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The Influence and Mechanism of ESG Peer Effect on Green Innovation of Heavy-Polluting Enterprises

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Abstract: With the establishment of the Chinese "dual-carbon" goal, green innovation is becoming increasingly important for enterprises, and ESG performance provides opportunities for green innovation development by conveying non-financial information to the market. Although studies have demonstrated that ESG performance impacts green innovation, it is still necessary to clarify the peer effect perspective of this relationship. Thus, from the standpoint of industry spillovers, this article examines how peer firms' publication of ESG ratings affects target firms' innovation in green technologies. The research object for the paper is the listed businesses of major polluters in the Chinese A-share market between 2009 and 2022. It empirically examines the impact of peer ESG disclosure on corporate green innovation and the mechanism of its role. The results show that there is indeed a peer effect on ESG disclosure of heavy polluters, and corporate ESG performance is affected by ESG ratings of peers. Meanwhile, the peer effect promotes improving the green innovation level of target companies. It still holds after robustness tests. The mediating mechanism test shows that the ESG peer effect promotes green innovation by alleviating financing constraints, mitigating information asymmetry, and increasing firms' green awareness. Heterogeneity analysis finds that the impact of ESG peer effects on green innovation is more significant in State-owned firms, large-scale firms, and firms in the east-central region.

Keywords: ESG Ratings; Peer Effects; Green Technology Innovation; Financing Constraints; Information Asymmetry

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1.Introduction

In recent years, environmental pollution, global warming, and other issues have become the focus of attention of countries worldwide [1]. The Party Central Committee has decided to "Aim for carbon neutrality by 2060 and carbon peaking by 2030" as a key strategic move. The report of the 20th National Congress of the Communist Party of China pointed out that it is necessary to coordinate industrial restructuring, pollution control, and ecological protection and promote ecological priority, conservation and intensification, and green and low-carbon development.

ESG (Environmental, Social, and Governance) concept takes into account economic benefits and social development, advocates green, low-carbon, and environmental sustainability, focuses on the development ability of enterprises in the environment, social responsibility, and governance.

Given the "dual carbon" goal, heavy-polluting businesses urgently need to perform green transformation based on enhancing their potential for green innovation [2]. Since the ESG concept has emerged as a crucial metric for assessing an organization's

non-financial data, many literature studies have discovered that ESG performance also has a necessary effect on the quality of green technology innovation across organizations.

The study on how peer information disclosure affects businesses' behavioral choices has been limited to focusing on peer social responsibility [3] and peer product quality information [4]. However, studies on the effect of peer ESG disclosure on corporate green innovation are scarcer, and this study adds something new to the pool of existing literature. In light of the aforementioned research gaps, this study investigates whether ESG peer effects impact target firms' green innovation and identifies the mechanism behind the effect.

This study thoroughly examines how peer ESG disclosure affects corporate green technology innovation using the theories of dynamic competition, games, and social comparison. It chooses relevant data from Chinese heavy pollution listed enterprises from 2009 to 2022 as the study sample, empirically tests it using a fixed-effect model, and uses robustness testing to guarantee the research findings' scientific validity.

The article's remaining content is arranged as follows: The literature review is the second section, and the theoretical analysis is the third, a meticulous and comprehensive examination of the topic with research hypotheses; the model setting and study design make up the fourth section; the data analysis is in the fifth; and the conclusion and suggestions are in the sixth.

2.Literature review

2.1 Studies on corporate ESG practices

The literature currently in publication concentrates on the determinants and economic impacts of corporate ESG performance. The macroeconomic climate and the firm's attributes are the primary determinants of corporate ESG disclosure. Scholars of macroeconomic factors have examined the state of economic development at the national level [5], financial policy uncertainty [6] and international trade [7], global trade and capital markets [8], etc. on firms' ESG performance. Regarding the firm's characteristics, it has been found that firm size [9], internal corporate governance structure [10], and stock price [11], executive characteristics [12], institutional investors' shareholding [13] significantly affect corporate ESG performance. Innovation, financial risk, and company value are the main topics of the literature on the economic impacts of ESG disclosure. Meira [14] et al. found that active ESG activities help firms to develop differentiation strategies, which in turn enhance firm value.

2.2 Studies on intra-industry spillovers

The term "peer effect" describes how a company's actions are impacted by both individual traits and the actions of other companies operating in the same sector. Lieberman and Asaba [15] developed a theoretical framework to support corporate imitation behavior by classifying corporate imitation motives into two essential types: information-based and competition-based. Regarding peer effects, scholars have found that corporate mergers and acquisitions [16, 17], corporate governance [18] Green innovation [19] Investment [20] and share buybacks [21, 22] and other behaviors have peer effects. In addition, scholars have found peer effects in financial decisions through empirical tests, and by differentiating the empirical results, it is found that peer effects in financial decisions are mainly caused by product market competition, learning, and internal capital markets.

In summary, most of the literature on corporate ESG focuses on how a company's ESG performance affects its value, risk, innovation, and other behaviors, treating firms as individuals in action and ignoring peer-to-peer interactions. However, firms practice observing and learning from their peers' behavior to reduce decision-making risks and costs. Less research has been done on how ESG peer effects affect green innovation. In order to fill the related research gap, this paper will investigate the relationship between target firms' green innovation and the ESG performance of other firms through peer effects.

3.Theoretical analysis and research hypotheses

3.1 Peer ESG disclosure on green innovation spillovers from target firms

First, Based on the theory of dynamic competition, firms' behavioral decisions are influenced by individual characteristics and the interaction effect with other firms in the industry. Thus, they will be influenced by other competitors.

Second, according to game theory, enterprises make different decisions under different environmental information disclosure rules when making green innovation decisions. When other businesses disclose more ESG information, the zero-sum game competition between peers based on ESG performance intensifies.

Third, according to social comparison theory, individuals compare themselves to others to maintain self-esteem and self-worth [23,24]; in general, firms are similar to individuals and tend to compare themselves to each other [25] that tends to achieve a social performance level that is higher than the industry average.

The following research hypotheses are put forth in this paper in light of the analysis above:

H1. ESG performance in the same industry will encourage green innovation in the target company.

3.2 Financing constraints, information asymmetry, and the mediating role of green consciousness

Funding limitations are critical for enterprise green technology innovation. Firms facing higher financing constraints lack the resources and assets to promote green innovation and strengthen their edge over competitors. Unlike general innovation, green innovation is complex and requires significant financial, material, and human investment.

ESG is a business philosophy that emphasizes both financial performance and sustainable development. For investors, companies with good ESG performance can convey non-financial information to the market, help stakeholders identify investment risks, enhance their willingness to invest, and provide more capital support for corporate green innovation. Secondly, as the capital market recognizes ESG ratings, investors focus on ESG performance when investing [26]. Finally, there is a high level of uniformity among businesses in the same sector [27]; investors assume that businesses with and without ESG practices share similar inclinations toward green development, which helps to target firms to bring in capital. This study puts forth the second research hypothesis in light of the analysis above:

H2. The ESG peer effect can encourage the development of green technologies by easing the target firms' financial burden.

The positive ESG information disclosure of a specific industry can convey a signal of good development prospects to the outside world, draw in analysts' and institutional investors' attention, and decrease information asymmetry by fully utilizing professional intermediaries' "information effect" [28], enhance the connection between enterprises and market investors, help the outside world obtain information on corporate characteristics, break the information gap, and improve investment efficiency [29]. The study's third hypothesis is presented in comparison with the previous analysis:

H3. The ESG peer effect can raise the level of green innovation attained by target firms by lowering the level of information asymmetry.

Enterprise green innovation activities require a sustained capital outlay, often a lengthy process, and generally do not prioritize the allocation of resources in the strategic decision-making process, thus requiring an enterprise-wide eco-culture and green awareness on the part of management and employees. Corporate green awareness is a critical factor in developing green innovation strategies and improving green innovation levels [30].

Recently, listed companies' ESG performance has been a subject of increasing and widespread market attention. A strong ESG performance is not just a measure of a company's potential for sustainable development but also influences its market and media visibility [31]. This external attention pressure often catalyzes target firms to enhance their environmental consciousness and actively participate in green innovation developments. In this context, we give the fourth research hypothesis:

H4. The ESG peer effect may increase target firms' green awareness, promoting green innovation.

4.Research design

4.1 Sample selection and data sources

This research takes the listed Chinese heavy-polluting enterprises from 2009 to 2022 as a sample group. We chose 2009 as the study's starting point because the ESG data in this paper is based on CSI's ESG ratings, which were first released in 2009. To guarantee the study's validity and scientific integrity, we treated the samples in the following ways: we excluded ST, *ST samples, and samples with significant missing data and applied 1% indentation to the continuous variables, resulting in 11,100 annual observations. This paper's ESG performance is based on the ratings disclosed by "Shanghai Huazheng"; based on Li et al. [32], we use the values "9" - "1" respectively to replace the rating "AAA-C" indicator, with larger values representing higher ratings. The explanatory variables (green innovation level), control, and mediating mechanism variables are all from CSMAR.

4.2 Main variables

4.2.1 Dependent variable: green innovation (Green)

Green technological innovation, a significant aspect of enterprise R&D, encompasses a variety of technological advancements that prioritize energy conservation and environmental preservation. Among various indicators, the overall quantity of green patent applications is a reliable indicator of a company's capacity for technological innovation. These applications, which include utility model applications and patents for green inventions, are crucial. We use the number of green patent applications plus one logarithmic process as a proxy variable to measure the degree of green innovation.

4.2.2 Core independent variable: ESG peer effect (ESG_peer)

According to Sahin et al. [33], ESG ratings have evolved into a reference standard for measuring enterprises' environmental protection, social responsibility, and sustainable growth. Thus, this study adopts the ESG ratings provided by the Shanghai CSI information platform to assess the ESG efficiency of corporations. This paper measures the ESG peer effect by this year's average ESG rating value for the same industry, excluding this company.

4.2.3 Mediating mechanism variables

(1) Financing constraints (SA). The existing literature has WW, SA, and KZ indexes to evaluate financing constraints. However, to ensure the SA index's reliability, Hadlock and Pierce [34] meticulously constructed it using only exogenous variables, such as firm size and age, following the KZ methodology. This careful approach helps to avoid endogenous disturbances and enhances the index's credibility. We calculated the SA index using the following formula:

$$SA_{i,t} = -0.737 \times Size_{i,t} + 0.043 \times Size_{i,t}^{2} - 0.04 \times Age_{i,t} \quad (1)$$

$Size_{i,t}$ is the firm's total assets data processed into millions of dollars and then logarithmically processed, and $Age_{i,t}$ is the length of time the company has been listed. The SA index is negative, and a higher value indicates that the firm is less constrained by financing.

(2)Information asymmetry (Asy). This paper utilizes data on stock transactions of listed companies to capture the degree of the information asymmetry between inside-knowledgeable traders and outside investors. Drawing on Amihud et al. [35] Liquidity ratio indicator LR, Amihud [36] Illiquidity ratio indicator ILL, and Pastor & Stambaugh [37] Return reversal indicator, we rigorously extract the first of these three indicators' principal components. This component is related to asymmetric information and is known as the symbol for information asymmetry Asy. The degree of information asymmetry increases with a more extensive Asy index.

(3) Green awareness (CSRReport). Green awareness was measured by whether the company disclosed environmental information in its annual social responsibility report, with a value of 1 if it did and 0 otherwise.

4.2.4 Control variables

We select company size (Size), operating cash flow (Cash), growth capacity (Growth), profitability (Roa), and gearing ratio (Lev), etc. as control variables. We define the variables in Table 1, and the relevant data can be obtained from the CSMAR database.

Table 1. Definition of variables.

Variable Category	Variable Name	Abbreviation	Variable Explanations
Dependent variable	Green innovation	Green	The degree of green innovation is measured by taking the natural logarithm of the quantity of green patent applications submitted by firms plus one.
Independent variable	ESG Peer Effect	ESG_peer	The average ESG ranking of other firms in the same industry do not include current year's performance.
Intermediary variable	Financing constraints	SA	Financing constraints index. The larger the index, the fewer financing restrictions the firm faces.
	Information asymmetry	Asy	The first principal components are extracted to determine the level of information asymmetry for the liquidity indicator LR, the illiquidity indicator ILL, and the return reversal indicator GAM.

Variable Category	Variable Name	Abbreviation	Variable Explanations
Grouping variable	Green awareness	CSRReport	If the firm disclosed environmental information in its annual social responsibility report, CSRReport=1; otherwise, it would be 0.
	Nature of property rights	Soe	Whether the actual controlling shareholder is a state-owned enterprise (1-yes, 0-no).
	Company size	Size_big	Size_big = 1 if the firm size exceeds the sample median; if not, 0.
	District	District	The region to which the enterprise belongs is divided into eastern, central, and western areas, with East=1 representing that the business is located in the eastern region, Middle=1 representing that the enterprise is located in the central area, and East=0 and Middle=0 representing the enterprise's location in the western area.
Control variables	Company size	Size	Natural logarithm of total company assets.
	Operating cash flow	Cash	Company's net cash flows from operations/total assets
	Growth capacity	Growth	Revenue growth rate.
	Ratio of sole director	Indirect	Number of independent directors/number of board directors
	Executive Team Size	Tmtsize	The natural logarithm of the number of executives plus one.
	Profitability	Roa	Net profit/total assets
	Asset-liability ratio	Lev	Total liabilities/total assets
	Shareholding concentration	Top10	The proportion of the top ten shareholders' shares.
	Age of business	LnAge	Natural logarithm of age of business

4.3 Modeling

4.3.1 Baseline regression model

This study examines how the ESG peer effect affects the degree of green innovation using a fixed-effect model. The following is the benchmark regression model:

$$\mathrm{Green}_{it} = \alpha_1 + \beta_1 \mathrm{ESG\_peer}_{it} + \sum_j \beta_j \mathrm{Controls}_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (2)$$

In the above equation, Green represents companies' green innovation levels, ESG_peer represents the ESG peer effect, and Controls represents firm size, profitability, and several additional control variables listed above. i denotes firm, t denotes year, and λ_i is the fixed effect of the individual, and μ_t is the time fixed effect, and ε represents the term for random error. Where the coefficient in front of ESG_peer β_1 reflects the impact of ESG peer effects on company Green Development, if β_1 is significantly positive, indicating that raising the industry average for ESG can encourage green innovation in the target company.

4.3.2 Mediating mechanism test model

To analyze the mediating mechanism effect of ESG peer effects through alleviating financing constraints, mitigating information asymmetry, and increasing corporate green awareness, thus promoting green innovation, reference is made to Zhang et al.[17] research method, the following two-stage regression model is constructed based on equation (2):

$$\mathrm{MV}_{it} = \alpha_2 + \beta_2 \mathrm{ESG\_peer}_{it} + \sum_j \beta_j \mathrm{Controls}_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$\mathrm{Green}_{it} = \alpha_3 + \beta_3 \mathrm{ESG\_peer}_{it} + \gamma \mathrm{MV}_{it} + \sum_j \beta_j \mathrm{Controls}_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (4)$$

In model (3), MV refers to the three mediating mechanism variables SA, Asy, and CSRReport selected in this paper, and the equation describes the ESG peer effect regression model on each mediating variable. If β_2 is significantly positive, it means that the ESG peer effect positively impacts the mechanism variable and vice versa. Model (4) belongs to the two-stage regression method's second step, and the coefficients β_3 illustrate how the ESG peer effect affects green innovation. γ indicates the

result of mediating mechanism variables on green innovation. According to the stepwise regression method, if β_1、β_2、γ are significant, and is less than , it is demonstrated that the mechanism variables establish the indirect influence of the ESG peer effect on corporate green innovation.

4.4 Descriptive statistical analysis

In this paper, Table 2 displays the descriptive statistics for the primary variables. It is evident from there that Chinese heavy pollution listed firms' ESG ratings are as low as C and as high as AA, with a 4-point mean and a 1.1005 standard deviation, which indicates that the enterprises' ESG ratings are generally low and do not differ much. With a standard deviation of 0.21, a minimum of 2.66, a maximum of 5.25, and a mean value of 4, the ESG peer effect, or ESG_peer, shows minimal variation in the ESG peer effect among heavy pollution industries.

Table 2. Descriptive statistics.

Variable	N	Mean	SD	Minimun	Maximum
ESG	11100	4.05018	1.100543	1	8
ESG_peer	11100	4.048734	0.2199509	2.666667	5.25
Green	11100	0.7091325	1.055869	0	6.931472
Size	11100	22.30502	1.36283	18.15785	28.63649
Cash	11100	0.0582079	0.0780332	-1.686297	2.221612
Growth	11100	6.844198	566.9389	-4.491724	59411.55
Indirect	11100	0.3709759	0.0522486	0.1667	0.7143
Tmtsize	11100	1.955233	0.298371	0.6931472	3.091043
Roa	11100	0.0395337	0.1256281	-3.199699	7.445077
Lev	11100	0.4281924	0.2227112	0.007521	3.261896
Top10	11100	57.44867	15.63286	1.3103	98.5883
Lnage	11100	2.846079	0.370877	0.6931472	3.828641

5.Data analysis

5.1 Basic regression test and robustness tests

5.1.1 Basic regression test

The findings of this paper's basic regression are displayed in Table 3. Column (1) is the outcome of the test of whether the ESG peer effect exists among heavy-polluting enterprises. When individual and year effects have been taken into account, at the 1% level, the ESG_peer coefficient is 0.463, implying that the ESG peer effect exists. Columns (2) and (3) are without and with control variables, respectively. When individual and time effects have been taken into account, ESG_peer coefficients for the impact of ESG peers on green innovation levels are 0.164 and 0.186, respectively, which, at the 1% level, are both statistically positive, indicating that peer ESG disclosure encourages green innovation in the target companies. As a result, this paper's H1 is true.

Table 3. Basic regression results

Variable	(1)	(2)	(3)
	Esg	Green	Green
Esg_peer	0.463***	0.164***	0.186***
	(9.79)	(4.39)	(5.08)
Size	0.220***		0.252***
	(11.56)		(17.07)
Cash	-0.248**		0.0606

Variable	(1)	(2)	(3)
	Esg	Green	Green
	(-2.08)		(0.66)
Growth	-0.0000456***		0.00000281
	(-3.21)		(0.26)
Indirect	1.202***		0.413**
	(5.34)		(2.37)
Tmtsize	0.0440		0.00781
	(1.04)		(0.24)
Roa	0.0509		0.0232
	(0.72)		(0.42)
Lev	-0.860***		0.00427
	(-12.98)		(0.08)
Top10	0.000669		0.00202**
	(0.64)		(2.49)
Lnage	-0.337***		-0.235***
	(-3.35)		(-3.01)
Observations	11100	11100	11100
Firm Effect	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes
Adj.R-squared	0.1597	0.113	0.142

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

5.2 Robustness Tests

5.2.1 Changing the regression model

Because there are many zeros in corporate green patent applications, the Tobit model is used to estimate more accurately for robustness testing. The Tobit model test is shown in Table 4's column (1), and at the 1% level, the ESG_peer coefficient of 0.223 is significant. It shows that after changing the regression model, peer ESG disclosure still contributes significantly to the advancement of green innovation initiatives in target companies.

5.2.2 Shorter sample period

Before conducting the test, this paper excludes data after 2020 to exclude the epidemic's effect on businesses' innovation in green technologies. Table 4's column (2) displays the regression results, and the ESG_peer coefficient is 0.203; it remains significantly positive at the 1% level, proving the validity of the conclusion that the ESG peer effect stimulates green innovations, which is in line with the previous findings.

5.2.3 Use of first-order and second-order lag terms for explanatory variables

The endogeneity problem is due to some unmeasured factors left out and the potential for reverse causality between ESG peer effects and green innovation. Therefore, this study employs the explanatory variable ESG_peer's first- and second-order lagged terms as instrumental variables for endogeneity tests. Table 4's columns (3) and (4) display the test results, and regression results display the outcomes of the test's second stage in the two-stage regression, where the coefficients of the core explanatory variables, the first-order lag L.ESG_peer and the second-order lag L2.ESG_peer are both significantly positive at the 1% level, which is consistent with the finding of the baseline regression and proves the research findings' validity.

5.2.4 Propensity score matching

Firms in the same industry may share specific characteristics, leading to sample selection bias that impacts the study's findings. Therefore, the article uses the propensity score matching (PSM) method to match the control variables as covariates in a 1:1 near-neighbor matching to match the experimental and control groups better. The Table 4's column (5) displays the regression results upon matching, and the core independent variables' coefficients remain positive, showing that the research conclusions of this article are valid.

Table 4. Robustness check.

Variable	Changing the regression model	Shorter sample periods	First-order lag of explanatory variables	Second-order lag of explanatory variables	Propensity score matching
	(1) Green	(2) Green	(3) Green	(4) Green	(5) Green
ESG_peer	0.223***	0.203***			0.241***
	(2.97)	(4.30)			(4.74)
L.ESG_peer			0.307***		
			(6.97)		
L2.ESG_peer				0.249***	
				(5.13)	
Control variable	Yes	Yes	Yes	Yes	Yes
Observations	11100	8201	10121	9153	6622
Firm Effect	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes
Adj.R-squared		0.3578	0.4194	0.4024	0.4312

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

5.3 Mechanism testing

5.3.1 Mechanism test based on financing constraints

The financing constraint mechanism test results are displayed in Table 5's columns (1) and (2). Column (1) displays the regression findings of the ESG peer effect on financing constraints, and the ESG_peer coefficient is significantly positive, which indicates that peer ESG disclosure can help decrease the target firms' financial restrictions. Next, both financing constraints and ESG peer effects are included in the model, and Column (2)'s findings demonstrate that both coefficients are significantly positive. This proves how financial constraints mediate green innovation and ESG peer effects, and H2 holds.

5.3.2 Mechanism test based on information asymmetry

Table 5's columns (3) and (4) display the research results of the information asymmetry mediation mechanism test; column (3) indicates that the ESG peer effect reduces the degree of information asymmetry, and column (4)'s findings demonstrate that simultaneous incorporating the information asymmetry and ESG peer effects into the model, ESG_peer has a significantly positive coefficient. In contrast, the Asy has a significantly negative one. This result supports the mechanism role of information asymmetry in ESG peer effect to encourage green innovation, and H3 holds.

5.3.3 Mechanism test based on green awareness

Table 5's columns (5) and (6) display the test results. The ESG_peer coefficient of 0.0436 in the result of column (5) is significantly positive, suggesting that the ESG peer effect has a positive influence on the enterprise's green awareness has a positive facilitating effect. Column (6) shows how the regression model incorporates green awareness and the ESG peer effect

to investigate the impact on corporate green innovation. The significance and direction of the coefficients demonstrate that green innovation mediates the ESG peer effect to promote green innovation. This outcome validates H4.

Table 5. ESG Peer Effect Mediation Mechanism Test Results.

Variable	Financing constraints		Information asymmetry		Green awareness	
	(1) SA	(2) Green	(3) Asy	(4) Green	(5) CSRReport	(6) Green
SA		1.535***				
		(10.13)				
Asy				-0.2192***		
				(-10.02)		
CSRReport						0.0647***
						(4.44)
ESG_peer	0.0121***	0.023***	-0.0307***	0.1656***	0.0436***	0.1692***
	(3.72)	(6.49)	(-6.30)	(4.46)	(3.00)	(9.78)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11100	11100	11100	11100	11100	11100
Firm Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.2140	0.2168	0.1314	0.1050	0.1967	0.2095

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

5.4 Heterogeneity analysis

5.4.1 Character of property rights

This study separates the sample into state-owned businesses, and those that are not, and the benchmark regression model is regressed into groups. The study results are displayed in Table 6's columns (1) and (2), where the core explanatory variables' coefficients are significantly positive at the 1% level regarding the state-owned as well as the non-state-owned enterprise group; however, the state-owned enterprise group's coefficients are more significant. It could be related to the status of state-owned businesses in the national economy, which are responsible for the production and distribution of essential products and receive more social attention.

5.4.2 Company size

This study separates the sample into large and small companies, and the statistical results are displayed in Table 6's columns (3) and (4). Statistically, the coefficients are favorable for the large firm group and negative but not significant for the small firm group, indicating that peer ESG disclosure's impact on green innovation exerts its influence only in large firms and does not significantly affect small firms.

5.4.3 District

Given the specific inequalities in economic growth, policy resources, and public awareness among Chinese eastern, central, and western areas, firms in different locations may embrace different levels of ESG construction and green business investments when facing ESG disclosure by their peers. Consequently, this study separates the area where the sample enterprises are located into east, center, and west for group regression. The test results, as displayed in Table 6's columns (5), (6), and (7), show that ESG peer effects coefficients are significantly positive in the center and eastern areas. In contrast, the western region's coefficients are not significant.

Table 6. Heterogeneity analysis results.

Variable	Nature of property rights		Company size		District		
	(1) State-owned enterprise	(2) Non-state-owned enterprise	(3) Big corporation	(4) small corporation	(5) Eastern region	(6) Central region	(7) Western region
ESG_peer	0.194***	0.096**	0.257***	-0.026	0.1214**	0.2961***	0.1209
	(3.21)	(2.04)	(4.86)	(-0.54)	(2.52)	(3.63)	(1.43)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4448	6499	5880	5220	6662	2329	2109
Firm Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.1021	0.0542	0.0562	0.0217	0.0386	0.0888	0.0833

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

6.Conclusions and Recommendations

This study focuses on the impact and mechanism of ESG peer effects on green innovation by using competition theory, game theory, and signalling theory to enrich our comprehension of the connection between green innovation and ESG peer effects by taking Chinese heavily polluting listed firms as the research object from 2009 to 2022. The study's findings are as follows:

First, based on the essential regression findings, when the ESG disclosure level of peer firms increases, target firms will take action to improve their ESG performance based on competitive pressure and comparative tendency; that is, the ESG peer effect exists. After the robustness test, the spillover effect of peer ESG disclosure still exists.

Second, according to the intermediate mechanism test's findings, improving ESG performance by peers can encourage target enterprises' green innovation by reducing financial limitations, information asymmetry, and green awareness.

Third, according to heterogeneity tests, the influence of peer ESG performance on green innovation is significantly more significant in SOEs, large-scale businesses, and businesses located in the eastern central region.

The following are the study's policy recommendations: First, the government and regulators should improve the mechanism for ESG disclosure and the system for rewards and penalties, provide financial subsidies, tax breaks, credit support, and other benefits to companies that do well in ESG, and penalize and supervise companies that do poorly in ESG. Second, industry management departments should actively optimize the industry's competitive environment, create a business-friendly environment, improve the information environment, and promote healthy competition among enterprises. Third, enterprises should create ESG development strategies and integrate green awareness into corporate strategy, management systems, and daily operations.

Additionally, this study has certain limitations. First, there is not enough sample coverage. Only the heavily polluting listed enterprises are selected, and other industries are not included in the study, which may lead to limited universality of the research conclusions. Second, this paper's research conclusion is based on the Chinese institutional environment, and whether it impacts developed countries needs to be tested. In the future, we can continue to track the practice frontier and constantly improve relevant research.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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