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Innovation under environmental constraints: Does corporate environmental responsibility matter in green innovation?

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ABSTRACT

When human civilization is thriving to the rapid economic and social development, the deteriorating ecological environment has also pressured the society to put environmental protection issues on the agenda future development. Therefore, green innovation is not merely a requirement for a corporate's long-term development but the basics of sustainable development of human society. As an objective indicator to measure a company's commitment to social responsibility, corporate environmental responsibility has an extremely important impact on a corporate's business philosophy and innovation strategy. However, the existing literature rarely studies between these two variables. This paper collects the data of listed companies from 2010 to 2019 and empirically tests the impact of corporate environmental responsibility on corporate green innovation. The study finds that corporate environmental responsibility can promote green innovation by reducing financing constraints, improving corporate governance and increasing government subsidies and R&D investment, and the result is still significant under a series of robustness checks. The placebo test suggests that the Jiangsu enterprise responsibility construction pilot has facilitated the development of enterprises' green innovation to a great extent. The conclusions enrich existing literature on corporate environmental responsibility and corporate green innovation, providing implications for government policy orientation, social atmosphere guidance and corporate strategic decision-making process.

KEYWORDS

Corporate social responsibility; Corporate green innovation; Finance constraint; Corporate governance; Government subsidy; Research and development investment

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1. Introduction

Green development is an effective way to coordinate ecological protection, promote economic development and reduce carbon emissions (Tsang et al. 2022). In today's world, green development is increasingly deemed as the core goal for global sustainable development and the prioritized sector for human development (Zhou et al, 2020). At the same time, adhering to the path of green development is the best way to improve the quality and efficiency of China's economic development. As the most populous developing country in the world, China's resource share per capita is low, with weak carrying capacity of the ecological environment (Suriyapongprapai et al. 2022). China is also the world's largest energy consumer, ranking first in the world in terms of total carbon dioxide emissions. Its energy consumption per unit of GDP is twice the world average and its carbon emissions per capita exceed 40% of the world average (Wang et al. 2021). Over the past decades, China has adhered to the concept of prioritizing economic development over ecological protection. The traditional cognition ignores the value of the ecological environment when booming the economy, which is inconsistent with the sustainable development path. This has caused serious resource shortages and environmental pollution. In order to meet the ecological demands of the people and strengthen environmental governance, Chinese government has enacted a series of environmental regulation policies. Enterprises are driven to solve pollution problems through administrative orders, binding requirements or the coercive force of laws and regulations (Yang and Chai 2015; Jiang et al., 2020). However, the regulation policies with coercive force often pay more attention to the “ex-post” treatment, such as formulation of pollution emission standards and the introduction of a carbon tax, etc., ignoring the “ex-ante” investment stage. In addition, the technical standards of these policies are usually difficult to digest in the industry. And they are difficult to be internalized into corporate action guidelines, resulting in weak implementation effects and failure to fundamentally solve problems (Jaffe et al. 2012).

Therefore, to better solve the problem of environmental pollution and promote economic development, it is necessary to take the “input” perspective beforehand. Innovation not only plays an increasingly critical role in stabilizing economic growth, but is also a core breakthrough for input-side solution. In the context of ecological civilization construction and green development, traditional technological innovation can no longer meet people's dual needs for economic growth and environmental protection. However, green innovation could create economic benefits and reduce environmental pollution simultaneously, so it has become the best choice for economic development mode optimization and green economic development (Ouyang 2015). As essential economic entities, enterprises should shoulder their responsibility for green innovation. They can participate in green innovation in many ways, such as improving energy efficiency, waste recycling, green product design and corporate environmental management. These approaches could be roughly divided into two categories: green product innovation and green process innovation (Chen 2006). The government and society have created a favorable policy environment and market atmosphere to encourage enterprises to undertake environmental responsibilities and carry out green innovation. Besides, consumption and investment trends are deeply influenced by environmental protection. Accordingly, enterprises should actively fulfill their environmental responsibilities to better adapt to the market environment and release positive signals. Taking environmental responsibility and promoting green innovation can also drive social and economic development and generate positive externalities to the environment. However, the characteristic of green innovation, namely the technical difficulties and uncertainties, have been the main obstacles for companies to conduct green innovation activities (Hsu 2014). So, will corporate environmental responsibility positively impact corporate green innovation? If so, what is the mechanism of this effect? In order to solve the above problems, this paper explores whether corporate environmental responsibility fulfillment has a positive impact on the improvement of corporate green innovation. Simultaneously, this paper also attempts to

analyze the impact mechanism of corporate environmental responsibility on corporate green innovation from four aspects: R&D investment intensity, financing constraints, corporate governance capabilities and government subsidies.

2. Literature review and hypotheses proposition

2.1. From corporate social responsibility to corporate environmental responsibility

The modern ideation of corporate social responsibility theory dated back to the 1950s. However, it was until 1979 when the most widely accepted definition, namely "three-dimensional model" was proposed by Carroll, who analyzes corporate social responsibility from four aspects: economic, legal, moral, and humane. According to their definitions, moral responsibility refers to factors such as environmental protection, human rights and other elements that are generally regarded as an externality of business operations, while humanitarian responsibility focuses more on the company's contribution to the community, education, arts, etc (Carroll 1979).

The exiting theories studying the essence of corporate social responsibility mainly fall into two groups. The "Corporate Social Responsibility Tool Theory" believes that corporate social responsibility is a strategic mean applied by enterprises for competitive advantages and better economic performance. In contrast, "Corporate Social Responsibility Ethics theory" emphasizes the importance of corporate social responsibility in meeting the expectations of corporate stakeholders in order to solve "agent problem". However, both theories believe that corporate social responsibility can portray a good social image and help corporates reap certain economic benefits (Hasan et al., 2022).

With the deterioration of environmental degradation and disturbed economic balance, corporate environmental responsibility has gradually become the focus of society and corporate stakeholders. Corporate environmental responsibility, which is an essential part of CSR, can be defined as corporates undertaking relevant environmental protection responsibilities by pursuing new environmental knowledge and practicing environmental protection (Xu et al. 2021) The research of Villiers and Staden locks the connotation of corporate environmental responsibility from two perspectives, namely corporate environmental responsibility and corporate environmental legality (Villiers, Naiker and Staden 2011). Corporate environmental responsibility could be measured from the perspective of transparency, responsiveness and obedience (ISEA 1999). And "environmental legitimacy" measures the degree to which a company's environmental performance is recognized by stakeholders (Bansal and Clelland 2004).

Based on the forementioned definition, the theory of motivation for corporate undertaking environmental responsibility could be classified into three groups. The "institutional theory" proposed by Powell et al. focuses on the externalities of the production and operation of enterprises, arguing that the principal reason is to alleviate environmental pressure from the government, society and the media. The stakeholder theory contends that an enterprise fulfills its environmental responsibilities in order to satisfy its stakeholders' demand for the enterprise's environmental protection. Legitimacy theory emphasizes that enterprises seek the approval of stakeholders by proving their business activities are reasonable and legal (Freeman 1994; Deegan and Blomquist 2006).

The impact of corporates environmental responsibility performance could also be analyzed from two aspects. From the perspective of the externalities of the production and operation activities, by improving the production technology and promoting green production, corporates will contribute to the promotion of environmental protection, promoting the concept of environmental protection to be further popularized and driving more enterprises to realize that the necessity of conforming to relevant green production standards for corporates' sustainable development (Mishra and Suar 2010; Rehman, Khan and Rahman 2020).

From the perspective of corporates' strategic development, performing environmental responsibility could

portray a positive social image, which improves corporates' business performance (Sarkar, Qian and Peau 2020). Referring to the stakeholders' theory, once stakeholders realize corporates' undertaking social responsibility is beneficial for their own profit, they would be more likely to improve their performance (Orlitzky, Schmidt and Rynes 2003; Mughal et al. 2021). For corporate employees, companies performing CER activities will improve employees' physical and mental health, entailing the improvement of productivity. Since the government is the main driving force for environmental protection, corporates' fulfillment of environmental responsibility will help them win more political resources for corporates' future development (Li et al. 2017). Furthermore, the disclosure of a more open and transparent green production environment is conducive to solving the problem of information asymmetry between enterprise managers and owners, helping corporate's obtain stable financial support (Qin, Harrison and Chen 2019). Research has shown that in a corporate crisis, investors punish responsible companies much less than those less responsible ones in a way that responsibility help companies get financial support to survive the crisis.

Wong's study suggests that CER is a future-oriented investment (Wong et al. 2018). This could be reflected in the increase of corporates' intangible assets such as innovation, brand value, and knowledge capital (Egbu 2004) . By fulfilling corresponding environmental responsibilities, corporates could greatly alleviate financing constraint, which make them more likely to receive relevant green funds subsidies and practice green production process (Ghoul, Guedhami and Kim 2017; Liu et al. 2021). These will help the corporate expand to the new market and attract new customer groups (Xu et al. 2021). A positive corporate image established through performing responsibly reduce the loss of existing customers, increase employee participation, and ultimately achieve increased production efficiency and long-term profitability (Dong et al. 2014; Sarkar, Qian and Peau 2020). In summary, most studies believe that CER is a win-win option for promoting not only the sustainable development of corporates but also human society in the long run.

2.2. Corporate green innovation

The proposal of corporate green innovation stems from the urgent demand for environmental protection. On one hand, the economic take-off drives drastic social changes and improves human beings' living standards to a great extent; on the other hand, the immature mode of production has greatly damaged the environment and threatened human being's survival. As a critical driving force to promote economic and social development, corporates' upgrading and transforming production mode is of great necessity for environmental protection. In 1999, Klemmer et al. proposed the concept of corporate green innovation in a broad sense for the first time. The series of corporate green innovation corporates can take that could (1): increase R&D investment, promote the application of products or introduce new technologies and ideas; (2): mitigate related environmental burdens or relevant means of achieving the goal of sustainable development (Lehr and Löbbe 2000). Rennings further subdivided green innovation into four categories: technological, organizational, social, and structural. Corporates' green innovation behavior is mainly reflected in terms of promoting technological innovation to control or prevent environmental pollution (Rennings 2000). According to Lončar, corporates that invest in the development of green technology could achieve sustainable and green development without harming business interests (Lončar et al. 2019). Through R&D investment and adoption of green production technologies, Oltra believes that companies will be able to realize the goal of higher production efficiency as well as better product quality, reaping long-term benefits (Oltra 2008).

After reform and opening up, Chinese society has begun to realize the increasingly urgent problems of environmental protection under the influence of Western environmental protection theories. Since 2012, the Chinese government has released the signal of paying closer attention to environmental protection in a series of meetings and has taken concrete measures to further strengthened the construction of ecological civilization. These included strictly implementing energy conservation and emission reduction policies to promote the development

of carbon emission cut-off pilot projects, and leaving environmental taxes on high-polluting companies. Existing research has found that on the premise of an open and transparent market information system, the economic measures adopted by the government, such as levying environmental taxes, exert significant influence on pressuring corporates to reduce emission costs and facilitate the development of green innovation (Milliman and Prince 1989; Dragone, Lambertini and Palestini 2013). In his research, Wang and Yu have further classified the environmental tax into two groups, namely air pollution tax and water pollution tax, and holds that the relationship between the amount of air pollution taxes levied and the corporate green innovation is not linear. The finding also suggests that the air pollution tax levied by the Chinese government is well below the optimal level (Dragone, Lambertini and Palestini 2013). The research from Joo, Seo and Min indicates that four types of supportive government measures, including financial subsidies, can promote the ability of corporate green innovation (Wang and Yu 2021). Other studies find that in addition to the government's macro-control measures, market and technology are both important forces driving the development of corporate green innovation. Kammerer argues that certain green innovation products can provide added value for customers. This kind of "customer benefit" can help corporates overcome the "dual externalities" problems of green innovation, thereby promoting the progress of corporate green innovation technology (Joo, Seo and Min 2018). In his research, Rennings further expanded the motivation of market forces into customer benefit and cost saving. The results suggest that the cost-saving motive and green innovation significantly impact the development of corporate green innovation (Kammerer 2009). From a technological perspective, the research of Horbach et al. suggests that knowledge capital could stimulate the development of corporates' future green innovation. However, the aforementioned research mostly focuses on the performance of green innovation under "external pressure" such as government interference and market control, while the role of corporates' "internal force" has long been neglected.

2.3. Corporate social responsibility and the impact of green innovation

Based on the theory of stakeholders, Corporate social responsibility, which serves as an important means for companies to actively coordinate with internal stakeholders of the company, has a critical impact on the production and operation activities of the modern corporation (Horbach 2008). Existing literature explores the potential influence mechanism of corporate social responsibility and corporate environmental responsibility on corporate green innovation, which lays the foundation for the research of this paper. However, there are still many deficiencies in existing research. First, the existing literature disagrees with whether corporate social responsibility could positively promote corporate innovation. Luo and Du contend that performing social responsibility could enhance the network connection between a corporate and its stakeholders, improving the corporate's organizational learning ability and ultimately accelerating the development of new products. The research of McWilliams and Siegel indicates that fulfilling social responsibilities will financially pressure certain corporates. Based on the motivation of portraying a positive image, corporates tend to diversify their products to meet the public's expectations for their corporate image, which eventually boosts the R&D investment. On the contrary, other scholars argue that corporate social responsibility cannot always promote the improvement of the corporate innovation level. Excessive corporate social responsibility may also divert the resources and management power invested by the company in its main business, entailing a decline in corporates' overall profitability (Hull and Rothenberg 2008). Meanwhile, according to Auty's "resource curse" hypothesis, although CSR can help corporates win the support from external stakeholders, it virtually strengthens the external stakeholders' interference in the corporates' operation and financing activities. This unnecessary intervention would negatively impact corporate technological innovation (Auty 2002). Therefore, the study of Hafsi et al. suggests that corporate social responsibility has an inverted "U" shape impact on corporate technological innovation (Gao, Wu and Hafsi 2017). This paper contends that there are two reasons for the divergence in existing research. First, most of the existing literature does not

distinguish corporate green innovation from product innovation, thereby ignoring the possible "gloss over" problem of corporate social responsibility. This could greatly affect the objectivity of the results. Reducing relevant costs, promoting the corporates' transformation and upgradation, and eventually promoting companies' green and sustainable development are the main motivations for corporate green innovation. In contrast, the incentive for corporate production innovation is to avoid relevant environmental damage penalties by upgrading products or advancing technologies, thereby improving the corporate overall profitability (Haley 1996; Gao, Wu and Hafsi 2017). To conclude, indiscriminately measuring the impact of CSR on corporates' overall innovations could draw contradictory conclusions. Second, corporates' motivation to fulfill responsibility may vary greatly from each other. Fooks believes that the main purpose of performing social responsibilities by highly polluting companies such as BAT is to evade the government and legal constraints, which leads to greater harm to public interests (Fooks et al. 2013). The research of Wickert et al. further divides corporate social responsibility into CSR "talking" and CSR "walking." CSR "talking" means that corporates create a socially responsible image by actively taking various publicity campaigns or labeling products; on the contrary, CSR "walking" indicates that concrete measures are taken to upgrade corporate production mode and reduce the impact on the environment (Wickert, Scherer and Spence 2016). Through contrasting two different ways of performing CSR, Wickert argues that compared to small companies, it is far easier for large companies to "talk" social responsibility than to actually "walk" social responsibility, which means large companies may be more inclined to make more investment in shaping a so-called "Responsible" corporate image rather than taking real responsibility. Compared to corporates' taking "whitewashing" social responsibility, the extent to which the corporates fulfill environmental responsibility should be considered as a more objective measurement for CSR. Only companies that are devoted to performing their environmental responsibilities could truly cater to the demands of stakeholders for environmental protection, which would receive financial and technical support to achieve long term development. Based on this, this paper argues that performing corporate environmental responsibility exerts a positive impact on promoting corporate green innovation and thus proposes the main hypothesis as follows:

H_1: Corporate taking environmental responsibility can promote corporate green innovation.

Finally, most existing literature applies a simple linear regression model to study the impact of corporate social responsibility on corporate innovation, which ignores the possible endogeneity problems. Based on this, the marginal contributions of this paper are as follows: (1) Use corporate environmental responsibility instead of corporate environmental responsibility as an explanatory variable to study the impact on corporate innovation and further enrich related research. (2) Use the number of green innovation patents obtained by corporates as an explanatory variable to measure corporates' green innovation capability to separate the corporate green innovation from general corporate innovation activities, thereby enhancing the robustness of the results. (3) By applying the instrumental variable method, this paper uses the number of temples within 300 kilometers of the target companies as an instrumental variable to replace corporate environmental responsibility, filling the gap of relevant literature.

3. Methodology and data

3.1. Methodology

3.1.1. Baseline model

In order to study the impact of corporate environmental responsibility on corporate green innovation, this paper establishes a multi-dimensional fixed-effects regression model:

$$ginnov_{it} = \beta_0 + \beta_1 ecsr_{it} + \sum \beta_k X_{it} + \mu_i + \delta_j + \theta_k + \upsilon_l + \gamma_t + \varepsilon_{it} \quad (1)$$

In this model, $ecsr_{it}$ represents the environmental responsibility of corporate i in year t, X_{it} is the matrix that consists of the asset-liability ratio (arate), the number of directors (director), the total assets (asset), and the total net profit ratio (profit). μ_i, δ_j, θ_k and υ_l represent firm, industry, city and province fixed effect, respectively. γ_t represents the time-fixed effect and ε_{it} is the random error term.

3.1.2. Regression control method

In the policy effect test, in order to study the impact of the pilot measures of corporate social responsibility taken in Jiangsu Province on corporate green innovation, the "regression control model" proposed by 0 is taken as a reference. Here we select several other provinces that have not been affected by the policy to fit a "virtual" Jiangsu province to predict the "counterfactual result" based on the assumption that the policy had no impact on Jiangsu province under the same condition. An inference could be made about the policy effect after comparing the fitted result with the actual observation,

The underlying logic of the regression control method is that unobservable common factors existing in the economic environment will lead to cross-sectional correlations among different individuals. In this example, it is assumed that Jiangsu province and other provinces are simultaneously affected by the economic cycle and other government macro policies, resulting in a correlation between corporate green innovation in Jiangsu province and that in other provinces. The proposition of the "regression control method" has been widely used in the field of "regional policy evaluation", especially under circumstances where only one or a few regions are subject to policy shock (Ching et al. 2011; Du and Zhang 2015; Ouyang and Peng 2015; Li and Bell 2017).

Here we suppose T_0 is the number of periods before the policy was implemented in the sample data, and T_1 is the number of periods after policy shock. Therefore, the total time dimension could be defined as $T = T_0 + T_1$. In this study, T_0 equals to 7 (2010-2016) while T_1 equals to 3 (2017-2019), and the overall time dimension T is 10. Assuming that y_{it}^1 represents the level of green innovation in province i after being impacted by the social responsibility construction policy in period t, and y_{it}^0 represents counterfactual results of the green innovation level of the provinces without any external policy shock. Therefore, the policy effect on the corporate green innovation capability in period t can be expressed as follows:

$$\Delta_{it} = y_{it}^1 - y_{it}^0 \tag{2}$$

In fact, Jiangsu province is the only province that has been affected by the policy shock while other provinces haven't. Therefore, the actual observation could be rewritten as:

$$y_{it} = d_{it} * y_{it}^1 + (1 - d_{it}) * y_{it}^0 \tag{3}$$

d_{it} represents the dummy variable which indicates whether the province is affected by the policy. To be more specific, d_{it} is equal to 1 for the province, which has not been affected by the policy, and d_{it} equals 0 for affected provinces. In order to fit the counterfactual results of Jiangsu province to measure the policy effect, here we refer to the method introduced by Ching et al. Suppose all individual corporates that are not affected by the policy are under the influence of common factors, then y_{it}^0 could be represented as:

$$y_{it}^0 = \alpha_i + \beta_i' f_t + u_{it} \ ; \ (i = 1,2 \dots N; \ t = 1,2 \dots T) \tag{4}$$

α_i represents the individual fixed effect, f_t represents the $K \times 1$ common factors matrix, and β_i' stands for the corresponding $1 \times K$ "factor loading" matrix, which means that the effect of each common factor on different individuals y_{it}^0 can be different. u_{it} is a deliberate disturbance term for individual i at time t. Through a series of canonical transformations, the initial equation (3) can be reduced to the following regression equation:

$$y_{it} = \mu_0 + \mu' \overline{y^t} + \varepsilon_{1t} \tag{5}$$

$\overline{y^t}$ represents the matrix $\left(y_{1t},\ y_{2t} \ldots y_{(i-1)t},\ y_{(i+1)t} \ldots y_{Nt}\right)'$,which is corporate green innovation level for all individuals at time t in control group. Applying the basic OLS method, the estimated value of individual i at period t can be obtained as:

$$\widehat{y_{it}^0} = \widehat{\mu_0} + \widehat{\mu}'\overline{y^t} \tag{6}$$

In order to measure the fitting effect, we first fit the individual i with the data of the control group province in T_0 period. Then data from the period of T_1 could be plugged into the derived equation. The policy effect could be represented as $\Delta_{it} = y_{it}^1 - \widehat{y_{it}^0}$.

3.2. Variables

3.2.1. Definition of key variables

Corporate green innovation (ginnov): Here, the number of green patents applied by corporates each year is used to quantify the ability of corporate green innovation, and the sample period is from 2010 to 2019.

Corporate environmental responsibility (escr): Corporate environmental responsibility is the dependent variable in this study. Referring to Xue's practice, this paper uses the Corporate Environmental Responsibility Score (Greencsr) published by Hexun.com to measure corporate environmental responsibility (0). According to the professional evaluation system for social responsibility reports of listed companies on Hexun.com, the environmental responsibility score is based on five indicators: environmental protection awareness, environmental management system certification, environmental protection investment amount, the number of pollutant discharge types and the number of energy conservation types. The scoring process differs depending on whether the indicators are numerical or logical. The score of numerical indicators is obtained according to the calculation model of Hexun Data Center. The score of logical indicators is based on whether the social responsibility report discloses this indicator and whether the disclosure is detailed or not. Finally, the scores of the above five indicators are weighted and averaged. Taking manufacturing as an example, the environmental responsibility score could be calculated based on the following formula: Corporate environmental responsibility score = Environmental awareness score x4% + environmental management system certification score x5% + environmental protection investment amount score x7% + sewage type score x7% + energy saving type score x7%.

Control variables: Referring to the existing research, this paper adds the corporate asset-liability ratio (arate), the number of corporate directors (director), the total corporate assets (asset), the net profit margin of total corporate assets (profit), and government subsidies (subsidy) as control variables into the model. Corporate governance is calculated using principal component analysis from the perspective of incentives, supervision and decision-making based on key elements, including executive compensation and its shareholding ratio, independent director ratio, the board size, institutional shareholding ratio, equity balance, and the degree of separation of two rights. A higher corporate governance index suggests a better corporate governance performance and vice versa. Government subsidies are obtained by taking the natural logarithm of government subsidies received by firms. R&D investment intensity (rdi) is calculated by dividing gross domestic product (GDP) into corporate's R&D investment (R&D) expenditure.

Variables in robustness check: ecsr' represents corporate environmental responsibility during the shortened period of 2018-2019. Corporate Employee Responsibility (emcsr) and Corporate Retailer Responsibility (scsr) are components of the corporate social responsibility defined by Hexun.com.

Instrumental variable: In order to solve the possible endogeneity problem, referring to the existing literature

practice, the number of Buddhist temples within 300 kilometers of the enterprise is selected as an instrumental variable to be regressed on the dependent variable. Taking 0 as a reference, we first use Google Earth to determine the latitude and longitude position of the target corporation and the surrounding temples, from which the relative distance is calculated. The number of temples within 300 kilometers of the firm's location is then treated as the instrumental variable.

3.2.2. Source of data

Data used in this research is mainly on the level of individual corporate. Corporate green innovation (ginnov), corporate asset-liability ratio (arate), number of corporate directors (director), total corporate assets (assect), corporate net profit margin (profit), government subsidies (subsidy) and other corporate-related data are collected from Csmar and Wind databases. Corporate Environmental Responsibility (escr) comes from the Corporate Environmental Responsibility Score published by Hexun.com. Corporate employee responsibility and corporate retailer responsibility come from the corporate social responsibility score published by Hexun.com. The total number of temples within 300 kilometers of the corporate's location is calculated based on the geographical position displayed on Google Maps. Detailed data description is in table 1.

Table 1. Descriptive statistics.

Variable	Definition	Obs	Mean	S td. dev.	Min	Max
ginnov	Corporate green innovation	15,294	0.002	0.015	0.000	0.111
ecsr	Environmental responsibility	15,294	0.000	0.000	0.000	0.003
arate	Asset-liability ratio	15,294	0.422	0.209	0.007	1.758
director	Number of directors	15,289	2.130	0.197	1.099	2.890
asset	Total corporate assets	15,294	0.016	0.083	0.000	2.730
profit	Net profit margin	15,293	0.040	0.070	-1.146	0.675
subsidy	Government subsidy	14,998	0.005	0.026	0.000	1.127
Fincance	Finance constraint	8,109	0.633	0.482	0.000	1.000
Governance	Corporate governance	8,109	1.788	1.775	0.327	11.176
rdi	R & D investment	12,756	0.020	0.108	0	7.384

4. Results and discussion

4.1. Baseline regression analysis

This paper uses OLS to conduct a baseline regression analysis on corporate environmental responsibility and green innovation. In order to ensure the robustness of the results, the regression analysis is carried out by adding control variables one by one. Since different companies in different provinces and cities have certain gaps in basic conditions, they also have their own specificity at different times. This paper introduces individual fixed effects for regression, fixing province, city, industry, company and year. The results are shown in the table 2.

It could be inferred that without adding any control variables, the regression coefficient of corporate green innovation on corporate environmental responsibility is significant at the 5% level. It can be found that corporate environmental responsibility is related to corporate green innovation. And the improvement of corporate environmental responsibility will promote the development of corporate green innovation. After gradually adding the control variables asset-liability ratio, the number of directors, total assets, net profit margin of total assets and government subsidies, the coefficient of corporate environmental responsibility is basically unchanged and still significant. This shows that the improvement of corporate responsibility still significantly promotes the improvement of the green innovation level of enterprises when different control variables are considered.

Table 2. Baseline results.

Variables	1	2	3	4	5	6
ecsr	0.010**	0.010**	0.010**	0.009*	0.009*	0.009**
	-2.168	-2.107	-2.128	-1.936	-1.923	-1.998
arate		0.000*	0.000*	0.000*	0.000**	0.000**
		-1.747	-1.784	-1.807	-2.079	-1.982
director			-0.000***	-0.000***	-0.000***	-0.000***
			(-3.202)	(-3.190)	(-3.232)	(-2.966)
asset				-0.000*	-0.000*	-0.000*
				(-1.890)	(-1.910)	(-1.913)
profit					0	0
					-1.188	-1.177
subsidy						0
						(-0.167)
_cons	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	-1172.735	-271.232	-56.867	-56.9	-56.742	-55.876
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	15246	15246	15241	15241	15240	14941

4.2. Robustness Check

To further verify the baseline model results, this section will use the following methods to test their robustness. Firstly, to reduce the time interval. Considering the selection of time intervals may impact the results, the sample period used in this study was shortened from 2010 to 2019 to 2018 to 2019. The results are shown in column (1) of Table 3. The second robustness check is to replace the explained variable. Under the condition of high-quality development, the subject of corporate innovation is no longer limited to individuals or companies but is increasingly promoted through social network. Internally, corporate environmental responsibility depends on the contribution made by employee participation, cooperation, interaction and knowledge sharing. Externally, corporate environmental responsibility is related to the influence of corporate retailers' responsibility concepts. Therefore, this study replaces the explained variable “corporate environmental responsibility” with “corporate employee responsibility” and “corporate retailer responsibility” for regression. The corresponding results are shown in columns (2) and (3) of Table 3, respectively.

4.3. Endogeneity problem analysis

Based on the analysis of the baseline model, the number of green patents applied for by corporates with better environmental responsibility performance is higher than others. However, a possible bidirectional relationship could exist between corporate environmental responsibility and corporate green innovation. Obtaining more green patents suggests that companies have developed stronger green environmental protection ability, rendering them more capable of taking relevant environmental responsibilities. For instance, companies with stronger pollution control and prevention technologies in the petrochemical industry pay lower environmental taxes than their counterparts, making them more financially capable of undertaking CER such as energy conservation and emission reduction. In order to solve the possible endogeneity problems, referring to Du et al. 2014, this paper selects the number of Buddhist temples within 300 kilometers of the corporates’ location as an instrumental variable to be

Table 3. Robustness check.

Variables	Robustness check(1)	Robustness check(2)	Robustness check(3)
ecsr'	0.00931**		
	(1.998)		
emcsr		0.00001***	
		(3.082)	
scsr			0.00001*
			(1.722)
_cons	0.002***	0.002***	0.002***
	(55.876)	(55.747)	(55.866)
Control Variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
N	14941	14941	14941
r2_a	1.000	1.000	1.000

regressed on the dependent variable. As one of the most influential religions in China, Buddhism has an important influence on Chinese enterprises' production and business philosophy. Buddhism advocates the ecological concepts of “dependent origination and emptiness”, “relentless nature”, and “purity of the land”. Traditional Buddhist ideas hold that the connection between man and nature is universal and objective, especially emphasizing that man should live in harmony with nature (James and Cooper 2017). This coincides with the proposition that corporates should bear corresponding environmental responsibilities. According to sociological theory, people tend to choose a living environment that is consistent with their own personal characteristics. The locations of the companies are also closely related to corporates’ management concept. Companies around the temple are deemed to have a stronger environmental protection awareness. Therefore, the number of Buddhist temples around the company and corporate environmental responsibility are positively related (Du et al. 2014).

At the same time, the number of temples around the corporates does not directly affect the level of corporate green innovation. Therefore, it is reliable to select the number of Buddhist temples within 300 kilometers of the corporates’ location as an instrumental variable.

Table 4. Endogenous analysis results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
ecsr	0.447***	0.249***	0.203***	0.415***	0.226***	0.190***
	(5.523)	(8.504)	(8.746)	(6.070)	(9.437)	(9.330)
_cons	-0.000***	-0.000***	-0.000***	0.001***	0.000***	0.000***
	(-3.907)	(-5.758)	(-5.196)	(4.549)	(5.905)	(5.471)
Control Variables	No	No	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
City FE	No	No	Yes	No	No	Yes
Wald test	30.50	86.09	505.01	53.66	139.30	571.28
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	8108	8108	8108	8108	8108	8108

Table 4 reports the regression results of the new explanatory variable escr fitted by the instrumental variable on corporate green innovation. As suggested, the impact of esr on corporate green innovation is still significant at 99% after adding control variables and fixed effects. The Wald statistics of all models are much higher than the

critical value, indicating that the weak instrumental variables problem does not exist. The results indicates that corporate green responsibility does exert significant influence on corporate green innovation, which is consistent with the regression results of the baseline model.

4.4. Influence mechanism analysis

As inferred from the results of the baseline regression and the robustness test, corporates' environmental responsibilities have a rough stem effect on corporate green innovation. Therefore, this paper intends to further explore the influence mechanism of corporate environmental responsibility on corporate green innovation. The number of companies patents measures the level of green innovation each year. The development of green patents is characterized by high investment and technology. The increase in R&D investment intensity means more financial support. According to the existing literature, when enterprises face financing constraints, they will reduce emission reduction expenditure to avoid financing obstacles. At this time, enterprises' relative cost of environmental protection behavior will increase, negatively impacting innovation (Xu, Liu & Shang 2020; Jiang et al.,2022). Corporates' comprehensive development is increasingly embodied in corporate governance. The improvement of governance ability is conducive to reducing operational risk, resolving the contradictions between internal and external stakeholders, and improving the development quality of the enterprise (Xue et al. 2022). The governance pressure comes from internal stakeholders such as the board of directors and external legal and regulatory systems. These pressures will prompt enterprises to improve their governance and actively take environmental responsibility (Kock et al. 2012). Besides environmental regulation, government subsidies are the most important driver of green innovation. Specifically, there are many uncertain factors such as failure of green innovation, increase of corporate financial risks and the sluggish green consumer market, etc. These factors will significantly lower corporates' motivation for green innovation (Johnson 2016; Xu and Zhang 2009). Government subsidies use the "leverage effect" to directly relieve internal financial constraints and reduce the costs of green innovation, thereby solving the problem of green R&D market and the shortage of green innovation caused by "dual externalities" (Chen and Nie 2016; Dzonzi-Undi and Li 2016)

Therefore, this paper selects four variables for transmission mechanism: R&D investment intensity, financing constraints, corporate governance and government subsidies. As the results in table 5 suggest, corporate environmental responsibility significantly promotes corporate governance, government subsidies and R&D investment intensity while showing significant negative impacts on financing constraints.

Table 5. Mechanism verification of CER.

Variables	Governance	Finance Constraint	Subsidy	rdi
ecsr	11.560*	-64.150*	596.115***	5.753***
	-1.683	(-1.824)	-6.958	-3.407
_cons	-4.558***	-1.055***	-8.529***	0.008***
	(-65.265)	(-2.949)	(-9.793)	-9.85
Control Variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
N	8109	8109	8109	12756
r2_a	0.557	0.144	0.612	0.375

Next, this paper will analyze and explain the mechanism of financing constraints, corporate governance, government subsidies, and R&D investment intensity on corporate green innovation.

Firstly, the increase in R&D investment could promote corporate green innovation. R&D investment is a series of technical research expenditures, infrastructure expenditures and other expenditures related to employee

participation during the development of new products and services (Tou 2019). High R&D investment often means that companies will invest more manpower and material resources, thereby enhancing green innovation capabilities. Bogliacino argues that increase in R&D investment will effectively promote corporate innovation, and suggest higher profitability. Thus, forming a virtuous circle (Bogliacino 2013). The study by Jian Xu et al. concluded that the increase in R&D investment has positive impact on the green innovation performance. And ESG (environmental, social and governance) performance can increase the number of green invention patents (Xu and Shang 2020). According to the research of Scarpellini et al., the sectors with the greatest potential to carry out green innovation are transportation, logistics, manufacturing, and energy supply (Scarpellini et al. 2019). The production processes of these departments are highly polluting and energy-intensive. Increasing the intensity of R&D investment can reduce energy consumption and pollution.

Secondly, financing constraints have a negative impact on corporate green innovation. Research by Himmelberg et al. believes that external financing constraints will make small enterprises' R&D investment less than company's cash flow, thus limiting the ability to carry out innovative activities (Himmelberg 1994). Strict financing constraints will also increase corporates' operating costs and bring economic burdens. Corporates are placed under the adverse situation of lacking sufficient funds to invest in green innovation (Wong et al. 2020). When enterprises fulfill their corresponding responsibilities and reduce "information asymmetry", the "agent problem" will be further solved, thereby easing the external financing constraint and promoting green innovation (Li 2021)..

Thirdly, the increase in government subsidies has a positive incentive effect on green innovation. As economic entities, enterprises are naturally important force for innovation. According to the externality theory, government subsidies have become an important means to internalize the externalities of enterprise innovation (Bloom N 2013). The study by Liu et al. shows that government subsidies can bridge the gap between private innovation investment and desirable investment. Enterprises receiving government subsidies will have higher expectations for innovation and are more willing to take risks (Carboni 2017; Yang, Tang and Zhang 2021). In particular, the government's subsidies can resolve the uncertainty of subsidy direction and provide stable financial support for enterprises to carry out green innovation (Ivus 2021). In addition to the redistribution of funds, government subsidies will promote the rational allocation of human resources (Giebel 2020). Communication between enterprises and innovators will help form a network, improve the reliability of information dissemination and facilitate enterprises to integrate existing resources. These will contribute to new ideas and thinking for realizing green innovation (Schilling 2007).

Finally, the improvement of corporate governance can promote corporate green innovation. According to the "Quiet life" hypothesis put forward by Bertrand and Mullainathan, when not participating in the fierce market competition, the managers will lose the motivation to maximize profits. They will also reduce the related measures and increase their own income to enjoy the current "easy life" (Bertrand and Mullainathan 2003). As part of corporate innovation strategy, corporate green innovation requires a lot of additional management efforts (Kock 2012). Amore's research believes that the practice of green innovation means not only the simple division of R&D investment planning but also the introduction of new business methods and the emergence of research problems (Amore 2015). Once the concept of "easy life" is deeply ingrained, enterprise managers will easily settle for the status quo. And it will be difficult to carry out systemic reforms necessary for innovation (OECD 2012). On the contrary, if enterprises can face up to the governance pressure and improve the governance mechanism, it will help stimulate the innovation potential (Berrone et al. 2013). Researchers such as Bloom have concluded that improving enterprise governance can reduce energy consumption and promote green innovation (Bloom et al. 2010). This further proves that the improvement of corporate governance can promote corporate green innovation.

In conclusion, corporate environmental responsibility has a significant promoting effect on financing constraints, government subsidies and R&D investment intensity, while negatively impacting corporate governance.

It further promotes the development of green innovation through these four variables.

4.5. Policy effect test

4.5.1. Selection of control group

In response to the central government's call for strengthening corporate social responsibility, local governments have been actively implementing the central government's instructions and issuing relevant guiding documents to promote the development of corporate social responsibility. “Corporate Social Responsibility Construction Pilot Demonstration Implementation Plan” promulgated by Jiangsu Province in 2017 has arisen wide attention, which is aimed to facilitate the development of CSR within the province. To further test the impact of the CSR construction pilot project on corporate green innovation, it is necessary to form a control group corresponding to Jiangsu Province that has not undergone policy shocks in order to fit a “virtual” Jiangsu Province referring to the “regression control method.” We can then measure the policy effect on corporate green innovation by comparing the level of corporate green innovation in “real” Jiangsu Province and “virtual” Jiangsu Province. We refer to the “Post-Lasso-OLS” estimation method proposed by Li and Bell to select the target variables to select a control group that maximizes the goodness of fit. The AIC information guidelines are first applied to select the optimal subset, then the “Least Absolute Shrinkage and selection operator” is used for specific variables selection. Lasso estimator could solve the general problem of sparsity in high-dimensional data, that is, the overfitting problem that occurs when the number of variables is larger than the number of samples. The basic idea is to minimize the sum of squared residuals given that the absolute value of the regression coefficient is at most equal to a fixed constant, thereby assigning the value of some to be strictly equal to zero. The expression for the Lasso estimator is as follows:

$$B_{Lasso} = arg_B \, min\left\{\left|Y - \sum_{i=1}^{n} X_i B_i\right|\right\} \tag{7}$$

$$s.t. \sum_{i=1}^{n} |B_i| \le \lambda \tag{8}$$

B_i is an $n \times k$ coefficient matrix, and λ is an “adjustment parameter.” The overall regression coefficient can be compressed by setting the value of λ. Through Lasso regression, variables with zero coefficients are dropped, and the regression equation for the target variable could be derived after regressing the remaining variables on the explained variables.

In this example, through Lasso-OLS regression, corporate green innovation in the five provinces (provincial administrative regions) of Jilin, Henan, Guangxi, Beijing, and Chongqing before the implementation of the policy are chosen as explanatory variables (i.e., T_0 period). After regressing these five variables on corporate green innovation in T_0 period of Jiangsu Province, the results could be derived as follows:

The R-squared of the regression equation is 0.99988, which indicates that the control group selected by Lasso estimation is relatively reliable.

The counterfactual predicted value of corporate green innovation in Jiangsu Province could be obtained after plugging the corporate green innovation data of the control group during the period T_1 into the above regression equation. The policy effect could then be measured by subtracting the fitted value from the actual value of Jiangsu Province. Detailed results are displayed in the table 6 and 7.

Table 6. Fitting results in the pre-treatment periods using OLS.

ginnov·Jiangsu	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ginnov·Jilin	3.7367	0.5601	6.67	0.000	2.4123	5.0610
ginnov·Henan	-3.2185	0.4896	-6.57	0.000	-4.3763	-2.0606
ginnov·Guangxi	1.6492	0.2074	7.95	0.000	1.1588	2.1396
ginnov·Beijing	0.6127	0.0411	14.92	0.000	0.5156	0.7098
ginnov·Chongqing	2.4404	0.3993	6.11	0.000	1.4963	3.3846
_cons	-292.2585	23.7115	-12.33	0.000	-348.3272	-236.1898
Mean Absolute Error = 24.71347				*Number of Observations =13*		
Mean Squared Error = 4.3e+02				*Number of Predictors = 5*		
Root Mean Squared Error = 20.63033				*R-squared = 0.99988*		

Table 7. Prediction results in the post-treatment periods using OLS.

Time	Actual Outcome	Predicted Outcome	Treatment Effect
2017	4842	4577.233	264.7671
2018	5432	4149.563	1282.438
2019	5373	5123.723	249.2769
Mean	5215.667	4616.84	598.8271

Notes: The average treatment effect over the post-treatment periods is 598.8271.

Through analyzing the results, it could be inferred that the corporate social responsibility construction pilot project in Jiangsu Province significantly influences the development of corporate green innovation. Compared to that in 2017, when the policy was implemented, and 2019, the corporate green innovation experienced the most significant increase in 2018, which is the lag one phase of the policy implementation. The figure amounts to 1282.438 in 2018, which is about five times the predicted effect in 2017 and 2019. This suggests that the policy has a hysteresis influence on corporate green innovation.

4.5.2. Placebo test

In order to verify that the difference between the actual value and the predicted value in the above experiment is caused by the implementation of policy rather than the model specification bias, a placebo test is performed in other provinces that are not affected by the policy. Under the assumption that other provinces are also affected by the policy shock, the Lasso estimation method is applied to select variables to fit the corresponding predicted value. "Placebo effect" could then be calculated by subtracting the fitted value from the actual observation. Comparing the placebo effect of other provinces with the policy effect of Jiangsu Province, the results are shown in figure 1.

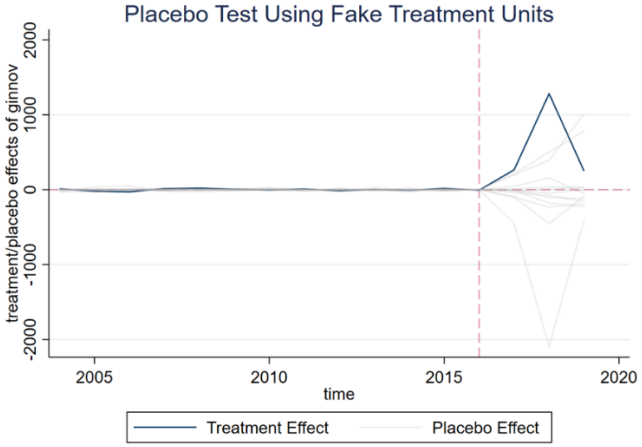

Figure 1. Placebo test results.

Table 8. Placebo test results using fake treatment units.

Unit	Pre MSPE	Post MSPE	Post/Pre MSPE	Pre MSPE of Fake Unit/ Pre MSPE of Treated Unit
Jiangsu	425.6107	5.92E+05	1391.6368	1
Anhui	57.2084	4.09E+05	7148.9785	0.1344
Beijing	1099.183	1.59E+06	1442.3415	2.5826
Chongqing	60.1843	74671.54	1240.7139	0.1414
Gansu	65.742	710.2999	10.8043	0.1545
Guangxi	114.094	27370.55	239.8948	0.2681
Guizhou	17.8997	10519.93	587.7146	0.0421
Hainan	142.2275	409.2418	2.8774	0.3342
Heilongjiang	584.5927	32680.85	55.9036	1.3735
Henan	103.2703	9810.485	94.9981	0.2426
Hubei	35.2908	3.02E+05	8567.0866	0.0829
InnerMogolia	18.7565	804.7884	42.9073	0.0441
Jilin	53.0183	8325.943	157.039	0.1246

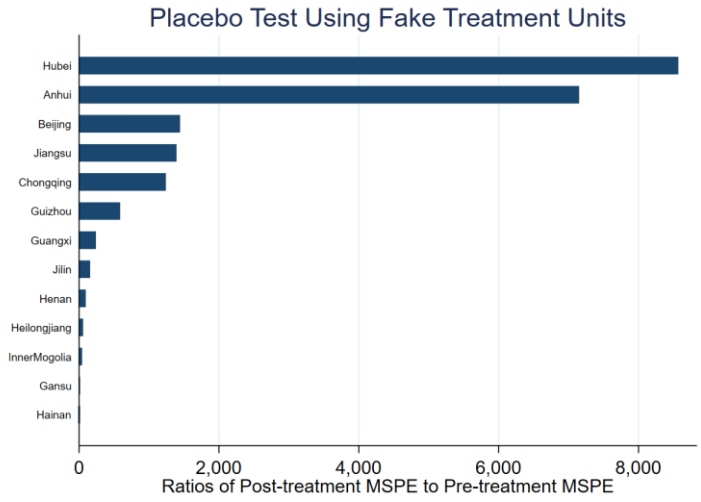

Figure 2. Ratio of post-treatment MSPE to Pre-treatment MSPE.

It could be inferred from the figure that the "policy effect" of Jiangsu Province and other provinces was basically zero before the implementation of the policy. However, after the policy was implemented, the gray line representing the "placebo effect" in other provinces has always been under the blue line that represents the effect of policy effect in Jiangsu Province. The gap is large enough to suggest that the obtained policy treatment effect of Jiangsu Province is robust.

In order to further verify the model specification, the MSPE of the regression equations of all provinces before and after policy shock are calculated. Here we take the ratio of pre-MSPE and post-MSPE to control the influence of the former on the results' significance. If the pilot project in Jiangsu Province does have a large treatment effect, while the placebo effects in other provinces are relatively small, the ratio of Jiangsu Province's "post-intervention MSPE" and "pre-intervention" should be significantly higher than other provinces. This could be supported by table 8 and figure 2 that the MSPE value of Jiangsu Province after the intervention divided by the MSPE value before the intervention reaching 1391.6368, ranking fourth among all provinces being tested.

Finally, we also calculated the policy effect of other provinces through a "placebo test", which is compared to the treatment effects of Jiangsu Province. Considering that the policy effects are mostly positive, we mainly focus on the right-sided p-value. It could be inferred from table 9 that at least on the significant level of 90%, the reform pilot

project of Jiangsu Province in the current policy implementation period and one lag phase has a significant impact on corporate green innovation. In 2019, the right-sided p-value was higher than 20%, indicating that the policy effect is relatively insignificant in the second lag phase. This further enhances the robustness of the results.

Table 9. Treatment effect of Placebo tests.

Time	Treatment Effect	Two-sided p-value	Right-sided p-value	Left-sided p-value
2017	264.7671	0.1538	0.0769	1
2018	1282.438	0.1538	0.0769	1
2019	249.2769	0.3077	0.2308	0.8462

Notes: (1) The two-sided p-value of the treatment effect for a particular period is defined as the frequency that the absolute values of the placebo effects are greater than or equal to the absolute value of the treatment effect. (2) The right-sided (left-sided) p-value of the treatment effect for a particular period is defined as the frequency that the placebo effects are greater (smaller) than or equal to the treatment effect. (3) If the treatment effects are mostly positive, then the right-sided p-values are recommended, whereas the left-sided p-values are recommended if the treatment effects are mostly negative.

5. Conclusion and policy recommendation

5.1. Conclusion

This paper uses the research sample of the public companies in 2010-2019. The number of annual green patents application represents their green innovation level, and the comprehensive score of corporate environmental responsibility awareness and practice published by Hexun. com is used to measure the level of corporate environmental responsibility. The data are subjected to a baseline model, transmission mechanism analysis and robustness test. The preliminary conclusion of the relationship between corporate environmental responsibility and green innovation is corporate environmental responsibility can promote green innovation. This paper also uses the regression control method and placebo test to explore the impact of the "Corporate Social Responsibility Construction Pilot Demonstration Implementation Plan" (promulgated in Jiangsu Province, 2017) on corporate green innovation in the province. The specific conclusions are as follows: (1) The baseline model results show that the improvement of corporate environmental responsibility significantly promote green innovation, and this effect exists in companies of different regions and industries. (2) The transmission mechanism analysis shows that corporate environmental responsibility has a significant promoting effect on financing constraints, government subsidies and R&D investment intensity and has a significant negative impact on corporate governance. It further promotes the development of green innovation through these three variables. (3) The regression control method and the placebo test show that the implementation of the policy has a significant positive impact on the green innovation of local enterprises. Still, the effect of the policy has a certain lag.

5.2. Policy recommendation

Based on the empirical research results, this paper proposes the following recommendations:

The government should improve the relevant regulations and policies to promote the construction of corporate environmental responsibility. In current stage of development, the importance of stimulating corporate green innovation through policy effects to spur economic growth is self-evident. It is confirmed that there is a significant and stable positive effect between corporate environmental responsibility and green innovation. Therefore, using regulations and policies to accelerate corporate environmental responsibility construction will further corporate green innovation development. The government has already focused on introducing information disclosure mechanisms and penalties for illegal polluting enterprises, so enterprises will "be forced" to conduct green

innovations. But these measures lack positive guidance. Promoting green innovation by strengthening the construction of corporate environmental responsibility aims to guide enterprises to undertake environmental responsibility and then lead to green innovation. Enterprises are in an active rather than passive position, which can release positive market signals and complement with mandatory regulations to form a better regulatory system. Furthermore, policy-favored companies with strong environmental responsibility fulfillment capabilities will have more competitive advantages in the capital market. Through this way, healthy competition in the capital market can be stimulated and financial pressure for enterprises carrying out green innovation or relevant activities can be reduced (Hao 2022).

Enterprises should actively undertake environmental responsibilities in thought and action and increase green innovation. At present, multiple environmental protection policies and green transformation have been carried out in enterprises. Many of them realize that taking environmental responsibility is beneficial, enjoying the dividends of policies, capital markets and consumer markets. However, some companies have a “short-sighted” problem in green innovation. They only pay attention to the short-term increase in costs but ignore the long-term positive effects on corporate environmental and economic performance (Zhenyu Zhang 2022). Thus, some enterprises are more inclined to create an image with a strong sense of environmental responsibility for themselves at low cost, rather than truly fulfilling their environmental responsibility by increasing investment in green innovation. For example, some large enterprises have set up environmental responsibility departments (responsible for environmental performance evaluation and information disclosure), but the research and development of green innovation in production are stagnant (Wickert 2016). The suspended corporate environmental responsibilities and insufficient green innovation ought to be improved. On one hand, companies must take a long-term perspective on the impact of fulfilling environmental responsibilities and strengthening investment in green innovation rather than focusing on short-term operating costs only. On the other hand, enterprises should clarify the unity of environmental responsibility awareness and practice, which is more conducive to maintaining a relatively stable advantage in the market. “Talking but not doing” will only hinder the pace of green innovation and technology realization. Specifically, enterprises can hire managers with strong environmental awareness and establish green innovation reward system to encourage corporate employees to raise their awareness of environmental responsibility and carry out green innovation. Moreover, enterprises can cooperate with enterprises and retailers that have a strong awareness of environmental responsibility to realize resource sharing and technology sharing and improve the green innovation efficiency.

The media and the public should support, encourage and supervise enterprises to fulfill their environmental responsibilities, strengthen green innovation, and create a good atmosphere of green environmental protection. The media can publicize the importance and necessity of enterprises' fulfillment of environmental responsibilities. Good public opinion orientation can be created by reporting relevant news about enterprises taking environmental responsibilities, carrying out green innovation and reaping overall benefits. The media can also alarm companies with little environmental responsibility and poor green innovation practices by reporting negative cases in which companies refuse to fulfill their environmental responsibilities and blindly pursue counterproductive economic benefits. The public should set up green consumption concept. They can choose to purchase environmentally friendly products to support green production enterprises and make their shopping choices positively affect the industrial chain through the consumer market and the investment trend. In addition, the public must strengthen civic awareness. They are obliged to pay attention to environmental issues, and report enterprises that illegally discharge pollutants to relevant departments promptly.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Appendix

A1. Institution background in China.

The development of my country's corporate environmental responsibility system is relatively late. For a long time, Chinese enterprises have not paid attention to the issue of environmental responsibility. In the early days of the founding of the People's Republic of China, our country was in a state of no corporate environmental responsibility. Until the first environmental protection work conference was held, our country began to realize the damage to the ecological environment caused by economic development, and gradually improved the legal system related to environmental protection. The government has begun to attach importance to and accelerate the implementation of corporate environmental responsibility, and our country's corporate environmental responsibility system has begun to develop rapidly. In 1979, our country promulgated and implemented the Environmental Protection Law (for trial implementation). At the end of 1983, the State Council announced that "environmental protection is a basic national policy of China". After the conference, China officially issued the "Ten Strategies for China's Environment and Development", which clarified China's "implementation of sustainable development strategies".

Since 2017, the Chinese government has taken "To build a strong, democratic, civilized, harmonious and beautiful modern socialist country" as an important goal for the government to enter a new stage, "adhering to the harmonious coexistence of man and nature" into the basic strategy for development in the new era, and incorporating ecological civilization. Construction and green development are placed in a prominent position, opening a new era of green development. The emergence of ecological civilization and new development concepts in China is inevitable. The development concept determines the development pattern, and the new development concept based on ecological civilization not only provides a way out for solving the drawbacks of the traditional development model, but also brings a lot of development opportunities. However, in order to make green development a reality, we must jump out of the thinking mode formed by the traditional industrial society. Most of the existing traditional concepts, contents, models, systems, policies, etc. on development are the products of and serve the traditional industrial age. They need to be systematically transformed on the basis of ecological civilization.

As the second largest economy in the world, China has established its dominant position in the market during more than 40 years of rapid economic growth. Under the traditional performance appraisal model that emphasizes economic growth, the country is becoming stronger and more prosperous. But at the same time, companies overemphasize profitability and ignore their green governance, resulting in increasingly prominent ecological and environmental problems. In this regard, the attitude of the party and the government is also very clear. The Sixth National Environmental Protection Conference in 2006 listed "building a resource-saving and environment-friendly society" as a basic national policy; in 2007, the Seventeenth National Congress of the Communist Party of China identified "building an ecological civilization" as "building a well-off society in an all-round way". In 2011, the

"Twelfth Five-Year Plan" outline included carbon emission intensity as a binding indicator for the first time. In 2012, the 18th National Congress of the Communist Party of China made a strategic decision to "vigorously promote the construction of ecological civilization", from 10 aspects Draws a grand blueprint for the construction of ecological civilization. In 2017, the 19th National Congress of the Communist Party of China included "adhering to the harmonious coexistence of man and nature" into the basic strategy for upholding and developing socialism with Chinese characteristics in the new era. In 2018, the 13th National People's Congress first The amendments to the Constitution passed at this meeting included the construction of ecological civilization into the powers and powers chapter of the State Council. In 2019, the Fourth Plenary Session of the 19th Central Committee proposed to implement the strictest ecological environmental protection system, comprehensively establish a system for efficient utilization of resources, and improve ecological protection and restoration. In 2020, the "Guiding Opinions on Building a Modern Environmental Governance System" was issued, which proposed to improve the corporate responsibility system for environmental governance and strengthen the construction of the corporate environmental governance responsibility system. In 2020, the "Proposal of the Central Committee of the Communist Party of China on Formulating the Fourteenth Five-Year Plan for National Economic and Social Development and Long-term Goals for 2035" will "broadly form green production and lifestyles, and carbon emissions will stabilize and decline after peaking." as a long-term goal. In 2020, President Xi Jinping mentioned in his important speech at the general debate of the 75th United Nations General Assembly that "carbon dioxide emissions should peak before 2030, and strive to achieve carbon neutrality before 2060". In the National Two Sessions in 2021, "carbon peaking" and "carbon neutrality" were written into the government work report for the first time. Under the guidance of the above ideas and programs, the central and local governments have adopted more or less environmental regulations to alleviate environmental problems, such as the implementation of environmental taxes, carbon emission trading rights pilots, and low-carbon city pilots. It can be seen that alleviating environmental problems and promoting sustainable development have become an important trend in my country's future development.

It is inevitable for ecological civilization and new development concepts to appear in China. The development concept determines the development pattern, and the new development concept based on ecological civilization not only provides a way out for solving the drawbacks of the traditional development model, but also brings a lot of development opportunities. However, in order to make green development a reality, we must jump out of the thinking mode formed by the traditional industrial society. Most of the existing traditional concepts, contents, models, systems, policies, etc. on development are the products of and serve the traditional industrial age, and need to be systematically transformed on the basis of ecological civilization.

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