



Local governments' environmental emphasis and corporate green innovation: evidence from China

Yueyang Zhao^{1,2} · Jinzhou Mao² · Yueshan Li³ 

Received: 6 February 2022 / Accepted: 4 April 2022 / Published online: 23 April 2022
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Abstract

To study the effect of green industrial policies comprehensively, this paper takes uses a sample of Chinese Shanghai and Shenzhen A-share listed companies from 2008 to 2019 to study the impact of local governments' environmental emphasis on corporate green innovation. The results show that local governments' environmental emphasis has a significant positive impact on the number of green patents of enterprises. More importantly, local governments' environmental attention mainly plays its role by improving the environmental protection awareness of corporate executives and increasing environmental protection subsidies. In addition, the effect of local governments' environmental emphasis is more pronounced in state-owned enterprises, firms with low financing constraints, and heavily polluting firms. Further research finds that local governments' environmental emphasis has a significant role in promoting the number of green invention patents and non-invention patents, but only green invention patents enhance the intrinsic value of enterprises.

Keywords Environmental importance · Green innovation · Environmental awareness · Environmental subsidies

JEL Classification C23 · L53 · Q55

✉ Yueshan Li
shanzhou20180901@126.com

Yueyang Zhao
yueyang23@126.com

Jinzhou Mao
zhouzhou20211019@163.com

¹ Center for China Public Sector Economy Research, Jilin University, Changchun 130012, China

² School of Economics, Jilin University, Changchun 130012, China

³ School of Business and Management, Jilin University, Changchun 130012, China

1 Introduction

In the wake of the COVID-19 pandemic, the economic downturn caused oil prices to plummet due to low demand and oversupply, triggering a series of negative effects (Yoshino et al. 2021). In response to the epidemic, some countries may relax their environmental regulations (De-la-Torre and Aragaw 2021; Dharmaraj et al. 2021). A diminished government focus on the environment may jeopardize the achievement of the Paris Agreement on climate change and several sustainable development goals. As countries successively announce their economic recovery plans, how to make economic development and green recovery coexist has become an urgent topic for academics to study.

Under this macro-background, green industry development, as the main means to deal with climate change, urgently needs to rethink within a short period of time. Moreover, it is particularly important to accurately measure the impact of relevant environmental protection policies on the development of enterprises. Some scholars believe that environmental regulation increases the costs incurred by enterprises and affects economic development (Fu and Jian 2021). However, Porter believes that strict and flexible environmental regulations can prompt enterprises to carry out more innovation activities, especially green innovation in emerging environmental protection fields, which can improve the productivity and competitiveness of enterprises. And, innovative compensation can partially or fully cover the costs caused by environmental protection (Porter 1991). Scholars have developed Porter's theory based on agency issues and market failures (Ambec et al. 2013), verified Porter's hypothesis through empirical research, and found that environmental regulation has a significant positive impact on corporate green innovation (Feng and Chen 2018). However, some scholars note that the premise for the realization of the Porter effect is mostly based on developed countries, and the requirements for a country's environmental policy are relatively high (Ibanez and Blackman 2016). These assumptions do not hold in most developing countries, rendering the Porter effect ineffective (Baksi and Bose 2016). Scholars indicate that the impact of environmental policies on green innovation is uncertain and complex (Borsatto et al. 2021; Bernauer et al. 2007) and environmental regulations that are too strict inhibit corporate green innovation (Borghesi et al. 2015). Therefore, with the continuous changes in environmental protection policies in various countries, especially developing countries facing increasingly urgent pressures for environmental protection and economic development, we need to further explore the relationship between environmental protection policies and corporate green innovation.

China's unique administrative system and environmental protection policies offer a suitable research context in which to explore the relationship between environmental protection policies and corporate green innovation. Local governments in China have played an important role in economic development. According to the "economic federalism" hypothesis, local government officials have high economic management authority within their jurisdictions (Montinola et al. 1995; Jin et al. 2005). Moreover, the fiscal decentralization reform has given local

governments sufficient incentives to accelerate regional economic growth (Guo et al. 2020). In this context, local governments often pay insufficient attention to environmental regulations and may pursue economic growth at the expense of the local environment (Cai et al. 2016; Yang et al. 2020; Zhao et al. 2021). However, as domestic environmental problems become more prominent and the pressure for environmental protection continues to increase, the central government increases its emphasis on environmental protection. China's unique party system ensures that the central government has a strong ability to control and coordinate local governments (Mertha 2005). Since 2007, under the supervision of the central government, various provinces in China have successively issued "Regulations on the Responsibility of Ecological Environmental Protection" and other documents. This document requires that a responsibility system and accountability system be established in accordance with the principle of "who is in charge, who is responsible"; that the effectiveness of environmental protection work be included in the performance assessment of leading cadres; and that the weight of environmental protection assessment be increased. Subsequently, the environmental protection inspection team established by the central government has conducted environmental inspection pilot work in some provinces to ensure that local governments perform their environmental protection responsibilities according to quality and quantity standards. Under this circumstance, local governments' emphasis on the environment has greatly increased, and the relationship between economic development and environmental protection has become prominent.

The Chinese context is valuable for the discussion of environmental policy and corporate green innovation behaviour because the scale and speed of China's economic development are remarkable, and China faces enormous environmental pressures both at home and abroad. The intense interaction between economic development and environmental protection in a short period of time can reflect the green innovation decisions that companies make. The particularity of China's administrative system ensures the universality of local government environmental protection policies and the exogenous nature of corporate green innovation decisions. At the same time, as the makers and executors of environmental policies, local governments' emphasis on the environment directly affects the strictness of environmental protection policies, which have different impacts on enterprises' green innovation decisions. Accordingly, this paper focuses on the environmental protection actions of various provinces in China and examines how these actions affect the green innovation of enterprises considering the environmental importance perceived by Chinese local governments. This approach allows a comprehensive measurement of the impact of green industrial policies on corporate green innovation.

Taking the Chinese stock market as the research sample, this paper draws the following conclusions. First, we construct an econometric model to verify that local governments' environmental emphasis can significantly improve the green innovation of enterprises. Second, the mediation effect model shows that local governments' environmental attention has a positive impact on the number of green patents mainly by improving the environmental protection awareness of corporate executives and environmental protection subsidies. Third, a heterogeneity test shows that the positive impact of local governments' environmental emphasis on

the green innovation of enterprises is more prominent in state-owned enterprises, enterprises with low financing constraints and heavily polluting enterprises. Fourth, local governments' environmental emphasis has a significant role in promoting the number of green invention patents and non-invention patents of enterprises, but only green invention patents enhance the intrinsic value of enterprises. Finally, the more accommodating and positive responses of Chinese enterprises to industrial policy have become the key to explaining the continuation of China's rapid economic development.

The contributions of this paper are as follows: First, this paper provides a new perspective for understanding the deep-seated reasons for the decision-making behind corporate green innovation. Starting by examining local governments' behavioural decision-making, this paper explores the spillover effect of local governments' environmental emphasis and supplements the academic research on enterprise green innovation. Second, this paper explores the channels through which local governments' environmental emphasis affects the green innovation of enterprises and clarifies the impact mechanism. Third, this paper studies the different evolutionary paths of corporate green innovation due to differences in firm characteristics. Fourth, this paper further refines the types of green innovation, which is conducive to deepening our understanding of corporate green innovation strategies. Fifth, China's green industry policy and the rapid market response of enterprises have provided a good reference material for various countries, especially less developed countries, to formulate green recovery plans in the post-epidemic era.

The rest of this paper is structured as follows: The second section presents the theoretical analysis and research hypothesis. The third section presents the descriptive statistics of the data and the design of the econometric model. The fourth section presents the empirical results, a robustness test and an endogeneity test. The fifth section discusses further research. The sixth section contains the research conclusion, contributions and suggestions.

2 Literature review and hypothesis development

2.1 Recent large-scale environmental protection measures in China

Since 2007, the Chinese government has increased its attention to protecting the environment and promoting green ecology. In 2007, China's environmental protection department proposed a roadmap for environmental economic policies, emphasizing the important role of the green economy in conserving energy, reducing emissions, improving resource utilization efficiency, and promoting economic transformation. The "Guiding Opinions on Carrying out the Pilot Work of Ecological Compensation" promulgated in 2007 proposed exploring the establishment of an ecological compensation mechanism in key areas. After the Ministry of Environmental Protection was upgraded to a component of the State Council in 2008, environmental and economic policies at the national and provincial levels were issued intensively. In 2008, the state promulgated the "Plastic Restriction Order" and formulated management measures for the paid use of plastic shopping bags in

commodity retail places. In 2009, the “Interim Measures for the Management of Comprehensive Environmental Improvement Projects of Central Rural Environmental Protection Special Funds” stated that attention should be given to the ecological environment in rural areas. In December 2014, the Ministry of Commerce, the Ministry of Environmental Protection, and the Ministry of Industry and Information Technology jointly issued the “Guidelines for Enterprise Green Procurement” guiding enterprises to implement green procurement and build a green supply chain and promoting the construction of a resource-saving and environmentally friendly society as well as green circulation and sustainable development. In October 2017, General Secretary Xi Jinping proposed for the first time in the report of the 19th National Congress of the Communist Party of China the three major battles of pollution prevention and control, placing environmental protection in a more prominent position. In 2017, the carbon emission trading market was launched nationwide, and the emission trading system was established in pilot areas. In 2018, the “Environmental Protection Tax Law” and the ecological and environmental damage compensation system were formally implemented and piloted nationwide. On March 11, 2018, the “Amendment to the Constitution of the People’s Republic of China” incorporated ecological civilization and “beautiful China” into the constitution. In October 2019, the Central Committee of China proposed “adhering to and improving the institutional system of ecological civilization”, providing clearer guidelines for further improving the construction of the environmental and economic policy system.

In general, since 2007, the Chinese government has increased its attention to the construction of the ecological environment, and it has also been committed to combining environmental protection and green production to create a green production chain with Chinese characteristics. Specifically, at the provincial level, local governments not only formulate environmental regulations to standardize the green management of enterprises but also take corresponding green environmental protection actions and adjust local green industry paths to influence the green strategic planning of enterprises. In addition, the central government requires local governments to solve problems such as insufficient law enforcement through the accountability mechanism, which can effectively enhance local governments’ attention to the ecological environment.

2.2 Local governments’ environmental emphasis and enterprise green innovation

The existing research on corporate green innovation can be roughly divided into two categories: internal factors and external factors. Enterprise internal factors mainly include: internal environment culture (Chen et al. 2012), high-performance work practices and departmental traits (Antonioli et al. 2013), corporate governance level (Amore and Bennesen 2016), R&D strategy and technology Paths (Sáez-Martínez et al. 2016). Pressure from outside the enterprise also has a certain impact on green innovation, such as supplier and customer demand (Kesidou and Demirel 2012). Regarding the macro-factors outside the enterprise, existing scholars mainly study the relationship between the mandatory environmental

regulation of local governments and green innovation decision-making (Ford et al. 2014; Borghesi et al. 2015; Fang et al. 2021). However, as the main influencer of local economic development, local governments not only influence the development of local industries by formulating regulations, but also convey their “attitudes” towards certain economic issues through differences in relevant decision-making efforts and may affect the relevant decision-making of enterprises. For example, Cull et al. (2017) showed through empirical research that the efforts of local governments in regional market development can have a significant positive impact on enterprise efficiency. Choi et al. (2015) believe that the improvement of provincial government governance quality can significantly improve the price-to-book ratio, return on assets and labour productivity of enterprises. Regarding the research on corporate green innovation, the previous literature overemphasized the impact of the government’s mandatory environmental protection regulations on green innovation, ignoring the soft constraint role of local governments in the transformation and regulation of green industries.

To achieve the goal of improving the ecological environment, policy makers often formulate a number of environmental laws and regulations involving aspects from various industries, such as tax incentives, government subsidies, administrative supervision, legal control and policy regulations. When local governments in different regions attach different levels of importance to the environment, they often adopt different green industry policies. These differentiated policies may help boost corporate green innovation, improve production and operation models, increase resource utilization, and develop green technologies that reduce environmental pollution, which may be in line with the Porter hypothesis. First, when the pollution cost of an enterprise increases, the profit decreases such that the marginal revenue gradually equals the marginal cost, and the enterprise may choose the green production mode at this time (Carter et al. 1998). Second, the strengthening of local environmental protection causes enterprises to spend more capital to control sewage costs. At this time, enterprises with more green patents may sell environmental protection technologies driven by profits, which will lead to increased green innovation efforts. High-quality green innovation may gradually become one of the important factors for enterprises to establish competitive advantage (Genchev 2009). Third, against the macro-level background of local governments vigorously rectifying polluting enterprises and promulgating a number of environmental regulations, enterprises often take the initiative to transform their green production models based on long-term development considerations. The more attention local governments devote to the environment, the more long-term and stable their environmental protection policies are. These policies suppress enterprises’ motivation for short-term speculation and make them more likely to follow industrial policies and cultivate their long-term development strategic advantages through green innovation. Accordingly, this paper proposes Hypothesis 1.

Hypothesis 1 Local governments’ environmental emphasis has a significant positive impact on the green innovation of enterprises.

2.3 Channel analyses

Local governments attaching importance to environmental issues may enhance corporate executives' awareness of environmental protection in the following two ways. On the one hand, local governments' emphasis on environmental protection must be accompanied by a series of policies related to environmental protection, which signal that the government attaches importance to the environment. As the main bodies comprising the micro-economy, enterprises may strengthen the environmental protection awareness of their executives and focus on reducing the pollution from their production processes in order to avoid punishment for failing to meet environmental protection standards. On the other hand, when green behaviour in executives' environment increases, executives are more likely to attach importance to environmental protection and actively engage in environmental protection activities to meet society's expectations for environmental protection (Duarte 2010; Zhang et al. 2015).

In addition, as executives are important decision makers in business operations, the enhancement of executives' environmental awareness may affect the green innovation of their companies through external pressures and internal driving forces. Regarding external pressures, executives with strong environmental awareness may sense the potential benefits brought by environmental protection strategies and thus formulate proactive environmental strategies (Sharma 2000). Moreover, executives with strong environmental awareness regard customer needs, resource suppliers and industry competitors' emphasis on green innovation as market opportunities and develop new products to meet customer needs, actively cooperate with suppliers to share risks, and compete for resources, occupying a dominant position (Egri and Herman 2000). With regard to internal driving forces, corporate executives with moral restraint and a sense of social responsibility may reduce environmental pollution in the course of business operations by promoting green innovation. Tseng et al. (2013) believe that the enhanced environmental awareness of executives is reflected in an open and inclusive attitude towards green innovation decision-making and an ability to integrate environmental protection-related information with existing corporate resources to respond positively to environmental protection issues. In summary, this paper proposes the following hypothesis.

Hypothesis 2 Local governments' environmental emphasis promotes green innovation by raising corporate executives' environmental awareness.

Green development is an important breakthrough for the high-quality development of enterprises, and green innovation is the core of enterprises' green production. Environmental regulation and government subsidies are the two main policy measures to promote the implementation of corporate green innovation strategies (Acemoglu et al. 2012). If the factors of production are completely substitutable, local governments can provide R&D subsidies to encourage enterprises to engage in green production. Due to the difficulty in realizing green innovation output in

the short term, enterprises have weak incentives to develop green products. Government subsidies can make up for the loss caused by the low realization ability of green products. In addition, companies that receive government subsidies may be subject to stronger government regulation and environmental supervision, which leads to greater pressure on these companies to improve their production processes and meet higher environmental standards through green innovation. Enterprises that receive government subsidies send a signal of government recognition and certification to the capital market (Kleer 2010). This enhances their reputation and enables them to obtain more investment, thereby speeding up the process of corporate green innovation. Based on the above analysis, this paper proposes hypothesis 3.

Hypothesis 3: Local governments' environmental emphasis promotes the green innovation of enterprises by increasing environmental protection subsidies.

3 Data and methodology

3.1 Sample selection and data source

This paper uses data from financial statements and publicly released information of Chinese A-share listed companies in Shanghai and Shenzhen from 2008 to 2019 and uses green patent data from the National Knowledge Security Bureau. According to the patent application time, the number of green patent applications and green patent authorizations of the sample companies each year was manually collected and calculated. The financial data and basic information on enterprises come from the CSMAR database and the Wind database. Macro-data for each region in China come from the National Bureau of Statistics. As discussed previously, China issued a number of policies and regulations in 2007 to signal the government's increased attention to the environment. Additionally, in 2007, China issued new accounting standards. To highlight the research theme and avoid research bias caused by changes in accounting standards, this paper uses 2008 as the starting point for enterprise data collection.

To avoid the impact of outliers on the measurement results, we exclude enterprises in financial and insurance industries, enterprises that experienced ST, ST* or delisting, enterprises with missing data on the main variables, and enterprises with less than 3 years of data. Considering the influence of extreme values, the main continuous variables are tailed by 1% up and down.

3.2 Key variables

3.2.1 Enterprise green innovation (*Patent_{it}*)

The explained variable of this paper is the green innovation of enterprises. Scholars have pointed out that due to the high failure rate and uncertain factors in the R&D process, innovation output better reflects the innovation level of enterprises

than innovation input (Cornaggia et al. 2015). Therefore, the measurement model presented later in this paper mainly uses innovation output to measure technological innovation capability. Due to the greater uncertainty in the number of patent grants, this paper uses the number of green patent applications to measure the level of green innovation of enterprises and uses the number of green patent grants as a surrogate indicator for enterprise green innovation in robustness tests.

3.2.2 Local governments' environmental emphasis ($Envir_t$)

When local governments attach importance to the ecological environment, they often invest more capital to monitor potential pollution behaviours, control existing pollution and maintain the existing good environment. Thus, this paper uses local governments' expenditure on environmental protection divided by the total population of the region and then takes the logarithm to measure local governments' environmental emphasis. To increase the reliability of the empirical results, in robustness tests, local governments' expenditure on environmental protection divided by their total financial expenditure is used to measure their environmental emphasis, and a measurement test is carried out.

3.2.3 Control variables

Considering that other enterprise factors may affect their green innovation, we select a series of factors affecting the economic characteristics of enterprises as control variables. The first factor is the size of the enterprise ($Size_t$). The literature shows that firm size is an important factor affecting firm innovation (Bu et al. 2020). The second factor is the age of the enterprise ($Lnage_t$). The age of an enterprise usually represents the maturity of the enterprise, and studies have shown that enterprises with higher maturity tend to have a stronger sense of innovation (Ucar 2018). The third factor is the asset-liability ratio (Lev_t). Moderate debt management can allow enterprises to have more abundant funds to carry out innovative activities such as technical equipment improvement and process improvement. The fourth factor is return on total assets ($Roat_t$). Studies have shown that companies with good operating conditions tend to pay more attention to the green innovation of their enterprises (Ren et al. 2021). The fifth factor relates to firm performance and structure. Taking into account the impact of factors such as corporate performance and structure on corporate green technology innovation, this paper controls the capital intensity of the company ($Capint_t$), the total number of employees ($Lnstaff_t$), the shareholding ratio of the top ten shareholders ($Top10_t$), the ratio of independent directors ($Indep_t$), and year and industry dummy variables. The definitions of the variables and English symbols are detailed in the Appendix.

3.3 Model specification

To empirically test the impact of local governments' environmental emphasis on the green innovation of enterprises, we construct the following model:

$$Patent_{i,t} = \beta_0 + \beta_1 Envir_{p,t} + \sum_k \beta_k Controls_{k,i,t} + \varepsilon_{i,t} \tag{1}$$

where i is the company, t is the year, and p is the region. The explanatory variable $Patent_{i,t}$ represents the number of green patent applications of company i in year t ; the explanatory variable $Envir_{p,t}$ represents the environmental protection importance perceived by the government in region p in year t . $Controls_{k,i,t}$ are control variables, including enterprise size ($Size_t$), company age ($Lnage_t$), capital intensity ($Capint_t$), return on total assets (Roa_t), total number of employees ($Lnstaff_t$), asset-liability ratio (Lev_t), the shareholding ratio of the top ten shareholders ($Top10_t$), the ratio of independent directors ($Indep_t$), industry dummy variables, and annual dummy variables. ε represents the residual. In addition, we use industry and year fixed effects to control for heterogeneity due to industry and year effects. According to the previous theoretical analysis, β_1 is positive and can provide a significance test. Since part of $Patent_t$ is 0, this paper uses the Tobit model for econometric regression. The definitions of all variables are shown in the Appendix.

4 Empirical results

4.1 Summary statistics

Table 1 reports the summary statistics of the main variables used in our empirical analyses. The sample contains annual observations for 29,937 companies from 2008 to 2019. With regard to the dependent variables, the mean of $Patent_t$ is 0.801 and the standard deviation is 0.147, indicating that the number of green patent applications varies greatly among different enterprises; the median of 0 indicates that few enterprises attach importance to green patents, showing the huge development

Table 1 Summary statistics

Variable	N	Mean	Std.	Min.	p50	Max.
$Patent_t$	29,937	0.801	1.147	0.000	0.000	4.625
$Envir_t$	29,937	5.695	0.663	3.687	5.669	7.526
$Size_t$	29,937	22.030	1.295	19.540	21.860	26.000
$Lnage_t$	29,937	2.779	0.384	1.386	2.833	3.466
$Capint_t$	29,937	2.561	2.280	0.395	1.907	15.300
Roa_t	29,937	0.042	0.069	-0.269	0.042	0.228
$Lnstaff_t$	29,937	7.577	1.286	4.190	7.525	11.040
Lev_t	29,937	0.430	0.211	0.051	0.422	0.913
$Top10_t$	29,937	59.030	15.740	22.340	60.130	93.410
$Indep_t$	29,937	0.285	0.166	0.000	0.333	0.571

This table reports descriptive statistics of local governments' environmental emphasis, corporate green innovation, and control variables for the 2008–2019 sample. All variables are defined in the Appendix

potential of green innovation. The company characteristic variables include company size ($Size_t$), company age ($Lnage_t$), capital intensity ($Capint_t$), return on total assets ($Roat_t$), total number of employees ($Lnstaff_t$), asset-liability ratio (Lev_t), top ten shareholders' holding ratio ($Top10_t$), and ratio of independent directors ($Indep_t$). Judging from the mean and standard deviation of these control variables, the financial and structural characteristics of enterprises are quite different. To prevent these factors from interfering with the empirical results, it is necessary to add these variables into the model for econometric regression.

4.2 Baseline results

Table 2 reports the econometric regression results of local governments' environmental emphasis and corporate green innovation. Column (1) shows the quantitative regression results for $Envir_t$ and $Patent_t$. The marginal coefficient of $Envir_t$ is 0.139, which is significant at the 1% level. After adding the important control variables firm size and firm age, as shown in column (2), the marginal coefficient of $Envir_t$ is 0.062, which is significant at the 1% level; 0.062 is less than 0.139, indicating that adding reasonable control variables can obtain a more accurate marginal promotion degree. For this reason, in column (3), we control for variables more comprehensively related to enterprise characteristics, as well as industry and annual fixed effects, to more accurately determine the marginal impact of local governments' emphasis on the environment on enterprise green innovation. $Envir_t$ increases by an average of one percentage point, and the green patent output of enterprises increases by an average of 7.2%. The measurement results in Table 2 show that local governments attaching importance to the environment can effectively increase the green innovation of enterprises.

Since the behavioural decision-making of local governments can affect the direction of economic development in a region, the measurement results in Table 2 are of great significance for understanding corporate green innovation strategic planning. Local governments attaching importance to environmental problems can not only effectively improve ecological problems at the macro-level but also provide a good example for micro-level enterprises and send a positive signal to encourage green development. This is conducive to the development of the green industry chain and forms a virtuous circle.

4.3 Robustness checks

Considering the limitations of local governments' environmental emphasis ($Envir_t$) and corporate green innovation ($Patent_t$) indicators, as well as the possible shortcomings of the measurement estimation methods or model design, we conduct the following robustness analysis.

First, we use alternative indicators to measure the level of corporate green innovation. The green patent authorization index ($Patent2_t$) is used to measure the green innovation level of enterprises and conduct related robustness tests. The empirical results are shown in column (1) in Table 3. The coefficient of $Envir_t$ is significantly

Table 2 The regression results of local governments’ environmental emphasis and enterprise green innovation

Dependent variable	<i>Patent_t</i>		
	(1)	(2)	(3)
<i>Envir_t</i>	0.139*** 10.86	0.062*** 5.34	0.072*** 6.27
<i>Size_t</i>		0.387*** 83.63	0.342*** 42.98
<i>Lnage_t</i>		-0.129*** -7.78	-0.182*** -10.55
<i>Capint_t</i>			-0.014*** -4.61
<i>Roa_t</i>			0.118 1.25
<i>Lnstaff_t</i>			0.059*** 7.87
<i>Lev_t</i>			-0.090** -2.53
<i>Top10_t</i>			-0.005*** -14.15
<i>Indep_t</i>			0.324*** 9.70
<i>Constant</i>	-0.629*** -7.85	-8.172*** -66.13	-7.295*** -50.26
Year fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Observations	29,937	29,937	29,937
Pseudo-R2	0.061	0.128	0.133

This table shows the measurement results of the impact of local governments’ environmental emphasis (*Envir_t*) on the green innovation of enterprises (*Patent_t*). Model (1) was used to carry out the econometric regression. Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, **, and *** indicate significance at the 10, 5%, and 1% levels, respectively

positive at the 1% level, which verifies that local governments’ environmental emphasis has a positive impact on the green innovation of enterprises.

Second, we use surrogate indicators to measure the importance local governments attribute to the environment. The environmental protection expenditure of local governments divided by local financial expenditure is used as a surrogate index (*Envir2_t*) of local governments’ perceived environmental importance, and a robustness test is carried out. The empirical results are shown in column (2) in Table 3. The coefficient of *Envir2_t* is significantly positive at the 1% level, which verifies that

Table 3 Regression results for robustness estimation

	(1)	(2)	(3)	(4)	(5)	(6)
	Tobit $patent2_t$	Tobit $patent_t$	Tobit $patent_{t+1}$	OLS $patent_t$	FE $patent_t$	Tobit $patent_t$
$Envir_t$	0.071*** 7.21		0.061*** 4.83	0.072*** 5.90	0.072*** 3.80	0.072*** 6.15
$Envir2_t$		3.529*** (5.66)				
$Size_t$	0.272*** 40.22	0.348*** 43.95	0.337*** 38.04	0.342*** 42.19	0.296*** 24.40	0.345*** 43.31
$Lnage_t$	-0.157*** -10.73	-0.180*** -10.42	-0.200*** -10.66	-0.182*** -10.56	0.158*** 2.83	-0.169*** -9.80
$Capint_t$	-0.008*** -3.20	-0.014*** -4.82	-0.013*** -3.90	-0.014*** -4.89	-0.015*** -4.70	-0.013*** -4.37
Roa_t	-0.165** -2.06	0.111 1.18	0.562*** 4.93	0.118 1.30	-0.001 -0.01	0.123 1.31
$Lnstaff_t$	0.046*** 7.17	0.053*** 7.16	0.060*** 7.22	0.059*** 8.38	0.089*** 8.62	0.054*** 7.14
Lev_t	-0.031 -1.01	-0.102*** -2.87	-0.006 -0.15	-0.090*** -2.64	-0.160*** -3.89	-0.069* -1.94
$Top10_t$	-0.004*** -11.81	-0.005*** -13.98	-0.004*** -10.42	-0.005*** -14.18	-0.004*** -7.61	-0.005*** -14.11
$Indep_t$	0.279*** 9.82	0.333*** 9.96	0.355*** 9.46	0.324*** 10.38	-0.072 -0.62	0.314*** 9.42
$Lngdp_t$						0.010*** 5.14
$Growth_t$						0.005*** 4.15
$Density_t$						0.010** 1.99
$Constant$	-5.983*** -48.48	-7.132*** -50.68	-7.181*** -44.55	-7.295*** -46.84	-7.019*** -24.43	-7.516*** -51.10
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	29,937	29,937	25,848	29,937	29,937	29,937
Pseudo-R2/ Adjusted R2	0.138	0.134	0.127	0.338	0.258	0.134

The table shows the regression results of the robustness estimation of the impact of local governments' environmental emphasis ($Envir_t$) on the green innovation of enterprises ($Patent_t$). Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, **, and *** indicate significance at the 10, 5%, and 1% levels, respectively

local governments' environmental emphasis has a positive impact on the green innovation of enterprises.

Third, changing the measurement method, the ordinary least squares method and a fixed effect model are used to carry out a measurement regression. The explanatory variables and the control variables are lagged by one period to carry out a measurement regression and a robustness test. The empirical results are shown in columns (3–5) in Table 3. The coefficients of $Envir_t$ are all significantly positive at the 1% level, which verifies that local governments' environmental emphasis has a positive impact on the green innovation of enterprises.

Fourth, we add control variables. Local per capita GDP ($Lngdp_t$), local population density ($Density_t$) and local population growth rate ($Growth_t$) indicators are used as control variables, which are added to econometric regression Eq. (1) for regression. The empirical results are shown in column (6) in Table 3. The coefficient of $Envir_t$ is significantly positive at the 1% level, which verifies that local governments' environmental emphasis has a positive impact on the green innovation of enterprises.

4.4 Endogeneity concerns

There may be endogeneity between local governments' environmental emphasis and the green innovation of enterprises. First, companies that do not pay attention to green innovation may cause serious environmental pollution problems, which in turn cause local governments to pay attention to environmental protection issues, resulting in reverse causality. Second, local governments' emphasis on environmental protection may affect the green innovation strategies of only heavily polluting companies, resulting in biased estimates. Third, possible omitted variables can introduce endogeneity problems into the model. Thus, we adopt propensity score matching (PSM) and the instrumental variable method (IV) to alleviate the endogeneity problem.

4.4.1 Propensity score matching

To alleviate the problem that local governments' environmental emphasis on the marginal impact of corporate green innovation may be biased, PSM to address endogeneity. Sample firms whose $Envir_t$ value is larger than the median during the study period are given the value 1 and included in the treatment group, and firms whose $Envir_t$ value is smaller than the median are given the value 0 and included in the control group. Then, based on the PSM method of nearest neighbour matching (1:1) and (1:2), the control group firms matching with the treatment group firms are screened out (Yuan et al. 2016), and the quantitative regression of model (1) is carried out. The results are shown in columns (1) and (2) of Table 4. In column (1), the coefficient of $Envir_t$ is 0.058, and in column (2), the coefficient of $Envir_t$ is 0.069, both of which are significantly positive at the 1% level. The PSM model test strengthens the conclusion that local governments' environmental emphasis has a positive effect on the green innovation of enterprises.

Table 4 Regression results of endogeneity tests

Dependent variable = $Patent_t$	PSM		IV	
	1:1 matching (1)	1:2 matching (2)	The first stage (3)	The second stage (4)
$Envir_t$	0.058*** 2.84	0.069*** 4.11		0.652*** 5.29
$Waste_disposal_t$			0.008*** 18.55	
$Size_t$	0.338*** 22.98	0.342*** 28.08		0.297*** 23.36
$Lnage_t$	-0.189*** -5.96	-0.181*** -6.97		-0.154*** -8.14
$Capint_t$	-0.015*** -2.82	-0.014*** -3.15		-0.014*** -4.44
Roa_t	-0.028 -0.15	0.189 1.25		0.231** 2.29
$Lnstaff_t$	0.054*** 3.96	0.053*** 4.62		0.084*** 8.91
Lev_t	-0.231*** -3.54	-0.151*** -2.80		0.018 0.41
$Top10_t$	-0.005*** -7.33	-0.006*** -9.73		-0.006*** -14.32
$Indep_t$	0.415*** 6.89	0.383*** 7.65		0.299*** 8.50
<i>Constant</i>	-7.285*** -25.16	-7.277*** -30.76	3.798*** 84.79	-9.207*** -21.30
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
F Test			271.199***	
Observations	9103	13,203	29,937	29,937
Pseudo-R2/Adjusted R2	0.118	0.122	0.500	0.282

This table shows the measurement results of the endogeneity test of the impact of local governments' environmental emphasis ($Envir_t$) on the green innovation of enterprises ($Patent_t$). Columns (1) and (2) use propensity score matching, and columns (3) and (4) use IV estimates. Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, **, and *** indicate significance at the 10, 5%, and 1% levels, respectively

4.4.2 Instrumental variable method

The IV method is used to further weaken the possible reverse causality between local governments' environmental emphasis and the green innovation of enterprises. First, we use local residents' domestic waste decontamination rate ($Waste_disposal_t$) as an IV of local governments' environmental emphasis ($Envir_t$). The more importance a local

government attaches to environmental issues, the more it aims to improve the harmless treatment rate of local residents' domestic waste; this rate does not affect the specific implementation of a company's green innovation strategy. Therefore, the requirements of IV exogeneity and correlation are met. The regression results of the IV estimation are shown in columns (3, 4) in Table 4. In the first stage, the coefficients of *Waste_disposal_t* are all significantly positive at the 1% level. In the second stage, the coefficients of *Envir_t* are all significantly positive at the 1% level. The F statistics are far greater than 10, indicating that there is no weak IV problem. The IV estimation model shows that under the premise of weakening endogeneity, local governments' emphasis on the environment has a positive impact on the green innovation of enterprises, which verifies the reliability of the research conclusion.

5 Additional analysis

5.1 Channel analysis

According to the above theoretical analysis, local governments' environmental emphasis may indirectly affect green innovation by affecting the environmental protection awareness of corporate executives and environmental protection subsidies. Therefore, based on an intermediary model, we further the transmission mechanism of the positive impact of local governments' environmental emphasis on the green innovation of enterprises.

We construct an indicator of corporate executives' environmental awareness (*Manner_t*) based on four aspects. If a company discussed environmental protection, environmental policy, environmental management organizational structure, circular economy development models, green development, or related concepts, the value is 1; otherwise, it is 0. If a company disclosed achieved or future environmental protection goals, the value is 1; otherwise, it is 0. If a company held education and training related to environmental protection, the value is 1; otherwise, it is 0. If a company conducted environmental protection activities or other social welfare activities, the value is 1; otherwise, it is 0. We sum these four dummy variables, add one to take the logarithm, and construct an indicator of the environmental awareness of company executives (*Manner_t*). We take the logarithm of the amount of environmental protection subsidies received by a company in the current year and use this as an environmental protection subsidy indicator (*Subsidy_t*).

To test the action mechanism, models (2) and (3) are constructed to test whether local governments' environmental awareness has an indirect impact on corporate green innovation by improving corporate executives' environmental awareness and environmental subsidies. The model is as follows:

$$Manner(Subsidy)_{i,t} = \rho_0 + \rho_1 Envir_{p,t} + \sum_k \rho_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (2)$$

$$Patent_{i,t} = \delta_0 + \delta_1 Envir_{p,t} + \delta_2 Manner(Subsidy)_{i,t} + \sum_k \rho_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (3)$$

where i is the company, t is the year, and p is the region. The explained variables $Manner_{i,t}$, $Subsidy_{i,t}$ and $Patent_{i,t}$ represent executives' environmental awareness, the amount of environmental subsidies, and the number of green patent applications of company i in year t , respectively. The explanatory variable $Envir_{p,t}$ represents the environmental importance of the government in region p in year t . $Controls_{k,i,t}$ are control variables, including enterprise size ($Size_i$), company age ($Lnage_i$), capital intensity ($Capint_i$), return on total assets (Roa_i), total number of employees ($Lnstaff_i$), asset-liability ratio (Lev_i), the shareholding ratio of the top ten shareholders ($Top10_i$), the proportion of independent directors ($Indep_i$), industry dummy variables, and annual dummy variables. ε represents the residual. In addition, we use industry and year fixed effects to control for heterogeneity due to industry and year effects. Since part of $Patent_i$ is 0, we use the Tobit model for econometric regression. When the explanatory variables are $Manner_i$ and $Subsidy_i$, the ordinary least squares method is used, and the econometric models are all clustered according to the company code. All variables are described in the Appendix.

The measurement results of models (2, 3) are shown in Table 5. In column (1), the coefficient of $Envir_i$ is 0.014, which is significantly positive at the 1% level, indicating that local governments' environmental emphasis has a significant positive impact on corporate executives' environmental awareness. In column (2), both $Envir_i$'s coefficient and $Manner_i$'s coefficient are significantly positive at the 1% level, indicating that local governments' emphasis on environmental protection indirectly has a positive impact on corporate green innovation by improving corporate executives' awareness of environmental protection. In column (3), the coefficient of $Envir_i$ is 0.069, which is significantly positive at the 5% level, indicating that local governments' environmental emphasis significantly increases a company's environmental protection subsidies. In column (4), both $Envir_i$'s coefficient and $Subsidy_i$'s coefficient are significantly positive at the 1% level, indicating that local governments' emphasis on environmental protection indirectly has a positive impact on the green innovation of enterprises by increasing environmental subsidies. The Sobel test is significantly positive at the 1% level, indicating that local governments' environmental emphasis indirectly has a positive impact on corporate green innovation by improving corporate executives' environmental protection awareness and increasing environmental protection subsidies.

5.2 The mediating effects of firm characteristics

5.2.1 Sub-sample research according to the nature of enterprises

There are differences between state-owned enterprises and private enterprises in terms of resource endowments, goals, and values, and these differences are reflected in policy implementation and environmental responsibility. In contrast to private enterprises, state-owned enterprises pay attention not only to their short-term energy conservation and emission reduction effects but also to green innovation to achieve their long-term

Table 5 The regression results of the mediation effect model

	(1) <i>Manner_t</i>	(2) <i>Patent_t</i>	(3) <i>Subsidy_t</i>	(4) <i>Patent_t</i>
<i>Envir_t</i>	0.014*** 2.73	0.074*** 6.31	0.069** 2.06	0.074*** 6.38
<i>Manner_t</i>		0.138*** 10.62		
<i>Subsidy_t</i>				0.015*** 7.38
<i>Size_t</i>	0.146*** 40.32	0.319*** 38.35	0.828*** 35.40	0.327*** 39.49
<i>Lnage_t</i>	0.030*** 3.83	-0.193*** -11.03	-0.480*** -9.53	-0.181*** -10.36
<i>Capint_t</i>	-0.009*** -6.48	-0.012*** -4.04	-0.159*** -18.32	-0.011*** -3.63
<i>Roa_t</i>	0.044 (1.03)	0.142 (1.48)	-1.597*** (-5.77)	0.172* (1.79)
<i>Lnstaff_t</i>	0.020*** 5.78	0.058*** 7.73	0.282*** 12.97	0.057*** 7.50
<i>Lev_t</i>	-0.096*** -5.91	-0.053 -1.45	-0.530*** -5.04	-0.058 -1.60
<i>Top10_t</i>	0.000 0.22	-0.005*** -13.12	0.007*** 5.85	-0.005*** -13.33
<i>Indep_t</i>	-0.054*** -3.57	0.336*** 9.96	0.882*** 9.06	0.315*** 9.33
<i>Constant</i>	-3.273*** -49.77	-6.829*** -44.62	-4.412*** -10.40	-7.216*** -48.95
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Sobel test	6.465***	15.020***		
Observations	29,509	29,509	29,509	29,509
Pseudo-R2/Adjusted R2	0.218	0.134	0.313	0.133

The table shows the quantitative regression results of local governments' environmental awareness (*Envir_t*), corporate executives' environmental awareness (*Manner_t*), and environmental subsidies (*Subsidy_t*). It presents the measurement regression results of local governments' environmental awareness (*Envir_t*), corporate executives' environmental awareness (*Manner_t*) and corporate green innovation (*Patent_t*) as well as the quantitative regression results of local governments' environmental emphasis (*Envir_t*), environmental protection subsidies (*Subsidy_t*) and corporate green innovation (*Patent_t*). Models (2) and (3) were used to carry out the correlation econometric regression. Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, ** and *** indicate significance at the 10, 5%, and 1% levels, respectively

energy conservation and emission reduction effects. At the same time, state-owned enterprises pay more attention to environmental and social benefits than private enterprises. Therefore, when there are differences in the environmental importance perceived by local governments, the extent to which promoting the green innovation of enterprises is promoted may also be related to the nature of enterprises due to the close political connections between state-owned enterprises and the government.

We divide enterprises into state-owned enterprises and non-state-owned enterprises and examine whether the positive effect of local governments' environmental emphasis on the green innovation of enterprises is affected by the nature of enterprise ownership. The measurement results are shown in columns (1)–(2) in Table 6, showing that the marginal promotion effect of local governments' environmental emphasis on the green innovation of state-owned enterprises is 0.029, which is significant at the 10% level. This value for non-state-owned enterprises is 0.092, which is significant at the 1% level. The coefficient difference test is significantly positive at the 1% level, indicating that there is a significant difference in the effect of local governments' environmental emphasis on promoting green innovation in state-owned enterprises and non-state-owned enterprises. This effect is stronger for state-owned enterprises.

5.2.2 Sub-sample study according to the degree of corporate financing constraints

Firms with high financing constraints may find it more difficult to raise the funds needed for green innovation, which inhibits green innovation. In contrast, enterprises with low financing constraints can obtain more outside financial support and improve their green innovation level. Enterprises need substantial R&D funds to carry out green innovation; the R&D cycle is long, and the risk is high. Therefore, the degree of influence of local governments' environmental emphasis on corporate green innovation may be related to the degree of corporate financing constraints.

To verify whether there is a difference in the impact of local governments' environmental emphasis on the green innovation of enterprises with different financing constraints, we divide companies with low financing constraints and high financing constraints according to the median of corporate financing constraints to conduct group research. Financing constraints are measured using the SA index (Hadlock and Pierce 2010). The measurement results are shown in columns (3, 4) in Table 6. In columns (3) and (4), $Envir_i$'s coefficients are 0.106 and 0.029, significant at the 1% and 10% levels, respectively. The coefficient difference test is significantly positive at the 1% level, indicating that there are significant differences in the effect of local governments' environmental emphasis on the promotion of green innovation of enterprises with different financing constraints. This effect is stronger for enterprises with low financing constraints.

5.2.3 Sub-sample study according to the degree of pollution in the production processes of enterprises

Industry characteristics play a crucial role in determining corporate strategic decisions, and corporate investment decisions and behaviours are inevitably affected

Table 6 Regression results for heterogeneity test

Dependent variable = <i>Patent_t</i>	Non_SOE	SOE	Low financing constraints	High financing constraints	Non-heavily polluting industries	Heavily polluting industries
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Envir_t</i>	0.029* 1.93	0.092*** 5.10	0.106*** 6.61	0.029* 1.74	0.065*** 4.88	0.135*** 6.03
<i>Size_t</i>	0.293*** 27.92	0.386*** 29.84	0.367*** 33.79	0.320*** 26.42	0.339*** 36.07	0.365*** 24.60
<i>Lnage_t</i>	-0.141*** -6.98	-0.278*** -8.15	-0.150*** -6.18	-0.120*** -3.86	-0.138*** -6.95	-0.184*** -5.65
<i>Capint_t</i>	-0.003 -0.83	-0.026*** -5.35	-0.014*** -2.97	-0.014*** -3.41	-0.009*** -2.67	-0.021*** -3.44
<i>Roa_t</i>	0.323*** 2.86	-0.137 -0.80	-0.070 -0.52	0.318** 2.43	0.299*** 2.64	-0.091 -0.56
<i>Lnstaff_t</i>	0.085*** 8.85	0.017 1.44	0.033*** 3.08	0.074*** 7.12	0.071*** 8.22	0.052*** 3.52
<i>Lev_t</i>	0.074* 1.66	-0.372*** -6.22	-0.225*** -4.45	0.013 0.25	0.035 0.83	-0.341*** -5.41
<i>Top10_t</i>	-0.007*** -14.04	-0.004*** -6.79	-0.006*** -10.59	-0.005*** -10.09	-0.007*** -15.17	-0.001 -1.47
<i>Indep_t</i>	0.137*** 3.04	0.568*** 10.89	0.295*** 6.46	0.357*** 7.34	0.272*** 6.70	0.321*** 5.70
<i>Constant</i>	-6.237*** -31.01	-7.806*** -32.87	-7.752*** -41.11	-7.007*** -28.27	-7.348*** -42.79	-8.117*** -31.63
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Coefficient difference test	96.79***		16.54***		23.15***	
Observations	18,540	11,397	14,398	15,539	21,671	8266
Pseudo-R2	0.114	0.170	0.158	0.113	0.144	0.139

This table shows the measurement results of the heterogeneity of the impact of local governments' environmental emphasis (*Envir_t*) on the green innovation of enterprises (*Patent_t*). Model (1) was used to carry out the econometric regression. Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, ** and *** indicate significance at the 10, 5%, and 1% levels, respectively

by the industry environment and industry characteristics (Chiasson and Davidson 2005). When local governments attach importance to environmental protection issues, they may introduce a series of environmental protection measures, and the degree of their impact on enterprises may be affected by the industry to which enterprises belong. This article is based on the notice issued by the Ministry of

Environmental Protection of the People’s Republic of China in June 2008 on the “List of Industry Classification Management of Listed Companies for Environmental Protection Verification”, which includes thermal power, steel, cement, electrolytic aluminium, coal, metallurgy, chemical industry, petrochemical, building materials, papermaking, brewing, pharmaceuticals, and fermentation. Sixteen industries, such as textiles, tanning and mining, are defined as heavily polluting industries, and other industries are defined as non-heavily polluting industries. A sub-sample study is carried out.

The measurement results are shown in columns (5, 6) in Table 6. In columns (5) and (6), $Envir_{i,t}$ ’s coefficients are 0.065 and 0.135, respectively, and are significant at the 1% level. The coefficient difference test is significantly positive at the 1% level, indicating that there are differences in the positive impact of local governments’ environmental emphasis on the green innovation of different polluting enterprises. This impact is stronger for enterprises in heavily polluting industries.

5.3 Extended research

We divide enterprise green innovation into green invention innovation ($Patented_{i,t}$) and green non-invention innovation ($Non_patented_{i,t}$) and then study the difference in the impacts of local governments’ environmental emphasis on different types of green innovation.

To study the effect of different types of green innovation more deeply, we further study the relationships between different types of green innovation and enterprise value ($Tq_{i,t}$). The model is as follows:

$$Patent(Non_patent)_{i,t} = \theta_0 + \theta_1 Envir_{p,t} + \sum_k \theta_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (4)$$

$$Tq_{i,t} = \omega_0 + \omega_1 Patent_{i,t} + \omega_2 Non_patent_{i,t} + \sum_k \omega_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (5)$$

where i is the company, t is the year, and p is the region. The explained variables $Patented_{i,t}$, $Non_patented_{i,t}$, and $Tq_{i,t}$ represent the green invention innovation and green non-invention innovation of company i in year t , respectively. The explanatory variable $Envir_{p,t}$ represents the environmental importance perceived by the government in region p in year t . $Controls_{k,i,t}$ are control variables, including enterprise size ($Size_{i,t}$), company age ($Lnage_{i,t}$), capital intensity ($Capint_{i,t}$), return on total assets ($Roa_{i,t}$), total number of employees ($Lnstaff_{i,t}$), asset-liability ratio ($Lev_{i,t}$), the shareholding ratio of the top ten shareholders ($Top10_{i,t}$), the proportion of independent directors ($Indep_{i,t}$), industry dummy variables, and annual dummy variables. ε represents the residual. In addition, we use industry and year fixed effects to control for heterogeneity due to industry and year effects. Since some cases of $Patented_{i,t}$ and $Non_patented_{i,t}$ are 0, a Tobit model is used for quantitative regression. When the explained variable is $Tq_{i,t}$, the ordinary least squares method is used, and the econometric model is clustered according to the company code. All variables are described in the Appendix.

The measurement results of models (4, 5) are shown in Table 7. In columns (1, 2), the coefficients of $Envir_t$ are all significantly positive at the 1% level, indicating that local governments’ emphasis on the environment can promote the green invention innovation and green non-invention innovation of enterprises. In column (3), the coefficient of $Patented_t$ is significantly positive at the 1% level, and the coefficient

Table 7 Regression results of extended study

	(1) $Patented_t$	(2) $Non_patente_t$	(3) Tq_t	(4) Tq_{t+1}
$Envir_t$	0.087*** 8.91	0.067*** 7.15		
$Patented_t$			0.096*** 10.34	0.094*** 8.72
$Non_patented_t$			0.004 0.40	0.009 0.84
$Size_t$	0.286*** 42.76	0.236*** 36.46	-0.445*** -40.60	-0.436*** -37.31
$Lnage_t$	-0.121*** -8.37	-0.149*** -10.61	0.245*** 13.65	0.211*** 10.81
$Capint_t$	-0.010*** -4.06	-0.004* -1.78	0.041*** 8.96	0.045*** 9.05
Roa_t	0.046 0.58	0.096 1.26	2.285*** 14.35	2.097*** 11.33
$Lnstaff_t$	0.036*** 5.75	0.045*** 7.45	0.005 0.57	0.003 0.35
Lev_t	-0.138*** -4.60	0.079*** 2.72	0.088* 1.73	-0.169*** -3.04
$Top10_t$	-0.004*** -12.52	-0.002*** -7.99	-0.008*** -19.43	-0.006*** -12.67
$Indep_t$	0.282*** 10.05	0.187*** 6.87	0.337*** 8.81	0.303*** 7.18
<i>Constant</i>	-6.184*** -50.74	-5.357*** -45.31	10.562*** 55.54	11.414*** 55.39
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
<i>N</i>	29,937	29,937	29,937	25,848
Pseudo-R2/Adjusted R2	0.127	0.128	0.328	0.327

The table shows the econometric regression results of local governments’ environmental emphasis ($Envir_t$) and enterprises’ green invention innovation ($Patented_t$) and green non-invention innovation ($Non_patented_t$). It presents the quantitative regression results of green invention innovation ($Patented_t$), green non-invention innovation ($Non_patented_t$) and firm intrinsic value (Tq_t). Models (4) and (5) were used to carry out the correlation econometric regression. Descriptions of the variables are presented in the Appendix, and all continuous variables are tailed at the 1% level. Standard errors are corrected using the double-clustering (firm and year) method. t-statistics are shown in bold values

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

of *Non_patented_t* is not significant, indicating that only green invention patents promote the intrinsic value of enterprises. In column (4), after the explanatory variables and control variables are lagged by one period, the empirical results show that green invention patents have a significant promoting effect on the intrinsic value of enterprises, while green non-invention patents have no significant impact on the intrinsic value of enterprises. In summary, the empirical results of models (4) and (5) reveal in more detail the impact of local governments' environmental emphasis on different types of green innovation of enterprises as well as differences in the impact of different types of green innovation on the intrinsic value of enterprises.

6 Conclusion and policy recommendation

Based on data of Chinese Shanghai and Shenzhen A-share listed companies from 2008 to 2019, this paper demonstrates the impact of local governments' environmental emphasis on the green innovation of enterprises and the mechanism of action. The study finds that local governments' environmental emphasis can significantly promote the green innovation output of enterprises, and this conclusion still holds when robustness and endogeneity tests are conducted. The mediating effect model shows that local governments' environmental attention indirectly promotes the green innovation of enterprises by enhancing the environmental protection awareness of corporate executives and increasing environmental protection subsidies. A heterogeneity analysis shows that the positive impact of local governments' environmental emphasis on the green innovation of state-owned enterprises, enterprises with low financing constraints and heavily polluting enterprises is more prominent. Further research shows that local governments' environmental emphasis can significantly promote green invention innovation and green non-invention innovation of enterprises, but only green invention innovation can significantly enhance the intrinsic value of enterprises.

The behavioural decisions of local governments can lead them not only to formulate strict economic regulations but also to signal their treatment of economic problems, thereby affecting the green innovation strategies of enterprises in the region. The conclusions of this paper have the following implications. First, local governments' emphasis on environmental issues has a soft binding force that can set an example for enterprises to care for the ecological environment, thereby helping enterprises attach importance to green management and formulate reasonable green innovation strategies. Second, this paper clarifies the influence path of local governments' environmental emphasis on the green innovation of enterprises, which can provide a reference for governments in making environmental protection decisions. Third, based on the heterogeneity of enterprises, this paper finds differences in the impact of local governments' environmental emphasis on green innovation, indicating that the spillover effect of this emphasis should be analysed according to the specific situation of enterprises. Fourth, this paper verifies the role of green invention and innovation in enhancing the intrinsic value of enterprises, and green non-inventive innovation has no significant impact on

the intrinsic value of enterprises. This conclusion provides theoretical support for the concept of green innovation drive and green recovery.

Based on these findings, this paper puts forward the following suggestions. First, local governments should increase the incentive mechanism for green innovation of enterprises, especially green invention innovation, so as to encourage enterprises to increase their efforts in green research and development. Second, local governments should formulate differentiated green innovation support policies according to corporate attributes, so as to better promote the balanced development of the green innovation industry chain. Third, in the early stage of transforming its business mode into a green model, an enterprise may encounter difficulties such as low business performance and unsuitable replacement of the production model. Local governments should provide substantial incentives to these enterprises, such as tax reduction or exemption or financial subsidies. This will help enterprises reduce operational frictions, thereby promoting green technology innovation and application more efficiently.

This paper preliminarily examines the causal effect between local governments' environmental emphasis and corporate green innovation, but due to the availability of data, the empirical results of this paper have some limitations. This paper measures local governments' attention to environmental issues based on their total environmental expenditure. However, the specific aspects of environmental expenditure are not analysed in detail, and it is not clear that some specific behaviours of the government can more effectively promote the green innovation of enterprises. In addition, this paper fails to identify the temporary and persistent characteristics of green innovation development in enterprises. As more data are disclosed, these contents need to be further expanded.

Appendix

Variable definitions

Variable name	Variable symbol	Variable definition
The number of green patent applications	$Patent_t$	Add one to the number of green patents applied for in the current year and take the logarithm
The number of green invention patent applications	$Patented_t$	Add one to the number of green invention patents applied for in the year to take the logarithm
Green non-invention patent applications	$Non_patented_t$	Add one to the number of green non-invention patents applied for in that year and take the logarithm
The local government's environmental emphasis	$Envir_t$	The local government's environmental protection expenditure divided by the average population for the year

Variable name	Variable symbol	Variable definition
Enterprise size	$Size_t$	The logarithm of the company's annual average total assets
Company age	$Lnage_t$	Subtract the year in which the company was founded and take the logarithm
Capital intensity	$Capint_t$	Total assets divided by operating income
Return on total assets	Roa_t	Operating profit divided by annual average total assets
Total number of employees	$Lnstaff_t$	Logarithm of the total number of employees in the company
Assets and liabilities	Lev_t	Total liabilities divided by annual average total assets
Shareholding ratio of top ten shareholders	$Top10_t$	The total percentage of shares held by the top ten shareholders
Proportion of independent directors	$Indep_t$	Number of independent directors divided by total number of directors
Environmental awareness of executives	$Manner_t$	According to the company's social responsibility report, the four aspects of environmental protection concept, environmental protection goals, environmental protection education and training, and environmental protection public welfare activities are comprehensively scored, and then, the logarithm is taken
Government subsidies	$Subsidy_t$	The logarithm of the amount of government subsidies received by the company in the current year
GDP per capita	$Ln GDP_t$	Logarithm of local GDP per capita
Local population density	$Density_t$	Population (person)/area (square kilometres)
Local population growth rate	$Growth_t$	(regional population at the end of the year-regional population at the beginning of the year)/regional average population $\times 1000\%$
Corporation value	Tq_t	The ratio of the firm's market value to the capital replacement cost
Industry dummy variable	Ind	According to the 2012 version of the industry code, the second-level classification of manufacturing and the first-level classification of other industries

Acknowledgements We acknowledge financial support from the Fundamental Research Funds for the Central Universities “Research on the System Characteristics and Perfection of Modern State-owned Enterprises with Chinese Characteristics” [Grant No.: 2019zz023].

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