

Leverage or crowd out: the National Independent Innovation Demonstration Zone policies and green innovation efficiency of enterprises

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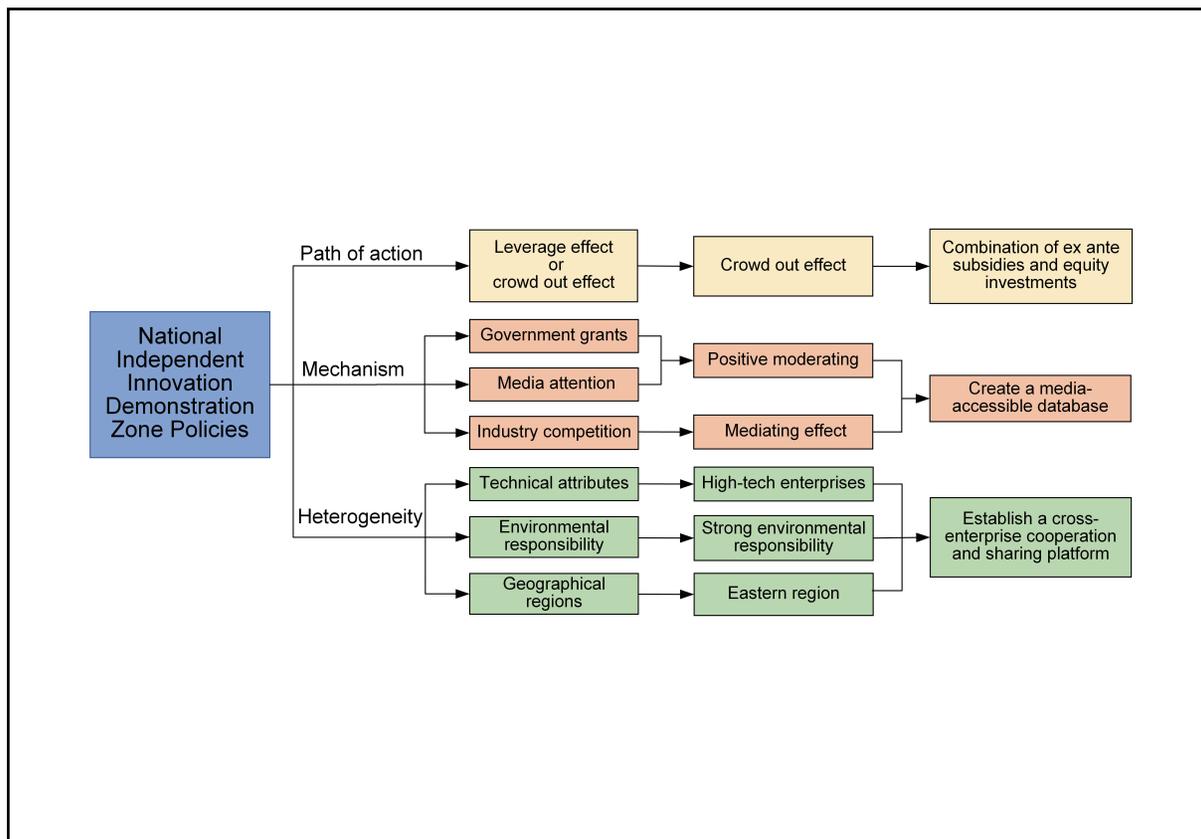
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Graphical abstract



Research methods and conclusions based on a multi-period difference-in-differences model.

Public summary

- The impact and action path of National Independent Innovation Demonstration Zone (NIIDZ) policies on green innovation efficiency (GIE) was studied.
- The positive impacts of the implementation of the NIIDZ policies on GIE were determined.
- The green innovation triggered by the NIIDZ policies was found to exert not a leverage effect but a crowd out effect.

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Abstract: The National Independent Innovation Demonstration Zone has been assigned the unique mission of demonstrating and leading national innovation and playing a key supportive role in enhancing green innovation. Based on the sample data of A-share listed companies in China from 2007 to 2021, we apply a multi-period difference-in-differences model to analyze whether the implementation of the National Independent Innovation Demonstration Zone policies plays a leverage effect or a crowd out effect on the green innovation efficiency of enterprises and systematically test the regulatory mechanism of government grants and media attention in the process of this influence. The empirical results show that the implementation of the National Independent Innovation Demonstration Zone policies has a positive impact on the green innovation efficiency of enterprises and that the green innovation induced by this reform is not the leverage effect of additional R&D investment on the basis of the existing innovation activities of enterprises but rather the result of the reallocation of resources to crowd out existing non-green innovation. It is further found that government grants and media attention positively moderate the positive driving effect of National Independent Innovation Demonstration Zone policies on the green innovation efficiency of enterprises.

Keywords: National Independent Innovation Demonstration Zone policies; green innovation efficiency; leverage effect; crowd out effect

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1 Introduction

In the report to the 20th National Congress of the Communist Party of China, General Secretary Xi Jinping emphasized the need to accelerate the implementation of the innovation-driven development strategy to achieve high-level scientific and technological self-reliance. As an important “experimental field” in China’s innovation at the core of future development, National Independent Innovation Demonstration Zones (NIIDZs) play a particularly important role in promoting high-quality economic development in China^[1]. Furthermore, the report of the Fifth Plenary Session of the 19th Central Committee of the Communist Party of China clearly stated that there must be a firm implementation of the new development concept of innovation, coordination, green, openness, and sharing, with special emphasis on placing green and innovation at the core of future development, which points out the direction for the development of the NIIDZs^[2]. NIIDZs should provide similar or different support measures according to their development needs and policy objectives to help enterprises flourish in the field of green innovation. As China’s first independent innovation demonstration zone, Zhongguancun not only provides tax incentives and financial

support to promote scientific and technological innovation but also has innovation incubators, technology parks, and technology transfer centers to provide enterprises with knowledge resources and professional consulting support. Shanghai Zhangjiang Independent Innovation Demonstration Zone actively encourages enterprises to carry out technological innovation and industry-academia research collaboration, provides tax incentives, financing support, and research and development (R&D) facilities for technology enterprises, and promotes the development of enterprises in high-tech fields.

As a national strategic platform, NIIDZs provide enterprises with advantageous conditions such as policy support, innovation resources, and market platforms, and provides unique opportunities and support for green innovation. However, there are also many problems, the most important one being that enterprises may face technical and knowledge bottlenecks and cannot effectively carry out green innovation activities, which further leads to the problem of the green innovation efficiency (GIE) of enterprises. The report of the 20th National Congress of the Communist Party of China clearly stated that accelerating the green transformation and promoting the green and low-carbonization of the economy

and society are the key components in achieving high-quality development. This means that driving the improvement of the green innovation capabilities of enterprises may become one of the main themes of the high-quality development of NIIDZs in the future. Therefore, this paper attempts to start from the perspective of enterprises, select efficiency measurement indicators that can reflect the whole process of green innovation, analyze the impact and mechanism of NIIDZ policies on GIE, and explore solutions and methods for the problems existing in NIIDZ policies in order to provide references for the formulation of relevant measures for improving GIE in NIIDZ policies.

2 Literature review

Analysis of related studies reveals that the literature related to the research topic of this paper is mainly classified into the following three categories: NIIDZs and enterprise innovation, innovation pilot policies and enterprise innovation, and leverage and crowd out effects.

2.1 NIIDZs and enterprise innovation

The Central Committee of the Communist Party of China and the State Council have made NIIDZs a major strategic deployment to enhance China's innovation capabilities and accelerate innovation development. Existing research on NIIDZs mainly focuses on the fields of innovation capability evaluation, industrial transformation and upgrading, and green and high-quality development.

Firstly, the innovation capabilities of NIIDZs have been extensively evaluated by various scholars. Liang and Liu^[3] employed the multi-period propensity score matching and difference-in-differences (DID) approaches to evaluate the innovation-driven efficiency of NIIDZs and concluded that the establishment of NIIDZs has significantly improved the level of regional innovation development. Similarly, Qin et al.^[4] utilized the DID approaches to study the impact of NIIDZs on regional innovation capabilities, and the results showed that the implementation of NIIDZ policies has significantly promoted regional innovation capabilities. Furthermore, Refs. [5–7] have evaluated the innovation capabilities of NIIDZs by constructing an innovation capability index system and have proposed innovative ideas and suggestions.

Secondly, regarding the research on NIIDZs and industrial transformation, Wang and Ma^[8] used the entropy-weight TOPSIS model to evaluate the industrial transformation and upgrading levels of NIIDZs and found out that there are differences between the industrial transformation and upgrading levels of each demonstration zone. Ma and Wang^[9] introduced government innovation subsidies to analyze the industrial transformation path of NIIDZs and believed that innovation subsidies can help to promote the development of the industrial structure to a higher level and in a more rational direction. Ma and Jiang^[10] have used the fuzzy-set qualitative comparative analysis approach to explore the multiple paths for NIIDZs to achieve industrial transformation and upgrading. They proposed that high R&D innovation investment and high innovation efficiency are the core elements for the NIIDZs to achieve industrial transformation and upgrading.

Finally, regarding the research on NIIDZs and the green and high-quality development, Han et al.^[1] utilized a multi-period difference-in-differences model and difference-in-difference-in-differences model to investigate the path of the establishment of NIIDZs on green and high-quality development; Ma et al.^[2] constructed a green and high-quality development evaluation system based on the connotation of green and high-quality development, which was then used to assess the green and high-quality development level of the NIIDZs. The results indicate that the green and high-quality development level of the NIIDZs is low, and the development of each demonstration zone varies in magnitude; Wang^[11] has empirically verified the impact of the establishment of the NIIDZs on the number of corporate green innovations from the perspective of enterprises. The results show that the establishment of NIIDZs has a positive effect on corporate green innovation.

In general, most of the existing research on NIIDZs focuses on evaluating their innovation capabilities and industrial transformation, and in-depth research on their connection with green development has not yet been conducted. Although very few scholars have linked NIIDZs to green development, their research has been limited to examining the impact of NIIDZs on green and high-quality development and the quantity of enterprises' green innovations, neglecting the key role that GIE plays in optimizing resource allocation, enhancing the quality of green innovations, and reflecting the effectiveness of policies. GIE is not only related to the competitiveness of enterprises but also an important basis for policymakers to assess and adjust incentive mechanisms. This research therefore aims to explore in depth the impact and role of NIIDZ policies on corporate green innovation efficiency from an enterprise perspective. It not only expands the fields of NIIDZ policies and corporate green innovation but also deepens the local government's understanding of policy implementation, providing important insights and accumulation of practical experience for formulating policies and measures to improve corporate green innovation capabilities.

2.2 Innovation pilot policies and enterprise innovation

Enterprises are a valuable perspective for measuring green innovation efficiency. Treating enterprises as research units can provide a deeper understanding of the connotation of green innovation efficiency. The existing innovation pilot policies related to the level of enterprise innovation mainly include the NIIDZ policies, the National Innovative City Pilot (NICP) policies, and the National Innovative Enterprise Pilot (NIEP) policies.

Firstly, for the study of NIIDZ policies and enterprise innovation level, Zhu and Li^[12] selected the number of patents obtained by enterprises as a measure of independent innovation and analyzed it from three aspects: government grants, market competition, and R&D investment intensity, for the study of NIIDZ policies on the impact mechanism of the level of enterprise innovation. Similarly, Yan et al.^[13] used the number of patents applied for by enterprises as a proxy variable for the enterprise's innovation level and verified that the "policy effect" and "agglomeration effect" are related to the relationship between NIIDZ policies and the level of

enterprise innovation, which plays an intermediary role. Guo et al.^[14] measured enterprise innovation from the perspective of both input and output. Specifically, they selected the ratio of enterprise R&D investment to operating income and the total number of annual patent applications of enterprises to serve as indicators. Through this multi-dimensional approach, the researchers further proved that NIIDZ policies promote enterprise innovation by leveraging policy incentives, market competition, and transaction costs.

Secondly, regarding the study of NICP policies and corporate innovation levels, Ran and Zheng^[15] selected the number of corporate patent applications as a measure of innovation levels to explore how pilot policies affect corporate innovation activities and proved the intermediary role of industry-academic-research collaborative innovation and technological complementation. Yang and Li^[16] used the number of patent authorizations as the explained variable measurement index and empirically verified that the NICP policies promote enterprise innovation mainly through policy effects and agglomeration effects.

Finally, regarding the study of the NIEP policies and the level of enterprise innovation, Yang et al.^[17] chose the patent growth rate to describe enterprise innovation and argued that the policies promote enterprise innovation by expanding the scale of small- and medium-sized enterprises' recognition and increasing the support, and fostering of innovative enterprises in economically underdeveloped regions. In addition, the number of patent applications was chosen by other scholars^[18] as the measurement indicator of the explained variable. The results revealed that the NIEP policies have a significant positive effect on enterprise innovation performance.

The existing literature on innovation pilot policies and corporate innovation can be summarized from two perspectives: indicator selection and mechanism analysis. From the perspective of indicator selection, most scholars choose to measure the level of corporate innovation using the number of patents, while some scholars assess corporate innovation from both the input and output aspects. However, green innovation is a dynamic R&D process, and relying only on the single static indicator of the number of patents or considering innovation input and output in isolation cannot reflect the real production R&D process. Therefore, this paper regards the R&D process as an overall input-output system, chooses input and output indicators in a targeted way, and applies the DEA-SBM model to measure the GIE, which not only fits the actual green innovation R&D process but also evaluates the impact of the NIIDZ policies on GIE in a more representative way.

From a mechanism analysis perspective, most scholars focus on the policy effect and agglomeration effect between innovation pilot policies and enterprise innovation. However, the discussion on the direction of enterprise green innovation remains relatively limited. To enhance the effectiveness of government support, it is necessary to systematically interpret, from a theoretical standpoint, the role of NIIDZ policies on the efficiency of enterprise green innovation. Specifically, the key question is whether the establishment of the NIIDZs has a leverage effect or a crowd out effect on the efficiency of enterprise green innovation. In addition, NIIDZ policies play

a key role in encouraging enterprise green innovation, attracting widespread attention from many media. However, the existing literature has not yet answered what role media attention plays between the two. This study empirically tests whether an increase in media attention strengthens the impact between NIIDZ policies and GIE, providing a new perspective for objectively evaluating the impact mechanism between the two.

2.3 Leverage effect and crowd out effect

From the perspective of the innovation-driven strategy, NIIDZ policies provide enterprises with resource support while also having a diverse range of effects on their innovation inputs. After the establishment of the NIIDZs, enterprises have obtained more available funds through government grants, and under the superimposed influence of factors such as increased reasonable pressure and the expectation of obtaining long-term competitiveness, enterprises may further increase R&D investment on the basis of the original innovation and actively carry out green innovation activities on the basis of the established innovation activities to enhance the enterprise's green innovation capability and produce the green innovation "leverage effect". However, in the face of the enterprise's own resource constraints, the enterprise may also reconfigure existing material and non-material resources, transfer existing resources from non-green innovation to the field of green innovation, reduce resource investment in non-green innovation, and fully promote green innovation activities, resulting in the "crowd out effect" of green innovation on existing non-green innovation.

Notably, the leverage effect in this paper is different from the facilitating effect^[19] or stimulating effect^[20] of established studies. As the most common incentive policy for accelerating the high-quality development of NIIDZs, government grants also have many different paths of action for green innovation in enterprises. However, existing studies have mainly examined the impact of government grants on R&D expenditures and the proportion of R&D expenditures to operating revenues, and have not examined the effects of the NIIDZ policies on the overall innovation activities of enterprises. Therefore, there is a need for a theoretical and systematic interpretation of whether the establishment of NIIDZs prompts enterprises to exert the leverage effect of increasing green innovation inputs on the basis of existing innovations or the crowd out effect of reallocating resources to carry out green innovation activities at the cost of squeezing out existing non-green innovations. Specifically, after the establishment of the NIIDZs, enterprises may increase their investment in innovation and R&D funding to improve their long-term competitiveness, thus creating a leverage effect on the enterprises green innovation. At the same time, it is also possible that enterprises do not increase their innovation inputs due to insufficient resources of their own or excessive R&D input costs, etc., but instead reconfigure their existing resources and transfer R&D, human capital, and other resources from non-green innovation to green innovation, generating a crowd out effect of green innovation on existing non-green innovation.

3 Research assumptions

3.1 Value of the NIIDZ policies

NIIDZs combine a number of benefits, including high-tech talents, cutting-edge technology, and policy support, to create an environment that fosters green innovation. First of all, government policies support and direct the NIIDZs. The government encourages companies to invest in green innovation by providing tax incentives, innovation subsidies, and other incentives. Secondly, technological push factors are important driving forces of green innovation^[21]. As the economy transitions from a high-growth stage to a high-quality development stage, it continues to help enterprises to improve their green innovation efficiency. Finally, the NIIDZs have attracted an influx of high-tech and innovative talents, which has brought new ideas, new technologies, and new business models to enterprises, thereby providing intellectual support for their green innovation efforts^[21, 22]. Encouraged by these policies, NIIDZs prioritize the allocation of technical resources and human resources to ensure stable economic growth while promoting corporate green technology innovation and effectively improving corporate green innovation levels. Therefore, we propose the following hypothesis:

Hypothesis 1. NIIDZ policies can significantly improve GIE.

3.2 Leverage effect and crowd out effect

By virtue of their forward-looking policy design and financial support, NIIDZs pressure technological progress while stimulating the innovation vitality of enterprises. In the face of such pressure, enterprises may take the following two measures: On the one hand, enterprises may further increase investment and R&D inputs on the basis of existing innovation inputs and actively carry out green innovation activities, generating a leverage effect on enterprises' green innovation. On the other hand, owing to resource constraints, enterprises do not invest more in R&D but reallocate existing resources such as R&D and human capital and transfer resources from existing non-green innovation to green innovation, resulting in the crowd out effect of green innovation on non-green innovation. The green innovation process undertaken by enterprises is characterized by large investments and long cycles^[23]. As a result, the government grants are only a small fraction of the total resources required and are insufficient to effectively alleviate the financial pressure faced by enterprises in their innovation activities. Consequently, companies may need to divert resources from their existing non-green innovation activities toward green innovation efforts, thereby producing a crowd out effect on non-green innovation. Therefore, this study proposes the following hypothesis:

Hypothesis 2. The green innovation activities of firms induced by the NIIDZ policies are a crowd out effect at the expense of established non-green innovation activities.

3.3 Mechanisms of action

3.3.1 Moderating effect of government grants

Green innovation is a key strategic initiative that requires long-term, sustained, and stable resource investment. The

“first priority” for green innovation investment is solving the resource constraints and insufficient incentives faced by enterprises^[24]. As a financial support tool, government grants can provide financial support to enterprises, thereby alleviating the high costs required for green innovation projects and reducing their financial burden, further improving the efficiency of green innovation. Government grants also serve as a significant incentive mechanism that stimulates enterprises to actively participate in green innovation. This enthusiasm plays a crucial role in enhancing innovative thinking and promoting technological development. In general, government grants can alleviate capital shortages in the green innovation process of enterprises to a certain extent, thereby reducing the risks and costs of green innovation for enterprises, promoting their enthusiasm for R&D, and effectively motivating enterprises to explore and develop green innovation^[25]. Therefore, we propose the following hypothesis:

Hypothesis 3a. Government grants play a positive moderating role between NIIDZ policies and GIE.

3.3.2 Moderating effect of media attention

NIIDZs, established by the government as leading innovation zones, possess unique advantages that have garnered the attention of various media outlets. These advantages include policy support, scientific and technological infrastructure, and the introduction and training of innovative talents. The media attention received by the NIIDZs can motivate enterprises to innovate, encourage increased R&D investment in green innovation, and facilitate the undertaking of green innovation initiatives by these enterprises. This is specifically reflected in the following two aspects: The media's attention can play a significant governance role from the perspective of the public, and to a certain extent, it can arouse the public's attention toward the green behavior of enterprises^[23]. From the perspective of investors, high attention from the media can alleviate the information asymmetry between investors and enterprises to a certain extent, thereby helping investors to improve the rationality of their decision-making, which will further encourage enterprises to carry out green innovation. The higher the media attention, the more the enterprise will focus on maintaining its own social responsibility and public image, and the more actively it will carry out green innovation activities^[26]. Therefore, we make the following hypothesis:

Hypothesis 3b. Media attention plays a positive regulatory role between NIIDZ policies and GIE.

3.3.3 Mediating effect of industry competition

NIIDZs have created a favorable innovation atmosphere and conditions to effectively alleviate the industry competition pressure faced by enterprises. This has been achieved by optimizing the policy environment, improving resource allocation, and strengthening information exchange and financing services^[27]. As a key area for pioneering, exploring experience, and making demonstrations in promoting national independent innovation and the development of high-tech industries, the NIIDZs usually enjoy a series of support policies provided by the government, such as tax incentives and R&D funds. These measures have reduced the financial burden of enterprises, allowing them to invest more resources in R&D

and innovation activities rather than in price competition among competitors. The establishment of NIIDZs has attracted many enterprises in the same industry to work together. This has promoted cooperation and knowledge sharing among these enterprises rather than fierce competition. As industry competition weakens, enterprises focus more on green innovation activities to enhance their green innovation capabilities without the need to invest many resources in fighting with competitors. Therefore, we propose the following hypothesis:

Hypothesis 3c. NIIDZ policies improve GIE by weakening industry competition.

In summary, the research framework of this study is shown in Fig.1.

4 Research design

4.1 Econometrics model

Since 2009, the Chinese government has successively approved the establishment of 23 NIIDZs, including those with a single city or city agglomeration as the administrative unit, involving a total of 60 cities. Given the time batch differences in the pilot establishment of NIIDZs in different cities, this article applies a multi-period difference-in-differences model to evaluate the impact of NIIDZs on GIE. To ensure that the conclusions are not subject to heteroskedasticity problems, city-level clustering processing is performed on the regression data. The specific model settings are as follows:

$$GIE_{it} = \alpha + \beta NIIDZ_{ct} + \gamma X_i + \varphi Y_c + \gamma_i + \mu_t + \varepsilon_{it}, \quad (1)$$

where GIE_{it} is the dependent variable and represents the GIE of i the enterprise in year t . The core independent variable $NIIDZ_{ct}$ is a dummy variable used to identify the NIIDZ policies. Its coefficient β is used as the key observation value, which represents the impact of NIIDZ policies on GIE. X_i represents the control variable at the enterprise level, and Y_c represents the control variable at the city level. γ_i represents the individual fixed effect, μ_t represents the time fixed effect, and ε_{it} is the random error term.

4.2 Variable selection

4.2.1 Dependent variable: GIE

Inputs and outputs are important factors of production that are inextricably linked and mutually reinforcing. Only by considering these two factors at the same time can enterprise innovation be accurately measured^[28]. However, in previous studies on enterprise innovation in the NIIDZs, scholars usually chose outputs to estimate enterprise innovation, such as the

number of patent applications^[13], and this simplification may produce unreliable efficiency estimates. Therefore, this paper draws on the methods used by related scholars to measure GIE and considers green innovation as a complete R&D process, including both inputs and outputs. Specifically, the initial resource inputs include the number of R&D personnel and the internal expenditure on R&D funding; the final green outputs include the number of patent applications, the number of effective invention patents, and the number of green invention patent applications of the enterprise. It should be noted in particular that the internal expenditure on R&D funding is deflated by the R&D price index and is in the form of stocks^[29]. Considering the policy effect and the fact that the transformation of inputs into outputs has a certain time lag, this paper sets the lag period as one year, and uses the DEA-SBM model to calculate the GIE.

4.2.2 Core independent variable: NIIDZ

The dummy variable for the city where the NIIDZ is located is multiplied by the time dummy variable before and after the policy implementation to obtain the proxy variable for the NIIDZ policies. Considering that the transformation of green inputs and outputs of enterprises has a lag, this paper lags the time node of policy implementation by one year for regression analysis, i.e., from the year after city c , where enterprise i is registered, is approved by the State Council to be selected as a NIIDZ, the proxy variable for the policy, $NIIDZ_{ct}$, is assigned a value of 1, and the current year and the year before that year are assigned 0.

4.2.3 Control variables

The efficiency of enterprise green innovation is affected not only by the development of the enterprise itself, but also by the level of urban development. Based on existing relevant research, this study selects control variables at the enterprise level and the city level. The control variables at the enterprise aspect scale (X_i) include enterprise scale (*Size*): the natural logarithm of total assets; enterprise age (*FirmAge*): the logarithm of the observation year minus the year of establishment plus 1^[30]; enterprise profitability (*ROA*): the net profit of the enterprise divided by the average balance of total assets of the enterprise^[31]; and the city aspect control variables Y_c includes the foreign investment level (*FDI*): expressed as the share of actual utilized foreign investment in GDP^[32]; the level of human capital (*Hum*): expressed as the logarithmic number of university students per 10000 population^[33]; and the strength of scientific research support (*SCI*): expressed as the logarithm of the total government expenditure on science in

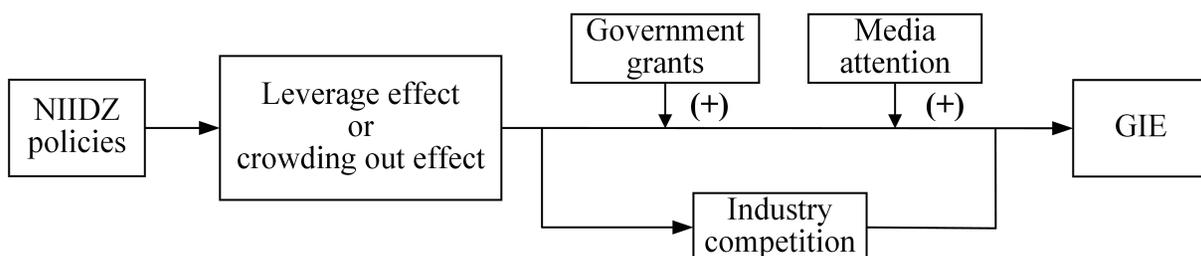


Fig. 1. Research framework.

the year^[34]. The definitions and descriptions of the main variables are shown in Table 1.

4.3 Data description

The Changchun Independent Innovation Demonstration Zone and the Harbin-Daqing-Qiqihar Independent Innovation Demonstration Zone were approved in April and May 2022, respectively, and were not included in the study because of their short approval times, which makes it difficult to fully reflect the effect of the GIE. This study uses the panel data of China's A-share listed companies from 2007 to 2021 as the research sample, and the data include multiple sources. The enterprise aspect data were sourced from the CSMAR database and the annual reports of publicly listed companies. Additionally, patent data and human capital data were retrieved from the CNRDS database and the Wind database, respectively. The data utilized in this study were obtained from *China City Statistical Yearbook*, which provides city-level information. To ensure the validity of the data, four types of samples were removed from the analysis. First, the sample of financial industry companies was excluded. Second, the sample of special treatment (ST) companies was removed. Third, the sample of companies registered in the four municipalities directly under the Central Government was deleted. Fourth, the sample with missing data on key variables was omitted. After these data were cleaned, the final sample size consisted of 23116 observations. Descriptive statistics were performed for each main variable, and the results are shown in Table 2.

5 Estimation results

5.1 Baseline regression results

Table 3 reports the estimation results of the GIE in the

NIIDZs. In particular, column (1) shows the estimation results without the inclusion of control variables, and column (2) shows the estimation results with the inclusion of control variables. It can be found that the estimated β of NIIDZ, which is the focus of this paper, is significantly positive regardless of whether the control variables are added. This shows that the implementation of the NIIDZ policies can significantly improve GIE. With the addition of control variables, the coefficient of NIIDZ and the goodness of fit of the model increase, and the final regression coefficient is 0.00976, which indicates that, compared with the control group, NIIDZs provide strong policy support for the enterprises in the pilot cities, which promotes the enterprise's R&D motivation and ability of enterprises to improve and stimulates the enterprise's exploration and development of enterprises in the field of green innovation and R&D, thus effectively enhancing their green innovation efficiency. This also verifies Hypothesis 1; that is, NIIDZs have a positive driving effect on GIE.

5.2 Leverage effect and crowd out effect

After the establishment of the NIIDZs, enterprises are under the pressure of innovation and technological progress, and may choose to further increase their R&D investment on the basis of the current innovation investment, carry out green innovation activities on the basis of the established innovation activities, and enhance the green innovation capability of enterprises, thus generating a leverage effect on green innovation; or they may not increase their R&D investment due to insufficient funds and other reasons, and may instead reconfigure the existing R&D, human capital, and other resources, transfer R&D and other resources from the established non-green innovation field to the green innovation field, reduce the input of non-green R&D projects, and focus the resources on

Table 1. Summary of notation definitions.

Category	Notation	Definition
Dependent variable	<i>GIE</i>	Green innovation efficiency of enterprises
Core independent variable	<i>NIIDZ_{ct}</i>	Dummy variable used to identify the NIIDZ policies
	<i>Size</i>	Natural logarithm of total assets
Control variables	<i>ROA</i>	Net profit of the enterprise divided by the average balance of total assets of the enterprise
	<i>FirmAge</i>	Logarithm of the observation year minus the year of establishment plus 1
	<i>FDI</i>	Share of actual utilized foreign investment in GDP
	<i>SCI</i>	Logarithm of the total government expenditure on science in the year
	<i>Hum</i>	Logarithmic number of university students per 10000 population

Table 2. Descriptive statistics for variables.

Variable	Observations	Mean	SD	Min	Median	Max
<i>GIE</i>	23116	0.51305	0.22004	0.13334	0.49873	0.99860
<i>NIIDZ</i>	23116	0.35750	0.47927	0.00000	0.00000	1.00000
<i>Size</i>	23116	22.09905	1.28987	14.10822	21.96146	28.29301
<i>ROA</i>	23116	0.04091	0.22036	-9.11692	0.03770	20.78764
<i>FirmAge</i>	23116	2.86029	0.35866	0.69315	2.89037	4.15888
<i>FDI</i>	23116	0.03089	0.02152	0.00010	0.02692	0.22732
<i>SCI</i>	23116	21.40814	1.68364	15.47944	21.46399	24.73962
<i>Hum</i>	23116	5.74464	0.92435	2.13417	5.77474	7.16603

Table 3. Baseline regression results.

	(1)	(2)
<i>NIIDZ</i>	0.00689** (0.00348)	0.00976** (0.00381)
<i>Size</i>		-0.01217 (0.01202)
<i>ROA</i>		-0.00018 (0.00139)
<i>FirmAge</i>		-0.00584 (0.00602)
<i>FDI</i>		0.00242 (0.00176)
<i>SCI</i>		-0.00688** (0.00271)
<i>Hum</i>		0.04288 (0.11703)
_cons	0.51700*** (0.00133)	0.69669*** (0.07788)
<i>R</i> ²	0.49531	0.49759
Company	YES	YES
Year	YES	YES

***, **, and * in the table indicate that the significance levels of the measures are 1%, 5%, and 10%, respectively, and the values in parentheses are robust standard errors of clustering at the city level. The same as in the following tables.

green innovation activities, thus generating the crowd out effect of green innovation on non-green innovation.

Based on the above two possibilities, this paper examines the role of the NIIDZ policies and the GIE, and selects the following variables as the independent variables for the regression: 1) overall innovation: the logarithm of the number of patent applications in the current period of the enterprise; 2) R&D investment: the ratio of R&D expenditures to operating revenues; and 3) human capital: the ratio of the number of employees with a college degree or above to the total number of employees. The regression results are shown in columns (1)–(3) of Table 4. Compared with those in the control group, the overall innovation, R&D investment, and human capital of the enterprises in the treatment group do not increase

significantly after the establishment of NIIDZs. This means that the establishment of NIIDZs does not have a real leverage effect on the green innovation of enterprises, i.e., instead of increasing R&D investment or utilizing human capital to promote green innovation, enterprises adjust the allocation of their existing R&D and human capital resources and transferred the original R&D and other resources used for the non-green innovation of the enterprises to green innovation, and the crowd out effect of the existing non-green innovation takes place.

This may be due to the following reasons: Enterprises mainly rely on internal resources to carry out innovation activities, and the shortage of resources and insufficient incentives are the main reasons leading to the lower efficiency of enterprises in green innovation^[24, 35]. This paper examines the impact of NIIDZ policies on enterprises' resource constraints and regresses cash flow as an explanatory variable; the regression results are shown in column (4) of Table 4. The results show that the cash flow of enterprises in the treatment group significantly decreased after the establishment of NIIDZs. Since it usually takes a long time for enterprises to carry out innovation activities before they can obtain innovation outputs, they need continuous financial support during the process, and government grants are only a tiny part of R&D investment, which can only have a weak reinforcing effect on enterprise green innovation. Therefore, the enhancement of GIE essentially comes from the crowd out of existing non-green innovations. Based on the above analysis, to encourage enterprises to better utilize the leverage effect, the government can compensate for the lack of funds faced by enterprises in the process of green innovation through a combination of ex ante subsidies and equity investment to reduce the risk of enterprises in green innovation activities.

5.3 Mechanism analysis

5.3.1 Government grants

As an important part of government expenditure, government grants are an important financial tool for local governments to promote technological development and combat pollution. Local governments have greater financial autonomy and independent decision-making power over the object and amount of grants, so government grants have become an important means for local governments to intervene in the green

Table 4. Test results for leverage or crowd out effects.

	(1)	(2)	(3)	(4)
	Overall innovation	R&D investment	Human capital	Cash flow
<i>NIIDZ</i>	0.00629 (0.06397)	-0.00085 (0.00144)	-0.00282 (0.00845)	-0.08751** (0.04432)
_cons	-1.96396* (1.12438)	0.21763*** (0.06870)	0.81380*** (0.26801)	-3.48374*** (1.09609)
<i>R</i> ²	0.00629	-0.00085	-0.00282	-0.08751**
Controls	YES	YES	YES	YES
Company	YES	YES	YES	YES
Year	YES	YES	YES	YES

innovation behavior of enterprises to achieve the goal of sustainable development. Drawing on He et al.'s approach^[36], the ratios of government grants received by enterprises to total assets and operating income, *Sub1* and *Sub2*, are used to measure the government grants received by enterprises separately, and the estimation results are shown in columns (1) and (2) of Table 5. The results show that the interaction terms are all significantly positive, indicating that government grants can enhance the effect of the NIIDZ policies on GIE. The reason is that the government provides financial support to enterprises, such as tax incentives and R&D incentives, which helps to alleviate the financial pressure faced by enterprises in the process of green innovation so that enterprises have more energy to carry out green innovation, thus improving the efficiency of green innovation.

5.3.2 Media attention

The NIIDZs have an important demonstration, radiation, and driving role in the process of promoting green innovation and the green and high-quality development, which will attract extensive media attention. The information transparency and public opinion pressure brought about by media attention have a direct governance effect on corporate pollution, which in turn promotes corporate green innovation behaviors^[37]. Drawing on the practices of existing studies^[38, 39], the total number of news items of listed companies that appear in headlines on the Internet and in newspapers is used to measure the degree of media attention faced by listed companies.

Table 5. Moderating effect test results for government grants and media attention.

	(1)	(2)	(3)
	Government grants	Government grants	Media attention
<i>NIIDZ</i>	0.00859** (0.00368)	0.01168*** (0.00395)	0.00937** (0.00378)
<i>Sub1</i>	0.00229 (0.00151)		
<i>NIIDZ_Sub1</i>	0.00525** (0.00229)		
<i>Sub2</i>		0.00012 (0.00133)	
<i>NIIDZ_Sub2</i>		0.00432** (0.00210)	
<i>Media</i>			0.00062 (0.00088)
<i>NIIDZ_Media</i>			0.00236** (0.00120)
_cons	0.69963*** (0.08907)	0.70163*** (0.08699)	0.72161*** (0.08041)
<i>R</i> ²	0.49713	0.49411	0.49839
Controls	YES	YES	YES
Company	YES	YES	YES
Year	YES	YES	YES

To avoid the regression coefficients being too small, the total number of headline appearances is reduced by 100 times, and the regression results are shown in column (3) of Table 5. The regression coefficient of the interaction term is 0.00236, indicating that there is a significant positive moderating effect of media attention between NIIDZ policies and GIE. This may be because when the media pays more attention to the green innovation behaviors of the relevant enterprises in the NIIDZs, to prevent damage to their own good social reputation, enterprises will strengthen their environmental responsibility, improve the strategic decision-making behaviors of the enterprise's environmental innovation, and drive the enterprise to carry out green technological innovation, which enhances the positive impact of the NIIDZ policies on GIE.

5.3.3 Industry competition

Enterprises face a variety of competitions, among which industry competition determines the external survival environment of enterprises and plays a crucial role in their green innovation process. Specifically, competitive pressure from peers may motivate a small number of firms to take the lead in green innovation and seek technological breakthroughs, thereby improving their core competitiveness and prioritizing industry leadership. However, competitive pressure from the industry may also depress firms' enthusiasm for innovation, making them tired and therefore making it difficult to focus their attention on green innovation activities. Referring to Ref. [40], the industry concentration ratio (*ICR*) is chosen to measure industry competition, and Table 6 reports the results of the test of the mechanism of the role of industry competition in the relationship between NIIDZ policies and GIE.

The regression coefficient of *NIIDZ* in Column (2) is -0.02620, which indicates that the establishment of NIIDZs has weakened industry competition and alleviated the pressure of industry competition. The regression coefficient of *NIIDZ* in Column (3) is 0.01033, which is lower than that in the benchmark regression of Column (1), which is 0.00976, and the regression coefficient of *ICR* is negatively significant, which not only indicates that the establishment of NIIDZs improves GIE by alleviating industry competition pressure but also indicates that industry competition pressure plays a mediating role between NIIDZ policies and GIE. As the

Table 6. Moderating effect test results for industry competition.

	(1)	(2)	(3)
	<i>GIE</i>	<i>ICR</i>	<i>GIE</i>
<i>NIIDZ</i>	0.00976** (0.00381)	-0.02620*** (0.00933)	0.01033** (0.00409)
<i>ICR</i>			-0.01164** (0.00556)
_cons	0.69669*** (0.07788)	-0.18646 (0.26384)	0.64983*** (0.09236)
<i>R</i> ²	0.49759	0.79333	0.49174
Controls	YES	YES	YES
Company	YES	YES	YES
Year	YES	YES	YES

establishment of NIIDZs provides more innovation resources and market opportunities for multiple enterprises in the same industry, it eases the pressure of industry competition, promotes cooperation and knowledge sharing among enterprises, stimulates enthusiasm for enterprises' green innovation, and then helps to improve GIE.

5.4 Robustness test

5.4.1 Parallel trend test

The core identifying assumption of the multi-period difference-in-differences method is the parallel trend assumption, i.e., if the policy had not occurred, the outcome variables of the treatment and control groups would have had the same time trend. The event study method can intuitively observe and test the between-group differences and dynamic responses of individual behaviors before and after the occurrence of the policy^[41]. Therefore, this paper chooses to test, with the help of the event study method, whether the treatment group and the control group have similar time trends before the occurrence of the policies to determine whether the parallel trend assumption is valid, and the results are shown in Fig. 2.

According to Fig. 2, it can be seen that before the establishment of NIIDZs, the coefficients of GIE of the treatment group and the control group were not significant, indicating that there was no significant difference between the GIE located in the demonstration zone and the non-demonstration zone prior to the implementation of the policies, i.e., the assumption of the parallel trend of the treatment group and the control group was fulfilled.

5.4.2 Placebo test

In order to avoid the promotion effect of NIIDZ policies on GIE due to other random factors, this paper conducts robustness analyses by means of a placebo test. This paper refers to Wang et al.^[42], which obtains a randomized policy treatment group by randomly selecting the sample and randomly generating the year of policy implementation, and generates pseudo dummy policies interaction terms for the placebo test. To improve the validity of the placebo test, 500 random samples were used in this study, and regression analyses were performed according to Model (1). As shown in Fig. 3, the true

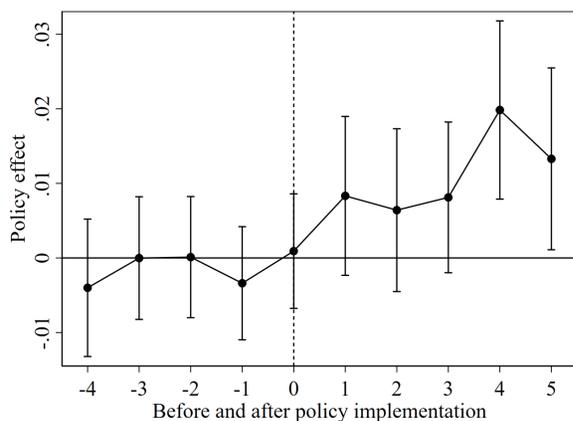


Fig. 2. Results of parallel trend test.

sample estimates represented by the vertical dashed lines deviate from the main distribution of the estimated coefficients of the random sample, indicating that the estimates of the random sample are insignificant and significantly different from those of the true sample, and that significant estimation errors are less likely to occur as a result of environmental and unobservable factors.

5.4.3 Changing the clustering hierarchy

There may be a correlation between the green innovation efficiency of different industries. In order to make the regression results robust, this paper conducts robust standard error tests from the clustering at the industry level, and the regression results without and with the inclusion of control variables are shown in columns (1) and (2) of Table 7. The regression results indicate that the coefficient of the independent variable NIIDZ is significantly positive and that the conclusion that NIIDZ policies can significantly promote GIE still holds after the clustering level is changed. Furthermore, according to the sample data in this paper, enterprises in the same industry in the same city are generally supported by similar policies, making the basic assumption that samples within the same group lack mutual independence. Therefore, the paper estimates robust standard errors for city–industry clustering, and the regression results are reported in columns (3) and (4) of Table 7. It is easy to see that the direction of the regression coefficients for the core independent variable, NIIDZ, is clearly consistent with the results of the baseline regression. This suggests that the above findings still hold after adjusting

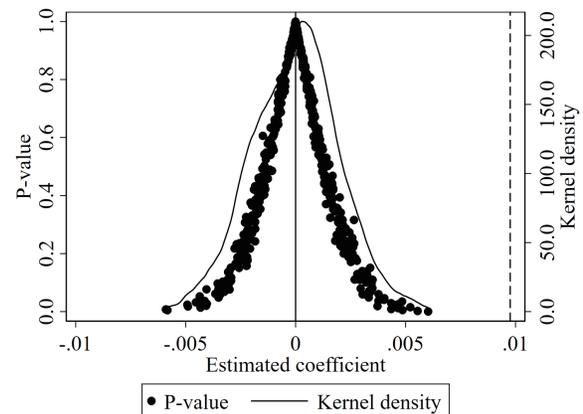


Fig. 3. Results of placebo test.

Table 7. Standard error clustering hierarchy test.

	(1)	(2)	(3)	(4)
	Industry		City–industry	
NIIDZ	0.00689*** (0.00204)	0.00976*** (0.00330)	0.00689*** (0.00121)	0.00976** (0.00358)
_cons	0.51700*** (0.00078)	0.69669*** (0.05266)	0.51700*** (0.00046)	0.69669*** (0.04714)
R ²	0.49531	0.49759	0.49531	0.49759
Controls	NO	YES	NO	YES
Company	YES	YES	YES	YES
Year	YES	YES	YES	YES

the covariance matrix of the residuals for city–industry clustering. All of the above results indicate that the conclusion that the NIIDZ policies can significantly promote GIE does not fluctuate significantly with the change of the standard error level, which further verifies that the results of Hypothesis 1 of this paper are robust.

5.4.4 Variable indentation processing

In order to further verify the robustness of the previous conclusions, this paper uses bilateral tailoring at the 1% quantile to eliminate the potential impact of extreme outliers in GIE on the findings and subsequently re-examines the regression analyses using a new sample. The results in column (1) of Table 8 show that the effect of NIIDZ policies on GIE is still positive and significant after the shrinking treatment of the dependent variables, which suggests that the above conclusion still holds.

5.4.5 Excluding time samples

The 2020 disruption caused by the COVID-19 pandemic has awakened awareness of the importance of health and sustainability. Enterprises may become increasingly aware of the importance of environmental protection and green innovation in reducing risk, increasing resilience, and shaping a sustainable future, thus increasing their investment in green innovation, which in turn improves the efficiency of green innovation. Therefore, this paper excludes the 2020 sample from the regression; the regression results are shown in column (2) of Table 8, and the estimation results are consistent with the regression results.

5.4.6 Exclusion of other policy interferences

The net effect of the policies of the NIIDZs may also be disturbed by other policies during the sample period selected for this paper. For example, the low-carbon city pilot policies (LCCP) were implemented in 2010, the carbon emission

trading pilot policies (CETP) were implemented in 2011, and the smart city pilot policies (SCP) were implemented in 2012. Referring to Bai et al.^[43], this paper adds three dummy variables for the year of policy implementation sequentially in the baseline regression model to control for their impact on the estimation results. Columns (3)–(5) of Table 8 report the estimation results after excluding the interference of the above policies, respectively, and it can be seen that the estimated coefficients of the NIIDZ are still significantly positive, which indicates that the NIIDZ policies have a positive driving effect on GIE, and the results are still robust.

6 Heterogeneity analysis

In order to further explore the heterogeneous impact of NIIDZ policies on GIE, this paper mainly explores and analyzes three aspects: the heterogeneity of technical attributes, the heterogeneity of environmental responsibility, and the heterogeneity of geographical regions.

6.1 Technical attributes

Since the needs and potentials of high-tech enterprises and non-high-tech enterprises are different, the establishment of the NIIDZs may have different impacts on them. This paper constructs a dummy variable for the technical attributes of enterprises, with 1 for high-tech enterprises and 0 for non-high-tech enterprises, which is included in the baseline regression model for regression. The regression results in columns (1) and (2) of Table 9 show that the establishment of NIIDZs has a positive impact on the green innovation efficiency of high-tech enterprises. This is because high-tech enterprises usually possess advanced technologies and knowledge assets, which make it easier for them to develop and adopt environmentally friendly and green technologies. These technologies can help enterprises to reduce their resource consumption and pollution emissions, thus improving their green innovation efficiency.

6.2 Environmental responsibility

Enterprises' environmental responsibility behaviors may be related to their motivation and willingness to engage in green innovation, so the establishment of NIIDZs may make a difference in GIE with different environmental responsibilities. Referring to the measurement method of Kong et al.^[44], corporate environmental responsibility is measured by the environmental information disclosure quality indicator, and the sample is divided based on its median. If the quality of environmental disclosure of a company is higher than the median, it is said to be strong in environmental responsibility, which takes a value of 1; conversely, it is said to be weak in environmental responsibility, which takes a value of 0. The regression results in columns (3) and (4) of Table 9 show that the GIE with strong environmental responsibility in the NIIDZs is significantly positive. This may be because enterprises with strong environmental responsibility are more likely to identify and take advantage of market opportunities related to green technologies, which may motivate them to be more active in green innovation activities to meet the growing demand for green products and services.

Table 8. Other robustness tests.

	(1)	(2)	(3)	(4)	(5)
	Indentation	Excluding time	LCCP	CETP	SCP
NIIDZ	0.00972** (0.00380)	0.00887** (0.00391)	0.00918** (0.00404)	0.00928** (0.00402)	0.00878** (0.00392)
LCCP			-0.00237 (0.00369)		
CETP				-0.00115 (0.00594)	
SCP					-0.00114 (0.00425)
_cons	0.69601*** (0.07776)	0.66100*** (0.08038)	0.66276*** (0.07957)	0.67530*** (0.08122)	0.66098*** (0.08040)
R ²	0.49761	0.50041	0.50042	0.49974	0.50041
Controls	YES	YES	YES	YES	YES
Company	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES

Table 9. Heterogeneity analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Non-high-tech	High-tech	Weak	Strong	Eastern	Central	Western
<i>NIIDZ</i>	0.01030 (0.00634)	0.00981** (0.00479)	0.00408 (0.00619)	0.01184** (0.00508)	0.01631*** (0.00587)	0.00585 (0.00690)	0.01272 (0.00771)
<i>_cons</i>	0.59887*** (0.12260)	0.75355*** (0.09961)	0.53166*** (0.16805)	0.72746*** (0.09697)	0.61535*** (0.12906)	0.68929*** (0.15674)	0.63895*** (0.18799)
<i>R</i> ²	0.50374	0.49182	0.52186	0.53855	0.49654	0.50391	0.49199
Controls	YES						
Company	YES						
Year	YES						

6.3 Geographical regions

There are significant differences in the level of economic development and technological resources among the eastern, central, and western regions of China, and these differences may significantly affect GIE. The regression results in columns (5)–(7) of Table 9 show that the establishment of the NIIDZs has a significant positive impact on the eastern region. As the eastern region has a higher level of economic development as well as technical talents, this helps to promote technological innovation and the application of green technologies, which further enhances the green innovation efficiency of eastern enterprises.

7 Conclusions

7.1 Research conclusions

The essence of the high-quality development of the NIIDZs is green high-quality development. Promoting corporate green innovation serves as important support for advancing the green and high-quality development of the NIIDZs. This paper empirically examines the impact of NIIDZ policies on GIE with the help of data from China’s A-share listed companies in the period of 2007–2021, applying a multi-period difference-in-differences model, focuses on whether NIIDZ policies play a leverage effect or a crowd out effect on enhancing GIE, and further analyzes the role mechanism of the NIIDZ policies in enhancing GIE from the perspective of media attention. We also further analyze the mechanism by which NIIDZ policies enhance GIE from the perspective of industry competition. In addition, we also analyze the heterogeneity of the policy implementation effects of the NIIDZs from various perspectives in order to help the government to formulate more targeted policy measures.

The results of the study show that, first, the implementation of the NIIDZ policies significantly enhances GIE. Second, since the grants provided by the government are tiny compared with enterprises’ green innovation inputs, the green innovation induced by the NIIDZ policies is not a leverage effect of increasing R&D inputs but a crowd out effect on established non-green innovations. Third, government grants and media attention positively moderated the promotion of GIE by NIIDZ policies. Fourth, the green innovation

efficiency of high-tech firms, firms with strong environmental responsibility, and firms located in the eastern region are more affected by the NIIDZ policies. These differences suggest that the existing NIIDZs, which apply uniform policy standards to listed companies with different attributes, may have limitations in addressing the diverse development needs of green innovation.

7.2 Policy recommendations

In summary, the following policy insights can be drawn. First, the government can broaden the scope of the application of ex ante grants by focusing not only on the R&D stage of enterprises but also taking into account start-up and seed-stage enterprises. Moreover, equity investment can be introduced to share results and risks with enterprises, encouraging them to actively invest in the field of green innovation. The combination of ex ante subsidies and equity investment can reduce the costs and risks of green innovation activities by enterprises, thus avoiding the crowd out effect of green innovation on existing non-green innovation.

Second, the advantages of media attention can be fully exploited. The government can create a media-accessible database to record and display successful cases of enterprises in the field of green innovation so that it is easier for the media to access and report on them and stimulate the participation of other enterprises; it can also establish a mechanism for collaboration between the government and the media, organize regular meetings on the interpretation of green innovation policies, provide the media with detailed information on the policies to deliver the policy information to a wider audience, improve enterprises’ understanding of green innovation policies, and further promote their active participation in green innovation.

Third, local governments should take full account of the heterogeneity of industry attributes and provide special technical training and support programs to non-high-tech enterprises to help to upgrade technology and accelerate its transformation, thereby improving GIE. Moreover, local governments can establish cross-enterprise cooperation and sharing platforms so that high-tech enterprises can share their experiences and resources with non-high-tech enterprises to promote the progress and diffusion of green technologies, enhance overall efficiency, and promote the common progress

of all enterprises.

7.3 Limitation and future research

The green innovation process usually consists of an R&D stage and a transformation stage (i.e., commercialization of R&D achievements). This study only measured the GIE at the R&D stage and did not consider the conversion stage, which may limit the comprehensive assessment of the entire green innovation life cycle. Therefore, future research could incorporate the transformation stage in the measurement of the GIE of enterprises, which not only helps to improve and enrich the research related to the NIIDZ policies and the GIE of enterprises but also can form research conclusions with more practical significance and application value.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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