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Impact of National Innovative City Policy on Enterprise Green Technology Innovation—Mediation Role of Innovation Environment and R&D Investment

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Abstract: This study investigates the impact of the national innovative city policy on enterprise green technology innovation amid China's transformation from a resource-dependent to an innovation-driven economy. Working on city- and enterprise-level data from 2003 to 2018, this study employs the multi-period difference-in-differences (DID) model and the Sobel test to explore the impact of innovative city policies. The empirical results demonstrate that the innovative city policy has improved both the quantity and quality of enterprises' green technology innovation output. This positive impact is accomplished via improving the urban innovation environment and stimulating enterprise research and development (R&D) investment. The promoting effect of the policy is stronger in attaining green utility patents by state-owned enterprises and green invention patents by non-state-owned enterprises. The positive policy impact is more pronounced for large enterprises. This study provides micro-level evidence regarding the policy's impact on green innovation, and the results carry valuable policy implications.

Keywords: national innovative city policy; green technology innovation; innovation environment; enterprise R&D; influence mechanism



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1. Introduction

Green innovation strives to achieve a strategic balance between economic development and ecological protection, fostering China's transition from a resource-dependent economy to an innovation-driven economy. The Chinese government has vowed to position China among the leading innovative nations by 2035. The primary task of building an innovation-driven economy is to create a supportive innovation environment, and the national innovative city policy is a key measure to pursue this ambition [1]. It began with Shenzhen in 2008, and by 2013, 57 cities had been identified as national innovative pilot cities. Regional innovation development, represented by cities and regional networks, has become the principal driving force for transforming the economy. As participants of the policy, enterprises serve as the junction of economic development and ecological civilization at the micro level. China's ambition for an ecologically sustainable economy relies on the progressive development of green technology innovations at the enterprise level.

The essence of the national innovative city policy is to improve regional innovation environments, thereby encouraging enterprises to increase their inputs in innovation. Studies on this policy have mainly focused on evaluating its macroeconomic effects, such as the impact on regional innovation capabilities and the spatial spillover of policy effects. Also explored are its impact on structural adjustment in the economy, factor mobility, and the quality of direct foreign investment. However, few studies have evaluated the policy

effects at the level of individual entities. Therefore, this study examines several research questions: Has the national innovative city policy promoted green technology innovation at the enterprise level? If so, is the promoting effect achieved through the improvement of the regional innovation environment and elevated innovation inputs by enterprises? Does the policy affect all enterprises equally?

To address these research questions, this study treats the national innovative city policy as a quasi-natural experiment. Working on panel data from 370 cities and green patent data for listed companies from 2003 to 2018, we employ a multi-period difference-in-differences (DID) model and the Sobel test to explore the impact of the innovative city policy on enterprise green technology innovation and its influence mechanisms.

This study makes several contributions to the literature. First, we assess the impact of the innovative city policy on the outcome of green innovation activities at the enterprise level, as represented by granted green technology patents. The assessment considers both the quantity and quality of green technology innovation by enterprises. Several robustness checks, including PSM-DID and the placebo test, are conducted to mitigate the endogeneity and selection bias concerns. Their results help to confirm the causal impact of the innovative city policy on enterprise green innovation. Second, we examine the two influence mechanisms of the policy, by empirically testing and confirming the mediating effects of innovation environment quality and enterprise research and development (R&D) investment. Such findings prove that the innovative city policy has worked as intended. Third, a heterogeneity analysis reveals that the policy's effects vary by enterprise ownership and size. Non-state-owned enterprises have greater success in attaining high-quality green innovation than state-owned enterprises, and small enterprises are less productive than large ones in achieving green innovation.

The rest of the paper proceeds as follows. A literature review and research hypotheses are presented in Section 2, and the research design is described in Section 3. The research methodology and empirical results are presented in Section 4. An exploration of influence mechanisms is conducted in Section 5. Heterogeneity in policy effects is investigated in Section 6. Section 7 summarizes and discusses the main results, and policy recommendations are made in Section 8.

2. Literature Review and Research Hypotheses

2.1. Literature Review

Innovative cities represent a top-level design for knowledge-driven economic development, as they facilitate the aggregation of diverse resources to promote urban creativity and competitiveness [2]. Research on China's innovative city policy has primarily focused on its macroeconomic effects. Liu et al. [3] studied the impact of establishing national innovative cities on regional innovation capabilities. Zheng and Yang [4] empirically demonstrated that the innovative city policy enhances urban innovation by strengthening government execution ability, cultivating innovative talents, and stimulating corporate financing. Wang et al. [5] pointed out that the establishment of innovative cities upgrades traditional industries and strategies for technological development, thereby promoting coordinated development of the economy and technology. Sandrine [6] showed that the national innovative city policy has a positive impact on the quality of direct foreign investment. Research has also been conducted on the essence of the innovative city policy. Wei and Kong [7] argued that the core connotation of the innovative city policy lies in improving macro-level innovative facilities and mobilizing micro-level inputs for innovation. Fang et al. [8] argued that science and technology development in a city can influence innovation in the region, which was confirmed by Yu et al. [9]. In short, these studies suggest that the innovative city policy improves the overall innovation environment and infrastructure of cities and regions. They focus primarily on the policy's impacts on macro indicators for designated cities, including innovation facilities, the economy, and finance; however, little attention has been paid to policy evaluation at the level of micro-subjects. This paper studies the impact of innovative city policy on the innovation outputs of enterprises, which fills a gap in the literature.

In the meantime, a growing body of literature has assessed corporate technology innovation from the perspectives of markets, governments, and enterprises. Regarding corporate innovation, Xu et al. [10] argued that under the stimulation of industrial policies, enterprises, in order to obtain government subsidies and other benefits, may increase the quantity of innovation but neglect its quality. Zhang et al. [11] conclude that R&D investment in emerging industries significantly enhances enterprises' technological innovation capabilities. Yang and Xu [12] pointed out that as government R&D subsidies are crucial for stimulating enterprise innovation, attention should be paid to designing the optimal subsidy scheme to impede opportunistic innovation. As for corporate green technology innovation, Liu et al. [13] employed a DID model to examine the inducement effect of emission trading policies on green innovation. Liang et al. [14] confirmed the incentive effect of pollution charges on corporate green innovations from the perspective of government regulation. Li and Liu [15] investigated the inducement effect and influencing mechanism of a low-carbon pilot city policy on corporate green technology innovation. Hou et al. [16] reported that low-carbon city and innovative city pilot policies significantly curb carbon emissions, by promoting green innovation and upgrading industrial structures in pilot cities. Compared to these pilot policies—including government subsidy policies [17], government support policies [18,19], carbon trading pilot policies [20,21], low-carbon city pilot policies [22], and smart city pilot policies [23]—the national innovative city policy focuses more on technological innovation and has a deeper impact on green technology development [24]. However, studies on this policy have been relatively rare, especially regarding its impact on green technology innovation outputs. If its effects and influence mechanisms are better understood, the policy may provide an even stronger boost to China's ambition to become an innovation powerhouse. Based on its nature as a quasi-natural experiment, this paper explores the impact of the innovative city policy on the green technology innovation of enterprises and promotes a more nuanced understanding of the policy.

This study also contributes to a global conversation on innovation policies, which have become increasingly popular over the last three decades [25]. Research has evolved from the meaning of innovation policies [26] to their rationales [27] and impacts [28]. While the conventional innovation support measures—financial subsidies in particular—seem to have narrow positive effects on firms' R&D investments [29,30], attention has been turned to more systematic approaches [31–33]. China's innovative city policy represents such an experiment. This paper reveals some encouraging results regarding the impact of this policy on green innovation, thus contributing to the ongoing global discourse.

2.2. Research Hypotheses

2.2.1. Effect of National Innovative City Policy on Enterprise Green Technology Innovation

The national innovative city policy impacts micro-level green technology innovation with policy incentives and financial support. First, the national innovative city policy can trigger policy incentive reactions. Constructing innovative cities can enhance local enterprises' innovation incentives and accelerate green technology innovation. Second, the national innovative city policy can attract resources. The purpose of building innovative cities is to integrate innovative resources and establish a comprehensive innovation mechanism conducive to the rapid aggregation of capital, talents, technology, and information. It can attract and accommodate more innovative talents and entities, refine specialized industries, upgrade industrial structures, and consolidate the core productive forces of local enterprises to improve their green technology innovation. Lastly, the national innovative city policy can provide financial support. The construction of innovative cities can promote the inflow of external funding, particularly for strengthening financial support and providing preferential benefits for green innovation activities. It can mitigate the challenges faced by enterprises, such as high R&D expenditure, lengthy developmental circles, and high liquidity risk. It allows green technology innovation to permeate enterprises. For these reasons, the following hypothesis is proposed:

H1. *The national innovative city policy can promote enterprise green technology innovation.*

2.2.2. The Influence Mechanisms

This study proposes two mediating mechanisms through which the innovative city policy affects enterprise green innovation: innovation environment and R&D investment.

Porter [34] advocates the creation of a sound innovation coordination system and a quality innovation service environment as essential for stimulating corporate innovations. The construction of innovative cities integrates information, technology, and talent, and it creates a composite innovation resource by synergizing individual resources. It provides a rare spatial carrier for micro-level scientific and technological innovation activities. Innovative cities' administrative coordination mechanisms can reduce the implementation costs of innovation activities, including approval, verification and authorization, and provision of guarantees (if warranted) for the implementation of enterprise innovation strategies. The leadership mechanism and innovation assurance coordination systems of innovative cities facilitate the efficient aggregation of elite talents and technological capital. They provide vital support for stimulating enterprises' pursuit of green technology innovation. Moreover, innovative cities pay more attention to the protection and utilization of intellectual property rights, thereby promoting knowledge and technology diffusion. Thus, the following hypothesis is proposed:

H2a. *The national innovative city policy promotes enterprise green technology innovation by improving the cities' innovation environments.*

R&D activities often require significant investments in essential equipment and instruments and specially trained personnel, which often creates innovation barriers, especially for small enterprises. Under the support of the innovative city policy, local governments usually adjust resource allocation, change fiscal expenditures, and provide the infrastructures needed for scientific and technological research. Moreover, governments and relevant organizations direct more funds to innovation activities by providing financial subsidies and tax benefits to companies that actively engage in green technology innovation. Elevated R&D investment raises the level of enterprise green innovation and hence may generate more innovation outcomes.

H2b. *The national innovative city policy promotes enterprise green technology innovation by stimulating enterprises to increase R&D investment.*

3. Research Design

3.1. Data

The implementation of the innovative city policy took place in phases between 2008 and 2013. This study selects the green patent data and economic indicators of A-share listed companies in China during the period of 2003–2018. The green patent data were obtained from the State Intellectual Property Office (SIPO) of China (State Intellectual Property Office: www.cnipa.gov.cn, accessed on 8 October 2022). Other company-level data were retrieved from the Wind economic database (Wind economic database: www.wind.com.cn, accessed on 9 October 2022) and the China Stock Market & Accounting Research (CSMAR) database (China Stock Market & Accounting Research: www.csmar.com, accessed on 9 October 2022). Using the “IPC Green Inventory” (IPC Green Inventory: www.wipo.int/classifications/ipc/green-inventory/home, accessed on 10 October 2022), the numbers of green utility patents and green invention patents as well as the total number of green patents granted were used as proxies for enterprise green technology innovation. The 57 cities that implemented pilot policies between 2008 and 2013 constituted the experimental group, and over 300 other cities formed the control group. The following procedures were applied to the data: (1) removal of data of companies in official financial stress, i.e., whose stocks were labeled with ST, *ST, and PT; (2) exclusion of observations with key data missing; and (3) winsorization of continuous variables at the 1st and 99th percentiles, to mitigate the impact of extreme values.

3.2. Variables

Dependent variables: This study examined the impact of the innovative city policy on green technological innovations of A-share listed companies in China. Measures of green patents granted were the dependent variable, including the total number of green patents (pataut), green invention patents (pataut-invention), and green utility patents (pataut-utility) [15,35]. Compared to patent applications, patents granted are a better indicator of green technological innovation because the innovation quality has been officially certified [36,37]. Invention patents typically embody more significant technological breakthroughs than utility patents, so they can better represent the quality of green innovation [38,39]. The total number of green patents represents the quantity of green innovation.

Independent variables: The dummy variable NICP, denoting the National Innovative City Policy, indicates the implementation of the innovation. The innovative city policy implemented by the central government provides a rare quasi-natural experimental opportunity for innovation research.

Control variables: Following Liang et al. [14], Zeng et al. [40], and Liu et al. [41], various firm characteristics that may influence green innovation in companies were selected as control variables. These included the following: (1) Firm size (Size): large companies may have advantages in allocating adequate resources to improve their innovation and sustainable development. (2) Cash holdings (Cash): sufficient cash holdings can provide stable financial backing for green innovation activities. (3) Capital expenditure (Lnoutcap): investment in long-term capital assets may help maintain or strengthen companies' innovation infrastructures. (4) Economic indicators related to business performance and governance structure, including return on assets (Roa), capital intensity (Density), proportion of independent directors (Ind), and board size (Board).

Mediating variables: To measure the quality of the innovation environment, the Urban Innovation Index (UII) was adopted from the "China City and Industry Innovation Capability Report 2017." In addition, investment in R&D activities was adopted as another mediating variable. The main variables are described in Table 1.

Table 1. Description of main variables.

Category	Variable Name	Symbol	Description
Dependent variables	Number of green patents granted	Pataut	Logarithm of the number of green patents granted to an enterprise in a year plus 1
	Number of green utility patents granted	Pataut-utility	Logarithm of the number of green utility patents granted to an enterprise in a year plus 1
	Number of green invention patents granted	Pataut-invention	Logarithm of the number of green invention patents granted to an enterprise in a year plus 1
	Number of green patent applications	Patapp	Logarithm of the number of green patent applications by an enterprise in a year plus 1
	Number of green utility patent applications	Patapp-utility	Logarithm of the number of green utility patent applications by an enterprise in a year plus 1
	Number of green invention patent applications	Patapp-invention	Logarithm of the number of green invention patent applications by an enterprise in a year plus 1
Independent variable	National innovative city policy	NICP	Dummy variable that takes a value of 1 for innovative cities upon and after policy implementation, or zero otherwise.
Control variables	Enterprise size	Size	Logarithm of total assets at year end
	Cash holdings	Cash	Ratio of cash and cash equivalents to total assets at year end
	Capital expenditure	Lnoutcap	Logarithm of capital expenditure
	Return on assets	Roa	Net profit divided by average total assets
	Capital intensity	Density	Ratio of total assets at year end to sales
	Board independence	Ind	Proportion of independent directors on the board
	Board size	Board	Logarithm of the number of board members
Mediating variables	Urban innovation index	UII	Retrieved from "China City and Industry Innovation Capability Report 2017"
	R&D investment	R&D	Logarithm of investment amount in R&D

4. Research Methodology and Empirical Results

4.1. Analysis of Benchmark Regression Results

This section estimates the impact of the national innovative city policy on enterprise green technology innovation using a time-varying DID model, because the policy implementation dates vary across different regions. The model is specified as follows:

$$\text{Pat}_{it} = \beta_0 + \beta_1 \text{NICP}_{jt} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (1)$$

Pat_{it} represents the green patent counts of company i in year t , including green patents (Pataut), utility patents for green technology (Pataut-utility), and invention patents for green technology (Pataut-invention). The core explanatory variable NICP_{jt} is the product of D_u and D_t : D_u is a dummy variable that takes a value of 1 if the city is an innovative city or zero otherwise, and D_t is a dummy variable that takes a value of 1 for the years of and post policy implementation or zero otherwise. X_{it} collects the control variables, including firm size (Size), cash holdings (Cash), capital expenditure (Inoutcap), return on assets (Roa), capital intensity (Density), proportion of independent directors (Ind), and board size (Board). v_i represents fixed firm effects, and γ_t represents fixed year effects. The coefficient β_1 is the focus of attention, as it reflects the effect of the innovative city policy on green technology innovation. The baseline regression results are shown in columns (1), (3), and (5) of Table 2.

Table 2. Baseline and placebo test regression results.

Variable	Pataut		Pataut-Utility		Pataut-Invention	
	(1)	(2)	(3)	(4)	(5)	(6)
NICP	0.0834 *** (0.000)	0.0365 (0.172)	0.1330 ** (0.014)	0.0274 (0.860)	0.1892 *** (0.000)	0.2416 * (0.063)
Size	0.0449 *** (0.000)	0.0333 *** (0.002)	0.3941 *** (0.000)	0.3677 *** (0.001)	0.4146 *** (0.000)	0.4194 * (0.055)
Cash	0.0168 *** (0.000)	0.0168 *** (0.007)	0.0234 (0.474)	0.0270 (0.628)	−0.0183 (0.520)	−0.0218 (0.666)
Inoutcap	0.0288 *** (0.000)	0.0303 *** (0.000)	0.0997 *** (0.000)	0.1015 * (0.062)	0.1080 *** (0.000)	0.1114 (0.159)
Roa	−0.0001 * (0.086)	−0.0001 (0.116)	−0.0001 0.504	−0.0001 (0.514)	0.0001 (0.674)	0.0001 (0.349)
Density	−0.0053 * (0.062)	−0.0008 (0.869)	−0.0266 * (0.079)	−0.0153 (0.488)	−0.0397 *** (0.000)	−0.0409 (0.187)
Ind	0.1052 (0.119)	0.2057 (0.219)	0.2737 (0.557)	0.4854 (0.595)	1.0311 *** (0.001)	0.9830 * (0.054)
Board	−0.0573 *** (0.004)	−0.0053 (0.919)	−0.3638 *** (0.004)	−0.2540 (0.326)	−0.0552 (0.637)	−0.0848 (0.763)
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes
Fixed firm	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.0610	0.0695	0.0287	0.0297	0.0190	0.0195
N	30,854	30,854	30,854	30,854	30,854	30,854

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively, with the p -value reported in parentheses underneath each estimate.

The regression results reveal a significantly positive effect of the innovative city policy on green technology innovation. Overall, the positive impact of the innovative city policy on green technological innovation was significant at the 1% level. When the patent categories were separated in columns (3) and (5), the positive effect of the innovative city policy on invention patents was stronger and statistically more significant than that on utility patents. These results are consistent with the literature [42,43]. The innovative city policy boosts both the quantity and quality of enterprise green innovation. Therefore, Hypothesis 1 is supported.

4.2. Parallel Trend Test

The validity of DID results rests on the parallel trend assumption between the experimental and control groups [13]. The essence of the parallel trend assumption is that before policy implementation, both groups should have displayed a similar trend. After the policy implementation, distinct trends between the two groups would then indicate a significant impact of the policy. Figure 1 shows the difference in green technological innovation between the experimental and control groups over time. The x -axis represents time, where $t - 2$ represents the 2 years before policy implementation, t represents the policy implementation year, and $t + 1$ represents the year after policy implementation. Following Hu and Li [42] and Yu et al. [43], the period just before the implementation of the policy (i.e., year $t - 1$) was selected as the reference point. As shown in Figure 1, the confidence intervals of the difference before policy implementation intersect with the horizontal axis $y = 0$, indicating no significant difference between the two groups. Therefore, the result passes the parallel trend test for the DID model. After policy implementation, however, the confidence intervals steadily deviate further from $y = 0$ as time passes. A progressive enhancement of the policy's positive effect after its implementation is evident.

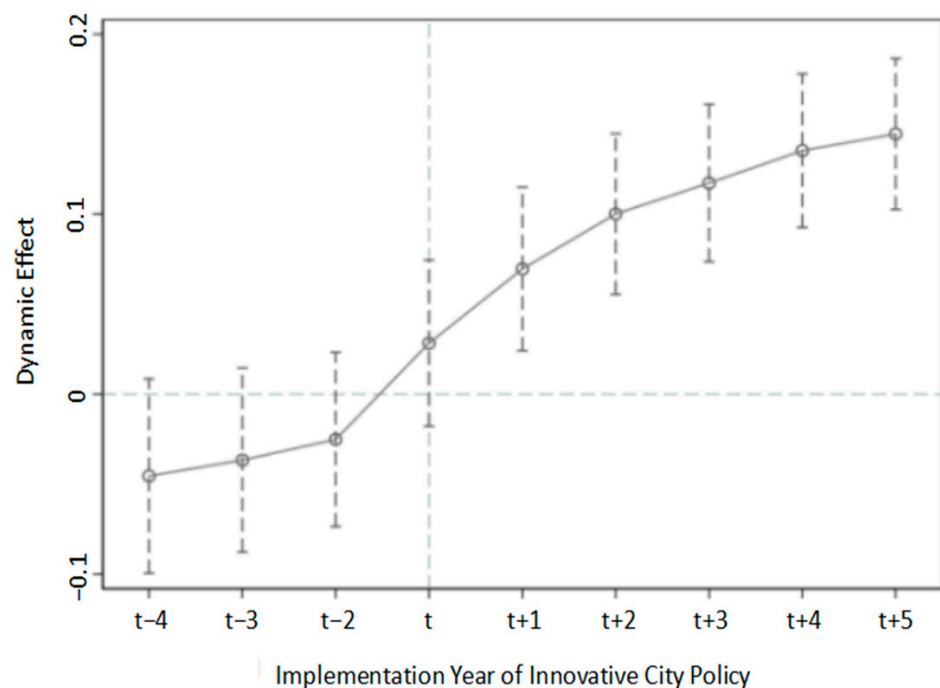


Figure 1. Trend in difference between experimental and control groups.

4.3. Robustness Tests

4.3.1. PSM-DID

To address potential sample selection bias, this section adopts the propensity score matching (PSM) method to construct a better control group. Specifically, a logit model is used to estimate the propensity scores of economic variables that may affect green technological innovation in enterprises. Observations that do not meet the common support condition are eliminated. Then, one-to-one nearest neighbor matching ($k = 1$) is performed on the experimental group. To ensure the quality of propensity score matching, the balance of the experimental and control groups is tested, following the method in Shipman et al. [44] and Crown [45]. The results of the balance test are shown in Table 3.

Table 3. Balance test.

Variable	Average				Deviation Reduction Rate (%)	t-Test	
	Sample	Experimental Group	Control Group	Deviation (%)		<i>t</i>	<i>p</i> > <i>t</i>
Size	Unmatched	22.154	21.69	33.7	99.3	29.77	0.000
	Matched	22.142	22.146	−0.2		−0.18	0.859
Cash	Unmatched	19.922	19.308	38.5	96.3	33.64	0.000
	Matched	19.911	19.888	1.4		1.15	0.248
Inoutcap	Unmatched	18.43	18.339	4.8	89.0	4.16	0.000
	Matched	18.423	18.413	0.5		0.40	0.686
Roa	Unmatched	1.6752	2.7979	−1.7	99.2	−1.36	0.174
	Matched	1.6762	1.6678	0.0		0.12	0.905
Density	Unmatched	0.27974	0.35041	−7.6	86.8	−6.58	0.000
	Matched	0.2802	0.2895	−1.0		−0.88	0.380
Ind	Unmatched	0.38125	0.37771	6.1	80.7	5.28	0.000
	Matched	0.38128	0.38059	1.2		0.94	0.347
Board	Unmatched	2.1196	2.1295	−4.9	70.6	−4.27	0.000
	Matched	2.1191	2.1162	1.4		1.15	0.250

Table 3 shows that the absolute standardized differentials for the matched variables are all within 2%. For example, the differential in Size decreases remarkably from 33.7% before matching to −0.2% after matching. All variables have *p*-values greater than 0.20 in the *t*-test after matching, indicating no significant differences between the experimental and control groups. The DID regression was rerun with the PSM-generated control group, and the results (These results are not tabulated in consideration of space.) were similar to those in Table 2. The sample selection bias thus has a limited impact on the baseline findings.

4.3.2. Placebo Test

To mitigate the influence of random unobservable factors on the experimental results, a placebo test was conducted to ensure that the changes in the granted number of green patents are indeed caused by the implementation of the innovative city policy. The idea is to examine whether the regression results would change if the innovative city policy were not implemented [11,46]. Specifically, all policy implementations between 2008 and 2013 are shifted forward by 2 years when calculating the difference. If the coefficient of NICP is insignificant, it would support the robustness of the baseline regression results. The placebo test results are reported in columns (2), (4), and (6) of Table 2. The coefficients of NICP in columns (2) and (4) are insignificant, thus passing the placebo test. The regression coefficient of NICP in column (6) is significant at the 10% level, indicating that the policy's effect on green invention patents may be slightly influenced by some unobservable factors.

4.3.3. Alternative Dependent Variables

As argued by Zhang et al. [35], the number of green patent applications better reflects the output of green innovation. Therefore, we employ as alternative measures the numbers of green patent applications, green utility patent applications, and green invention patent applications. The regression results are shown in columns (1)–(3) of Table 4, where the coefficients of NICP are all positive and significant at the 1% level. They confirm that the innovative city policy promotes both the quantity and quality of enterprise green innovation.

Table 4. Regression results of robustness tests.

Variable	Patapp	Patapp-Utility	Patapp-Invention	Pataut	Pataut-Utility	Pataut-Invention	Pataut (t + 1)	Pataut (t + 2)	Pataut (t + 3)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NICP	0.1919 *** (0.000)	0.0982 *** (0.000)	0.1660 *** (0.000)	0.0896 *** (0.000)	0.1051 * (0.081)	0.1897 *** (0.000)	0.0909 *** (0.000)	0.0982 *** (0.000)	0.1057 *** (0.000)
Size	−0.0091 (0.278)	−0.0037 (0.538)	−0.0088 (0.275)	0.0411 *** (0.000)	0.3457 *** (0.000)	0.1795 *** (0.000)	0.0437 *** (0.000)	0.0422 *** (0.000)	0.0413 *** (0.000)
Cash	−0.0032 (0.733)	−0.0108 * (0.096)	−0.0035 (0.706)	0.0241 *** (0.000)	0.0585 (0.131)	0.0367 *** (0.010)	0.0171 *** (0.000)	0.0178 *** (0.000)	0.0182 *** (0.000)
Inoutcap	0.0491 *** (0.000)	0.0367 *** (0.000)	0.0385 *** (0.000)	0.0195 *** (0.000)	0.0347 ** (0.013)	0.0133 (0.153)	0.0289 *** (0.000)	0.0292 *** (0.000)	0.0294 *** (0.000)
Roa	−0.0001 *** (0.000)	−0.0001 *** (0.000)	−0.0001 *** (0.000)	−0.0001 ** (0.011)	−0.0001 ** (0.025)	−0.0001 ** (0.370)	−0.0001 * (0.086)	−0.0001 * (0.083)	−0.0001 * (0.075)
Density	−0.0330 *** (0.000)	−0.0160 *** (0.003)	−0.0261 *** (0.000)	−0.0076 ** (0.011)	−0.0305 * (0.059)	−0.0189 ** (0.032)	−0.0048 * (0.085)	−0.0045 (0.111)	−0.0043 (0.127)
Ind	0.2054 *** (0.009)	0.1516 ** (0.014)	0.1988 *** (0.002)	0.1066 (0.158)	0.5877 (0.295)	0.3512 (0.239)	0.1106 (0.101)	0.1153 * (0.087)	0.1210 * (0.073)
Board	0.0270 (0.139)	−0.0014 (0.918)	0.0446 *** (0.003)	−0.0719 *** (0.000)	−0.4212 *** (0.001)	−0.1548 (0.204)	−0.0533 *** (0.008)	−0.0504 ** (0.011)	−0.0476 ** (0.017)
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.1535	0.1019	0.1193	0.0499	0.0184	0.0154	0.0619	0.0626	0.0633
N	22,997	22,997	22,997	24,699	24,699	24,699	30,854	30,854	30,854

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively, with the *p*-value reported in parentheses underneath each estimate.

4.3.4. Removal of Some Observations in Sample

The studies by Liu et al. [3] and Yu [9] indicate significant spatial spillover effects of the innovative city policy. Due to their status and resource advantages, megacities directly under the central government and provincial capitals exhibit systematic differences from other cities. To avoid the influence of these cities with preferential status, we removed them from the sample and conducted the regressions again. The results are shown in columns (4)–(6) of Table 4, where the coefficients of NICP are all significantly positive, consistent with the baseline results.

4.3.5. Lagging Effects in Green Innovations

Due to the time-consuming nature of research, experimentation, and approval processes associated with green patents, the impact of the innovative city policy on enterprise green innovation may show a time-lagging effect. Therefore, we examined the effect of policy implementation on enterprise green innovation in subsequent years. The regression results for 1, 2, and 3 year lagged green innovation are shown in columns (7)–(9) of Table 4. They are similar to the baseline results and consistent with the observation in Figure 1.

5. Influence Mechanisms

The essence of the national innovative city policy lies in the construction of a vibrant urban innovation ecosystem and the mobilization of micro-subjects' input of innovation resources, so as to foster city development driven by scientific and technological innovations [7]. In the previous sections, it was established that the innovative city policy promotes enterprise green innovation. Does the innovative city policy really influence enterprise green innovation through these two channels? We constructed mediation models

and conducted Sobel tests to investigate the influence mechanisms of the innovative city policy on enterprise green innovation.

5.1. Mediation Effect of Innovation Environment

We adopted the urban innovation index (UII) to measure the quality of the urban innovation environment [47]. The data for the urban innovation index was taken from the “China City and Industry Innovation Report 2017”. Due to the unavailability of recent data, only the innovation indexes for 338 cities between 2003 and 2016 were integrated with the original sample data. The data outside this time range (i.e., after 2016) and cities not covered by the “China City and Industry Innovation Report 2017” were excluded. The mediation model constructed was as follows:

$$\text{Pataut} = \beta_0 + \beta_1 \text{NICP}_{jt} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (2)$$

$$\text{UII} = \beta_0 + \beta_2 \text{NICP}_{jt} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (3)$$

$$\text{Pataut} = \beta_0 + \beta_3 \text{NICP}_{jt} + \beta_4 \text{UII} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (4)$$

In models (2) and (3), significant coefficients β_1 and β_2 would demonstrate the significant impact of the innovative city policy on the number of green patents granted and on the urban innovation index. When the UII is introduced in model (4), a significant β_4 would indicate the presence of a mediation effect. If the mediation effect is partial, β_3 would be significant as well; an insignificant β_3 would suggest a complete mediation effect. Furthermore, in the Sobel test, the Goodman-1 (Aroian) test statistics also attest the significance of the mediation effect. Column (1) in Table 5 shows that UII is a partial mediation factor for the impact of the innovative city policy on enterprise green innovation. The significant β_1 , β_2 , and β_4 indicate that the innovative city policy positively impacts both the number of green patents granted and the urban innovation index, and the urban innovation index also has a positive effect on the number of green patents. The significant β_3 and Goodman-1 (Aroian) test result reveal a significant partial mediation effect. The mediation effect was 0.0526, accounting for 62.79% of the total effect. These results demonstrate that the policy can promote enterprise green technological innovation in part by upgrading the urban innovation environment. Thus, hypothesis H2a is supported.

Table 5. Mediation analysis.

Name	(1) UII	(2) R&D
β_1	0.0837 ** (0.000)	0.0980 *** (0.000)
β_2	3.0541 *** (0.000)	0.3214 *** (0.000)
β_3	0.0312 *** (0.001)	0.0539 *** (0.000)
β_4	0.0172 *** (0.000)	0.1374 *** (0.000)
Goodman-1 (Aroian)	0.0526 *** (0.000)	0.0441 *** (0.000)
Indirect effect	0.0526 *** (0.000)	0.0441 *** (0.000)
Direct effect	0.0312 *** (0.001)	0.0539 *** (0.001)
Total effect	0.0837 *** (0.000)	0.0980 *** (0.000)
Indirect effect/total effect	0.6279	0.4504
Indirect effect/direct effect	1.6874	0.8195
Total effect/direct effect	2.6874	1.8195

Note: **, and *** represent significance at the 5%, and 1% levels, respectively, with the *p*-value reported in parentheses underneath each estimate.

5.2. Mediation Effect of R&D Investment

Applied or approved patents can only reflect the policy's positive impact on enterprise green innovation from an outcome-oriented perspective, and these measures overlook the innovation process and lack timeliness. In contrast, enterprise R&D investment has a shorter response time to policy implementation than green patent data. In addition, R&D investment can enhance enterprises' innovation capacity even without yielding patents. Based on this consideration, we examine the mediation effect of enterprise R&D investment [48,49] using the following model:

$$\text{Pataut} = \beta_0 + \beta_1 \text{NICP}_{jt} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (5)$$

$$\text{R\&D} = \beta_0 + \beta_2 \text{NICP}_{jt} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (6)$$

$$\text{Pataut} = \beta_0 + \beta_3 \text{NICP}_{jt} + \beta_4 \text{R\&D} + \alpha X_{it} + v_i + \gamma_t + e_{it} \quad (7)$$

The roles of coefficients in this model are the same as for Equations (2)–(4). Column (2) in Table 5 shows that the innovative city policy positively affects both green innovation and R&D investment and that R&D also positively impacts green innovation. The coefficient β_4 indicates a significant mediation effect of enterprise R&D, and β_3 and the Goodman-1 (Aroian) test suggest that the effect is partial. The mediation effect accounts for 45.04% of the total effect. Hence, the innovative city policy can promote enterprise green innovation by stimulating enterprises' R&D investment. Hypothesis H2b is thus supported.

6. Heterogeneity in Policy Effects

6.1. Enterprise Ownership Heterogeneity

Large differences exist across different types of Chinese firms with respect to their innovative behaviors [50]. To detect the potential difference in policy impact among enterprises of different ownership, we divided the sample into state-owned and non-state-owned enterprises. The subsample regression results of Equation (1) are shown in Table 6; they are generally consistent with the baseline results. However, the overall impact of the innovative city policy on enterprise green innovation (as measured by Pataut) is stronger for non-state-owned enterprises. The stimulating effect of policy implementation on green technological innovation by state-owned enterprises is mainly manifested in green utility patents. In contrast, the stimulating effect on non-state-owned enterprises is primarily conspicuous in green invention patents. This difference may be caused by several factors. First, business decision-making among different types of firms follows distinct behavioral patterns termed "routines" [51]. State-owned enterprises are more likely to obtain preferential policy incentives in tax benefits and financial resources [52], but the parallel implementation of multiple policies may lead to substitution effects and reduce incentive effects for innovation. Second, non-state-owned enterprises can only sustain long-term development by increasing capital investment, acquiring talents, and consolidating innovative technologies. Therefore, the incentive effect for innovation in non-state-owned enterprises is more pronounced. Third, state-owned enterprises are dominant in key domains and thus show less apprehension when facing environmental legitimacy pressure [38,39]. Compared to utility patents, invention patents better reflect the quality of innovation [53]. Therefore, the stimulating effect of the innovative city policy on green technology innovation seems to have yielded more technological advancement or breakthroughs in non-state-owned enterprises.

Table 6. Heterogeneity analysis according to enterprise ownership.

Variable	Pataut		Pataut-Utility		Pataut-Invention	
	(1) State-Owned	(2) Non-State-Owned	(3) State-Owned	(4) Non-State-Owned	(5) State-Owned	(6) Non-State-Owned
NICP	0.0476 *** (0.000)	0.0999 *** (0.000)	0.2039 *** (0.000)	0.0523 (0.515)	0.0651 (0.477)	0.1849 *** (0.000)
Cons	−2.0426 *** (0.000)	−1.6285 *** (0.000)	−10.6500 *** (0.000)	−11.6679 *** (0.000)	−15.6293 *** (0.000)	−5.4943 *** (0.000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes
Fixed firm	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.0808	0.0510	0.0507	0.0214	0.0228	0.0212
N	13,454	17,400	13,454	17,400	13,454	17,400

Note: *** represent significance at the 1% levels, with the *p*-value reported in parentheses underneath each estimate.

6.2. Enterprise Size Heterogeneity

Enterprises of different sizes may respond differently to the policy implementation. This section classifies all enterprises into two categories: large and non-large (i.e., medium, small, and micro) enterprises (The categorization of enterprises follows the standards issued by China's National Bureau of Statistics). Subsample regressions were conducted on Equation (1); the results are reported in Table 7. Although the innovative city policy enhances green innovation for both categories, the simulating effect is stronger for large enterprises. Large-scale enterprises possess more innovation capabilities [54]. They can integrate more innovative resources and provide steady and sufficient financial support for innovation activities. Compared with smaller firms, large enterprises have more robust adaptability and control over high-end technologies and possess advantages for acquiring talent, information, and other resources. In addition, large enterprises actively pursue innovation to maintain their market power and repel emerging competitors.

Table 7. Heterogeneity analysis per firm size.

Variable	Pataut		Pataut-Utility		Pataut-Invention	
	(1) Large	(2) Small, Medium, and Micro	(3) Large	(4) Small, Medium, and Micro	(5) Large	(6) Small, Medium, and Micro
NICP	0.0847 *** (0.000)	0.0713 *** (0.000)	0.1352 ** (0.037)	0.0716 (0.240)	0.2022 *** (0.000)	0.0560 *** (0.000)
Cons	−1.7526 *** (0.000)	0.0089 (0.920)	−11.2443 *** (0.000)	−0.1569 (0.547)	−12.4531 *** (0.000)	−0.0717 (0.582)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes
Fixed firm	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.0637	0.0217	0.0366	0.0010	0.0207	0.0091
N	25,240	5614	25,240	5614	25,240	5614

Note: **, and *** represent significance at the 5%, and 1% levels, respectively, with the *p*-value reported in parentheses underneath each estimate.

7. Conclusions and Discussion

The national innovative city policy is imperative for changing China's development pattern and establishing an innovative nation. In recent years, this policy has attracted increasing attention from academics and policy makers. While many studies have assessed its macro impact, there is a growing need to examine its impact at the individual entity level, particularly for enterprises. Using data on green patents from A-share listed companies, this study examines the impact of the national innovative city policy on enterprise green technological innovation using a multi-period DID model. We explored three key issues.

First, we assessed whether the national innovative city policy has actually elevated green technology innovation at the enterprise level. While previous studies have shown that the policy has had positive impacts on regional innovation capacity, it is important to determine whether these impacts have yielded more innovation output at the enterprise level. Our empirical results show that the policy has indeed significantly promoted green technology innovation for enterprises, both in terms of quantity and quality. This conclusion holds well in a series of robustness tests, including the parallel trend test, PSM-DID model estimation, the placebo test, and lag tests. The fact that the policy has a stronger impact on invention patents suggests that the policy is promoting more advanced and cutting-edge innovations.

Second, we tried to understand the mechanisms through which the policy affects enterprise green innovation. The essence of the innovative city policy lies in its focus on improving the innovation environment and activating micro-level input factors. The examinations conducted in this study provide strong evidence that the innovative city policy has in fact promoted enterprise green innovation by enhancing the urban innovation environment and stimulating enterprise R&D investment. In summary, all three research hypotheses are supported by the empirical results.

Third, we investigated whether the policy affects all enterprises equally, or whether its impact may vary according to certain enterprise attributes. Our investigation revealed that the policy affects enterprises differently depending on their ownership and scale. Specifically, the incentive effect of urban policy on state-owned enterprises is mainly reflected in practical green patents, while the influence on non-state-owned enterprises is mainly reflected in invention green patents. This shows that state-owned enterprises tend to focus on developing functional and utility-oriented green technologies. This policy provides them with the necessary support and incentives to innovate in this direction, which leads to more green utility patents. In contrast, non-state-owned enterprises with a stronger entrepreneurial spirit are more likely to explore and develop cutting-edge and novel green technologies. The policy, which emphasizes creating a supporting environment for innovation and providing resources, seems to have a stronger resonance with these enterprises, resulting in more green invention patents. The analysis based on enterprise size shows that the positive impact of innovative city policy on large enterprises is more evident. With greater financial and research capabilities, large firms can better take advantage of policy incentives and invest in green technology innovation. This policy is an important catalyst for these enterprises to pursue innovation, resulting in a significant increase in green patents.

It is worthwhile to note that the findings might be applicable only to the sample studied. For instance, the policy may have a distinct impact on smaller companies not listed in the A-share market. In a future project, we plan to examine how the innovative city policy affects companies listed in the growth enterprise market (GEM).

8. Policy Recommendations

Based on the findings, this study offers several policy recommendations. First, we recommend expanding the scope of pilot projects for innovative cities with differentiated priorities. Given its stimulating effects on green patents, expansion of the policy—especially considering its spatial spillover effects—into less developed regions may focus on infrastructure and capacity building, to lay the foundation for green innovation. In developed regions, the focus may be on fostering advanced technology clusters and promoting collaborations between enterprises and research institutions. Second, we should take advantage of the innovative city policy to the fullest extent. Building on the positive momentum, governments and industries should continue to invest in innovation infrastructure, improve the integration of resources to meet innovation requirements, maintain or increase financial incentives for innovation, and reduce enterprises' implementation costs for scientific and technological research. Resources should be allocated to promote joint investment and research endeavors in green innovation. Third, differentiated or targeted policies

should be provided to meet the needs of enterprises with different capacities and incentives. Specifically, preferential policies should be formulated to support the innovation efforts of small enterprises. The enthusiasm of non-state-owned enterprises should be braced for their pursuit of technological breakthroughs. It is important to ensure that all enterprises have equal opportunities to pursue green innovation so that the benefits of this policy are fairly distributed.

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