New Energy Demonstration City Policy and Green Innovation of New Energy Enterprises——A Quasi-Natural Experiment Based on Green Patent Applications of Listed Companies in China

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Abstract. The innovation and development of the new energy industry is crucial to guaranteeing China's energy security, promoting high-quality economic development and alleviating the global climate crisis. New Energy Demonstration City Policy (NEDC) is one of the important policies to promote the development of the new energy industry in China. Academic research on their green innovation effect on new energy enterprises and the explanation of their influence mechanism still needs to be deepened. This paper utilizes panel data from listed companies in China spanning from 2011 to 2019 and employs the triple difference method to empirically investigate the impact of NEDC on the green innovation of new energy enterprises. Findings of the study are as follows: (1) The implementation of NEDC significantly promotes green innovation among new energy enterprises, a conclusion that holds true under a series of robustness tests; (2) Further analysis suggests that, from the perspective of patent heterogeneity, the "incremental" manifestation of this policy effect is more pronounced; (3) From the perspective of ownership heterogeneity, distinct from state-owned enterprises, the promotion of green innovation among private new energy enterprises is notably significant under the policy; (4) Mechanism analysis reveals that NEDC can alter the ways in which new energy enterprises acquire and utilize funds, thereby increasing R&D investment and facilitating green innovation. The research conclusions of this paper bear certain policy implications, providing theoretical foundations and empirical references for government departments to optimize and promote NEDC.

Keywords: New Energy Demonstration Cities, New Energy Enterprises, Green Innovation, R&D investment, triple difference model.

1. Introduction

Since the beginning of the 21st century, issues related to energy and the environment have increasingly become critical factors constraining global economic growth and social progress, placing human society in a state of greater uncertainty and more challenging risks. In response to energy concerns and the climate crisis, the Chinese government has actively promoted the development of the new energy industry and fulfilled its international obligations for carbon reduction and emission control. The national "14th Five-Year Plan" and the long-term goals for 2035 clearly set forth a "dual carbon" target, aiming to peak carbon emissions before 2030 and striving to achieve carbon neutrality by 2060. In terms of energy consumption, China has led the world in renewable energy consumption for six consecutive years, with rapid development in the new energy sector. However, the consumption structure reveals that coal consumption still dominated in 2022, accounting for 55.47% of primary energy consumption, indicating an energy structure that lags behind the times. As the country with the highest energy consumption and carbon dioxide emissions globally, how to control the rapid consumption of traditional fossil fuels, develop clean and renewable new energy industries, promote the transformation and upgrading of the energy structure, and ensure national energy security, has become a crucial practical issue for China in achieving high-quality development.

The report from the 20th National Congress of the Communist Party of China explicitly stated that to achieve the scheduled peak carbon emissions and carbon neutrality, there is a need to accelerate the green transformation of development modes, foster green and low-carbon industries, and expedite the research, development, and application of advanced energy-saving and carbon-reduction technologies. Green innovation by new energy enterprises is not only a key means for them to enhance their technological level and gain profits but also has become a major driving force in the development of China's low-carbon industry. Therefore, in the development process, evaluating the efficacy of new energy policies in promoting corporate green innovation becomes particularly important. To promote the development of the new energy industry and explore new models of sustainable urban development, the Chinese government announced in 2014 the *Notice on the Announcement of the First Batch of New Energy Demonstration Cities (Industrial Parks),* identifying the first batch of 81 pilot new energy demonstration cities and eight new energy demonstration industrial parks. Hence, the questions arise: Can the new energy demonstration city policy effectively promote green technological innovation in related enterprises? Is its impact robust? What factors influence its effectiveness? Through what mechanisms does this policy exert its influence? These questions will form the main research agenda of this paper.

The current academic research on this issue remains to be deepened, with the extent of impact and operational mechanisms still unclear and some disagreements in understanding. Some perspectives argue that a series of environmental protection and new energy development policies, exemplified by the new energy demonstration city policy, will enhance environmental regulation [1], on one hand, increasing corporate investment in environmental protection, thereby crowding out research and development investments, and on the other hand, complicating corporate activities in production, sales, and management, which could hinder green technological innovation [2]. In contrast, other studies suggest that the new energy demonstration city policy can facilitate green-oriented technological innovation in new energy enterprises through two channels: enhanced environmental regulation and increased research and development investments [3].

To deepen the understanding of the above issues, this paper takes 2014 as the policy implementation point, using data on green patent applications of Chinese listed companies from 2011 to 2019. It employs a triple difference model to assess the impact of the new energy demonstration city policy on corporate green technological innovation. The study conducts a heterogeneity analysis focusing on patent types and corporate ownership and emphasizes the policy's mechanisms in alleviating financing constraints, expanding operational cash flow, and increasing fixed asset investment from the micro perspective of how new energy enterprises obtain and use funds. The empirical results, after undergoing parallel trend tests to rule out interference from other policies, passed various robustness checks including indicator settings, fixed effects, and clustering levels.

Compared to the existing literature, the principal marginal contributions of this paper include: (1) evaluating the implementation effects of the new energy demonstration city policy from the micro-perspective of corporate green innovation, using microdata of green patent applications by A-share listed companies to quantitatively analyze the green innovation capability of firms; (2) treating the new energy demonstration city policy as a quasi-natural experiment, considering the impacts of policy implementation regions, time points, and enterprise types, and comparing the differences in green innovation outputs between the experimental and control group companies, thus providing new empirical evidence for the policy's role in promoting corporate green technological innovation; (3) dissecting and verifying the mechanisms through which the new energy demonstration city policy affects corporate green technological innovation from the perspective of how firms obtain and use funds, offering significant insights for the nationwide promotion of the policy.

The rest of the paper is structured as follows: the second section conducts theoretical analysis and posits research hypotheses; the third section outlines the research design, including model specification, variable definition, and data description; the fourth section presents the analysis of empirical results, including baseline regression, parallel trend tests, robustness checks, and heterogeneity analysis; the fifth section performs a mechanism analysis, and the sixth section concludes with the main findings and provides policy recommendations.

2. Literature review

This paper integrates classical theories and existing research findings to conduct a literature review in three key areas:

2.1. Research related to new energy demonstration city policy

Studies in this area focus on evaluating the post-2014 implementation effects of the new energy demonstration city policy in terms of environmental protection, resource utilization, and economic growth, providing policy suggestions for subsequent deepening of reforms and achieving high-quality development. As an important urban-level comprehensive environmental regulation and new energy development tool, the policy has effectively promoted carbon emission reduction [1, 4, 5] and alleviated environmental pollution [6, 7] in terms of environmental protection. In resource utilization, the implementation of this policy has notably improved green total factor productivity [8], land use efficiency [9], and waste emissions [10], with a significant increase in the utilization rate of renewable energy and a more rational energy structure. In terms of economic development, the new energy demonstration city policy, through supportive measures like green finance policies, targeted financial support, and specialized promotional activities, has guided industries to transform production methods, fostered the new energy sector, and stimulated urban green innovation vitality [11], significantly enhancing the level of green low-carbon development [12], playing a role in attracting foreign investment [13], driving the development of the green economy [14], promoting regional economic growth [15], and significantly enhancing urban sustainable development capabilities.

Existing studies cover various aspects of the new energy demonstration city policy, providing an objective and comprehensive assessment of its effects and valuable policy recommendations for the development of the new energy industry at the urban level. However, the current literature mainly focuses on the macro-level of cities, and there is still insufficient attention in the academic community to the green innovation effects of the policy from the micro-perspective of new energy enterprises.

2.2. Main Factors Influencing Green Technological Innovation in New Energy Enterprises

This category of literature focuses on exploring the drivers of green technological innovation in new energy enterprises. Studies have found that in terms of environmental policy, environmental regulations [16, 17, 18] and research and development (R&D) investments [19, 20] are two key factors influencing corporate green innovation. Specifically, the impact of environmental regulations on corporate green innovation exhibits a “U” shaped curve, showing an initial suppression followed by promotion, and R&D investment can positively moderate the effect of environmental regulations on corporate green innovation, with government fiscal subsidies becoming an important means for companies to alleviate financing constraints and increase R&D investment [21].

Additionally, against the backdrop of contemporary development, factors such as industrial agglomeration [22], intelligent transformation [23], the digital economy [24], intellectual property protection [25,26], ESG ratings [27], and tax reforms [28] also indirectly affect the willingness and capability of new energy enterprises to innovate green technologies. The study by Lü J. et al. (2019) systematically categorized and summarized the driving factors of corporate green innovation from the perspectives of government, business, and environment using grounded theory [29]. The research by Ma W. and Zhu H. (2023) examined the factors affecting the green innovation efficiency of new energy enterprises, starting from the characteristics of the enterprises themselves, based on a three-stage DEA model [30].

Existing literature, integrating various policies implemented during the research period, has conducted in-depth discussions on the main factors affecting green innovation in new energy enterprises, with some studies systematically organizing and summarizing these factors using qualitative or quantitative theoretical methods. However, there are few studies that consider the new energy demonstration city policy as a main influencing factor of green innovation in new energy enterprises. Therefore, this paper will draw on the theoretical methods of existing research to explore the impact of the new energy demonstration city policy on corporate green innovation.

2.3. The Relationship between New Energy Demonstration City Policy and Green Innovation in New Energy Enterprises

Regarding whether the new energy demonstration city policy can promote corporate green innovation, the academic community primarily revolves around two differing perspectives based on the “Porter Hypothesis” and the “Constraint Hypothesis.” The “Porter Hypothesis” posits that moderate environmental regulation policies can stimulate targeted technological innovation in enterprises, resulting in positive environmental and economic benefits [31]. In contrast, the “Constraint Hypothesis” suggests that environmental regulations increase the costs of pollution control for enterprises, exert a crowding-out effect on innovation, and reduce competitiveness, with the negative effects on economic growth offsetting the social benefits of environmental protection [32].

The new energy demonstration city policy exhibits both guiding and constraining characteristics. Building on these hypotheses and the policy traits of demonstration cities, the study by Zhou A. and Wang S. (2023) utilized a difference-in-differences approach to affirm the positive role of the new energy demonstration city policy in fostering green innovation within new energy enterprises, and analyzed the policy’s mechanisms in enhancing R&D investment and strengthening environmental regulation [3]. Li Y. et al. (2023) observed that the implementation of the new energy demonstration city policy significantly boosted green innovation vitality in demonstration cities but had a spillover and siphoning effect on surrounding cities, leading to certain negative impacts [11]. Conversely, Li F. and Zhang X. (2023), using data from 282 prefecture-level cities in China between 2006 and 2019 and employing the PSM-DID method, found that the policy has not significantly promoted green technological innovation [12].

The policy effects in this area are usually influenced by multidimensional heterogeneity such as geography, time, corporate ownership, and enterprise type. Similar divergences are found in studies of analogous policies internationally, and a clear consensus has yet to be reached on the above perspectives. However, many views and conclusions from these studies provide insights for policy-making and further research, offering valuable references. Therefore, they remain of significant importance.

2.4. Literature Summary and Evaluation

Research focusing on the relationship between the new energy demonstration city policy and green technological innovation in new energy enterprises is continually enriching, utilizing data at various levels and analyzing from multiple perspectives, yielding substantial scholarly contributions. However, there are three main limitations: (1) Research theme: There are relatively few articles choosing the promotion of green innovation in new energy enterprises by the new energy demonstration city policy as the central theme, coupled with unclear definitions of the research subject, often leading to confusion between green innovation in new energy enterprises and general technological innovation or urban green innovation vitality. These studies fail to clearly delineate the topic through appropriate variable definitions and research methodologies; (2) Research perspective: The existing studies predominantly adopt a macro policy perspective, mainly using statistical data at the prefecture-level city scale in China, which shows significant inter-group differences and limited data volume. Rarely do studies integrate macro and micro perspectives, resulting in a lack of empirical evidence at the corporate level; (3) Mechanism of action: Current articles provide somewhat rudimentary analysis in this aspect, merely discussing the mediating effects of increased R&D investment or enhanced environmental regulation by policies. There is a lack of systematic and in-depth study on the mechanisms of policy, failing to form a logical loop and lacking persuasiveness.

Therefore, the subsequent sections will focus on improving these three areas to enrich the existing literature.

3. Policy Background, Theoretical Analysis, and Research Hypotheses

3.1. Policy Background

Since the 21st century, against the backdrop of rapid development in renewable energy technologies, to advance the energy production and consumption revolution, promote ecological civilization construction, and leverage renewable energy's role in adjusting the energy structure and protecting the environment for high-quality development, the Chinese government has introduced a series of policies to promote the development of the new energy industry at multiple levels. Among these, the new energy demonstration city policy launched in 2014 stands as a typical urban-level policy. The *Notice on the Announcement of the First Batch of New Energy Demonstration Cities (Industrial Parks)* by the National Energy Administration announced the first batch of 81 new energy demonstration cities, including Changping District in Beijing and Chengde City in Hebei Province, marking China's initial attempts to explore new energy urban development models.

As a voluntary, non-binding, and industry-specific urban development policy, the national level did not set specific targets for new energy demonstration cities, such as the proportion of renewable energy production and consumption, the output value and growth rate of the renewable energy industry. Instead, it decentralized the authority to formulate, implement, and supervise policies to local governments, requiring each city to promote the development of the new energy industry according to local conditions. The notice document only provides a unified explanation of the strategic issues for the construction of new energy demonstration cities.

The document states that the construction of new energy demonstration cities should aim to promote sustainable urban development, establish a renewable energy development priority strategy, fully utilize local renewable energy resources, and significantly increase the proportion of renewable energy consumption in cities. Additionally, new energy demonstration cities should innovate in renewable energy development methods, fully leverage market mechanisms, engage various investment and demand entities actively, and stimulate market vitality. In terms of regulation, the construction of new energy demonstration cities should strengthen planning and coordination, integrate the construction into economic and social development planning and annual plans, and propose binding development indicators.

Addressing the actual financing constraints in the new energy sector, the notice also clarifies that banking and financial institutions are encouraged to support the construction of new energy demonstration cities. The National Energy Administration, in collaboration with the National Development Bank, has initiated financial innovation pilots in new energy demonstration cities, encouraging financial institutions to establish local investment and financing platforms, provide innovative financial services for the construction of new energy demonstration cities, establish financing models suitable for distributed new energy characteristics, prioritize credit fund scale, and support small-scale enterprises and individuals through a collective borrowing and repayment model.

3.2. Impact of New Energy Demonstration City Policy on Green Technological Innovation in New Energy Enterprises

Compared to the traditional industrial sector, which has developed over a century, the new energy industry is not as mature in terms of industrial chain performance, and it lacks advantages in product pricing, cost-effectiveness, talent reserves, technical equipment, and financial support. Thus, under the market mechanism, green technological innovation is the most effective way for the new energy industry to achieve breakthroughs. Green technological innovation in new energy enterprises brings multiple benefits. First, it can promote the development and application of renewable energy, creating new industrial chains to replace traditional fossil fuel consumption, thereby reducing carbon emissions. Second, without compromising product quality, new energy enterprises can reduce waste, pollutant emissions, and energy consumption in the production process. This not only avoids penalties from environmental regulations but also increases cost-effectiveness and gradually achieves price parity with traditional industry products. Furthermore, considering the current national carbon emission trading (CET), green certificate trading (TGC), and other emission trading policies, new energy enterprises can also gain certain income through market mechanisms [33,34,35]. Therefore, in the context of national advocacy for low-carbon development and active implementation of innovation-driven development strategies, promoting green technological innovation in new energy enterprises becomes a necessary factor to consider in policy formulation.

The primary objective of the new energy demonstration city policy is to promote the rapid development of the new energy industry in demonstration cities. Referring to the two hypotheses mentioned earlier, the new energy demonstration city policy may have both positive and negative impacts on green innovation in new energy enterprises. Research by Xie M. et al. (2014), using data from China's high-pollution industry listed companies, found that environmental regulation has certain incentives and promotes R&D investment and technological innovation, partially validating the “Porter Hypothesis” [36]. Therefore, based on the “Porter Hypothesis,” under the premise of appropriate environmental regulatory strength, through policy promotion and financial guidance, the new energy demonstration city policy can stimulate targeted green innovation in new energy enterprises, achieving the policymakers' expectations. Referring to the study by Wang S. and Xu Y. (2015), enterprises facing environmental policies will make different types of investments, including increasing technology investments to enhance existing technology levels or financial investments to achieve diversified operations, and there may be a crowding-out effect between different types of investments [37]. Hence, based on the “Constraint Hypothesis,” the new energy demonstration city policy might intensify environmental regulations on energy-related enterprises, forcing them to reduce production projects primarily based on traditional energy in the short term, decrease corporate revenue, and reallocate funds to expand the production scale of new energy projects and manage carbon emissions and environmental pollution, rather than investing in R&D, which could suppress green technological innovation in new energy enterprises. Combining the above analysis, the following hypotheses are proposed in this paper:

H1a: The new energy demonstration city policy can promote green technological innovation in new energy enterprises.

H1b: The new energy demonstration city policy will suppress green technological innovation in enterprises.

3.3. Heterogeneity Analysis of Policy Effects

The academic community has yet to reach a consensus on the implementation effects of the new energy demonstration city policy in the field of green technological innovation, and the heterogeneity of policy effects is a significant factor causing divergent views.

The new energy demonstration city policy is a voluntary and open policy, allowing cities to promote the development of the new energy industry according to local conditions, without unified execution standards. Also, referencing the study by Qi S. et al. (2018), this paper posits that green technological innovation has different evaluation standards in terms of "quality" and "quantity," and the characteristics of the enterprises themselves will also impact the policy effects. Therefore, the policy effects exhibit heterogeneity across different dimensions [38].

From the perspective of green technological innovation in new energy enterprises, the policy effects can be divided into two action directions: "improving quality" and "increasing quantity." From an overall market perspective, both "quality improvement" and "quantity increase" of technological innovation are equally important and inseparable, with policy actions generally showing concurrent changes. However, studies by Qi S. et al. (2018) and Wang Z. et al. (2021) found that environmental policies have a stronger inducing effect on green invention patent applications than on green utility model patents [38,39]. For individual new energy enterprises, the main goal of engaging in green innovation activities is to utilize the outcomes of green innovation to gain greater profits and enhance market competitiveness. Therefore, existing research commonly believes that new energy enterprises, when engaging in green technological innovation, will focus more on green invention patents, i.e., the "improving quality" direction. However, considering the differences in green innovation performance evaluation indicators within each demonstration city, and the choice between short-term benefits and long-term goals, new energy enterprises might also focus more on green utility model patents, i.e., the "increasing quantity" direction. Based on this, the following hypotheses are proposed in this paper:

H2a: The new energy demonstration city policy will promote green technological innovation in new energy enterprises in both "improving quality" and "increasing quantity" directions, with the "improving quality" direction having a more pronounced effect.

H2b: The new energy demonstration city policy has significant effects in both "improving quality" and "increasing quantity" directions of green innovation in new energy enterprises, with the "increasing quantity" direction showing more pronounced effects.

From the perspective of the inherent characteristics of new energy enterprises, considering corporate ownership as an example, it is generally believed that state-owned enterprises (SOEs), usually large in scale and bearing significant responsibilities for regional economic development, enjoy multiple policy supports such as government fiscal subsidies, tax incentives, financing convenience, and talent attraction [40], possessing all necessary conditions for green innovation. Meanwhile, SOEs are usually under the dual leadership of local governments and superior departments, relatively less affected by regional environmental regulations and energy development policies. In contrast, private enterprises face more intense market competition and heavier pressure from environmental regulations [41], are more affected by regional policies, and often have a more urgent willingness for green innovation, as shown in the study by Zhong C. et al. (2020), where private enterprises had a higher level of green innovation under the low-carbon pilot policy compared to SOEs [42]. Therefore, from the perspective of the marginal effects of environmental policies on promoting green innovation in new energy enterprises, the new energy demonstration city policy might have a more significant impact on the green innovation of private new energy enterprises. Accordingly, the following hypothesis is proposed:

H3: Compared to state-owned enterprises, the demonstration city policy has a stronger promoting effect on green technological innovation in private new energy enterprises.

3.4. Mechanism of Policy Effects

Unlike traditional enterprises, new energy enterprises often lack deep brand heritage and market accumulation. According to the resource-based theory, differentiated resource allocation is key to a firm's competitive advantage [43]. Therefore, the competitiveness of new energy enterprises largely depends on their level of green innovation. To achieve green technological innovation, research and development (R&D) investment is an essential factor that can provide financial, human, and equipment support to new energy enterprises.

From the perspective of the mechanism that R&D investment promotes innovation, scholars have used the Cobb-Douglas (C-D) function to determine the relationship between R&D investment and innovation output. Griliches (1986) studied the innovation activities of large manufacturing firms in the United States and found that increased R&D investment significantly enhances innovation output, increases productivity, and yields higher returns [44]. Thus, in the increasingly competitive market environment, new energy enterprises urgently need to increase R&D investment to continuously upgrade and renew new energy products, enhance product appeal, and ensure a sufficient market share.

From the perspective of environmental policy formulation, research by Liu Y. et al. (2024) shows a significant positive relationship between government grants and corporate green innovation [45]. Further analysis found that R&D investment plays an important mediating role in this mechanism. The study by Li R. and Liu L. (2021) also found that green finance policies can effectively promote corporate green innovation [46]. At the micro-level of new energy enterprises, the methods of obtaining and using funds determine the proportion of R&D investment. Regarding the new energy demonstration city policy, the "Notice" document clearly states that each demonstration city should introduce supporting green finance policies to alleviate the financing constraints of new energy enterprises, reduce the difficulty of obtaining funds externally, and aid in green innovation. Additionally, the new energy demonstration city policy can guide enterprises to allocate funds to green innovation through mandatory environmental regulations, targeted subsidies, and innovation incentives, increasing R&D investment. Based on this, the following hypothesis is proposed:

H4: The new energy demonstration city policy can alleviate financing constraints, expand operational cash flow, and increase the proportion of fixed asset investment, thereby changing the ways new energy enterprises obtain and use funds, increasing R&D investment, and consequently promoting corporate green innovation.

4. Research Design

4.1. Model Specification

This paper treats the new energy demonstration city policy as a quasi-natural experiment and applies the triple difference method to effectively isolate the "pilot policy effect". It systematically examines the causal relationship between the new energy demonstration city policy and corporate green innovation, and explores the micro mechanisms through which the new energy demonstration city policy influences corporate green innovation. Based on the principles and steps of the triple difference method, the following dummy variables are constructed: (1) Policy dummy variable ($Treated_c$): experimental group and control group, defined as 1 if the city where the enterprise is located belongs to the new energy demonstration city, and 0 otherwise; (2) Company dummy variable ($Company_i$)): type of company, defined as 1 if the company is related to new energy and thus is considered to be impacted by the policy, otherwise 0; (3) Time dummy variable ($Post_t$): the policy implementation node, with the new energy demonstration city policy being officially implemented since 2014, thus choosing 2014 as the policy impact year, and defining the period after 2014 as 1, and otherwise 0.

The specific model specification is as follows:

$$y = \beta_0 + \beta_1 NEDC_{cit} + \beta_2 Controls_{cit} + \mu_{ci} + \lambda_t + \varepsilon_{cit} \tag{1}$$

In this context, c,i and t denote the city, individual and time respectively, y represents the green innovation capability of firms related to new energy. $Controls$ stands for the matrix of related control variables, μ_{ci} and λ_t respectively indicate individual fixed effects and time fixed effects, while ε_{cit} represents the random error term. $NEDC_{cit} = Treated_c \times Company_i \times Post_t$ is the interaction term of policy dummy variable, company dummy variable, and time dummy variable, signifying the impact of the new energy demonstration city policy on the firms. $\beta_0 \sim \beta_2$ are the parameters to be estimated, where the triple difference interaction term coefficient β_1 is key to this study. If β_1 is significantly positive, it suggests that the new energy demonstration city policy has facilitated green innovation in new energy firms.

4.2. Variable Definitions

4.2.1. Dependent Variable

The aim of this paper is to assess the effectiveness of the New Energy Demonstration City policy through the analysis of green technology innovation activities data from publicly listed companies, thus validating the policy's impact at the corporate green innovation level. Green patents, as the core outcome of R&D innovation in the specialized fields of new energy enterprises, directly reflect the firms' green innovation capabilities. Drawing upon the studies of Hall & Harhoff (2012) and Dechezlepretre et al. (2011), and incorporating the approach of Qi S. et al. (2018), this paper selects the number of green patent applications ($EnvrPat$) of listed companies as the dependent variable, and applies a logarithmic transformation after incrementing by one [38, 47, 48].

The primary considerations are as follows: First, the volume of green patent applications by new energy-related listed companies within a certain period provides a more accessible and quantifiable metric for assessing the green innovation capability of firms, offering a more intuitive reflection of the output of corporate green activities under policy influence. Second, green patent grants are characterized by lengthy application processes and susceptibility to external factors; hence, using the number of green patent applications is timelier and more directly reflects the policy impact on green innovation in relevant enterprises within New Energy Demonstration Cities. Third, utilizing the number of green patent applications by firms to measure the green innovation effects at the micro-level in New Energy Demonstration Cities effectively excludes the influence of data from industries not impacted by the policy, thereby enhancing the credibility of the regression results.

For robustness checks, the paper also introduces a relative measure, the proportion of green patent applications ($RatioEnvrPat$), which is the ratio of the number of green patents applied for by a company to the total number of patents applied for in that year, to ensure the robustness of the baseline regression results.

In terms of heterogeneity analysis, the paper further categorizes green patents into green invention patents ($EnvrInvPat$) and green utility model patents ($EnvrUtyPat$), to examine the policy's impact on both the "quality" and "quantity" of green innovation.

4.2.2. Core Explanatory Variables

In this paper, the core explanatory variable is the interaction term of three variables: the policy dummy variable representing the pilot situation of New Energy Demonstration Cities ($Treated_c$), the company dummy variable indicating the type of enterprise ($Company_i$), and the time dummy variable for the implementation of the policy ($Post_t$), which is referred to as $NEDC_{cit}$ previously mentioned. Only when a company is located in a New Energy Demonstration City, is classified as a new energy-related enterprise, and the time period is 2014 or later, do all three conditions concurrently satisfy, resulting in $NEDC_{cit} = 1$; otherwise, it takes the value of 0.

4.2.3. Control Variables

Considering that certain operational factors in real-world new energy enterprises may have a latent impact on their green technological innovation, to overcome the endogeneity problem caused by omitted variables, this paper, grounded in Schumpeterian innovation theory, and referencing a series of related studies[49,50,51,52], has selected the following indicators as control variables for the research: (1) Firm maturity: This study uses the logarithm of firm age ($lnage$) as a proxy variable for firm maturity, measured by the logarithm of the duration since the company's initial public offering. (2) Firm performance: The return on assets (ROA) is an intuitive reflection of a company's operational performance, measured as the ratio of net profit to total assets. (3) Firm leverage: The debt to capital structure (lev) is selected to measure the extent to which a firm utilizes debt as a financing method, calculated as the ratio of total debt to the sum of total debt and shareholders' equity. (4) Firm asset situation: The logarithm of the total asset value of the company ($lnassets$) is used for measurement. (5) Firm value: The ratio of a firm's market value to the replacement cost of capital, namely the Tobin's Q value ($lnTobinQ$), is used for assessment, with the study applying a logarithmic transformation to this variable.

4.2.4. Mechanism Variables

This paper primarily considers the micro-mechanisms of the New Energy Demonstration City policy's impact on green innovation among new energy-related enterprises at the financial level, thereby introducing the following three mechanism variables: (1) Financing constraints: Measured using the SA index (SA), following the approach of Hadlock & Pierce (2010), to ensure a financing variable that is relatively robust and devoid of endogenous characteristics [53]; (2) Cash Flow Ratio (CFR): Measured as the ratio of operating cash flow to total cash flow; (3) Fixed Asset Investment Ratio ($FAIR$): Measured as the ratio of fixed asset investment to total investment in the firm.

4.3. Data Description

The research in this paper selected patent data of A-share listed companies from the Shanghai and Shenzhen stock markets in China, along with microeconomic data related to corporate operations and city policies. To exclude the impact of the COVID-19 pandemic from 2020 to 2022, the time window was set from 2011 to 2019. The patent data of listed companies were sourced from the National Intellectual Property Administration's patent database. Green patents were identified based on the *International Patent Classification Green Inventory* published by the World Intellectual Property Organization (WIPO) in 2010, following the method used by Qi S. et al. (2018) [38]. Other micro-level operational data for enterprises are obtained from the Guotai'an (GTA) database. At the city policy level, the determination of the policy dummy variable is based on the list of cities identified in the *Notification on the Establishment of New Energy Demonstration Cities (Industrial Parks) (First Batch)* published by the National Energy Administration in 2014, with related data derived from the *China City Statistical Yearbook* over the years. In data processing, to eliminate the influence of outliers on the overall results, listed companies that are ST, *ST, or have missing or abnormal data were excluded. Moreover, considering that the primary impact of the New Energy Demonstration City policy is on the manufacturing sector, financial and service industries were excluded from the patent data selection, retaining only listed companies in the manufacturing sector. Non-new energy enterprises in New Energy Demonstration Cities, which are less impacted by the policy, were considered as the control group for this study.

Descriptive statistics for the main variables are presented in Table 1, and mean difference tests for the variables are shown in Table 2.

Table 1. Descriptive statistics of variables

	(1)	(2)	(3)	(4)	(5)
$VARIABLES$	N	Mean	sd	min	max
$EnvrPat$	13,175	0.605	1.016	0	7.342
$lnTobinQ$	13,175	1.022	0.609	-0.716	6.793
$lnassets$	13,175	22.16	1.277	19.14	28.64
lev	13,175	0.445	2.009	0.00219	204.8
ROA	13,175	0.0758	0.103	-1.517	1.013
$lnage$	13,175	2.709	0.397	0.693	3.664
$NEDC$	13,175	0.0206	0.142	0	1

Table 2. Mean difference test

$Variables$	G1(0)	Mean1	G2(1)	Mean2	MeanDiff
$EnvrPat$	12904	0.588	271	1.428	-0.840***
$lnage$	12904	2.708	271	2.775	-0.067***
ROA	12904	0.0760	271	0.0700	0.00500
lev	12904	0.445	271	0.467	-0.0220
$lnTobinQ$	12904	1.022	271	1.004	0.0180
$lnassets$	12904	22.15	271	22.68	-0.531***

The study collected 13,175 observations, and through descriptive statistics, it was found that the logarithmic mean of green patent applications was only 0.605, with a minimum of 0 and a maximum of 7.342. These findings are similar to those in the research by Xu J. and Cui J. (2020) [41], indicating that green innovation among Chinese listed companies remains at a relatively low level, with considerable variation between companies. The mean values of other indicators such as $lnage$, ROA, and lev are in line with findings from related studies by Li W. and Zheng M. (2016), Fang X. and Hu D. (2023), Li L. and Ma X. (2023), showing no data issues [50,54,55].

Furthermore, according to the research objective, new energy companies in demonstration cities were classified as the experimental group (G2), with 271 data sets, while the remaining listed companies were classified as the control group (G1), with 12,904 data sets. Mean difference tests revealed significant differences at the 1% level between the control group (G1) and the experimental group (G2) in terms of green patent numbers ($EnvrPat$), company maturity ($lnage$), and company asset situation ($lnassets$), with the logarithmic mean of green patent applications being 0.588 for the control group and 1.428 for the experimental group, indicating a clear difference. This aligns with the research findings of Zhou A. and Wang S. (2023) [3], preliminarily verifying the effectiveness of the new energy demonstration city policy in promoting corporate green innovation.

5. Empirical Analysis

5.1. Baseline Regression

Following the baseline regression model outlined above, this study employed the triple difference method (DDD) to examine the impact of the new energy demonstration city policy on the green innovation of related listed companies. Regression analyses were progressively conducted with the inclusion of control variables, accounting for individual and time-level fixed effects, with results presented in Table 3. Model (1) tested the impact of the new energy demonstration city policy ($NEDC$) on the green innovation of related listed companies; Model (2) included the five control variables mentioned previously, such as company maturity; Model (3) built upon Model (2) by further controlling for fixed effects at the city, company, and time levels. All regression models adjusted standard errors clustered at the city and industry levels.

The regression results from Table 3 indicate that in Models (1) and (2), the coefficient β_1 of the triple difference interaction term NEDC was significantly positive at the 1% level. After accounting for individual (including city and industry) and time-level fixed effects, the coefficient β_1 of $NEDC$ in Model (3) remained significantly positive at the 5% statistical level, though the significance level and the coefficient value decreased slightly. This suggests that there are indeed some interfering factors at the individual and time levels, necessitating the inclusion of fixed effects to accurately analyze the net impact of the new energy demonstration city policy. Therefore, the results from all three baseline regression models consistently show that the new energy demonstration city policy significantly promoted green innovation in the related listed companies. According to Model (3), green innovation, measured by the number of green patents ($EnvrPat$), increased by 24.64 percentage points compared to companies not impacted by the policy. These findings are somewhat consistent with the results of research by Li Y. et al. (2023) and Li F. et al. (2023) [11,12], supporting Hypothesis 1a.

From the perspective of control variables, the regression results are broadly in line with related studies, such as those by Xu J. and Cui J. (2020) [41]. The empirical results of Model (3) suggest that the company's asset situation has a certain promotional effect on its green technological innovation. This might be attributed to larger companies investing more resources in green technological innovation, alongside their stronger transformation awareness, R&D levels, and ability to attract relevant talent, leading to more green patent achievements. Additionally, the regression coefficients for variables such as company maturity, performance, debt situation, and market value were not significant, indicating that these factors do not have a major impact on the green innovation levels of listed companies.

Table 3. Baseline Regression Results

	(1)	(2)	(3)
$VARIABLES$	$EnvrPat$	$EnvrPat$	$EnvrPat$
$NEDC$	0.8398***	0.7089***	0.2464**
	(0.062)	(0.058)	(0.108)
$lnage$		-0.1519***	0.1101
		(0.021)	(0.145)
ROA		0.1967**	0.0372
		(0.082)	(0.056)
lev		-0.0029	-0.0002
		(0.004)	(0.001)
$lnassets$		0.2686***	0.0810**
		(0.007)	(0.031)
$lnTobinQ$		0.0174	-0.0169
		(0.014)	(0.024)
$Constant$	0.5880***	-4.9804***	-1.4791*
	(0.009)	(0.156)	(0.846)
$Individual, time$ $fixed\ effect$	No	No	Yes
$Observations$	13,175	13,175	13,101
$R-squared$	0.014	0.124	0.760

Note: Cluster-adjusted standard errors at the city and industry level are in parentheses, and *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent statistical levels, respectively. The following tables are identical.

5.2. Parallel Trends Test

According to the study by Harris et al. (2011), before the implementation of a policy, the experimental and control groups should satisfy the parallel trends assumption, meaning that both groups exhibit similar change trends or insignificant systematic differences [56]. Only under this condition can the triple difference model accurately identify causal relationships, thus validating the policy's effectiveness. Given the dual nature of the policy impact under study, this paper conducts a two-stage parallel trends test from two perspectives: whether listed companies are in new energy demonstration policy pilot cities, and whether the companies are related to new energy.

5.2.1. City-level Parallel Trends

Using 2014 as the base year, this study tested the parallel trends in green innovation data of listed companies in new energy demonstration policy pilot cities and non-pilot cities three years before and five years after the policy implementation. Figure 1 displays the trend of average green patent counts for listed companies in demonstration cities versus non-demonstration cities. It is evident that, prior to the implementation of the new energy demonstration city policy, the green innovation trends of listed companies in both demonstration and non-demonstration cities were largely consistent and showed no significant differences, passing the parallel trends test.

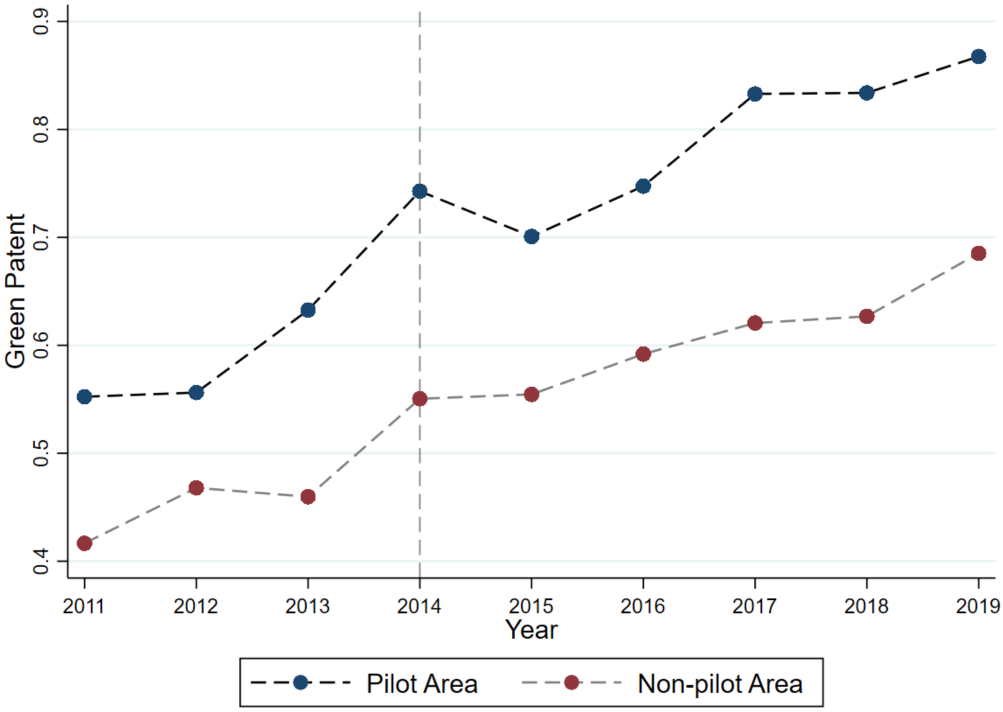

Figure 1. Parallel trend tests at the district level

5.2.2. Company-type-level Parallel Trends

Considering the varying degrees of policy impact on different types of companies, this study further divided the listed companies in new energy demonstration cities into new energy-related companies and non-new energy companies for an additional parallel trends test. The trend in the average number of green patents for new energy and non-new energy listed companies in demonstration cities is shown in Figure 2. Before the base year (2014), the trends for both were broadly similar, satisfying the parallel trends test. After being affected by the policy, the green innovation capability of non-new energy companies remained largely consistent with the pre-policy period, while that of new energy companies increased rapidly after 2016, showing a significant difference.

It is noteworthy that, first, the post-2016 difference in green innovation capability between different types of listed companies in Figure 2 is significantly greater than the difference between listed companies in demonstration and non-demonstration cities during the same period in Figure 1. This indicates that the policy of new energy demonstration cities primarily affected new energy companies within those cities. Second, a more significant disparity in green innovation between new and non-new energy companies emerged after 2016, the year of policy implementation. This could be attributed to the time lag required for the policy-induced impact to translate into green innovation outcomes, thus introducing a "lag effect."

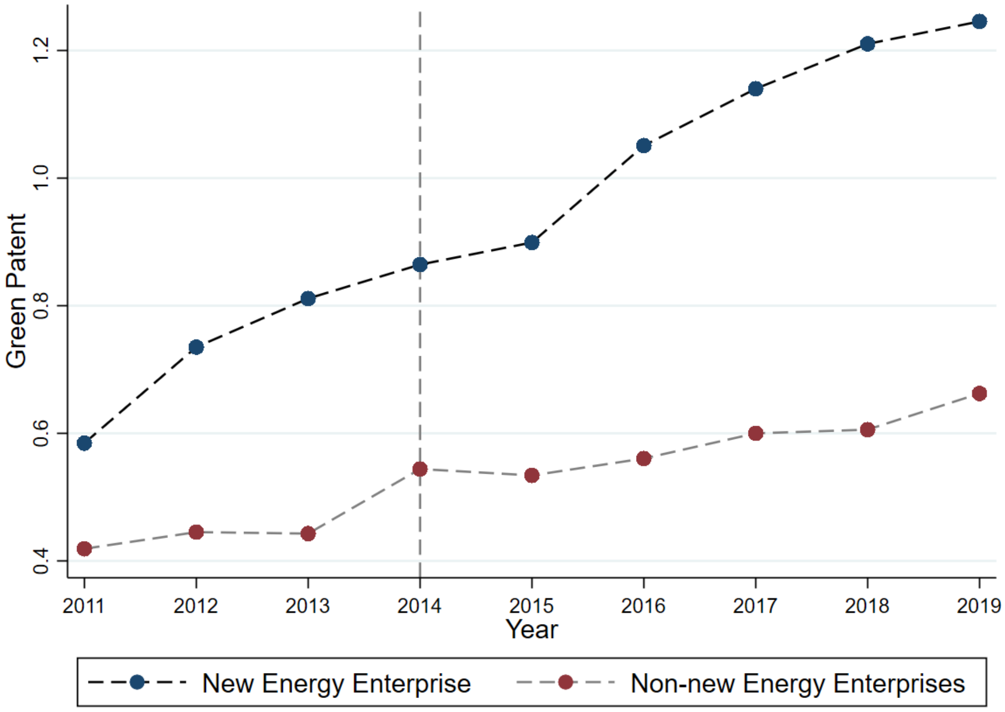

Figure 2. Parallel Trend Tests at the Firm Type Level

5.3. Robustness Test

5.3.1. Exclusion of Other Policy Effects

Given the lengthy research period from 2011 to 2019, other specific policies aimed at promoting corporate green technological innovation might interfere with causal identification. Thus, this paper, based on official documents such as the *National Smart City Pilot Temporary Management Measures* officially issued by the Office of the Ministry of Housing and Urban-Rural Development of the People's Republic of China on November 22, 2012, and in conjunction with existing research literature, finds that the scope of action and research samples of smart city policies ($smartcity$) partially overlap with this study. To eliminate the interference of this policy, $smartcity$ was set as a dummy variable, defined as 1 for cities or regions implementing smart city pilots, and 0 otherwise, further examining the impact of the smart city policy in the regression. The results are shown in Table 4 (1).

The results indicate that the coefficient for the interaction term $NEDC$, representing the impact of the new energy demonstration city policy on corporate green innovation, is 0.2505, still significantly positive at the 5% statistical level, while the coefficient for the dummy variable $smartcity$ is -0.0381 and not significant. This suggests that the promotional effect of the new energy demonstration city on corporate green innovation is not influenced by the smart city policy, indicating that the smart city policy is not a major factor affecting corporate green innovation.

5.3.2. Replacement of Dependent Variable

In the baseline regression, the study used the number of green patents ($EnvrPat$) of listed companies, an absolute indicator, to measure the green innovation capability of new energy-related listed companies, thus more intuitively reflecting the promotional effect of the new energy demonstration city policy on corporate green innovation. However, with the deepening implementation of the national "innovation-driven development" strategy in recent years, the total number of patent applications by listed companies has also increased annually, potentially leading to an increase in green patent numbers. To exclude the impact of other innovation-driving factors on corporate green technological innovation, the study employed the ratio of green patent applications ($RatioEnvrPat$) as a relative indicator for the dependent variable, to conduct a robustness test of the baseline regression results. The regression results are shown in Table 4 (2).

After replacing the dependent variable, the coefficient for the triple difference interaction term $NEDC$ is 0.0349, significantly positive at the 5% level, indicating that the new energy demonstration city policy significantly increased the percentage of green patent applications out of total patent applications, effectively promoting corporate green technological innovation. This also confirms the robustness of the baseline regression results.

Table 4. Robustness test results

	(1)	(2)
$VARIABLES$	$EnvrPat$	$RatioEnvrPat$
$NEDC$	0.2505**	0.0349**
	(0.104)	(0.014)
$smartcity$	-0.0381	
	(0.036)	
$Controls$	Yes	Yes
$Constant$	-1.4568*	0.1097
	(0.840)	(0.086)
$Individual, time$ $Fixed\ effect$	Yes	Yes
$Observations$	13,101	13,101
$R-squared$	0.760	0.540

5.3.3. Changing Fixed Effects

A comparison between columns (2) and (3) of the baseline regression results in Table 3 indicates that the setup of fixed effects has a substantial impact on the estimated coefficient β_1 of the interaction term ($NEDC$) and the significance of the regression results. To assess the impact of fixed effect settings on the robustness of the study's regression outcomes, five different fixed effect combinations, models a to e, were established: (1) Model a controlled for industry, city, and time fixed effects (consistent with the baseline regression); (2) Model b controlled for two types of interaction fixed effects: city×industry and city×time; (3) Model c represented the city×time and industry×time interaction fixed effects; (4) Model d included three interaction fixed effects: city×industry, city×time, and industry×time; (5) Model e controlled for four fixed effects: city×industry, city×time, industry×time, and time. Regression analyses were performed on each of these five models, obtaining the respective estimated coefficient values β_1 and 95% confidence intervals, with the results depicted in Figure 3.

The data shows that in models a toe, the estimated coefficient values β_1 and their 95% confidence intervals are all positive. This means that across different fixed effect settings, the estimated coefficient β_1 of the triple difference interaction term ($NEDC$) remains significantly positive at the 5% statistical level, indicating robustness in the baseline regression results.

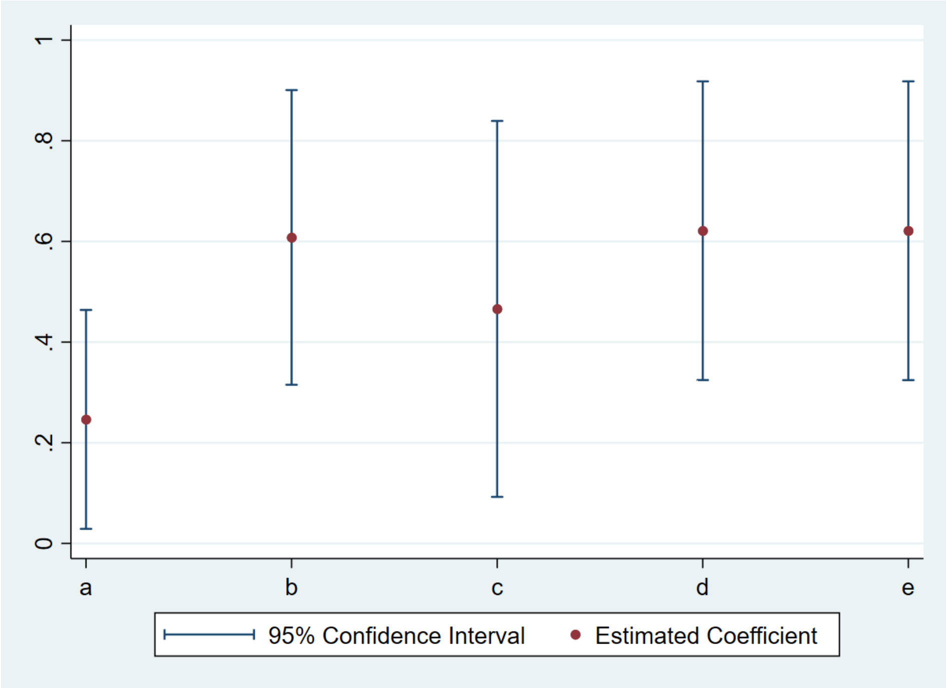

Figure 3. Results of Robustness Tests for Changing Fixed Effects

5.3.4. Changing Clustering Levels

Existing research suggests that changing clustering levels affects the number and size of categories, thereby influencing the variability between groups and offering different interpretative angles, impacting empirical results. To verify the robustness of the baseline regression results with respect to clustering levels, five new models, a toe, were constructed by applying different clustering levels to the baseline regression model. (1) Model a conducted regression analysis without clustering; (2) Model b clustered the regression results at the corporate individual level; (3) Model c clustered at the city level (consistent with the baseline regression), examining the impact of new energy demonstration city policy at the city level on corporate green innovation; (4) Model d clustered at both city and industry levels, capturing the research theme more accurately; (5) Model e went further from Model d, clustering the regression at the city, industry×year levels.

Regression analyses were conducted for these five models, yielding the respective estimated coefficient values β_1 and 95% confidence intervals, with the results shown in Figure 4: the estimated coefficient values β_1 and their 95% confidence intervals are all above the y-axis. This indicates that regardless of changes in clustering levels, the estimated coefficient β_1 of the triple difference interaction term ($NEDC$) remains significantly positive at the 5% statistical level, affirming the robustness of the baseline regression results.

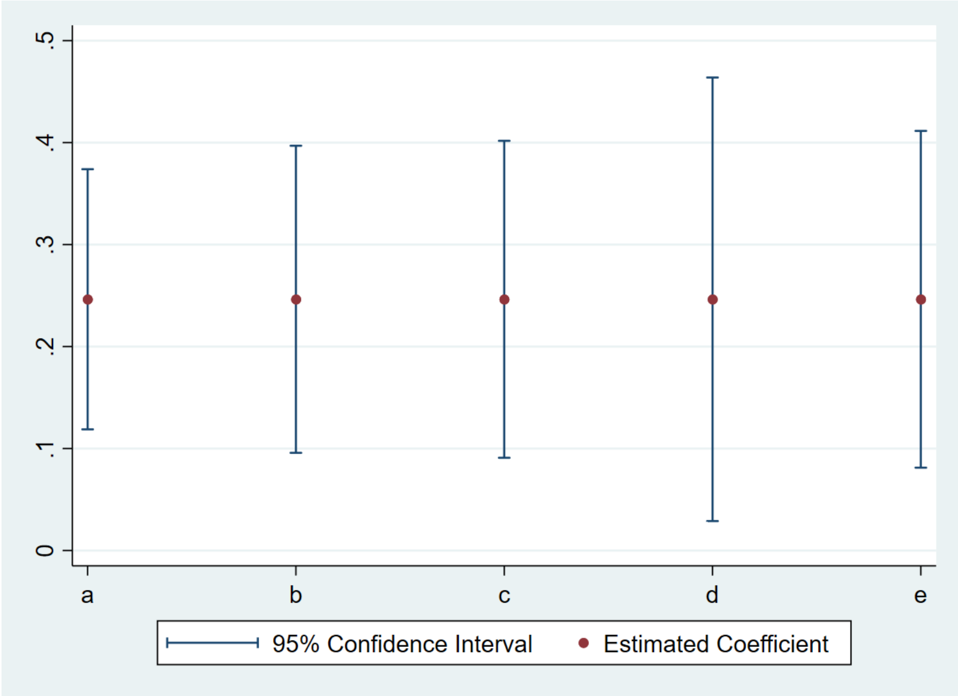

Figure 4. Robustness test results for changing the clustering hierarchy

5.4. Heterogeneity Analysis

Considering the heterogeneity in the forms and extents of policy impacts on different entities, this paper aims to delve into the effects of new energy demonstration city policies on the green innovation of relevant enterprises. To derive sound policy recommendations, the analysis will be conducted from two dimensions: types of patents and enterprise ownership. This approach will provide more comprehensive empirical evidence for the promotion of new energy demonstration city policies

5.4.1. Patent Heterogeneity

As previously mentioned, the number of green patent applications ($EnvrPat$) can be categorized into green invention patent applications ($EnvrInvPat$) and green utility model patent applications ($EnvrUtyPat$). The corresponding relative indicators are the proportion of green invention patent applications ($RatioEnvrInvPat$) and the proportion of green utility model patent applications ($RatioEnvrUtyPat$). Following Qi S. et al. (2018), green invention patents are considered to have higher value in green innovation [38]. Thus, this paper posits that the two types of green patents represent two different impacts of policy on corporate green innovation— "quality improvement" and "quantity increase." This section uses the aforementioned absolute and relative indicators as dependent variables to construct four triple difference models (1) to (4), performing regression analysis to examine the heterogeneity of the new energy demonstration city policy's effects on green innovation. The regression results are presented in Table 5.

Columns (1) and (3) in the table, measured by absolute indicators, show that the triple difference interaction terms' estimated coefficients β_1 are 0.2803 and 0.1472, respectively, both significantly positive at the 5% statistical level. When measured by relative indicators, comparing columns (2) and (4), the value of β_1 is larger and more significant when $RatioEnvrUtyPat$ is the dependent variable. This indicates that the new energy demonstration city policy positively affects both "quality improvement" and "quantity increase" of corporate green innovation, but the "quantity increase" is more pronounced when measured by relative indicators, particularly for green utility model patents. This empirical result supports Hypothesis 2b.

The potential reasons for this phenomenon include: First, green innovation is constrained by a firm's own research capabilities and resource reserves. From the perspective of input and output, applying for green utility patents requires relatively fewer resources. Consequently, new energy enterprises might prioritize allocating their limited resources to the research and development of green utility patents when pursuing green innovation. Second, compared to green invention patents, which have a longer incubation period, green utility patents can often yield more economic and environmental benefits in a shorter timeframe, making them more suitable for new energy companies facing greater profit pressures. Third, most new energy demonstration cities do not differentiate between these two types of patents in their green innovation indicators and fiscal subsidies. Hence, new energy enterprises tend to opt for green utility patents, which are easier to qualify for government funding. Therefore, in practice, the policies of new energy demonstration cities are more inclined towards an 'incremental' effect.

Table 5. Patent Heterogeneity Analysis Results

	(1)	(2)	(3)	(4)
$VARIABLES$	$EnvrInvPat$	$Ratio$ $EnvrInvPat$	$EnvrUtyPat$	$Ratio$ $EnvrUtyPat$
$NEDC$	0.2803**	0.0496*	0.1472**	0.0736**
	(0.117)	(0.025)	(0.072)	(0.030)
$Controls$	Yes	Yes	Yes	Yes
$Constant$	-1.2056*	0.1914	-1.0649	0.2039
	(0.685)	(0.157)	(0.672)	(0.293)
$Individual, Time$ $Fixed\ effect$	Yes	Yes	Yes	Yes
$Observations$	13,101	13,101	13,101	13,101
$R-squared$	0.717	0.406	0.758	0.276

5.4.2. Enterprise Ownership Heterogeneity

In China, the nature of enterprise ownership can influence innovation activities in various ways, including R&D investment and financial support, talent reserves and incentive mechanisms, decision-making speed and flexibility, policy constraints, intellectual property protection, and innovation investment risks. Therefore, this study divides listed companies into state-owned enterprises (SOEs) and private enterprises, using green patent applications ($EnvrPat$), green invention patent applications ($EnvrInvPat$), and green utility model patent applications ($EnvrUtyPat$) as dependent variables for triple difference analysis, and considers fixed effects for both enterprise individuality (including industry and region) and time to explore the heterogeneity of the new energy demonstration city policy across different types of enterprise ownership, also examining their interaction with patent heterogeneity. The regression results are shown in Table 6.

Columns (1) to (3) represent the estimated results for SOEs, where the triple difference interaction term ($NEDC$) coefficients β_1 are negative and not significant. Columns (4) to (6) represent the estimated results for private enterprises, where β_1 is positive and significantly positive at the 1% statistical level. This indicates that there is indeed heterogeneity in the impact of new energy demonstration city policies on corporate green innovation with respect to enterprise ownership. The policy may not be a primary factor influencing the green innovation of state-owned enterprises, but it can effectively promote green technological innovation in private enterprises. Moreover, in absolute terms, its impact is more significant on invention-type patents. This empirical finding also corroborates Hypothesis 3 mentioned earlier.

This may be due to several factors. First, as the pillars of the national economy, state-owned enterprises (SOEs) are subject to dual constraints from local governments and higher regulatory authorities, resulting in limited practical effects of policy enforcement, while private enterprises are primarily constrained by local government policies, exhibiting more pronounced effects. Second, drawing on the research by Han C. and Sang R. (2018), SOEs, due to their political influence, can mitigate the pressure from environmental regulations, leading to a lack of awareness and flexibility in energy structure adjustment and green innovation when facing policy constraints [57]. Third, compared to SOEs, private enterprises, driven by the pursuit of market profits and faced with more intense market competition, are compelled to engage in green innovation. In addition, there will be a greater focus on patenting green inventions with more tangible economic and environmental benefits.

Table 6. Results of the analysis of firm ownership heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
$VARIABLES$	$EnvrPat$	$Envr$ $InvPat$	$Envr$ $UtyPat$	$EnvrPat$	$Envr$ $InvPat$	$Envr$ $UtyPat$
$NEDC$	-0.0991	-0.1093	-0.0305	0.3614***	0.3955***	0.2206***
	(0.116)	(0.072)	(0.100)	(0.102)	(0.125)	(0.074)
$Controls$	Yes	Yes	Yes	Yes	Yes	Yes
$Constant$	-1.2683	0.0888	-1.5444*	-2.1029**	-1.8704**	-1.5880**
	(1.103)	(0.778)	(0.860)	(0.895)	(0.716)	(0.709)
$Individual, time$ $Fixed\ effect$	Yes	Yes	Yes	Yes	Yes	Yes
$Observations$	4,551	4,551	4,551	8,548	8,548	8,548
$R-squared$	0.805	0.763	0.809	0.723	0.687	0.706

6. Mechanism Analysis

The empirical analyses presented above indicate that the new energy demonstration city policy effectively enhances corporate green innovation, with heterogeneity observed across patent types and enterprise ownership dimensions. Unlike dedicated research institutions such as universities and research institutes, corporate green innovation often relies on larger capital investments and a more rational financial structure. Drawing on studies by Ju X. et al. (2013), Feng K. (2016), and Zhang C. et al. (2019), from the perspective of corporate finance acquisition and utilization, the degree of financing constraints, the uncertainty of cash flows, and the proportion of fixed asset investment emerge as influential factors on corporate innovation [58, 59, 60]. As an environmental regulation and innovation incentive mechanism at the city level, the new energy demonstration city policy, in its implementation, addresses the actual problems of financing difficulties for some new energy-related enterprises through complementary green financial policies, while also affecting the structure and allocation of existing corporate funds through fiscal policies, monetary policies, and market regulation. Thus, this section explores the mechanisms of the new energy demonstration city policy on corporate green innovation from the micro perspective of corporate finance, focusing on easing financing constraints, expanding operational cash flows, and increasing the proportion of fixed asset investment.

6.1. Easing Financing Constraints

To encourage the development of new energy-related industries and solve financing difficulties, all new energy demonstration cities have implemented complementary green financial policies. At the micro level, for new energy enterprises facing potential financing constraints in green innovation, these green financial policies can enhance the ease of financing, alleviate the financial pressures during technological transformation, and thereby promote green innovation.

To eliminate endogeneity issues, this paper measures the degree of financing constraints among listed companies in the sample using the SA index method proposed by Hadlock & Pierce (2010) [53], calculated using the following empirical formula:

$$SA = -0.737 \times size + 0.043 \times size^2 - 0.04 \times Age \quad (2)$$

where $size$ represents the company size, equivalent to the logarithm of total assets ($lnassets$), and Age denotes the company age. A negative and larger absolute value of the SA index indicates more severe financing constraints.

This study tests the mechanism of easing financing constraints by the new energy demonstration city policy ($NEDC$) from the micro data perspective of the SA index of listed companies, i.e., whether the policy can promote green innovation by alleviating financing constraints. The following model is constructed with SA index as the explanatory variable:

$$SA = \beta_0 + \beta_1 NEDC_{cit} + \beta_2 Controls_{cit} + \mu_{ci} + \lambda_t + \varepsilon c_{it} \quad (3)$$

The regression results of the triple difference method are presented in Table 7 (1), where the coefficient of the interaction term is 0.0182, significant at the 5% confidence level. This indicates that the New Energy Demonstration City policy and its accompanying green finance policies, through mechanisms such as easing loan quotas and establishing dedicated funds for green innovation, facilitate capital acquisition for new energy enterprises, effectively alleviating financing constraints. This finding provides empirical evidence for the mechanism of easing financing constraints in new energy demonstration cities, aligning with the findings of Wang X. and Wang Y. (2021), who observed that the release of green financial policies like the *Green Credit Guidelines* by the Banking Regulatory Commission led to more active green innovation performances among relevant companies. At the same time, they argue that green finance policies can significantly enhance environmental and social performance. This view further corroborates the mechanism by which new energy demonstration cities adopt complementary green financial policies to alleviate the financing constraints of new energy enterprises, thereby promoting green innovation [61].

6.2. Expanding Operational Cash Flow

In new energy demonstration cities, new energy enterprises often enjoy policy benefits such as tax reductions, financial subsidies, and support from market mechanisms like emission trading, improving their operational capabilities and financial situation. According to the analysis of control variables in the baseline regression presented earlier, new energy enterprises with better asset conditions are more likely to engage in green innovation. Therefore, this study hypothesizes that the new energy demonstration city policy can enhance corporate green innovation levels by improving business conditions and financial status.

Operational cash flow, the cash flow generated from daily business activities, is a crucial indicator of operational asset condition. This paper uses the operational cash flow ratio ($Cashflowratio$) as the dependent variable to examine whether the new energy demonstration city policy ($NEDC$) can boost corporate green innovation by increasing operational cash flow. The model is as follows:

$$Cashflowratio = \beta_0 + \beta_1 NEDC_{cit} + \beta_2 Controls_{cit} + \mu_{ci} + \lambda_t + \varepsilon_{cit} \quad (4)$$

The regression results shown in Table 7 (2) indicate that the interaction term coefficient is 0.0157, which is significantly positive at the 1% confidence level. This suggests that the New Energy Demonstration City policy enhances the operational cash flows of relevant firms, thereby improving their operational capabilities and asset conditions, and consequently promoting green innovation within these firms. A possible explanation is that New Energy Demonstration Cities can foster the agglomeration of local new energy industries through tax incentives, financial support, and subsidies. This, in turn, expands the customer base and market for new energy products, increases the operating income of related enterprises, and improves their operational capabilities and asset conditions. Positive market expectations may also stimulate decision-makers in firms to invest in green innovation [62].

6.3. Increasing Fixed Asset Investment Ratio

Based on Feng K. (2016), this paper posits a close link between fixed asset investment levels and corporate innovation capabilities. In terms of technological innovation, fixed asset investment plays a critical role, providing the necessary material foundation and support, especially in high-tech areas like green innovation. Thus, this study uses the fixed asset investment ratio ($Investmentratio$) of listed companies to investigate whether the new energy demonstration city policy can drive green innovation by increasing the fixed asset investment ratio. The model is as follows:

$$Investmentratio = \beta_0 + \beta_1 NEDC_{cit} + \beta_2 Controls_{cit} + \mu_{ci} + \lambda_t + \varepsilon_{cit} \quad (5)$$

The test results, as seen in Table 7 (3), show that the estimated coefficient β_1 is positive and statistically significant at the 10% level. This indicates that the New Energy Demonstration City policy can increase the proportion of fixed asset investment in enterprises, thus validating the effectiveness of this mechanism. However, in terms of the estimated coefficient and significance level, its impact appears to be weaker compared to the first two mechanisms. A possible reason is that new energy companies face severe market competition challenges. Consequently, their investment behavior is more influenced by market conditions, rendering the efficacy of a singular policy relatively limited.

Synthesizing the research from the aforementioned three aspects, the New Energy Demonstration City policy can facilitate green innovation in enterprises by altering the methods through which new energy firms acquire and utilize funds. This is achieved through channels such as alleviating financing constraints, expanding operational cash flows, and increasing the proportion of fixed asset investment. Consequently, Hypothesis 4 of this study has also been validated.

Table 7. Results of the analysis of mechanisms

	(1)	(2)	(3)
$VARIABLES$	SA	$Cashflowratio$	$Investmentratio$
$NEDC$	0.0182**	0.0157***	0.0086*
	(0.007)	(0.004)	(0.004)
$Controls$	Yes	Yes	Yes
$Constant$	-3.3475***	0.2309***	0.1748***
	(0.278)	(0.078)	(0.046)
$Individual, time$ $Fixed\ effect$	Yes	Yes	Yes
$Observations$	13, 101	12, 826	13, 101
$R-squared$	0.979	0.496	0.563

7. Conclusions and Policy Recommendations

7.1. Main Conclusions

This paper empirically analyzes the policy effects of the new energy demonstration city policy, implemented starting in 2014, on corporate green innovation using panel data of green patents from A-share listed companies in the Shanghai and Shenzhen stock markets from 2011 to 2019, employing a triple difference model. It conducts a multidimensional heterogeneity analysis and delves into the policy's mechanism from the perspective of financing and capital use by new energy enterprises. The main conclusions are as follows:

(1) The implementation of the new energy demonstration city policy significantly promotes green innovation in new energy companies, with an improvement effect of approximately 24.64%. This conclusion is supported by a series of robustness tests, including parallel trend tests, exclusion of other policy impacts, replacement of the dependent variable, changes in fixed effects, and clustering levels.

(2) The results of the mechanism analysis show that the new energy demonstration city policy can change the way new energy enterprises obtain and use funds through channels such as easing financing constraints, expanding operating cash flow and increasing the proportion of investment in fixed assets, thus promoting green innovation in enterprises.

(3) Heterogeneity analysis reveals that, in terms of patent heterogeneity, the new energy demonstration city policy positively impacts both the “quality” and “quantity” of green innovation in

new energy companies, with a more pronounced effect on the "quantity" aspect. In terms of ownership heterogeneity, the policy significantly boosts green innovation in private new energy enterprises but has a limited impact on the green innovation process of state-owned enterprises.

7.2. Policy Recommendations

Based on the conclusions drawn, the following policy recommendations are proposed:

(1) Summarize the experiences from new energy demonstration city pilots, expand the scope of these pilots, and promote broader green innovation among new energy enterprises, actively exploring new models for sustainable urban development. On one hand, government departments can summarize the policy experiences from over a decade of implementing the new energy demonstration city policy, create replicable standard model cases based on the current state of new energy industry development in various regions for other cities to reference, and gradually expand the pilot scope nationwide to foster innovative development in the new energy sector. On the other hand, strengthening policy promotion and implementation efforts to extend the concept of green consumption and innovation into broader areas is vital, aiming to create a green innovation trend covering all industries and citizens within demonstration cities. Moreover, establishing a fair, reasonable, and quantifiable green innovation monitoring and evaluation system tailored to local conditions within each demonstration city is crucial for government agencies to understand the policy's effectiveness and make subsequent improvements.

(2) Continue to strengthen policy support, actively expanding channels through which new energy enterprises can engage in green innovation. New energy companies often face difficulties in financing and inefficient use of funds. Based on the mechanism analysis results, local governments should focus on the specifics of how companies acquire and utilize funds, addressing common financial challenges with targeted enhancements to existing incentives and guiding increased investment in green innovation. Additionally, governments can lead in establishing platforms for cooperation and exchange in green innovation among new energy enterprises, integrating resources and technology to achieve a "triple-win" green innovation of enterprise, government, and environmental.

(3) Implement differentiated policy combinations to advance the green innovation process in new energy enterprises. Currently, new energy demonstration city policies face challenges, such as uniform evaluation methods, weak adaptability of measures, and insufficient targeting. In terms of patent heterogeneity, local governments should categorize and evaluate corporate green innovation based on actual development conditions and needs. In the long run, auxiliary policies should focus on green invention patents with higher value content, actively promoting higher-quality green innovation. Regarding ownership heterogeneity, policymakers should formulate differentiated policy combinations; for state-owned enterprises, innovative reforms should be actively promoted with mandatory innovation targets incorporated into management evaluations, urging SOEs to fully utilize existing resources and lead in green innovation. For private enterprises, considering their practical challenges, strengthening support through green finance, fiscal subsidies, and innovation incentives is essential to drive further progress in green innovation within the new energy sector.

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