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The role of high-tech certification in enterprise green innovation: from the perspectives of substantive innovation and strategic innovation

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Sustainable development comes from a balance between economic growth and environmental protection, with due consideration of long-term impacts on environment. Leveraging policy tools to promote green innovation is a critical strategy for achieving this objective. This paper examines the impact of high-tech certification on corporate green innovation, distinguishing between substantive and strategic green innovation. It develops a theoretical framework to analyze how high-tech certification influences enterprise green innovation through mechanisms such as tax preferences, government subsidies, financing constraints, and leveraging capital market attention. The study employs a zero-inflated negative binomial regression model and utilizes data of A-share listed companies from 2006 to 2023 to systematically assess the impact of high-tech certification on enterprise green innovation strategies, underlying mechanisms, and their heterogeneity. The research discovers that in general, high-tech certification significantly promotes enterprise green innovation, having a more prominent facilitating effect on strategic green innovation, resulting in a certain degree of green patent false prosperity. From the perspective of underlying mechanisms, high-tech certification increases the resources actually obtained by enterprises through tax preferences and government subsidies and alleviates financing constraints, thereby guiding enterprises to undertake more substantive green innovation; while enhancing capital market attention increases the expected resources obtained by enterprises, prompting enterprises to be more inclined towards strategic green innovation. Further analysis reveals that the impact of high-tech certification on corporate green innovation varies significantly across different ownership structures, industries, and regions. Specifically, in state-owned enterprises, technology-intensive sectors, and enterprises located in the central regions, the positive effect on substantive green innovation is particularly pronounced. This study contributes to the literature on policy tools and corporate green innovation strategies by offering robust empirical evidence to optimizing policy design, mitigating policy arbitrage, and preventing patent bubbles.

KEYWORDS

substantive green innovation, strategic green innovation, high-tech certification, zero-inflated negative binomial regression, green patent bubble

1 Introduction

Extensive economy inflicts severe damage upon natural environment and we are seeing more proofs of an increasingly over-stressed ecological system. Henceforth, environmental protection has emerged as the focus of current global public governance. Based on the experience of Western and European economies and the practice of the East Asian economic miracles, technological factors have played a core role in both economic growth and environmental protection (Tomizawa et al., 2020). In the context of escalating resource and environmental pressures, reducing energy consumption, mitigating environmental pollution, and achieving sustainable development have become central themes in national policies (Kou et al., 2024). With enterprises serving as both the primary source of pollution and the key driver of technological research and development, fostering green innovation within enterprises is essential for promoting economic transformation and addressing resource and environmental challenges (Cao and Yu, 2024). Specifically, from the perspective of development models, green technological innovation enables high-quality economic growth within environmental constraints. From an industrial development standpoint, such innovations leads the way for future industry development to drive industrial upgrading and transformation. From the perspective of individual enterprise, it helps enhance the international competitiveness of their products (Du et al., 2019). Therefore, advancements in green technologies is essential for achieving sustainable development and facilitating green transformation of economies (Wan et al., 2022). As the largest developing country in the world, China has promised to fulfill its international obligation for environmental protection and has committed to achieving carbon peaking and carbon neutrality targets. Consequently, stimulating green innovation among domestic enterprises and promoting green economic transformation have emerged as critical research priorities (Xu et al., 2023).

Enterprise innovation can be categorized into two types: substantive innovation, which involves development of new products or processes that significantly alter market dynamics; and strategic innovation, which focuses on redefining business models and competitive strategies to achieve a sustainable competitive advantage. Generally, R&D costs and risks of substantive innovation are far higher than those of strategic innovation. Substantive innovation is disruptive and can fundamentally transform production processes, technological flows, and product performances. By contrast, strategic innovation mainly concentrates on improvements in aspects such as appearance design and trademarks (Li et al., 2023). Hence, it can be reasonably deduced that there exist remarkable differences in nature between substantive green innovation and strategic green innovation for enterprises. Regarding factors impacting enterprise green innovation, scholars have carried out extensive discussions from multiple levels. External factors mainly comprise government policies (Xu et al., 2024), carbon trading systems (Xi and Jia, 2025), environmental legislation (Ma and Li, 2025), financial markets (Fang et al., 2024), international trade (Liu et al., 2024), green propensity of financial system (Wang et al., 2022), and public opinion supervision from stakeholders (Song et al., 2024). Internal factors include leadership inclination (Hu and Shi,

2025), ESG responsibility (Liu et al., 2024), and corporate governance (Amore and Bennedsen, 2016). In reality, promoting enterprise green innovation requires analysis from a more macroscopic perspective. Enterprise green innovation is the outcome of dynamic interactions between the government, enterprises, and stakeholders (Dore, 1988).

However, enterprises possess more patent information than government staff, thus having the motivation to exploit this information advantage to obtain policy dividends, which might result in the generation of a green patent bubble (Xie and Wang, 2024). Hu et al. (2023), using the “Green Credit Guidelines” issued by the Chinese government as the research focus, found that enterprises tend to increase the quantity of low-quality green innovations to meet basic requirements for accessing green finance and securing green financing support (Hu et al., 2023). Zhao et al. (2024), focusing on the government’s special subsidies for R&D projects, found that government subsidies have a promoting effect on strategic green innovation. However, their impact on substantive green innovation exhibits a threshold effect. When subsidies are below the threshold, they can alleviate cash flow constraints in enterprise R&D and enhance substantive green innovation capabilities. Conversely, when subsidies exceed the threshold, enterprises may engage in policy arbitrage by exploiting information asymmetry, leading to a decline in their enthusiasm for substantive green innovation (Zhao et al., 2024). Chen and Kim (2024), through an analysis of carbon emissions trading, found that carbon trading has a direct impact on enterprise profits. Consequently, when carbon prices increase, enterprises are more likely to pursue substantive green innovation (Chen et al., 2024). These findings indicate that enterprise green innovation strategies result from rational evaluations of external regulations and internal cost-benefit analyses. Based on these assessments, enterprises will choose between substantive and strategic green innovations. Therefore, the government should tailor policy tools according to enterprises’ green innovation performance to promote greater engagement in substantive green innovation.

This paper examines the impact of high-tech certification on enterprise substantive and strategic green innovation. High-tech certification influences green innovation through multiple channels. Firstly, from a resource-based perspective, it not only reduces tax rate for certified enterprises but also enhances government subsidies (Liu et al., 2020; Li et al., 2019; She et al., 2022). These financial benefits provide enterprises with additional resources to invest in green technologies and practices, thereby promoting both substantive and strategic green innovations. Secondly, due to government’s emphasis on environmental protection, environmental protection guiding policies have been introduced for high-tech enterprises, promoting their green technological innovation. High-tech Certification enhances technological advancement of enterprises, promoting their investment in and output from green innovation (Chen et al., 2023; Liu et al., 2020). These studies have analyzed mechanisms such as tax incentives, government subsidies, and financing constraints but have not thoroughly examined the impact of high-tech certification on substantive and strategic green innovations. Consequently, further research is critically needed to address this gap and provide a comprehensive understanding of how high-tech certification influences green innovation strategies.

To summarize, this paper focuses on analyzing the influence of high-tech certification on enterprises' substantive and strategic green innovations. By utilizing data from Chinese listed companies between 2006 and 2023, and accounting for the characteristics of the dependent variables, this study employs a zero-inflated negative binomial regression model to investigate the impact of high-tech certification on green innovation strategies, as well as its underlying mechanisms and heterogeneous effects.

The marginal contributions of this paper are primarily reflected in the following aspects. (1) From a research perspective, existing literature primarily focuses on the impact of high-tech enterprise qualification on traditional growth attributes such as total factor productivity (Pang et al., 2024) and export product quality (Chen and Chen, 2022). Although a limited number of studies have explored the effect of high-tech enterprise qualification on technological innovation and green innovation (Tang et al., 2023; Liang et al., 2025), these studies tend to be overly general and often fail to thoroughly examine the effectiveness and multidimensional nature of innovation. Specifically, corporate innovation behavior encompasses both substantive technological breakthroughs and more superficial innovations driven by strategic adjustments, such as optimizing operations or entering new markets. By distinguishing between substantive and strategic innovation, this paper systematically analyzes the driving effect of high-tech enterprise qualification on corporate green innovation. This approach not only enriches the existing literature on technological innovation and growth effects but also provides a novel theoretical perspective on green innovation. Furthermore, it contributes to a deeper understanding of the complexity inherent in green innovation. (2) In terms of research methodology, this paper employs the negative binomial regression model to empirically examine the driving effect of high-tech enterprise qualification on corporate green innovation. Although the difference-in-differences (DID) method is frequently utilized in the existing literature to assess the impact of high-tech enterprise qualification on firms (Chen and Kim, 2024; Dai and Wang, 2019), it is important to note that corporate green innovation is a count variable whose data do not meet the normal distribution assumption required by the OLS regression model (Schober and Vetter, 2021). Additionally, due to significant variations in the emphasis placed on green innovation across different firms, the data exhibit substantial overdispersion. In this context, the OLS regression model faces inherent limitations in applicability. Conversely, the negative binomial regression model is better suited to address these issues, as it introduces an additional dispersion parameter that effectively models the variance in the data, accommodating situations where the mean and variance are unequal. Consequently, the negative binomial regression model provides a more accurate fit for count data with high variance, thereby improving the model's reliability and robustness. Particularly when green innovation is measured using the number of green patent applications, the negative binomial regression method outperforms the traditional DID approach, as it more precisely captures the influence of high-tech enterprise qualification on green innovation. Therefore, the methodological approach adopted in this paper offers a more appropriate empirical analysis framework, allowing for a more accurate measurement of the role of high-tech enterprise qualification in fostering both

strategic and substantive green innovation. (3) From the perspective of an internal and external multi-factor system, this paper systematically analyzes the transmission pathways through which high-tech enterprise qualification influences corporate green innovation. Existing studies typically examine the impact of high-tech enterprise qualification on corporate behavior by focusing on a single external factor, such as government policies or the macroeconomic environment (Shan et al., 2018; Gregoire and Shepherd, 2012). In contrast, this paper not only highlights the role of external factors, such as government interventions, but also incorporates the influence of relevant stakeholders, including financial institutions and capital markets. It develops a comprehensive analytical framework that encompasses four channels: tax incentives, government subsidies, alleviation of financing constraints, and increased attention from capital markets. By integrating external policy incentives with the internal innovation motivations of enterprises, this paper deepens the understanding of the effects of high-tech enterprise qualification and uncovers its complex impact on green innovation through multiple pathways. This perspective not only expands the research scope of the existing literature but also provides a more nuanced theoretical foundation and practical guidance for policymakers and business managers.

The structure of this paper is organized as follows: chapter 2 presents the policy background and theoretical framework; chapter 3 outlines the research design; chapter 4 conducts an empirical analysis; and chapter 5 summarizes the findings, aside from providing policy recommendations and outlining future research directions.

2 Policy background and theoretical analyses

2.1 Policy background

The Chinese government has placed significant emphasis on the support of high-tech enterprises and has promulgated a series of policies, among which the core document is the "Administrative Measures for the Recognition of High-tech Enterprises." This policy document has undergone five major development phases.

- (1) During the Early Period of Reform and Opening Up (1978–1988): In 1978, China initiated extensive engagements with developed countries. Government leadership gradually recognized and reached consensus on the significant technological gap between China's high-tech industry and that of advanced foreign nations. Therefore, corresponding policy support needed to be in place for high-tech enterprises. For this purpose, the State Council released the "Outline of the National Science and Technology Development Plan from 1978 to 1985," proposing to attract foreign capital and to encourage domestic enterprises to transform in order to cultivate high-tech enterprises (Poo and Wang, 2015).
- (2) Establishment of Zhongguancun High-tech Industrial Park (1988): Through the economic development from 1978 to 1988, a batch of high-tech enterprises with development

potential had been cultivated in Beijing. To offer these enterprises special policy support, in 1988 the Beijing Municipal Government, upon the approval of the State Council, established the Zhongguancun High-tech Industrial Park. To attract high-tech enterprises to settle down in the park, the Beijing Municipal Government promulgated specialized documents, providing supportive policies including talent residency, bank loans, government subsidies, tax exemptions and preferential land supply. As a national-level high-tech development zone, Zhongguancun incubated a large number of high-quality enterprises within a short time span. After its example, other local governments followed suit in quick succession. Various types of high-tech parks were subsequently established nationwide, and local governments introduced region-specific preferential policies (Zhu and Tann, 2005).

- (3) The Formation of the Policy System (1991): In 1991, the central government concluded the initiatives by summarizing the experience and lessons learnt from establishing the various high-tech parks, and in an effort to direct future industrial development, promulgated the “Conditions and Measures for the Recognition of High-tech Enterprises in National High-tech Industrial Development Zones.” This document focused on enterprises within national-level high-tech parks, selected eight industries including information technology and new energy, and awarded high-tech enterprise certification to those enterprises that met the standards based on sales revenue and research and development expenses. This policy document signified that high-tech enterprise certification received governmental endorsement nationwide, significantly helping enhance the credibility of enterprises (Yan et al., 2024).
- (4) Policy popularization (2008): Between 1991 and 2008, domestic high-tech enterprises experienced significant growth, with a substantial number of promising enterprises emerging outside the parks. In response to the global financial crisis, traditional industries faced significant export challenges, which highlighted the urgent need to prioritize the development of high-tech industries within the country. In 2008, the Ministry of Science and Technology, in collaboration with the Ministry of Finance and the State Taxation Administration, jointly issued the “Administrative Measures for the Recognition of High-tech Enterprises.” Key features of these measures are: Recognizing enterprises outside national high-tech development zones for the first time, and encouraging local governments to formulate corresponding supportive policies; Easing application standards and industry restrictions for enterprises; Clarifying preferential tax policies, setting income tax rate for qualified enterprises at 15%, in contrast with 25% for general enterprises. This measure significantly relieved cash flow pressure on enterprises (Liu et al., 2020).
- (5) Introduction of Special Support Policies (2016): In 2016, the Ministry of Science and Technology, in collaboration with other relevant departments, revised the “Administrative Measures for the Recognition of High-tech Enterprises” once again. The revision further relaxed standards for the recognition of high-tech enterprise certification, specifically

by introducing special support policies for small and medium-sized enterprises (SMEs). This adjustment aimed to lower entry threshold for SMEs, encourages greater participation in high-tech innovation, thereby facilitating industrial upgrading and economic transformation nationwide.

To sum up, the optimization and refinement of high-tech enterprise certification policy not only facilitate technological innovation of enterprises at the policy level but also offer the academic community abundant research domains and theoretical development opportunities.

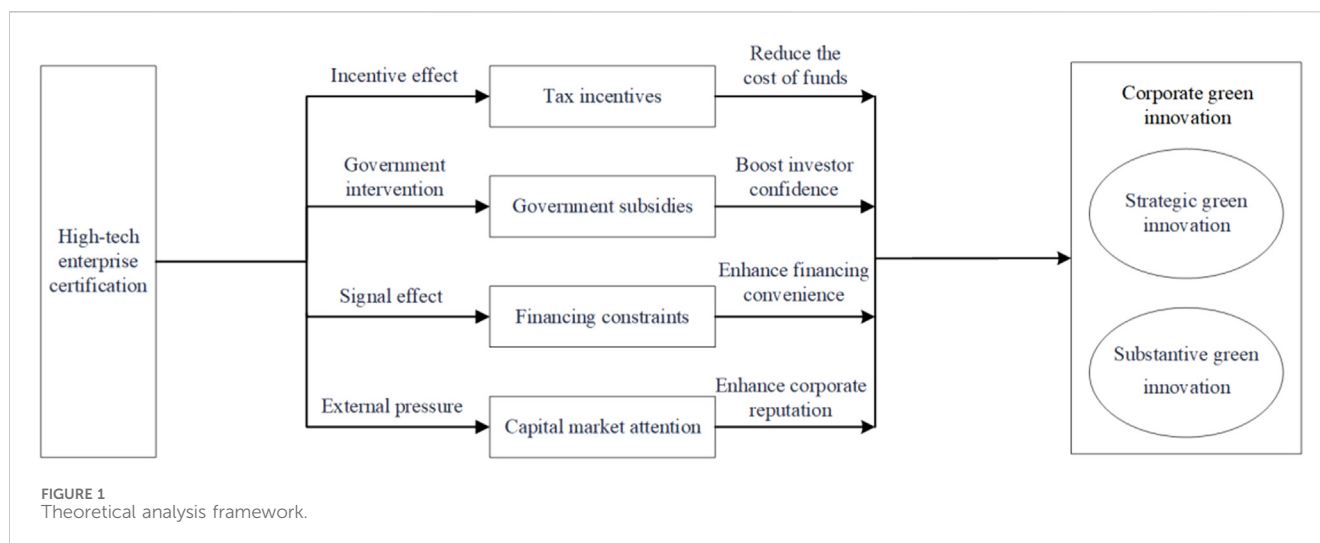
2.2 Theoretical analysis and research hypotheses

Under the current policy environment, the government has introduced a series of supportive policies for enterprises that have obtained high-tech certification. Concurrently, the state places significant emphasis on green transformation of the economy and has established corresponding social responsibility requirements for high-tech enterprises, highlighting their critical role in actively contributing to the country’s green transformation (Liu et al., 2020). As a result, high-tech certification not only influences enterprise R&D investment but also facilitates green technological innovation (Chen et al., 2023). This paper provides a comprehensive analysis of the impact of high-tech certification on substantive and strategic green innovations from two perspectives: direct effects and action mechanisms. Specifically, these action channels include tax preferences, government subsidies, financing constraints, and capital market attention. The research framework is illustrated in Figure 1.

2.2.1 The direct impact of high-tech certification on enterprises’ green innovation

According to the Resource-Based View (RBV) theory, the capabilities of an enterprise originate from its accessible resources. Hence, the green innovation capabilities of an enterprise are closely associated with its resource foundation (Barney, 1991). High-tech certification, as a strategic resource for enterprises, is both authoritative and scarce. Enterprises have to meet rigorous standards to acquire them. This certification not only represents government endorsement (Bitektine, 2011) but also conveys positive signals to the external environment, assisting enterprises in obtaining external support such as banks and venture capital investment, thereby facilitating R&D activities and promoting greener innovations (Dai and Wang, 2019).

However, an issue of information asymmetry exists between the government and enterprises (Millar et al., 2012). On one hand, when allocating resources to enterprises, the government sets fundamental requirements for their green innovation performance. On the other hand, enterprises face significant challenges in green innovation: substantive green innovation, as opposed to strategic green innovation, demands more resources and a longer R&D cycle, and entails a higher risk of failure (Bi et al., 2024). Hence, under the constraints of internal



resources and the asymmetry of external information from the government's side, enterprises have more incentive to engage in policy arbitrage. Furthermore, there is internal agency risk within companies to consider. In pursuit of performance the management tends to prioritize the quantity of innovation at the expense of its quality exploiting investors' lack of information (Jia et al., 2019), thereby giving rise to the emergence of a green patent bubble.

Based on the above, we put forward the following hypothesis:

Hypothesis 1: High-tech certification is capable of promoting enterprises' green innovation, and the promoting effect on strategic green innovation is greater than that on substantive green innovation.

2.2.2 The mechanism of tax

Based on Chinese legal provisions, enterprises can enjoy preferential tax rates upon obtaining high-tech certification, thereby alleviating their tax burden. Saved funds can be redirected toward green innovation initiatives (Wang H. et al., 2024). Jia and Ma (2017) analysed data from Chinese listed companies between 2007 and 2013, demonstrating that tax preferences can effectively encourage corporate R&D expenditure. Since tax preference to high-tech enterprises is a right explicitly stipulated by national law, enterprises have no motivation for policy arbitrage. In addition, in accordance with the current tax law, R&D expenses of enterprises can be deducted from taxable income. The greater the R&D expenses are, the larger the amount of tax that can be deducted. By definition, substantial green innovation demands a longer R&D cycle and higher investment. Institutional rationalization of corresponding R&D expenses effectively incentivizes enterprises to undertake significant green innovation initiatives.

Based on the above, we put forward the following hypothesis:

Hypothesis 2: High-tech certification enhances green innovation capacity of enterprises by reducing their tax burden, and the promoting effect of tax preferences on substantive green innovation is greater than that on strategic green innovation.

2.2.3 The mechanism of government subsidy

High-tech certification enhances the competitive advantage of enterprises, thereby facilitating them to obtain more government subsidies. These subsidies can effectively alleviate the issue of financial shortage for enterprises in green innovation (Shao and Chen, 2022). Generally, the stronger the fiscal autonomy of local governments is, the greater the amount of subsidies granted to enterprises will be. Hence, government subsidies are to some extent an unstable source of income for enterprises. Nevertheless, substantive green innovation demands a considerable amount of resources and long-term stable investment. Therefore, only when government subsidies reach a certain scale and last for a duration of time can they significantly help enhance innovation efficiency of enterprises (Wu et al., 2024). Ying et al. (2023) examined the impact of government R&D subsidies on Chinese new energy listed companies and found that enterprises often exploit loopholes in the subsidy system and the inadequate review capabilities of officials, thereby prioritizing strategic green innovation.

Based on the above, we put forth the following hypothesis:

Hypothesis 3: High-tech certification facilitates enterprise green innovation by augmenting government subsidies, and the facilitating effect of government subsidies on strategic green innovation is greater than that on substantive green innovation.

2.2.4 The mechanism of financing constraints

High-tech certification of enterprises effectively boosts their political connectivity, reduces tax burdens and augments government subsidies (Cheng et al., 2019). Government subsidies not only enhance the creditworthiness of enterprises (Meuleman and Maeseneire, 2012), but also convey positive signals to venture capitalists, thereby escalating financing opportunities for enterprises (Wu, 2017). In regions where the credit system is defective, governmental certification and endorsement significantly heighten the likelihood of enterprises obtaining bank loans (Li et al., 2019). Consequently, high-tech certification contributes to alleviating financing constraints on enterprises.

From the perspective of financial institutions such as banks, which operate in a more market-oriented mode, banks have a more

pronounced motivation than the government to evaluate the green innovation strategies of enterprises and determine whether to provide financing. Therefore, although substantive green innovation requires a longer R&D cycle, it can assist enterprises in gaining a competitive edge over their counterparts (Jiang and Bai, 2022). Consequently, as the financing constraints on enterprises are alleviated, they are more likely to opt for substantive green innovation to secure long-term financing advantages.

Based on the above, we put forth the following hypothesis:

Hypothesis 4: High-tech certification facilitates enterprise green innovation by alleviating financing constraints, and the facilitating effect on substantive green innovation is greater than that on strategic green innovation.

2.2.5 The mechanism of capital market attention

The attainment of high-tech certification demands that enterprises fulfil certain requirements. Hence, obtaining such certification can enhance an enterprise's visibility in the capital market (Min et al., 2022). The influence of the capital market on an enterprise's green innovation presents a complex pattern. On one hand, at present, corporate social responsibility and ESG performance are the focus of attention in the capital market. Negative information can directly impact an enterprise's reputation and stock price. Thus, the attention from the capital market can exert external pressure to push enterprises to undertake green innovation (Spyros, 2022; Nguyen et al., 2023). On the other hand, the current Chinese capital market is relatively deficient in long-term investors and is inundated with short-term investors who require enterprises to continuously provide stock price promoting news. When comparing substantive green innovation and strategic green innovation, enterprises tend to select strategic green patents that have lower costs and are equally capable of signifying to the capital market within a short period (Ji et al., 2021). Short-term arbitrageurs in the capital market often utilize such information for securities speculation and short-term arbitrage. In contrast, substantive green innovation requires a longer period to release information to the capital market and has a higher risk of R&D failure (Ning, 2018). Therefore, though pressure from the capital market can promote enterprise green innovation, the scarcity of long-term value investors in the market may contribute to the formation of a green patent bubble.

Based on the above, this study puts forward the following hypothesis:

Hypothesis 5: High-tech certification facilitates enterprise green innovation by heightening attention from the capital market, and the facilitating effect on strategic green innovation is greater than that on substantive green innovation.

3 Data and model setup

3.1 Source of data

We examine the impact of high-tech enterprise certification on both substantive and strategic green innovation through an empirical analysis of data from Chinese A-share listed companies

spanning 2006 to 2023. Green innovation data are sourced from the CNRDS database, whereas data on high-tech enterprise certification, control variables, and mediating variables are obtained from the CSMAR database. To guarantee the accuracy of the research findings, the data underwent rigorous screening and cleaning: Firstly, company samples that have been marked as ST, *ST, or PT in the securities market were eliminated. Secondly, companies at the brink of financial warning, namely those with liabilities exceeding assets, negative operating profits or net profits, and those relying on government tax rebates for operation (indicated by negative taxes), were excluded. Finally, the impact of financial factors was mitigated by removing the samples of companies listed on both A and B shares. Furthermore, the control variables and mediating variables were subjected to winsorization to mitigate the potential impact of extreme values on the analysis results. We use the number of green patent applications filed by listed companies as an indicator to measure corporate green innovation.

3.2 Variables

The dependent variable in this study is enterprise green innovation. Following the research of Zhao and Sun (2025) and Zhang et al. (2024), we use the number of green invention patent applications to measure substantive green innovation and the number of green utility model patent applications to measure strategic green innovation (Zhao and Sun, 2025; Zhang et al., 2024). In subsequent robustness tests, we employ the number of granted patents for analysis.

In this study, the independent variable is whether an enterprise acquires high-tech enterprise certification. Drawing on She et al. (2022), based on data from the CSMAR database, if a listed company is approved by the National High-tech Enterprise Certification Group, this variable is set to 1 in the year of approval and subsequent years. Otherwise, it is set to 0. With reference to the research of Liu et al. (2020) and Chen et al. (2023), we employ the following indicators to measure the distinct features of enterprises: the sustainable growth rate (Growth), which is utilized to evaluate the development potential of enterprises; the shareholding ratio of the top ten shareholders (Shareholder_ten), which is employed to measure the equity concentration of enterprises; the price-to-book ratio (PB), which is used to reflect the valuation expectations of the capital market for listed companies; the enterprise age (Age), which is adopted to measure the operating years of enterprises; the debt-to-asset ratio (Lev), which is utilized to measure the financial leverage level of enterprises; the total asset turnover (Tato), which is employed to measure the operating efficiency of enterprises. Referring to existing studies (Lu and Cheng, 2024; Li et al., 2023; Abbas et al., 2023; Wang et al., 2024b), we investigate its mechanism of action from the following four aspects. (1) Tax Incentives: tax reduction policies enjoyed by enterprises are measured by tax rate (Lu and Cheng, 2024); (2) Subsidy: it refers to direct financial support that enterprises obtain from the government, represented by the total amount of government subsidies specified in financial statements of the current year (Li et al., 2020); (3) Financing constraints: it reflects the degree of difficulty for enterprises to obtain financial support from financial institutions (such as banks), and is characterized by the cash flow ratio (Abbas et al.,

TABLE 1 Descriptive statistics of the main variables.

Variable	Obs	Mean	Std. Dev	Min	Max
<i>Pat_green_invent</i>	39,715	2.245	12.301	0.000	565.000
<i>Pat_green_utility</i>	39,715	1.871	8.721	0.000	443.000
<i>High_Tech_Certification</i>	41,495	0.641	0.480	0.000	1.000
<i>Growth</i>	41,482	0.078	1.144	−208.870	98.694
<i>Shareholder_ten</i>	40,658	60.241	15.535	4.453	100.020
<i>PB</i>	39,485	3.669	14.578	0.000	2788.704
<i>Age</i>	41,486	18.475	6.403	1.000	66.000
<i>Lev</i>	41,421	0.404	0.203	0.007	0.979
<i>Tato</i>	41,417	0.640	0.511	0.003	11.345
<i>Tax_ratio</i>	41,458	0.038	0.051	0.000	4.316
<i>Gov_Subsidy</i>	22,596	0.022	0.087	−0.053	3.116
<i>FC</i>	34,651	0.509	0.270	0.000	0.997
<i>ACM</i>	29,092	19.706	24.558	1.000	298.000

2023); (4) Attention in capital markets (ACM): the popularity of enterprises in the capital market is measured by the frequency of analysis of enterprises in research reports of financial institutions (Wang et al., 2024a).

The data of the mediating variables are derived from the CSMAR database, and the descriptive statistics of the main variables are presented in Table 1.

3.3 Model setup

The dependent variables in this paper are substantive green innovation and strategic green innovation of enterprises, measured by the number of green invention patent applications and the number of green utility patent applications, respectively. Given that these dependent variables are typical count data, count models are preferred for analysis. Common count models include Poisson regression model and negative binomial regression model. The dependent variables in this study exhibit two key characteristics: First, the variance of the dependent variables significantly exceeds the mean, indicating an over-dispersed distribution; second, there is a substantial number of zero values in the dependent variables (Endawkie et al., 2024; Zhou et al., 2024; Zhang et al., 2024). Based on these characteristics, we prioritize the zero-inflated negative binomial regression model. The specific settings are as follows:

$$\begin{aligned} Pat_green_invent_{it} = & \alpha_0 + \alpha_1 High_Tech_Certification_{it} \\ & + \delta Control_{it} + \mu_t + \varphi_i + \varepsilon_{it} \end{aligned} \tag{1}$$

$$\begin{aligned} Pat_green_utility_{it} = & \alpha_0 + \alpha_1 High_Tech_Certification_{it} \\ & + \delta Control_{it} + \mu_t + \varphi_i + \varepsilon_{it} \end{aligned} \tag{2}$$

In Equations 1, 2, The subscript *i* represents the code of the listed company in the A-share market, and the subscript *t* represents the corresponding year of the listed company. *Pat_green_invent* denotes substantive green innovation, measured by the number of

applications for green invention patents; *Pat_green_utility* indicates strategic green innovation, measured by the number of applications for green utility patents. The variable is employed to measure whether the enterprise has obtained certification of a high-tech enterprise. If it has, it is set to 1; otherwise, it is set to 0. In the model, *Control_{it}* represents control variables, μ_t is utilized to measure time fixed effects, φ_i represents firm fixed effects, and ε_{it} is the random error term.

4 Empirical examination

4.1 Benchmark testing

The benchmark testing outcomes of this study are summarized in Table 2. Columns 1 and 2 report the regression results for Equation 1, showing the effect of high-tech certification on substantive green innovation. Columns 3 and 4 report the regression results for Equation 2, showing the effect of high-tech certification on strategic green innovation. Regression results indicate that the coefficient of *High_Tech_Certification* is positive and significant at the 1% level, suggesting a substantial promoting effect of high-tech certification on enterprises' green innovation. Further comparison of the coefficients reveals that the promoting effect on strategic green innovation is notably greater than that on substantive green innovation. This finding suggests the potential presence of green patent bubbles within enterprises. Specifically, high-tech certification can offer enterprises tax preferences, government subsidies, and can help alleviate their financing constraints and enhance their visibility in the capital market. These policy benefits will stimulate green innovation competition among enterprises, thereby augmenting the quantity of green patents held by enterprises. From individual enterprise's perspective, on the one hand, they will try to balance the costs and benefits of green innovation: substantive green innovation involves

TABLE 2 Baseline regression result.

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.448***	0.620***	0.492***	0.685***
	(0.011)	(0.012)	(0.013)	(0.014)
Growth		0.261***		0.419***
		(0.019)		(0.018)
Shareholder_ten		0.006***		0.008***
		(0.000)		(0.000)
PB		−0.020***		−0.043***
		(0.001)		(0.002)
Age		0.016***		−0.007***
		(0.001)		(0.001)
Lev		2.311***		2.751***
		(0.019)		(0.022)
Tato		−0.076***		−0.197***
		(0.007)		(0.010)
N	39715	39194	39715	39194
LR_chi2 (1)	1829.57	20622.47	1691.29	20333.86

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

higher R&D costs, longer durations, and greater risks, while strategic green innovation has lower R&D costs, shorter periods, and smaller risks; on the other hand, enterprises will exploit their information advantage over the government and give priority to the development of strategic green innovation to obtain more policy support. Hence, although high-tech certification facilitates green innovation, they may also trigger a green patent bubble (Xue et al., 2024). Therefore, Hypothesis 1 is verified.

From the aspect of control variables, the coefficient of the enterprise’s sustainable growth rate (Growth) is significantly positive and highly significant at the 1% level. This suggests that the higher the growth rate of an enterprise is, the more optimistic the external expectations for its future, thereby enhancing the enterprise’s financing capacity and enabling it to acquire more resources for research and development (He, 2021). On the other hand, enterprises will plan green innovation based on future development trends. The more optimistic future development prospects are, the greater the emphasis enterprises will place on green innovation. To maintain external information transparency and market image, enterprises will give priority to the development of strategic green patents. The coefficient of enterprise equity concentration (Shareholder_ten) is also significantly positive and highly significant at the 1% level. Given the high-risk nature of green innovation investment, internal consensus is essential. Higher equity concentration enhances the supervisory role of major shareholders over management, thereby reducing agency costs and facilitating internal consensus within individual enterprise (Zhang and Zhang, 2022). Under the current guidance of green policies, this consensus is more likely to align with policy objectives and promote green

innovation. Moreover, in the face of limited resources, enterprises prioritize strategic green innovation to promptly respond to policy demands. The coefficient of the enterprise’s age (Age) is also significantly positive and highly significant at the 1% level. This indicates that the longer the operating years of a company are, the more experience it accumulates in research and development and the stronger its financing ability (Yang et al., 2023). Against this backdrop, enterprises will pay greater attention to future development and tend to focus on substantive green innovation, while relatively reducing investment on strategic green innovation.

4.2 Robustness tests

4.2.1 Replacing the explained variable

To ensure the robustness of the research findings, firstly, considering that the explained variable is the number of applications for green patents, in this paper the explained variable is replaced and the number of granted green patents is used for analysis. From patent application to authorization, it needs to undergo the review of relevant government departments, and this process encounters two major issues: one is that the review period is relatively long, especially for patent applications of complex technologies; the other is that not all patent applications can be granted. Therefore, in this paper, the number of granted patents lagged by 1 year is employed as the outcome variable for regression analysis. In conjunction with the data analysis in Table 3, it can be observed that among the strategic green patent applications submitted by enterprises, a considerable proportion ultimately

TABLE 3 Replace the explained variable.

	(1)	(2)	(3)	(4)
	Pat_green_invent_grant01	Pat_green_invent_grant01	Pat_green_utility_grant01	Pat_green_utility_grant01
High_Tech_Certification	1.091***	1.370***	0.626***	1.080***
	(0.067)	(0.052)	(0.023)	(0.024)
Growth		1.100***		1.299***
		(0.088)		(0.040)
Shareholder_ten		0.003***		0.006***
		(0.001)		(0.000)
PB		−0.043***		−0.083***
		(0.004)		(0.002)
Age		0.015***		0.002**
		(0.001)		(0.001)
Lev		2.068***		2.809***
		(0.046)		(0.026)
Tato		−0.267***		−0.207***
		(0.020)		(0.011)
N	32013	31618	32013	31618
LR_chi2 (1)	326.85	3362.96	1015.43	17924.38

TABLE 4 Poisson method.

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	1.434*** (0.011)	1.653*** (0.011)	1.457*** (0.012)	1.766*** (0.012)
Growth		0.069*** (0.005)		0.114*** (0.005)
Shareholder_ten		0.006*** (0.000)		0.008*** (0.000)
PB		−0.048*** (0.001)		−0.078*** (0.002)
Age		0.027*** (0.001)		0.001** (0.001)
Lev		3.116*** (0.018)		3.437*** (0.020)
Tato		−0.090*** (0.007)		−0.155*** (0.008)
N	39715	39194	39715	39194
r2	0.0544	0.1445	0.0606	0.1700

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

failed to obtain patent authorization. This suggests that enterprises may be inclined to leverage the policy advantages brought by the certification of high-tech enterprises, resulting in the occurrence of the green patent bubble phenomenon.

4.2.2 Changing the regression model

From the perspective of the dependent variable, the number of green patent applications is a typical count data. Therefore, in the robustness analysis, we substituted the original zero-inflated negative binomial regression model with a Poisson regression model for examination (Gu et al., 2025). Results are presented in Table 4. The results indicate that coefficient of the core explanatory variable High_Tech_Certification is positive and significant at the 1% level, suggesting that high-tech certification has a significant promoting effect on enterprises’ green innovation. By comparing columns 1 and 3 with columns 2 and 4, we find that the impact of high-tech certification on strategic green innovation is greater than that on substantive green innovation, and this conclusion is confirmed in the robustness test.

4.2.3 Instrumental variable method

Drawing on Wang et al. (2022b), this study conducts a robustness test by altering the dependent variable. Specifically, the natural logarithm of the number of patent applications plus one is used to measure green innovation. The instrumental variable approach requires selecting appropriate instrumental variables from the control variables. From an enterprise perspective, the asset-liability ratio reflects financial leverage and risk, thereby influencing growth rate, price-to-book ratio, and total asset turnover. Therefore,

the lagged one-period and two-period asset-liability ratios are utilized as instrumental variables in this study. Results are presented in Table 5, where Columns 1 and 3 use the system GMM regression method, and Columns 2 and 4 employ the panel instrumental variable method. The results indicate that coefficient of the core explanatory variable High_Tech_Certification is positive and significant at the 1% level. Moreover, the promoting effect of high-tech certification on strategic green innovation is stronger than that on substantive green innovation, confirming this conclusion in the robustness test.

4.2.4 PSM-DID method

Referring to the study of Ye et al. (2024), we adopt the PSM-DID approach for robustness analysis. Results after data matching are depicted in Figures 2, 3. Outcomes of the PSM-DID approach are presented in Table 6. The results reveal that coefficient of the core explanatory variable, High_Tech_Certification, is positive and significant at the 1% level. Furthermore, the promoting effect of high-tech Certification on strategic green innovation is stronger than that on substantive green innovation, suggesting that the benchmark regression results exhibit considerable robustness.

4.3 Placebo test

In this paper, a placebo test is carried out by establishing virtual policies. Specifically, samples are randomly selected from the data to generate virtual policies, and this process is repeated 500 times to obtain corresponding policy coefficients (Xiao et al., 2023; Duan

TABLE 5 Instrumental variable method.

	(1)	(2)	(3)	(4)
	LnPat_green_invent	LnPat_green_invent	LnPat_green_utility	LnPat_green_utility
High_Tech_Certification	0.552***	0.086***	0.570***	0.161***
	(0.011)	(0.021)	(0.011)	(0.022)
Growth	0.315**	−0.017	0.346**	0.098**
	(0.120)	(0.038)	(0.143)	(0.040)
Shareholder_ten	0.001**	0.003***	0.001***	0.003***
	(0.000)	(0.001)	(0.000)	(0.001)
PB	−0.011***	−0.002	−0.020***	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Age	0.009***	0.055***	0.005***	0.044***
	(0.001)	(0.001)	(0.001)	(0.001)
Lev	1.004***	0.382***	1.054***	0.386***
	(0.032)	(0.065)	(0.032)	(0.066)
Tato	−0.033***	−0.015	−0.036***	−0.012
	(0.009)	(0.018)	(0.009)	(0.016)
N	26532	26005	26532	26005
r2	0.093	0.129	0.109	0.101

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

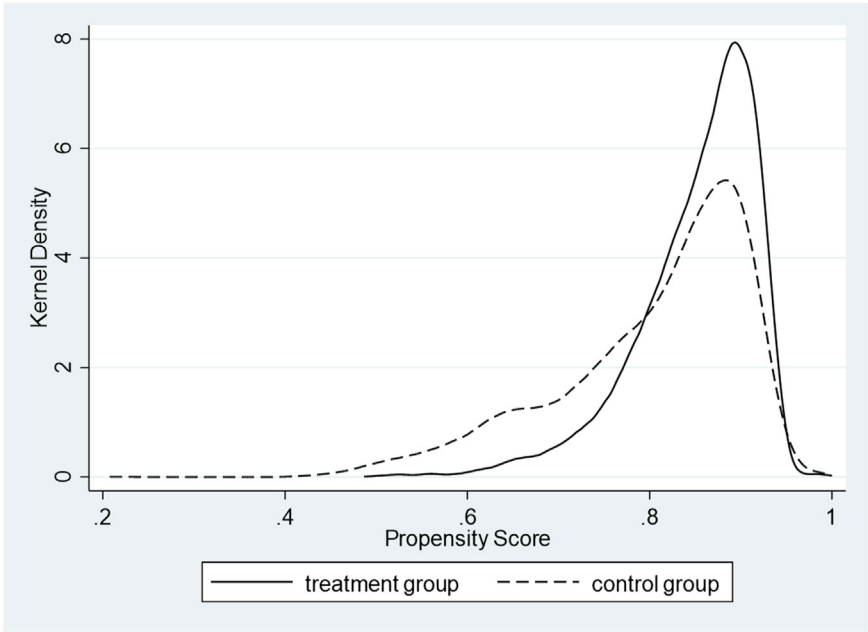


FIGURE 2
PSM-DID (LnPat_green_invent).

et al., 2023). Figure 4 displays the placebo test results for substantive green innovation, while Figure 5 presents those for strategic green innovation. The outcomes reveal that coefficients of the virtual policies show a normal distribution and significantly differ from the actual policy coefficients, further verifying the validity of the placebo test.

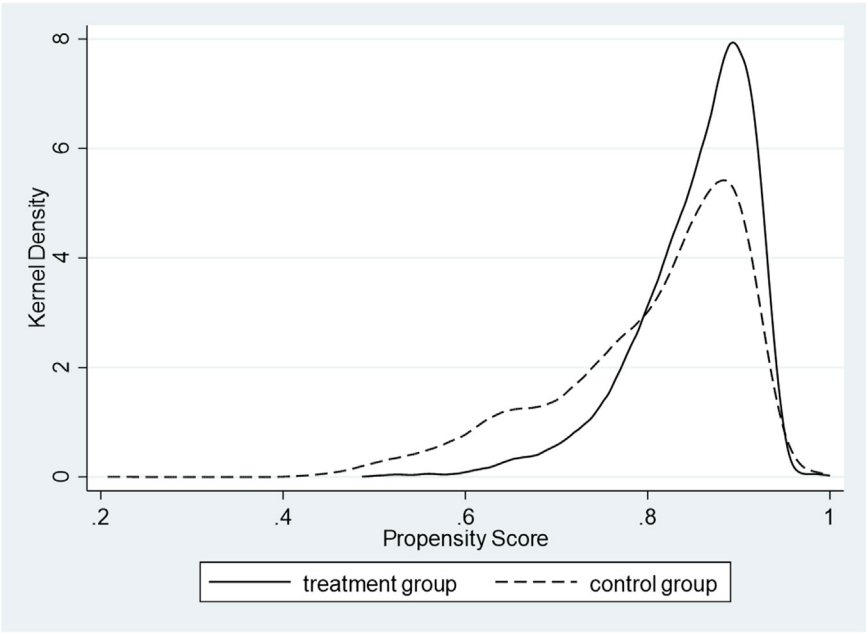


FIGURE 3
PSM-DID (LnPat_green_utility).

TABLE 6 PSM-DID method.

	(1)	(2)	(3)	(4)
	LnPat_green_invent	LnPat_green_invent	LnPat_green_utility	LnPat_green_utility
High_Tech_Certification	0.064***	0.064***	0.098***	0.098***
	(0.013)	(0.013)	(0.013)	(0.013)
Growth	−0.018	−0.012	0.061**	0.066**
	(0.026)	(0.026)	(0.028)	(0.028)
Shareholder_ten	0.002***	0.002***	0.003***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
PB	−0.004***	−0.004***	−0.005***	−0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
Age	0.048***	0.048***	0.042***	0.042***
	(0.002)	(0.002)	(0.002)	(0.002)
Lev	0.276***	0.277***	0.318***	0.319***
	(0.050)	(0.050)	(0.050)	(0.049)
Tato		−0.022		−0.020
		(0.023)		(0.020)
N	39157	39157	39157	39157
r2	0.139	0.139	0.121	0.121

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

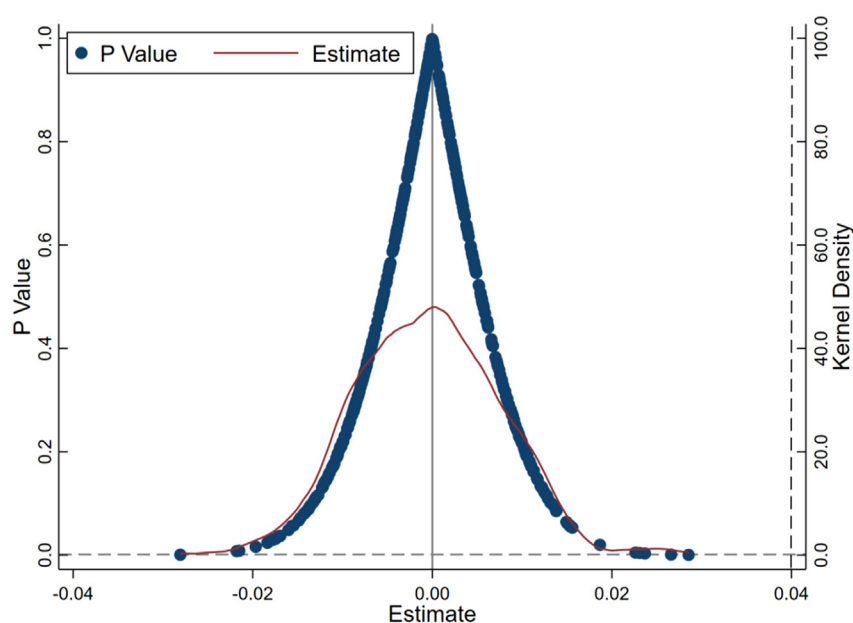


FIGURE 4
Placebo test (lnPat_green_invent).

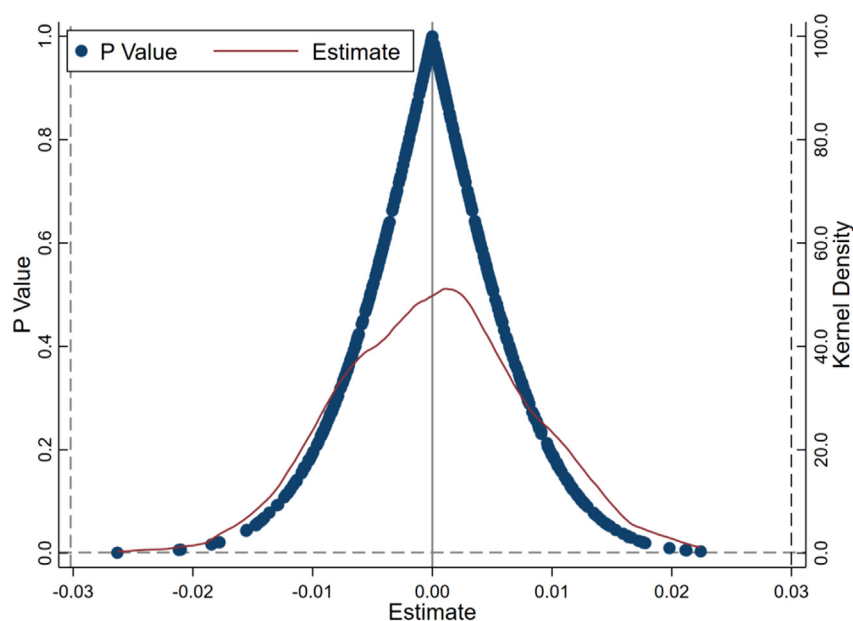


FIGURE 5
Placebo test (lnPat_green_utility).

4.4 Mechanism analysis

4.4.1 The mechanism of tax

The impact mechanism of tax rates is summarized in Table 7. In accordance with national laws and regulations, enterprises obtaining high-tech certification are eligible for preferential tax policies. Columns 1 and 2 of Table 7 reveal that high-tech certification significantly lowers the tax rate of enterprises. Columns 3 and

4 present the influence of tax rates on substantive green innovation, while columns 5 and 6 show the impact of tax rates on strategic green innovation. The results demonstrate that reduced tax rate can effectively promote green innovation. By comparing the various coefficients, it is observed that the promoting effect of reduced tax rate on substantive green innovation is stronger than that on strategic green innovation. This finding suggests that the guiding role of tax rates on green innovation has a favorable impact

TABLE 7 Mechanism test (Tax_ratio).

	(1)	(2)	(3)	(4)	(5)	(6)
	Tax_ratio	Tax_ratio	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	−0.010***	−0.011***				
	(0.001)	(0.001)				
Tax_ratio			−2.232***	−2.829***	−0.788***	−1.784***
			(0.124)	(0.137)	(0.122)	(0.151)
Growth	0.002***	0.003***	0.263***	0.299***	0.367***	0.437***
	(0.000)	(0.000)	(0.019)	(0.018)	(0.018)	(0.017)
Shareholder_ten	0.000***	0.000***	0.004***	0.004***	0.006***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PB	0.000**	0.000**	−0.019***	−0.019***	−0.040***	−0.040***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)
Age	0.000***	0.000***	0.018***	0.018***	−0.003***	−0.003***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Lev	−0.012***	−0.005**	2.114***	2.135***	2.546***	2.588***
	(0.002)	(0.002)	(0.019)	(0.019)	(0.022)	(0.022)
Tato		−0.022***		−0.096***		−0.218***
		(0.001)		(0.008)		(0.010)
N	39413	39413	39172	39172	39172	39172
r2	0.036	0.100				
LR chi2 (6)			17824.81	17993.42	16955.67	17484.69

TABLE 8 Mechanism test (Gov_Subsidy).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gov_Subsidy	Gov_Subsidy	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.006***	0.006***				
	(0.001)	(0.001)				
Gov_Subsidy			0.840***	0.836***	0.732***	0.752***
			(0.013)	(0.013)	(0.014)	(0.014)
Growth	0.000	0.000	0.593***	0.581***	1.004***	1.106***
	(0.001)	(0.001)	(0.035)	(0.035)	(0.043)	(0.041)
Shareholder_ten	0.000***	0.000***	0.004***	0.004***	0.006***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PB	−0.000	−0.000	−0.009***	−0.009***	−0.062***	−0.062***
	(0.000)	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)
Age	−0.001***	−0.001***	0.034***	0.034***	0.005***	0.004***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Lev	0.048***	0.048***	1.853***	1.841***	2.363***	2.410***
	(0.003)	(0.003)	(0.026)	(0.026)	(0.028)	(0.028)
Tato		0.000		0.043***		−0.274***
		(0.001)		(0.009)		(0.012)
N	22195	22195	22176	22176	22176	22176
r2	0.0215	0.0215				
LR chi2 (6)			13888.05	13908.53	13538.50	14070.01

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 9 Mechanism test (FC).

	(1)	(2)	(3)	(4)	(5)	(6)
	FC	FC	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	−0.014*** (0.003)	−0.013*** (0.003)				
FC			−2.585*** (0.020)	−2.588*** (0.020)	−1.932*** (0.021)	−1.948*** (0.021)
Growth	−0.000 (0.001)	−0.000 (0.001)	−0.107*** (0.030)	−0.077** (0.027)	0.201*** (0.023)	0.274*** (0.022)
Shareholder_ten	−0.001*** (0.000)	−0.001*** (0.000)	−0.003*** (0.000)	−0.003*** (0.000)	0.002*** (0.000)	0.002*** (0.000)
PB	0.000 (0.000)	0.000 (0.000)	0.022*** (0.001)	0.022*** (0.001)	−0.002 (0.001)	−0.002 (0.001)
Age	−0.013*** (0.000)	−0.013*** (0.000)	0.003*** (0.001)	0.003*** (0.001)	−0.011*** (0.001)	−0.011*** (0.001)
Lev	−0.596*** (0.007)	−0.600*** (0.007)	0.299*** (0.023)	0.322*** (0.023)	1.061*** (0.027)	1.104*** (0.027)
Tato		0.025*** (0.003)		−0.069*** (0.007)		−0.224*** (0.010)
N	34643	34643	34430	34430	34430	34430
r2	0.2922	0.2909				
LR chi2 (6)			33910.42	34001.25	24851.72	25440.87

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

on enterprises, indicating that the government should further optimize green tax policy to stimulate technological innovation. Therefore, [Hypothesis 2](#) is verified.

4.4.2 The mechanism of government subsidy

The influence mechanism of government subsidies is summarized in [Table 8](#). Columns 1 and 2 indicate that enterprises can acquire more government subsidies after obtaining high-tech certification. Columns 3 and 4 present the effect of government subsidies on substantive green innovation, while columns 5 and 6 show their impact on strategic green innovation. The results reveal that government subsidies significantly boost enterprises’ green innovation, with a stronger promoting effect on substantive green innovation compared to strategic green innovation. This outcome is closely linked to the current management policies for government subsidies: within the existing policy framework, there is a repeated game relationship between the government and enterprises, where the government allocates subsidies for the next development stage based on enterprises’ green innovation performance. In this mechanism, enterprises tend to utilize these subsidies for substantive green innovation to secure additional government support. Therefore, [Hypothesis 3](#) is verified.

4.4.3 The mechanism of financing constraints

The influence mechanism of financing constraints is recapitulated in [Table 9](#). Columns 1 and 2 indicate that enterprises markedly alleviate financing constraints subsequent to obtaining high-tech certification. Columns 3 and 4 illustrate the effect of high-tech certification on substantive green innovation, while Columns 5 and 6 delineate their influence on strategic green innovation. From the viewpoint of financial institutions, they are mandated to enforce green credit policies by the government. Consequently, financial institutions represented by banks are more predisposed to supporting enterprises with commendable green innovation performance. Under such a policy milieu, high-tech certification efficaciously mitigates the financing constraints of enterprises. Once enterprises receive support from banks and other financial institutions, they are obliged to fulfill policy requisites of these institutions, thereby more prone to undertaking substantive green innovation rather than strategic green innovation. Therefore, [Hypothesis 4](#) is verified.

4.4.4 The mechanism of capital market attention

The influence mechanism of capital market attention is recapitulated in [Table 10](#). Columns 1 and 2 evince that enterprises conspicuously augment capital market attention on them subsequent to obtaining high-tech certification, which

TABLE 10 Mechanism test (ACM).

	(1)	(2)	(3)	(4)	(5)	(6)
	ACM	ACM	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	6.5709*** (0.3197)	6.5871*** (0.3196)				
ACM			0.0127*** (0.0001)	0.0127*** (0.0001)	0.0128*** (0.0001)	0.0130*** (0.0001)
Growth	21.3014*** (1.0017)	20.6978*** (1.0087)	−0.5912*** (0.0494)	−0.6010*** (0.0500)	−0.0589 (0.0404)	0.0814** (0.0368)
Shareholder_ten	0.0608*** (0.0112)	0.0617*** (0.0112)	0.0018*** (0.0002)	0.0018*** (0.0002)	0.0041*** (0.0003)	0.0043*** (0.0003)
PB	0.5462*** (0.0351)	0.5421*** (0.0351)	−0.0481*** (0.0016)	−0.0481*** (0.0016)	−0.0653*** (0.0019)	−0.0660*** (0.0019)
Age	0.0970*** (0.0261)	0.1060*** (0.0262)	0.0195*** (0.0006)	0.0196*** (0.0006)	0.0015** (0.0007)	0.0010 (0.0007)
Lev	4.3871*** (0.8552)	3.9853*** (0.8587)	1.9701*** (0.0208)	1.9700*** (0.0208)	2.5284*** (0.0251)	2.5551*** (0.0250)
Tato		1.7779*** (0.3607)		0.0101 (0.0075)		−0.2515*** (0.0107)
N	28751	28751	28718	28718	28718	28718
r2	0.0490	0.0498				
LR chi2 (6)			33920.59	33922.43	27207.19	27800.44

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

reflects sensitivity of the capital market to enterprise value. Specifically, enterprises receiving high-tech certification can procure more government resources and policy dividends, thereby increasing their investment value and augmenting capital market attention to them. Columns 3 and 4 delineate the effect of capital market attention on substantive green innovation, while columns 5 and 6 portray its impact on strategic green innovation. The outcomes reveal that in current capital market milieu, enterprises adopt flexible research and development strategies. Owing to the capital market’s relatively greater emphasis on positive information, strategic innovation boasts a shorter research and development cycle and prompts efficacy, thus being capable of emitting positive signals in a short term. Hence, driven by this mechanism, the influence of capital market attention on strategic green innovation preponderates over that on substantive green innovation. Therefore, Hypothesis 5 is verified.

4.5 Heterogeneity analysis

4.5.1 Heterogeneity analysis of property rights

From the perspective of property rights heterogeneity, the impact of high-tech certification on state-owned enterprises (SOEs) are summarized in columns (1) to (4) of Table 11. The results indicate

that for SOEs, the stimulative effect of high-tech certification on substantive green innovation is significantly stronger than that on strategic green innovation. This suggests that SOEs have a robust response and execution efficacy in implementing government policies. The impact of high-tech certification on non-state-owned enterprises (NSOEs) is presented in columns (5) to (8). The findings reveal that after obtaining certification, NSOEs tend to prioritize the advancement of strategic green innovation. This implies that green innovation decisions of NSOEs are predominantly driven by their own interests. Therefore, the government is advised to intensify its guidance for NSOEs and to encourage them to place greater emphasis on substantive green innovation.

4.5.2 Analysis of industry heterogeneity

The influence of high-tech certification on labor-intensive industries is summed up in Table 12. The findings reveal that the promoting effect of high-tech certification on strategic green innovation is significantly stronger than that on labor-intensive green innovation. This suggests that current labor-intensive industries in China might be gradually losing their international competitiveness. In this context, labor-intensive enterprises are more prone to giving priority to the development of strategic green innovation in anticipation of obtaining more government support.

TABLE 11 Property rights heterogeneity.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.750***	0.903***	0.580***	0.872***	0.239***	0.362***	0.494***	0.483***
	(0.017)	(0.018)	(0.018)	(0.019)	(0.015)	(0.017)	(0.020)	(0.020)
Growth		0.217***		0.509***		0.361***		0.608***
		(0.028)		(0.024)		(0.037)		(0.037)
Shareholder_ten		0.014***		0.016***		−0.002***		−0.001**
		(0.000)		(0.000)		(0.000)		(0.000)
PB		−0.068***		−0.185***		0.007***		0.004**
		(0.003)		(0.004)		(0.002)		(0.002)
Age		0.006***		−0.025***		0.022***		0.010***
		(0.001)		(0.001)		(0.001)		(0.001)
Lev		1.330***		2.684***		2.865***		2.609***
		(0.030)		(0.037)		(0.027)		(0.031)
Tato		0.036***		−0.238***		−0.194***		−0.091***
		(0.009)		(0.013)		(0.012)		(0.014)
N	13463	13313	13463	13313	26252	25881	26252	25881
LR chi2 (1)	2531.88	7681.11	1273.64	13569.43	266.14	14565.48	775.64	9477.98

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 12 Industry heterogeneity (labour-intensive).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.462***	0.483***	0.691***	0.829***
	(0.022)	(0.023)	(0.022)	(0.023)
Growth		−0.158		1.698***
		(0.164)		(0.113)
Shareholder_ten		0.016***		0.020***
		(0.001)		(0.001)
PB		−0.268***		−0.416***
		(0.009)		(0.009)
Age		−0.016***		−0.041***
		(0.001)		(0.001)
Lev		2.717***		2.851***
		(0.056)		(0.052)
Tato		−0.316***		−0.433***
		(0.020)		(0.021)
N	10070	9939	10070	9939
LR_chi2 (1)	493.75	6794.78	1230.86	12725.97

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

The influence of high-tech certification on capital-intensive enterprises is summed up in Table 13. Outcomes indicate that the promoting effect of high-tech certification on strategic green innovation is significantly higher than that on substantive green innovation. This might be attributed to the fact that based on China’s industrial classification, there are a considerable number of heavily polluting enterprises in capital-intensive industries. Hence these enterprises, owing to the pollution they have caused, need to uphold their corporate image through more strategic green innovations.

The influence of high-tech certification on technology-intensive enterprises is summed up in Table 14. Findings demonstrate that the promoting effect of high-tech certification on substantive green innovation is significantly greater than that on strategic green innovation. This suggests that the supportive policies and guiding measures associated with high-tech certification have exerted a positive influence on the technology-intensive sector.

4.5.3 Analysis of regional heterogeneity

The influence of high-tech certification on enterprises in the eastern region is manifested in Table 15. Findings reveal that for enterprises in the eastern region, the facilitating effect of high-tech certification on strategic green innovation is conspicuously greater than that on substantive green innovation. Possible causes encompass: Firstly, there are more non-state-owned enterprises in the eastern region, and these enterprises take actions mostly taking into account their own interests. Secondly, the eastern region is rich in government resources, giving enterprises incentives to go for policy arbitrage. Finally, a considerable number of venture capital institutions are concentrated in the eastern region, and enterprises need to release

positive signals to them. The combined action of these factors makes enterprises in the eastern region more prone to opting for strategic green innovation.

The influence of high-tech certification on enterprises in the central region is summarized in Table 16. Results indicate that the facilitating effect of high-tech certification on substantive green innovation is significantly greater than that on strategic green innovation. This might be attributed to the relatively lower degree of marketization in the central region, where enterprises rely more on policy supports such as government subsidies and tax preferences. Under the existing policy guidance, enterprises are more prone to choosing substantive green innovation.

The influence of high-tech certification on enterprises in the western region is recapitulated in Table 17. Outcomes demonstrate that the facilitating impact of high-tech certification on strategic green innovation is significantly greater than that on substantive green innovation. This could be ascribed to the fact that the main industries in the western region encompass capital-intensive industries such as mining and labor-intensive industries like textiles. The features of these industries render enterprises more prone to undertaking strategic green innovation.

5 Conclusion and policy suggestions

5.1 Research conclusion

For developing nations, the traditional development model of “pollution first and then treatment” is unsustainable. Therefore, it is

TABLE 13 Industry heterogeneity (capital-intensive).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	−0.206***	0.052**	0.344***	0.542***
	(0.018)	(0.020)	(0.027)	(0.028)
Growth		0.130***		0.338***
		(0.039)		(0.028)
Shareholder_ten		0.020***		0.009***
		(0.001)		(0.001)
PB		−0.021***		−0.028***
		(0.004)		(0.004)
Age		0.024***		0.010***
		(0.001)		(0.001)
Lev		1.303***		1.768***
		(0.041)		(0.047)
Tato		−0.018		−0.282***
		(0.015)		(0.019)
N	11728	11570	11728	11570
LR chi2 (1)	124.63	3307.75	188.38	2453.71

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 14 Industry heterogeneity (technology-intensive).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.870***	0.626***	0.519***	0.382***
	(0.022)	(0.022)	(0.021)	(0.022)
Growth		0.815***		0.673***
		(0.030)		(0.041)
Shareholder_ten		0.002***		0.002***
		(0.000)		(0.000)
PB		−0.045***		−0.030***
		(0.002)		(0.002)
Age		0.026***		0.007***
		(0.001)		(0.001)
Lev		2.936***		2.893***
		(0.027)		(0.033)
Tato		0.021*		0.079***
		(0.011)		(0.016)
N	17917	17685	17917	17685
LR chi2 (1)	2305.93	20775.89	739.29	11241.15

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 15 Regional heterogeneity (eastern region).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.384***	0.620***	0.539***	0.754***
	(0.013)	(0.014)	(0.016)	(0.017)
Growth		0.256***		0.319***
		(0.020)		(0.022)
Shareholder_ten		0.005***		0.008***
		(0.000)		(0.000)
PB		-0.042***		-0.056***
		(0.002)		(0.002)
Age		0.010***		-0.010***
		(0.001)		(0.001)
Lev		2.653***		3.240***
		(0.022)		(0.026)
Tato		-0.089***		-0.222***
		(0.008)		(0.011)
N	28026	27681	28026	27681
LR chi2 (1)	1012.76	19941.24	1356.36	20370.40

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 16 Regional heterogeneity (central region).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	1.416***	1.212***	0.679***	0.690***
	(0.062)	(0.056)	(0.045)	(0.045)
Growth		0.035		1.076***
		(0.125)		(0.104)
Shareholder_ten		0.006***		0.006***
		(0.001)		(0.001)
PB		0.080***		0.029***
		(0.003)		(0.004)
Age		0.053***		0.035***
		(0.002)		(0.002)
Lev		1.414***		1.567***
		(0.053)		(0.059)
Tato		-0.308***		-0.282***
		(0.027)		(0.028)
N	5537	5456	5537	5456
LR chi2 (1)	1062.13	3377.49	321.23	1733.04

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

TABLE 17 Regional heterogeneity (western region).

	(1)	(2)	(3)	(4)
	Pat_green_invent	Pat_green_invent	Pat_green_utility	Pat_green_utility
High_Tech_Certification	0.166***	0.290***	0.247***	0.383***
	(0.029)	(0.031)	(0.029)	(0.031)
Growth		0.390***		1.194***
		(0.106)		(0.063)
Shareholder_ten		0.006***		0.003***
		(0.001)		(0.001)
PB		−0.039***		−0.039***
		(0.006)		(0.006)
Age		0.017***		−0.001
		(0.002)		(0.002)
Lev		1.074***		1.569***
		(0.066)		(0.066)
Tato		0.156***		−0.145***
		(0.022)		(0.030)
N	6141	6046	6141	6046
LR chi2 (1)	34.57	691.48	79.19	954.78

Standard errors in parentheses = “*p < 0.1**p < 0.05***p < 0.001”.

crucial for the government to utilize policy tools to steer enterprises toward substantive green innovation. We systematically evaluate the high-tech enterprise certification policy, a key policy tool driving enterprise innovation, using data from Chinese A-share listed companies from 2006 to 2023. We employ the zero-inflated negative binomial model, Poisson model, instrumental variable approach, and PSM-DID method to assess the impact of high-tech enterprise certification on both substantive and strategic green innovation. The mechanisms of actions are examined from four perspectives: tax incentives, government subsidies, financing constraints, and capital market attention. Considering the characteristics of the China market, heterogeneity analyses are conducted across three dimensions: property rights, industry, and region. The research reveals that, overall, there is significant policy arbitrage in the green innovation behaviors of enterprises, leading to a notable issue of green patent bubbles. Specifically, the promotional effect of high-tech enterprise certification on strategic green innovation is significantly stronger than that on substantive green innovation. This suggests that the government should place greater emphasis on the implementation of policies, and rationally allocate policy dividends based on enterprises' green innovation performance, adjusting evaluation criteria for enterprise green innovation performance promptly.

From the perspective of the functioning mechanism, high-tech enterprise certification can directly enhance cash flow by reducing corporate tax rates, increasing government subsidies, and alleviating financing constraints. Adequate cash flow support leads enterprises to prefer substantive green innovation over strategic green innovation. This reflects two key aspects:

Firstly, in the long term, substantive green innovation significantly enhances the competitiveness and development potential of enterprises. Therefore, after easing cash flow pressure, enterprises are more inclined to investing in substantive green innovation.

Secondly, the repeated games between the government and enterprises, as well as between banks and other financial institutions and enterprises, have formed an effective supervision mechanism, encouraging enterprises to prioritize substantive green innovation.

However, from the perspective of capital market attention, this study finds that high-tech enterprise certification has increased the attention enterprises receive from the capital market. Due to the lack of a long-term investment mindset among Chinese investors, under the pressure of capital market, enterprises tend to favor strategic green innovation. From the perspective of property rights differences, state-owned enterprises actively respond to the policy call for green development. Stimulated by the policy dividends brought by high-tech enterprise certification, performance of substantive green innovation by state-owned enterprises surpasses that of strategic green innovation. From the perspective of industry differences, technology-intensive enterprises, after obtaining high-tech enterprise certification, can significantly alleviate cash flow pressure in R&D activities and thus are more inclined toward substantive green innovation. From the perspective of regional differences, enterprises in the central region exhibit a significantly stronger preference for substantive green innovation over strategic green innovation under the influence of high-tech enterprise certification.

5.2 Policy suggestions

The conclusion of this paper enriches and extends the research on the influence of high-tech certification and the theory of green innovation. The following policy recommendations are put forth: Firstly, intensify governmental guidance on green innovation and refine management and assessment mechanism for high-tech enterprises. In light of the distinct requirements of substantive green innovation and strategic green innovation of enterprises, the government ought to incorporate specific considerations for green technological innovation during the certification process, encouraging enterprises to undertake substantive innovations that are both technologically ground-breaking and market-oriented. For this purpose, the government should establish a more elaborate assessment system, differentiating between enterprises that rely on certification to drive strategic innovation and those that are genuinely dedicated to green technology research and development, ensuring precise allocation of green innovation resources. Simultaneously, differentiated incentive measures should be implemented, providing more ample policy support to enterprises with technological innovation at their core operation and avoiding excessive appropriation of policy resources for strategic innovation.

Secondly, optimize allocation of resources to alleviate pressures of enterprise financing and resource shortages. Particularly in terms of the influence of high-tech certification on financing and resource allocation, the government could offer corresponding support for enterprises of different innovation types through differentiated financial support policies. For enterprises possessing substantive green innovation potential, higher amounts of green credit and tax preferences should be provided to expedite their technological innovation processes, whereas for enterprises mainly dependent on strategic green innovation, a phased support approach should be adopted to guarantee efficient utilization of resources and sustainability of green innovation.

Thirdly, Strengthen the leading role of state-owned enterprises to promote balanced regional development. State-owned enterprises exert a considerable exemplary effect in the research and development as well as market application of green technologies. Hence, the government ought to support their in-depth collaboration with non-state-owned enterprises in domains such as green technology standards and environmental protection technologies. Through technology sharing and experience inheritance, assist the latter in breaking through technical bottlenecks of green innovation and in accelerating the transformation of innovation outcomes. Additionally, the government should be attentive to regional disparities and implement differentiated policy support in response to the green innovation demands of enterprises in diverse regions. Particularly in the central and western regions where technology relatively lags behind, provide them with more policy and resource support to facilitate balanced development of green innovation across regions.

Fourthly, enhance capital market regulation and external supervision to promote transparency in green innovation. To facilitate long-term development of enterprises' green innovation, the government is required to further refine the capital market regulatory framework, enhance transparency of green innovation projects, and upgrade the evaluation criteria for investors. The influence of high-tech certification on the capital market must not be overlooked, particularly

in the capital operation of green innovation projects. The government should intensify the standardization of enterprises' green innovation information disclosure to ensure accurate assessment of enterprises' long-term technological innovation capabilities by the capital market. By augmenting information transparency in the capital market and averting investment behaviors that lean towards short-term profits, the government can steer investors to pay greater attention to enterprises' technological accumulation and long-term value in green innovation, thereby propelling enterprises towards substantive innovation.

Fifthly, formulate differentiated high-tech certification standards and incentive measures to promote coordinated development of regional green innovation. Given the distinct characteristics of strategic green innovation and substantive green innovation, the government can provide necessary support to enterprises engaging in strategic green innovation via certification, but should place greater emphasis on promoting enterprises with innovation potentials to achieve substantive breakthroughs in green technologies. Additionally, in supporting green innovation in both central and western regions and non-state-owned enterprises, the government should enhance the green technological innovation capabilities of these regions and enterprises by strengthening technical guidance and resource support, thereby promoting balanced green innovation development across the regions.

5.3 Research outlook

In subsequent studies, In subsequent studies, refinement can be carried out from the following two aspects:

- 1) This study primarily examines the influence of high-tech certification on enterprises from a literature review perspective. Future research could introduce mathematical models to comprehensively consider multiple factors affecting green innovation in enterprises and construct a tripartite game model involving the government, enterprises, and the public. This would provide robust theoretical support for the government to formulate more detailed green innovation policies.
- 2) This study conducts an empirical analysis using green patent application data. Future research can undertake comparative studies from the perspective of patent authorization to offer the government a more comprehensive reference for optimizing the management of high-tech certification.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: <https://data.csmar.com>.

Author contributions

ZL: Funding acquisition, Investigation, Visualization, Writing—original draft, Writing—review and editing. YS: Funding

acquisition, Supervision, Writing-review and editing. KY: Data curation, Writing-original draft, Writing-review and editing. JK: Funding acquisition, Project administration, Supervision, Writing-review and editing.

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