatNFC	0.0456
	(0.0490)
F3.treatNFC	0.1608
	(0.0618)
constant	−4.8898 *
	(2.5656)
controls	YES
city fixed	YES
year fixed	YES
observations	5439
R squared	0.943

Notes: * denotes $p < 0.1$.

4.3. Placebo Test

To further minimize potential biases from sample selection, this paper conducts a placebo test using randomly selected cities which were not covered by the NFCP. Specifically, a random sample of cities which did not implement the policy was selected as "placebo policy cities". For these randomly chosen cities, we constructed hypothetical policy implementation variables, assuming that their policy implementation years aligned with the actual policy implementation in the treated cities. A difference-in-differences (DID) model was then used to estimate the green innovation effects for these placebo policy cities.

To enhance the robustness of the results, the bootstrap method was employed to simulate the regression with 500 random samples. The resulting estimated coefficients and the kernel density of these estimates are displayed in Figure 2. As shown in the figure, the estimated coefficients and their density were distributed near zero, and the *p* values for the vast majority of the estimates were greater than 0.1. In contrast, the actual policy effect estimate, with a coefficient of 0.1665, was outside of the range of the placebo effect estimates. This indicates that the randomly assigned "placebo policies" had no significant effect on green innovation, further supporting the validity of the actual policy's effect.

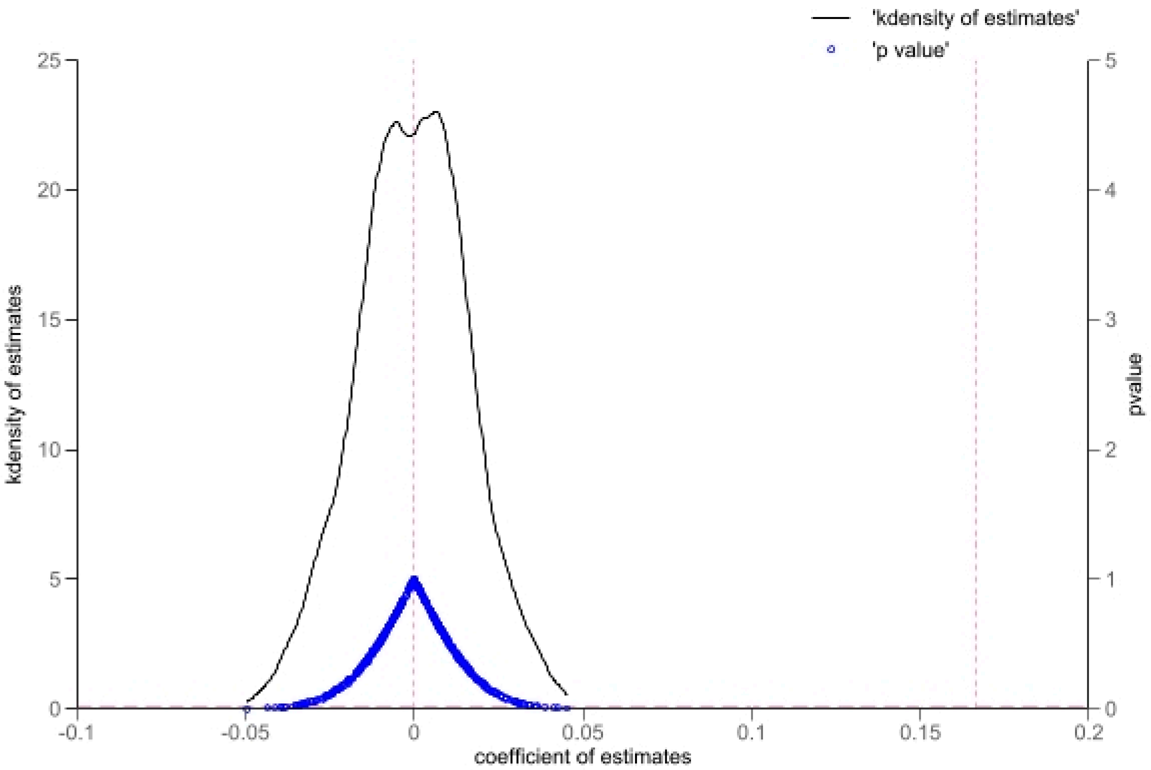

Figure 2. Placebo test.

In conclusion, the estimation results in this study were robust, and the NFCP had a genuine impact on promoting green innovation.

4.4. Additional Robustness Tests

To further ensure the accuracy and robustness of the estimation results, the following robustness tests were conducted. ① PSM-DID: A propensity score matching (PSM) DID approach was applied. A logit model was used to estimate the propensity scores for policy implementation based on the initial characteristics of the cities. The sample was then re-matched based on these propensity scores, and regression analysis was performed on the matched sample. ② **Replacement of the Dependent Variable:** The logarithm of the number of green patent grants was used as an alternative dependent variable to replace the logarithm of green patent applications. ③ **Winsorization:** The data were winsorized at the 1% level to reduce the impact of outliers and extreme values. ④ **Addition of Omitted Variables:** Additional control variables, including the level of urban industrialization (indstruc) and urban education expenditures (lneduexpd), were introduced to further account for city-specific characteristics.

The results of the four robustness tests are presented in Table 5. Models (1–4) correspond to the PSM-DID, replacement of the dependent variable, winsorization, and the addition of omitted variables, respectively. In all four models, the coefficient for the core policy effect (treatNFC) remained positive and statistically significant at the 1% level. These findings indicate that the estimation results were robust, affirming the positive impact of the NFCP on green innovation.

Table 5. Additional robustness tests.

	(1) PSM-DID	(2) Replacement of the Dependent Variable	(3) Winsorization	(4) Addition of Omitted Variables
Variables	***lngreenapply***	***lngreengrant***	***lngreenapply***	***lngreenapply***
treatNFC	0.1793 ***	0.1906 ***	0.1542 ***	0.1470 ***
	(0.0211)	(0.0218)	(0.0209)	(0.0209)
indstruc				0.0022
				(0.0016)
lneduexpd				0.3970 ***
				(0.0567)
constant	−10.7418 ***	−6.9487 ***	−13.0330 ***	−12.3604 ***
	(1.1363)	(1.1445)	(1.1713)	(1.1570)
controls	YES	YES	YES	YES
city fixed	YES	YES	YES	YES
year fixed	YES	YES	YES	YES
observations	6552	6279	6279	6279
R squared	0.944	0.941	0.945	0.945

Notes: *** denotes $p < 0.01$.

This comprehensive set of robustness tests strengthened confidence in the reliability of the results, ensuring that the conclusions drawn were not driven by specific model assumptions or data issues.

5. Mechanism Test

Based on the theoretical analysis presented earlier, this section aims to examine the mechanisms through which the NFCP influences green innovation. To accomplish this, we constructed the following mechanism testing model:

$$lngreenapply_{it} = \beta_0 + \beta_1 treatNFC_{it} \times Mechanism + \beta_2 treatNFC_{it} + \beta_3 controls + \mu_i + \sigma_t + \vartheta_{it} \quad (2)$$

In this mechanism test, the mechanism variables represent the channels through which the NFCP influences green innovation. These mechanism variables include environmental attention (*envattent*), talent aggregation (*talents*), and carbon reduction (*carbons*). Our primary focus was on the interaction term between the policy effect and each mechanism variable. If the coefficient of the interaction term β1 is statistically significant, then this suggests that the mechanism is validated and plays a role in the policy's effect on green innovation.

This study examines the mechanisms of the NFCP's impact on green innovation through three key channels: environmental attention, talent aggregation, and carbon reduction. The detailed results of the mechanism tests are presented in Table 6. The results indicate that the policy affected green innovation to varying degrees via these different pathways. Below is a detailed analysis of each mechanism.

Table 6. Mechanism test results for the green innovation effects of the NFCP.

	(1) Environmental Attention	(2) Talent Aggregation	(3) Carbon Reduction
Variables	***lngreenapply***	***lngreenapply***	***lngreenapply***
treatNFC × envattent	0.2294 ***		
	(0.0886)		
treatNFC × talents		0.0579 ***	
		(0.0119)	
treatNFC × carbon			−0.0917 ***
			(0.0110)
treatNFC	0.0545	−0.3384 ***	0.3404 ***
	(0.0479)	(0.1096)	(0.0279)
constant	−11.7126 ***	−11.7378 ***	−11.5974 ***
	(1.1986)	(1.1857)	(1.1788)
controls	YES	YES	YES
city fixed	YES	YES	YES
year fixed	YES	YES	YES
observations	6279	6279	6279
R squared	0.945	0.945	0.946

Notes: *** denotes $p < 0.01$.

Environmental Attention Mechanism (*treatNFC* × *envattent*): Environmental attention refers to the increased focus by the public, businesses, and governments on environmental issues, which can stimulate demand for green technologies and innovation. In this study, data were collected from government work reports on prefecture-level cities. The number of sentences mentioning environmental protection, resource conservation, pollution prevention, and ecological civilization were counted. The ratio of environmental protection-related sentences to the total number of sentences in the reports was used as a proxy variable for environmental attention.

In the mechanism test model, the regression coefficient for environmental attention was 0.2294 and statistically significant at the 1% level. This indicates that the NFCP significantly promoted green innovation by increasing environmental awareness. After the policy's implementation, the ecological environment of cities improved substantially, leading to heightened public environmental consciousness. Businesses, in response to these changes in policy and market demands, were more inclined to adopt green technologies. Moreover, governments may further incentivize green innovation through environmental regulation and fiscal incentives, encouraging firms to increase their investment in the research and development of green technologies. Specifically, implementation of the NFCP enhanced public awareness of environmental protection, encouraging active participation in eco-friendly initiatives and increasing demand for green technologies. Additionally, companies facing pressure from the public and market are more inclined to invest in green technologies to maintain competitiveness. The government can also encourage investment in green R&D through fiscal incentives and tax breaks. Furthermore, heightened environmental awareness fosters collaboration among the government, businesses, and civil organizations, accelerating the transfer and application of green technologies. Overall, the environmental attention mechanism significantly boosted green innovation and supported sustainable economic development.

These factors collectively drive green innovation at the city level. The significance of the environmental attention mechanism demonstrates that the NFCP directly fosters the development and innovation of green technologies by raising societal awareness of environmental issues. Thus, Hypothesis H1 is supported.

Talent Aggregation Mechanism (*treatNFC* × *talents*): Talent aggregation is considered a critical driver of technological innovation, particularly the gathering of high-quality talent, which greatly enhances a city's innovation capacity. In this study, the logarithm of the number of professionals engaged in scientific research, technology services, and related fields was used as a proxy variable for talent aggregation.

The mechanism test results show that the coefficient for talent aggregation was 0.0579, and it was statistically significant at the 1% level. This indicates that the NFCP promoted green innovation by attracting high-quality talent. As the ecological environment of cities improves, urban livability increases, drawing in more skilled professionals. These talents contribute to green innovation by bringing knowledge and technological expertise to the city. Additionally, through technology diffusion and spillover effects, they help propel the broader development of green technologies in a city.

The NFCP, by fostering a superior ecological environment, enhances the attractiveness of cities to high-caliber talent, which in turn boosts green innovation. Thus, Hypothesis H2 is supported.

Carbon Reduction Mechanism (*treatNFC* $\times$ *carbon*): Carbon reduction is a key goal for green development and technological innovation. The NFCP, through increasing forest coverage and improving urban ecology, has significantly reduced carbon emissions, which in turn has influenced green innovation. In this study, the ratio of a city's total carbon emissions to its GDP was used as a proxy variable for the carbon reduction mechanism.

The mechanism test results show that the coefficient for carbon reduction was −0.0917, which was statistically significant at the 1% level. This indicates that reductions in carbon emissions significantly promote green innovation. As carbon emissions decrease, businesses are compelled to adapt to stricter environmental standards, which motivates them to invest more in green and low-carbon technologies. The reduction in carbon emissions improves the overall ecological environment of cities, increases market demand for green technologies, and encourages firms to enhance their research and development efforts in low-carbon technologies.

Thus, carbon reduction not only helps improve environmental quality but also indirectly drives the advancement and application of green technologies by steering corporate innovation activities. As a result, Hypothesis H3 is supported.

6. Heterogeneity Analysis

6.1. City Size Heterogeneity

The impact of the NFCP on green innovation exhibited significant heterogeneity across cities of different sizes. According to official government classifications, cities are divided into mega cities, large cities, medium-sized cities, and small cities. By conducting group regression analysis, this study examined the effects of the policy in large cities versus medium and small cities, revealing that city size has a substantial influence on the policy's effectiveness. The detailed heterogeneity analysis results are presented in Table 7.

Table 7. City size heterogeneity.

	(1) Mega Cities	(2) Big Cities	(3) Medium Cities	(4) Small Cities
Variables	***lngreenapply***	***lngreenapply***	***lngreenapply***	***lngreenapply***
treatNFC	−0.0334	−0.0244	0.1712 ***	0.1191 ***
	(0.0829)	(0.0549)	(0.0318)	(0.0298)
constant	−157.6448 **	−17.9105 ***	−14.7336 ***	−11.0927 ***
	(58.7825)	(5.6122)	(2.3462)	(1.6093)
controls	YES	YES	YES	YES
city fixed	YES	YES	YES	YES
year fixed	YES	YES	YES	YES
observations	69	322	1794	4094
R squared	0.996	0.982	0.957	0.911

Notes: ** denotes $p < 0.05$. *** denotes $p < 0.01$.

Firstly, in large cities, the NFCP did not have a significant effect on green innovation. The regression coefficient was negative, specifically −0.0244, and it did not pass the significance test. This suggests that the policy's impact on green innovation in large cities is limited. Large cities generally have more resources, advanced technology, and a stronger innovation foundation, meaning their green innovation capacity is already relatively high. Therefore, the marginal effect of the NFCP may be smaller. In other words, since large cities already possess well-established green technology systems and infrastructure, the policy's implementation has not resulted in a significant further increase in green innovation. Second, large and mega cities face more complex socioeconomic structures. These cities often have diversified industrial layouts and a highly competitive market environment. In this context, companies may be influenced by other factors during the innovation process, such as market pressures, cost control, and competitive strategies, which could lead to a decrease in their enthusiasm for green technology innovation. Furthermore, implementation of the policy may also be constrained by the existing industrial structure. In large cities, traditional high carbon emission industries may dominate, making it more challenging for companies to transition to green innovation. Thus, despite the policy's aim to promote the research and application of green technologies, it may not effectively incentivize companies to make the necessary technological upgrades in these larger cities. Finally, ecological issues in large cities are often more complex and diverse, and the environmental challenges faced by enterprises and governments may affect the effectiveness of policy implementation. In such cases, the policy effects of the NFCP may be obscured by other environmental and social factors, making its direct impact on green innovation less visible.

Secondly, in medium and small cities, the NFCP had a significant positive effect on green innovation, especially in medium-sized cities. The regression results show that the policy effect coefficient for medium-sized cities was 0.1712, which was statistically significant at the 1% level. This indicates that green innovation in medium and small cities significantly improved following the policy's implementation. Unlike large cities, medium and small cities had relatively weak green technology foundations prior to the policy, and the introduction of the policy provided these cities with new opportunities for development. By increasing urban forest coverage and improving the ecological environment, the NFCP created a more favorable environment for green innovation in these cities. Additionally, the industrial structure in medium and small cities tends to be more flexible, making the policy's ecological guidance more apparent and thereby leading to a stronger impact on green technological innovation.

Based on this analysis, it is clear that the green innovation effects of the NFCP varied significantly across cities of different sizes. The policy's impact was notably stronger in medium and small cities than in large cities. Thus, Hypothesis 4-1b is supported.

6.2. Heterogeneity in Transportation Hub Cities

The green innovation effects of the NFCP exhibited significant heterogeneity between transportation hub cities and non-hub cities. Cities were classified into two groups based on whether they are transportation hubs. The regression results, shown in Table 8, indicate differences in the policy's impact between these two types of cities.

Firstly, in transportation hub cities, the policy's effect on green innovation was not significant. Specifically, the regression coefficient for transportation hub cities was 0.0468, but it did not pass the significance test. This suggests that implementation of the NFCP has not significantly boosted green innovation in transportation hub cities. These cities already benefit from well-developed infrastructure and transportation networks, which support high levels of economic activity and innovation capacity. As a result, the marginal effect of the policy in these cities may be limited. Furthermore, the complex industrial structure of transportation hub cities may weaken the direct impact of the policy, and it may take longer for the policy to show noticeable effects on green innovation. Economic activities in transportation hub cities are often more concentrated in traditional and resource-intensive industries. The industrial structure in these cities may be more complex, with traditional sectors dominating, which results in greater resistance for companies to undergo green transitions. In this context, the implementation of the NFCP may not effectively incentivize businesses in these cities to undertake the necessary innovations in green technology. Additionally, transportation hub cities typically face stronger market competition and economic pressures. As a result, companies may prioritize short-term economic benefits over long-term investments in green technologies. This short-term orientation may diminish their enthusiasm for innovation, even while complying with environmental regulations. Moreover, although transportation hub cities possess better infrastructure, this advantage may be offset by insufficient market demand and policy incentives in driving green innovation. In contrast, non-hub cities, due to their relatively inadequate infrastructure, may receive more policy attention and resource support following the implementation of the NFCP, making them more likely to promote green innovation.

Table 8. Heterogeneity of transportation hubs.

	(1) **Non-Hub Cities**	**(2)** **Hub Cities**
Variables	***lngreenapply***	***lngreenapply***
treatNFC	0.1630 ***	0.0468
	(0.0224)	(0.0458)
constant	−11.7847 ***	−10.7416 ***
	(1.2508)	(3.2452)
controls	YES	YES
city fixed	YES	YES
year fixed	YES	YES
observations	5934	345
R squared	0.937	0.986

Notes: *** denotes $p < 0.01$.

In contrast, the policy had a significant positive effect on green innovation in non-hub cities. The regression coefficient for non-hub cities was 0.1630, and it was statistically significant at the 1% level. This indicates that the NFCP effectively enhanced green innovation in non-hub cities. These cities typically lack the infrastructure and technological resources of hub cities, and the policy provides new opportunities for development and ecological improvement. The policy's guidance, along with improvements in the ecological environment, increased demand for green technologies in non-hub cities, which in turn led to a notable rise in green innovation activities.

Overall, the NFCP has produced heterogeneous effects across different city types. The policy's impact was relatively limited in transportation hub cities, while it had a much stronger effect in non-hub cities. Therefore, Hypothesis 4-2b is supported.

6.3. Economic-Geographical Regional Heterogeneity

According to the regression analysis, the impact of the NFCP on green innovation varied significantly across different economic-geographical regions. The **Hu Line** (Hu Huanyong Line), a major dividing line in China's economic, social, and geographical development, highlights the stark contrasts in policy effects between cities in different regions. In this study, cities were classified into economically developed regions (south of the Hu Line) and less developed regions (north of the Hu Line). The detailed results are presented in Table 9.

Table 9. Heterogeneity of economic geography regions.

	(1) North of the Hu Line	(2) South of the Hu Line
Variables	***lngreenapply***	***lngreenapply***
treatNFC	0.0786	0.1704 ***
	(0.1690)	(0.0212)
constant	−6.5119	−12.4863 ***
	(7.3831)	(1.2327)
controls	YES	YES
city fixed	YES	YES
year fixed	YES	YES
observations	161	6118
R squared	0.962	0.945

Notes: *** denotes $p < 0.01$.

The analysis revealed clear regional heterogeneity in the green innovation effects of the NFCP between the **southern region (south of the Hu Line)** and the **northern region (north of the Hu Line)**. Specifically, the policy significantly promoted green innovation in the southern region, whereas no significant effect was observed in the northern region.

The southern region, which includes economically advanced areas like the Yangtze River Delta and the Pearl River Delta, has a strong economic foundation and well-developed green technology research and development capabilities. The regression results indicate that the policy had a significant positive effect on green innovation in the southern region. This suggests that cities in the south, following the implementation of the NFCP, were able to leverage their existing technological advantages and resources to quickly drive green innovation activities.

The effectiveness of the policy in the southern region may be attributed to better resource allocation and stronger policy execution capabilities. These regions not only have superior infrastructure but also demonstrated higher efficiency in implementing ecological improvements and policy measures, allowing them to benefit more from the policy. Additionally, firms and the public in the southern region are more conscious of green development. As a result, after the policy's implementation, increased environmental awareness led businesses to focus more on the development and application of green technologies, significantly boosting the level of green innovation.

In contrast, the northern region lags behind in economic development, with weaker infrastructure and limited green technology capabilities. The regression results show that the policy's effect on green innovation in the northern region was not significant, indicating that the NFCP has not effectively stimulated green innovation in these areas. This may be due to the weaker foundation for green innovation in northern cities prior to the policy's implementation. Furthermore, northern regions often face challenges such as resource shortages, outdated technology, and inadequate infrastructure, which can hinder the effective execution of the policy, thereby reducing its overall effectiveness. The complex industrial structure in these regions may also limit the capacity of businesses to transition to greener technologies.

Moreover, the effectiveness of policy implementation was influenced by the capabilities of local governments and the level of public participation. In some northern regions, local governments may lack sufficient resources and policy support to effectively promote implementation of the NFCP, while public awareness of environmental protection may also be low, affecting the acceptance and execution of the policy. This situation further complicates the policy implementation process and leads to significant differences in outcomes across regions.

In summary, the heterogeneity in policy impact across different economic-geographical regions in China reveals the broader socioeconomic challenges encountered during the implementation of the NFCP. While economically developed regions like the south benefit significantly from the policy due to their robust infrastructure and awareness of green development, the less developed regions in the north struggle with foundational challenges which inhibit similar advancements. Therefore, Hypothesis 4-3a is supported; the NFCP had a more significant positive impact on green innovation in economically developed regions (south of the Hu Line) than in less developed regions (north of the Hu Line).

7. Conclusions and Policy Implications

7.1. Conclusions and Discussion

This paper conducted an empirical analysis using data from 273 prefecture-level cities in China to evaluate the impact of the NFCP on green innovation, while also examining the mechanisms through which the policy operates, such as environmental attention, talent aggregation, and carbon reduction. The main conclusions are as follows.

Firstly, the NFCP significantly promotes green innovation overall. Regardless of whether control variables, city characteristics, fixed effects, or time effects were considered, the policy had a significant positive effect on green innovation. By improving the ecological environment, the policy increased urban green innovation activities, as evidenced by the growth in green patent applications. This underscores the policy's positive influence on green technology development.

Secondly, the mechanism tests revealed that the NFCP primarily promoted green innovation through the mechanisms of environmental attention, talent aggregation, and carbon reduction. The increase in environmental attention significantly boosted public and corporate demand for green technologies, thereby enhancing the city's innovation capacity. At the same time, improvement in the ecological environment attracted more high-quality talent, providing intellectual and technical support for green technology innovation. Additionally, the carbon reduction mechanism also played a role in promoting green innovation, indicating a strong link between ecological improvements and the development of green technologies.

Finally, there was significant regional and urban heterogeneity in the policy's effects. In terms of **city size**, the policy's impact on green innovation was more pronounced in medium and small cities compared with large cities. Regarding **transportation hub status**, non-hub cities experienced a greater boost in green innovation than transportation hub cities. In terms of **economic-geographical regions**, the policy had a significant positive effect in the southern regions (south of the Hu Line), while no significant effect was observed in the northern regions (north of the Hu Line). These findings suggest that the NFCP has different effects across various regions and city types.

The findings of this study indicate that the National Forest City Policy (NFCP) significantly promotes green innovation in Chinese cities, particularly in small- and medium-sized cities and non-transportation hub cities. This observation aligns with the research conducted by Liao et al. (2021) [22], who demonstrated that urban greening policies can enhance environmental quality, thereby laying the groundwork for low-carbon development and subsequent green innovation. However, this study further illustrated that the NFCP not only improves ecological conditions but also directly drives green innovation through mechanisms such as heightened environmental attention and talent attraction, thereby enriching the understanding of the policy's impact on green innovation pathways.

In terms of policy mechanisms, this study revealed that the NFCP fosters green innovation by increasing environmental attention, which corresponds with the findings of Chen et al. (2022) [29]. They suggested that governmental environmental attention can significantly promote green innovation at the enterprise level. Nevertheless, this study extends the discussion by demonstrating how this mechanism operates at the urban policy level, highlighting the crucial role of environmental attention in stimulating overall green innovation activities within cities. By elevating public, corporate, and governmental awareness of environmental issues, the NFCP effectively stimulates green technological innovation at the urban level.

Furthermore, the impact of the NFCP exhibited notable heterogeneity across different regions, corroborating the results found by Luo et al. (2021) [18] and Xu et al. (2020) [24] regarding the regional differences in policy effectiveness. Particularly in the economically developed southern regions, the policy's influence was significantly more pronounced, likely due to stronger economic foundations and better access to innovation resources in these cities. Luo et al. emphasized that the developed economic structure and higher degree of marketization in southern regions facilitate the effective implementation of the policy, while this study further elucidated the mechanisms through which these factors contribute to the NFCP's success. In contrast, the limited effectiveness of the NFCP in underdeveloped northern regions is attributed to a scarcity of innovative resources and lower policy execution capabilities. Xu et al. (2020) [24] also highlighted that varying levels of economic development and infrastructure substantially affect the green innovation. Our research corroborated and expanded upon this conclusion through an investigation of the regional impacts of the NFCP.

In summary, this study builds upon the existing literature to validate the effectiveness of the NFCP in promoting green innovation and enriches the understanding of how ecological policies affect green innovation in diverse urban and regional contexts through detailed mechanism analysis and exploration of regional heterogeneity.

7.2. Policy Implications

The following sections of this paper will present targeted policy recommendations based on the previous mechanism testing results and heterogeneity analysis findings.

The mechanism testing results indicate that the National Forest City Policy (NFCP) positively impacts green innovation through three mechanisms: enhancing environmental attention, strengthening talent aggregation, and promoting carbon reduction. Therefore, to fully leverage the positive effects of these mechanisms, policymakers can implement the following measures.

Environmental Attention: Policymakers should raise public awareness of environmental issues through promotional and educational activities, encouraging community participation in environmental protection projects. Media and social platforms can be utilized to spread the importance of environmental protection, thereby increasing societal focus on green technologies and innovation. This heightened environmental attention will help drive demand for green innovation from both businesses and the public.

Talent Aggregation: To attract more skilled talent, the government should implement targeted talent attraction policies, offering financial incentives, career development opportunities, and a favorable living environment. Collaboration with universities and vocational training institutions is also essential to develop training programs focused on green technology, enhancing local talent's professional skills and innovation capabilities and building a stronger talent ecosystem.

Carbon Reduction: Policymakers should continue to advance carbon reduction policies related to green technologies, ensuring that businesses can achieve economic benefits while reducing carbon emissions. The government can encourage investments in green technology research and applications through financial subsidies and tax breaks, thereby achieving a win-win situation for carbon reduction and economic development.

However, it is important to note that while the NFCP promotes green innovation through carbon reduction mechanisms, there may be an inverse causal relationship between carbon reduction and green innovation. Therefore, it is necessary to discuss related policies which can better enhance and transform the socioeconomic benefits produced through carbon reduction mechanisms.

To ensure that the carbon reduction efforts under the National Forest City Policy (NFCP) achieve environmental goals and promote equitable socioeconomic outcomes, policymakers should implement the following key measures. First, integrate policies to combine carbon reduction with economic development goals. This will encourage investment in green technologies and renewable energy, creating job opportunities and stimulating local economic growth. Such integration allows businesses to gain economic returns while pursuing environmental objectives, promoting sustainable development. Second, establish systematic evaluation and monitoring mechanisms to track the socioeconomic impacts of carbon reduction efforts. This will enable policymakers to adjust strategies promptly, balancing environmental goals with socioeconomic benefits. Effective monitoring ensures that policies meet their intended outcomes and can be flexibly adjusted based on real conditions, enhancing both effectiveness and equity.

The heterogeneity analysis results indicate significant differences in the impact of the National Forest City Policy (NFCP) on green innovation based on urban scale, transportation hub status, and economic geographical region. Therefore, it is necessary to discuss and formulate corresponding policies to improve the variability in green innovation performance.

City Size: The NFCP had no significant positive impact on green innovation in large cities. To enhance the effectiveness of the NFCP in promoting green innovation in these areas, several targeted measures should be implemented. First, establish cross-industry collaboration mechanisms to facilitate resource sharing and technology transfer, thereby increasing the application of green technologies. Second, provide financial incentives and technical support to encourage businesses to invest more in green technology research and development, addressing the current stagnation in innovation. Finally, optimize urban spatial layouts to ensure that green infrastructure development aligns with urban growth. These measures will help overcome regional disparities and promote green innovation and sustainable development nationwide.

Economic Geographical Region: In terms of economic geographical heterogeneity, the NFCP has not significantly impacted green innovation in northern cities (underdeveloped areas). To enhance the NFCP's effectiveness in promoting green innovation in these regions, policymakers should adopt comprehensive measures. First, establish cross-regional technology cooperation parks to concentrate resources and talent for green technology research and application. These parks will provide essential R&D facilities and market access, accelerating technology exchanges between northern and southern cities. Second, encourage collaboration and knowledge transfer between these regions to optimize resource allocation and share best practices. Additionally, implement talent attraction policies with financial incentives to draw skilled professionals and collaborate with educational institutions to develop training programs focused on green technology. Lastly, local governments should secure sufficient financial support and resources to effectively implement the NFCP, enhancing their governance capacity to promote research and application in green technologies. By taking these measures, northern regions can effectively boost green innovation and foster collaborative development with southern areas, leading to more balanced sustainable development goals.

Transportation Hub Status: Regarding transportation hub heterogeneity, the NFCP showed no significant positive impact on green innovation in transportation hub cities, while it significantly promoted innovation in non-hub cities. To enhance the policy's effectiveness in transportation hubs, several measures should be considered. First, encourage these cities to optimize their industrial structure and facilitate the transition of traditional industries to green technologies by providing financial subsidies and technical guidance to reduce transformation costs. Second, strengthen market incentive mechanisms through tax breaks and financial incentives to boost market demand for green technologies. Additionally, establish cross-industry cooperation networks to promote resource sharing and technology exchanges, enhancing the application of green technologies. Local governments need to improve policy execution capabilities, ensuring effective implementation of measures and providing sufficient financial support. Furthermore, enhancing the ecological environment by increasing green spaces and infrastructure will encourage businesses to invest in green technologies. Finally, implementing successful green technology demonstration projects will showcase their effectiveness and build confidence in green innovation among businesses and the public. These measures will effectively promote green innovation and sustainable development in transportation hub cities.

7.3. Limitations and Furure Directions

Despite providing empirical evidence on the effectiveness of the National Forest City Policy (NFCP) in promoting green innovation, this study has several limitations. First, this paper focused on examining the impact of the NFCP on green innovation at the urban scale, assessing its effectiveness in urban green innovation. Therefore, it does not consider the potential interactions between urban and rural areas or the NFCP's impact on short-term economic growth. Second, the research objective was to investigate the net policy effects of the NFCP on green innovation, and thus we did not explore scenarios involving collaboration of the NFCP with other policies. Finally, while this paper analyzed the theoretical mechanism of the NFCP's impact on green innovation through carbon reduction, it acknowledges that there may also be an inverse causal relationship between green innovation and carbon reduction. Based on these research limitations, future researchers can explore the following aspects.

Urban–Rural Interaction Perspective on NFCP and Green Innovation: Future research should focus on urban–rural interaction and the heterogeneity of urban–rural policies. The effectiveness of urban–rural interaction systems is crucial for the success of the National Forest City Policy (NFCP). Differences in economic development and resource allocation between urban and rural areas can lead to varying policy outcomes. Therefore, policy design should promote collaboration between urban and rural regions to achieve comprehensive green development. Additionally, targeted measures addressing the unique challenges of urban–rural policy heterogeneity will enhance the effectiveness of implementation and support sustainable development goals.

Synergistic Perspective on NFCP: Future research should focus on the synergistic effects of the National Forest City Policy (NFCP) alongside other economic and industrial policies. While the NFCP significantly promotes green innovation and reduces carbon emissions, relying solely on urban greening measures may not achieve substantial emission reductions. Policymakers need to integrate the NFCP with energy policies, industrial upgrading, and technological innovation to maximize overall policy effectiveness. This coordinated approach can enhance the promotion of green technologies and support more balanced regional development.

Green Innovation and Short-Term Economic Growth: In future research, attention should focus on the trade-offs between promoting green innovation and short-term economic growth, especially in carbon-intensive industries. Companies in these sectors often prioritize short-term profits, which may discourage them from investing in necessary technological upgrades for green innovation. Therefore, policy design must address the specific needs of these industries to reconcile short-term benefits with long-term environmental goals. Effective incentive mechanisms can encourage firms to invest in green technologies while still pursuing immediate growth, thus supporting sustainable development.

Inverse Causal Relationship between Carbon Emission and Green Innovation: Future research should explore the inverse relationship between carbon reduction and green innovation. While the National Forest City Policy (NFCP) promotes green innovation by encouraging carbon reduction, green innovation can also lead to significant reductions in carbon emissions. Understanding this dynamic is crucial for policymakers. Effective policy design should integrate carbon reduction measures with green innovation incentives. Future studies can investigate how this relationship impacts policy implementation in various economic and social contexts and how to foster their synergistic development.

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References

1. Bherwani, H.; Banerji, T.; Menon, R. Role and value of urban forests in carbon sequestration: Review and assessment in Indian context. *Environ. Dev. Sustain.* **2024**, *26*, 603–626. [CrossRef]
2. Ramon, M.; Ribeiro, A.P.; Theophilo, C.Y.S.; Moreira, E.G.; de Camargo, P.B.; de Bragança Pereira, C.A.; Saraiva, E.F.; dos Reis Tavares, A.; Dias, A.G.; Nowak, D.; et al. Assessment of four urban forest as environmental indicator of air quality: A study in a brazilian megacity. *Urban Ecosyst.* **2023**, *26*, 197–207. [CrossRef]
3. Arzberger, S.; Egerer, M.; Suda, M.; Annighöfer, P. Thermal regulation potential of urban green spaces in a changing climate: Winter insights. *Urban For. Urban Green.* **2024**, *100*, 128488. [CrossRef]
4. Miao, X.; Pan, Y.; Chen, H.; Zhang, M.J.; Hu, W.; Li, Y.; Wu, R.; Wang, P.; Fang, S.; Niu, K.; et al. Understanding spontaneous biodiversity in informal urban green spaces: A local-landscape filtering framework with a test on wall plants. *Urban For. Urban Green.* **2023**, *86*, 127996. [CrossRef]
5. Xia, X.; Huang, T.; Zhang, S. The impact of intellectual property rights city policy on firm green innovation: A Quasi-Natural Experiment based on a Staggered DID Model. *Systems* **2023**, *11*, 209. [CrossRef]
6. Karimi, A.; Mohammad, P. Effect of outdoor thermal comfort condition on visit of tourists in historical urban plazas of Sevilla and Madrid. *Environ. Sci. Pollut. Res.* **2022**, *29*, 60641–60661. [CrossRef]
7. Luo, S.; Yimamu, N.; Li, Y.; Wu, H.; Irfan, M.; Hao, Y. Digitalization and sustainable development: How could digital economy development improve green innovation in China? *Bus. Strategy Environ.* **2023**, *32*, 1847–1871. [CrossRef]
8. Li, L.; Li, M.; Ma, S.; Zheng, Y.; Pan, C. Does the construction of innovative cities promote urban green innovation? *J. Environ. Manag.* **2022**, *318*, 115605. [CrossRef]
9. Chen, C.; Lin, Y.; Lv, N.; Zhang, W.; Sun, Y. Can government low-carbon regulation stimulate urban green innovation? Quasi-experimental evidence from China's low-carbon city pilot policy. *Appl. Econ.* **2022**, *54*, 6559–6579. [CrossRef]
10. Xia, X.; Chen, X.; Chen, Q. Evaluating the Impact of Low-Carbon Urban Policy on Corporate Green Innovation—Evidence from China's National Low-Carbon City Strategy Program. *Sustainability* **2024**, *16*, 4154. [CrossRef]
11. Qiu, L. Does the construction of smart cities promote urban green innovation? Evidence from China. *Appl. Econ. Lett.* **2023**, *30*, 2688–2696. [CrossRef]
12. Huang, Y.; Chen, C.; Lei, L.; Zhang, Y. Impacts of green finance on green innovation: A spatial and nonlinear perspective. *J. Clean. Prod.* **2022**, *365*, 132548. [CrossRef]
13. Hao, X.; Li, Y.; Ren, S.; Wu, H.; Hao, Y. The role of digitalization on green economic growth: Does industrial structure optimization and green innovation matter? *J. Environ. Manag.* **2023**, *325*, 116504. [CrossRef] [PubMed]
14. Yu, C.-H.; Wu, X.; Zhang, D.; Chen, S.; Zhao, J. Demand for green finance: Resolving financing constraints on green innovation in China. *Energy Policy* **2021**, *153*, 112255. [CrossRef]
15. Zhang, J.; Kang, L.; Li, H.; Ballesteros-Pérez, P.; Skitmore, M.; Zuo, J. The impact of environmental regulations on urban Green innovation efficiency: The case of Xi'an. *Sustain. Cities Soc.* **2020**, *57*, 102123. [CrossRef]
16. Zhang, Z.; Zheng, C.; Lan, L. Smart city pilots, marketization processes, and substantive green innovation: A quasi-natural experiment from China. *PLoS ONE* **2023**, *18*, e0286572. [CrossRef]
17. Wang, K.-L.; Zhang, F.-Q.; Xu, R.-Y.; Miao, Z.; Cheng, Y.H.; Sun, H.P. Spatiotemporal pattern evolution and influencing factors of green innovation efficiency: A China's city level analysis. *Ecol. Indic.* **2023**, *146*, 109901. [CrossRef]
18. Luo, Y.; Salman, M.; Lu, Z. Heterogeneous impacts of environmental regulations and foreign direct investment on green innovation across different regions in China. *Sci. Total Environ.* **2021**, *759*, 143744. [CrossRef]
19. Ullah, S.; Khan, F.U.; Ahmad, N. Promoting sustainability through green innovation adoption: A case of manufacturing industry. *Environ. Sci. Pollut. Res.* **2022**, *29*, 21119–21139. [CrossRef]
20. Feng, Y.; Chen, Z.; Nie, C. The effect of broadband infrastructure construction on urban green innovation: Evidence from a quasi-natural experiment in China. *Econ. Anal. Policy* **2023**, *77*, 581–598. [CrossRef]
21. Zhang, J.-X.; Cheng, J.-W.; Philbin, S.P.; Ballesteros-Perez, P.; Skitmore, M. Influencing factors of urban innovation and development: A grounded theory analysis. *Environ. Dev. Sustain.* **2023**, *25*, 2079–2104. [CrossRef] [PubMed]
22. Liao, L.; Zhao, C.; Li, X.; Qin, J. Towards low carbon development: The role of forest city constructions in China. *Ecol. Indic.* **2021**, *131*, 108199. [CrossRef]
23. Zhang, Y.; Zhang, T.; Zeng, Y.; Cheng, B.; Li, H. Designating National Forest Cities in China: Does the policy improve the urban living environment? *For. Policy Econ.* **2021**, *125*, 102400. [CrossRef]
24. Xu, C.; Dong, L.; Yu, C.; Zhang, Y.; Cheng, B. Can forest city construction affect urban air quality? The evidence from the Beijing-Tianjin-Hebei urban agglomeration of China. *J. Clean. Prod.* **2020**, *264*, 121607. [CrossRef]
25. Moser, S.; Avery, E. The multi-scalar politics of urban greening in Forest City, Malaysia. *Urban For. Urban Green.* **2021**, *60*, 127068. [CrossRef]
26. Koh, S.Y.; Zhao, Y.; Shin, H.B. Moving the mountain and greening the sea: The micropolitics of speculative green urbanism at Forest City, Iskandar Malaysia. *Urban Geogr.* **2022**, *43*, 1469–1495. [CrossRef]
27. Zhang, Z.; Cenci, J.; Zhang, J. Policies for Equity in Access to Urban Green Space: A Spatial Perspective of the Chinese National Forest City Policy. *Forests* **2024**, *15*, 608. [CrossRef]

28. Wang, Y.; Zou, F.; Guo, W.; Lu, W.; Deng, Y. Impact of Forest City Selection on Green Total Factor Productivity in China under the Background of Sustainable Development. *Forests* **2024**, *15*, 1064. [CrossRef]
29. Chen, J.; Li, Q.; Wang, X. Does the government's environmental attention improve enterprise green innovation?—Evidence from China. *Front. Environ. Sci.* **2022**, *10*, 999492. [CrossRef]
30. Chen, Z.; Liang, M. How do external and internal factors drive green innovation practices under the influence of big data analytics capability: Evidence from China. *J. Clean. Prod.* **2023**, *404*, 136862. [CrossRef]
31. Zhao, Y.; Mao, J.; Li, Y. Local governments' environmental emphasis and corporate green innovation: Evidence from China. *Econ. Change Restruct.* **2022**, *55*, 2577–2603. [CrossRef]
32. Wang, L.; Long, Y.; Li, C. Research on the impact mechanism of heterogeneous environmental regulation on enterprise green technology innovation. *J. Environ. Manag.* **2022**, *322*, 116127. [CrossRef] [PubMed]
33. Ai, H.; Zhou, Z. Green growth: The impact of urban forest construction on economic growth in China. *Econ. Model.* **2023**, *125*, 106366. [CrossRef]
34. Huang, X.; Zhang, S.; Zhang, J.; Yang, K. Research on the impact of digital economy on Regional Green Technology Innovation: Moderating effect of digital talent Aggregation. *Environ. Sci. Pollut. Res.* **2023**, *30*, 74409–74425. [CrossRef]
35. Zhang, J.; Chu, Z.; Sun, Z. Impact of low-carbon city pilot policies on urban green innovation from the perspective of spatial and temporal heterogeneity. *Environ. Sci. Pollut. Res.* **2023**, *30*, 114358–114374. [CrossRef]
36. Li, X.; Zhao, C. Can national forest city construction mitigate air pollution in China? Evidence from a quasi-natural experiment. *Environ. Geochem. Health* **2023**, *45*, 3003–3024. [CrossRef]
37. Li, H.; Su, Y.; Ding, C.J.; Tian, G.G.; Wu, Z. Unveiling the green innovation paradox: Exploring the impact of carbon emission reduction on corporate green technology innovation. *Technol. Forecast. Soc. Chang.* **2024**, *207*, 123562. [CrossRef]
38. Chen, Z.; Zhang, X.; Chen, F. Do carbon emission trading schemes stimulate green innovation in enterprises? Evidence from China. *Technol. Forecast. Soc. Chang.* **2021**, *168*, 120744. [CrossRef]
39. Liu, B.; Cifuentes-Faura, J.; Ding, C.J.; Liu, X. Toward carbon neutrality: How will environmental regulatory policies affect corporate green innovation? *Econ. Anal. Policy* **2023**, *80*, 1006–1020. [CrossRef]
40. Xu, Y.; Dong, Z.; Wu, Y. The spatiotemporal effects of environmental regulation on green innovation: Evidence from Chinese cities. *Sci. Total Environ.* **2023**, *876*, 162790. [CrossRef]
41. Zhou, Y.; Xu, X.; Tao, L. The impact mechanism of high-speed railway on regional green innovation spillover under multi-dimensional paths. *Environ. Impact Assess. Rev.* **2022**, *95*, 106795. [CrossRef]
42. Huang, Y.; Wang, Y. How does high-speed railway affect green innovation efficiency? A perspective of innovation factor mobility. *J. Clean. Prod.* **2020**, *265*, 121623. [CrossRef]
43. Liao, B.; Li, L. Urban green innovation efficiency and its influential factors: The Chinese evidence. *Environ. Dev. Sustain.* **2023**, *25*, 6551–6573. [CrossRef]
44. Liu, K.; Xue, Y.; Chen, Z.; Miao, Y. The spatiotemporal evolution and influencing factors of urban green innovation in China. *Sci. Total Environ.* **2023**, *857*, 159426. [CrossRef] [PubMed]
45. Callaway, B.; Sant'anna, P.H. Difference-in-differences with multiple time periods. *J. Econom.* **2021**, *225*, 200–230. [CrossRef]
46. Nie, C.; Ye, S.; Feng, Y. Place-based policy and urban green technology innovation: Evidence from the revitalization of old revolutionary base areas in China. *Econ. Anal. Policy* **2024**, *81*, 1257–1272. [CrossRef]
47. Dian, J.; Song, T.; Li, S. Facilitating or inhibiting? Spatial effects of the digital economy affecting urban green technology innovation. *Energy Econ.* **2024**, *129*, 107223. [CrossRef]