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Original Research

Does Environmental, Social, and Governance Performance Affect Corporate Green Innovation? Evidence from China

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Abstract

With the increasing emphasis on sustainable development worldwide, the innovative behavior of corporations is being gradually influenced by the changing times. Responsible innovation means that companies will increase their focus on environmental, social, and governance factors (ESG) and base their green innovation on this. It is worth further studying whether ESG advantages will enhance a corporation's green innovation. This article explores the impact of ESG advantages on corporate green innovation and their mechanisms based on stakeholder theory and incentive theory. Using publicly manufacturing corporations in China from 2003 to 2022 as samples, this study measures ESG through corporate environmental certification and social responsibility reports, green innovation through Green invention patents, financing constraints through financing costs, green investment behavior through environmental investment, and validates the hypotheses using a multidimensional fixed effects model. Firstly, this study finds that ESG advantages significantly promote corporate green innovation. Secondly, this study finds that it exerts influence through the mechanisms of alleviating financing constraints and increasing environmental protection investment. Finally, heterogeneity tests reveal that the impact of ESG advantages on green innovation is more pronounced in technology-leading companies and state-owned corporations. This study explains the pivotal role of responsible companies in achieving green technology leadership and providing policy implications for promoting China's economic transformation and upgrading, as well as achieving high-quality development and demonstrating responsible great power globally. It also aims to realize a community with a shared future for mankind, balancing the legitimate concerns of other countries while pursuing its interests and promoting the common development of all countries.

Keywords: environmental, social, and governance, stakeholder theory, incentive theory

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Introduction

With global economic development entering a new era, issues related to carbon emissions, global climate change, public health safety, epidemic prevention, and control, and many other issues involving the sustainable development of human society have increasingly attracted widespread attention in various countries. The demand for social responsibility brought about by green sustainable development is also reshaping the development concepts of various countries [1]. China's development philosophy is also deeply inspired by it and makes solemn commitments. For instance, the 20th National Congress of the Communist Party of China pointed out that "Nature provides the basic conditions for human survival and development. Respecting, adapting to, and protecting nature is essential for building China into a modern socialist country in all respects." Chinese leader Xi Jinping also announced at the United Nations General Assembly that "China strives to peak its carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060." With the approaching deadlines for carbon neutrality, the economic transformation based on green sustainable development as a new development concept is imminent. To achieve this development concept, incorporating the environmental, social, and governance (ESG) factors into innovative decision-making and promoting corporate green technological innovation to achieve carbon emission reduction targets is not only an effective way to achieve high-quality economic development in China but also an inevitable choice to address global sustainable development issues.

According to the "Chinese Listed Companies ESG Action Report (2022-2023)", as of December 31, 2022, China had a total of 624 ESG (environmental, social, and governance) public funds with a combined total size of approximately 518.2 billion yuan, accounting for only about 2% of the total market size of public funds in China. The overall market size is still relatively small but with huge development potential. In 2021, 162 new ESG mutual funds were established, marking a 205.6% year-on-year increase. In 2022, an additional 172 ESG mutual funds were added, indicating a 6.17% year-on-year growth. This demonstrates the increasing importance that asset management institutions place on ESG fund products. Meanwhile, the global ESG public fund assets reached 2.24 trillion US dollars, with a total of over 7,000 funds, and Europe and the United States accounted for more than 80%. The gap between China and developed countries and regions such as Europe and the United States in ESG investment is still significant. As environmental awareness and social responsibility among domestic investors increase, and investors pay more attention to the non-financial performance of companies, ESG is gradually becoming an important indicator for evaluating corporate sustainable development.

ESG represents the responsibilities that companies should undertake in their operations. Green innovation refers to technological innovation aimed at environmental protection, energy conservation, and sustainable development. Under the ESG framework, companies need to focus on their impact on the environment and society and take corresponding measures to mitigate their negative effects, such as reducing pollution, energy conservation, and improving employee welfare. Therefore, companies need to actively adopt green innovation strategies to develop products and services that align with the concept of sustainable development to mitigate their negative impact on the environment and society. Corporate green innovation also helps to promote the development of ESG investments.

ESG investment is an investment approach that considers environmental, social, and governance factors in investment decisions. The adoption of green technological innovation can help companies reduce their negative impact on the environment and society, improve governance, and gain favor with ESG investors. ESG and corporate green innovation can mutually promote each other, forming a virtuous cycle. Through the consideration and implementation of ESG, companies can better understand the needs of the environment and society, and promote the development of corporate green innovation. On the other hand, through green technological innovation, companies can better reduce their negative impact on the environment and society, and improve their ESG performance. Therefore, ESG and corporate green innovation are closely related, and companies need to combine both to drive the process of sustainable development and achieve coordinated development of the economy, society, and environment.

Against this background, this paper focuses on the impact and mechanisms of ESG on corporate green innovation based on stakeholder theory and incentive theory. Specifically, this paper analyzes the impact of a company's ESG performance on its green innovation through the analysis of green patent application data and ESG rating data of listed companies in the CSMAR database. Furthermore, the paper analyzes the internal mechanisms of how ESG ratings affect corporate green innovation from the perspectives of financial constraints and green investment behavior. The results show that ESG advantage significantly promotes corporate green innovation. The mechanism is that ESG advantage promotes green innovation by alleviating financial constraints and increasing green investment behavior. Heterogeneity analysis shows that ESG advantage has a more significant effect on promoting green innovation in technology-leading companies and companies in industries with stronger environmental regulations. This article, by deepening the understanding and awareness of these issues, is conducive to enhancing the long-term value of corporations, promoting carbon neutrality and economic transformation in China, advancing the coordinated development of the economic and social values of corporations, and promoting the high-quality development of the Chinese economy.

Theory and Hypotheses

ESG Advantage and Corporate Green Innovation

ESG, also known as Environmental, Social, and Corporate Governance, assesses the sustainability and societal impact of business operations from three dimensions: environmental, social, and corporate governance. Meanwhile, green technology innovation aims to protect the environment through innovative approaches such as green product design, eco-friendly materials, sustainable processes, environmentally conscious equipment, green recycling methods, and eco-friendly packaging.

Technological innovation serves as a long-term driver of economic growth and is a critical factor for continuous technological advancement [2]. Maximizing enterprise value has always been the operational objective pursued by businesses. Technological innovation can effectively facilitate corporations in gaining excess profits and achieving value maximization. However, modern corporate governance theory suggests that the modern management system based on the separation of management rights and ownership rights leads to asymmetric information games, which can result in agency problems. The actual operators of the enterprise possess information that major shareholders do not have, making it easier for them to encroach on the interests of major shareholders. Similarly, major shareholders possess information that minor shareholders do not have, making it easier for them to encroach on the interests of minor shareholders. Consequently, green innovation projects characterized by long cycles, high risks, and high investments are not easily prioritized by the actual operators [3], because they fail to bring short-term returns that would enhance the performance incentives of the actual operators. However, an ESG orientation towards corporate social responsibility and sustainable development effectively avoids this phenomenon. As the theory of green sustainable development represented by ESG is increasingly recognized and valued by the public, the public also begins to focus on the balance between the economic value and social value of corporations. This leads institutional investors to thoroughly evaluate the performance of corporations in environmental, social responsibility, and corporate governance to determine whether to invest. Based on ESG assessments, business operators are willing to engage in high-risk, long-term green innovation activities. Through ESG assessments, institutional investors effectively reduce the management of corporations, making corporate development more green, efficient, and sustainable.

Furthermore, outstanding ESG performance by corporations also helps establish better relationships with investors, supply chain upstream and downstream companies, consumers, and other stakeholders, forming a closer stakeholder network. Innovation is essentially a process of knowledge recombination, and corporations can search and learn from more diverse and heterogeneous external sources of knowledge in such a relationship network [4], thereby promoting corporate green technological innovation [5]. Lastly, incentive theory emphasizes the importance of performance evaluation in promoting corporate performance improvement. Institutional investors pay more attention to ESG evaluations, which stimulates corporations to make more green investments to improve environmental governance performance. This process leads to increased environmental governance-related R&D investment, thereby enhancing corporate green innovation capabilities to achieve better environmental governance effects. Based on the above analysis, the following hypothesis is proposed:

Hypothesis 1: ESG advantage leads to an increase in corporate green innovation.

Mechanisms Through Which ESG Advantage Influences Corporate Green Innovation

Financial constraints are a primary issue faced by corporations in their development and are also a major obstacle to corporate green innovation. With the increasing recognition and focus on sustainable development theories such as green environmental protection and corporate social responsibility, corporations with high ESG advantage are more likely to be favored by institutional investors, and high ESG advantage also helps improve the relationships of corporations with stakeholders such as supply chain upstream and downstream companies and internal employees [6]. This, in turn, helps lower the cost of financing and alleviates financial constraints. This prompts corporations to invest more resources into high-risk, long-term green innovation activities, thereby enhancing their green innovation capabilities. Conversely, corporations with less than ideal ESG performance are more likely to face consumer resistance and governmental regulatory risks, significantly reducing the willingness of financial institution investors to invest, and diminishing the commercial credit support of creditors and suppliers, thereby increasing the cost of debt and equity financing. This strengthens financial constraints, potentially leading to further financial crises, making it difficult for corporations to sustain high-risk, high-investment, long-term green innovation projects.

Moreover, corporations with high ESG ratings are expected to actively disclose information related to fulfilling social responsibilities. This encourages corporations to pay more attention to ESG in the environmental assessment dimension and increase investments in green environmental protection, thereby establishing a responsible corporate image to accumulate commercial credibility. With the increase in green investments, ESG practices promote the improvement of the technological level and product upgrades of corporations, enhancing their green innovation capabilities [6]. Therefore, as a result of the pursuit of ESG advantage by institutional investors and consumers, the reputation value and asset advantages brought

to corporations by ESG advantage will significantly enhance the corporations' competitive advantage [7], thereby improving corporate green innovation. Based on these arguments, the following hypotheses are proposed:

Hypothesis 2: ESG advantage leads to an increase in corporate green innovation by alleviating financial constraints.

Hypothesis 3: ESG advantage leads to an increase in corporate green innovation by increasing green investment behavior.

Heterogeneity Analysis of the Impact of ESG Advantage on Corporate Green Innovation

Technology-leading corporations possess advantages in terms of technological reserves and R&D personnel, making them more likely to produce innovative results. Conversely, corporations with backward technologies may find it challenging to have the corresponding technological reserves to transition their R&D activities towards green innovation, which lowers their efficiency in green innovation. Therefore, ESG advantage will significantly promote green innovation in technology-leading corporations.

Furthermore, the property rights of corporations also influence the relationship between ESG performance and green technological innovation. Prior literature has demonstrated that state-owned corporations have dual political and economic attributes and need to consider not only business performance but also factors such as increasing employment and stabilizing national security, requiring them to bear more social responsibilities [8]. Additionally, relevant policies stipulate that state-owned corporations control the lifeline of the national economy and have more resource inclinations. As a result, state-owned corporations are less troubled by problems such as financial constraints in green innovation activities. Additionally, as the concept of sustainable development represented by ESG becomes increasingly valued by the government, state-owned corporations have gradually become an important driver for the Chinese government to promote economic transformation and achieve high-quality development of green sustainability. This transforms the political assessment of state-owned enterprise executives from a single target of business performance to a comprehensive consideration of economic and environmental governance [8], making state-owned enterprise executives more motivated to enhance ESG performance, promote green technological innovation, and achieve green and low-carbon transformation. Therefore, compared to non-state-owned corporations, ESG advantage has a more significant impact on promoting green innovation in state-owned corporations, and state-owned corporations also exhibit a more lenient tolerance for failed green innovation. Based on this, the following hypotheses are proposed:

Hypothesis 4: ESG advantage has a more significant effect on promoting green innovation in technology-leading corporations.

Hypothesis 5: ESG advantage has a more significant effect on promoting green innovation in state-owned corporations.

Data and Variables

Data Sources

The study sample in this paper consists of Chinese manufacturing listed companies from 2003 to 2022. The reason for choosing this sample is that listed companies generally have a larger scale and a greater impact on the high-quality development of Chinese society and economy. The manufacturing industry was selected because the Chinese economy is transitioning and is currently at a critical stage of moving from low-end manufacturing to high-end manufacturing. Achieving manufacturing power is crucial for the high-quality development of the Chinese economy. Therefore, the manufacturing industry is also more likely to be influenced by sustainable development theories such as ESG. The potential for green innovation is greater, and thus, the research value is also increased. Green innovation is measured by the natural logarithm of the number of green inventions patents independently obtained in a given year, plus 1 [9-12]. Green invention patents refer to invention patents with the theme of promoting resource conservation, improving energy efficiency, and preventing and controlling pollution through green technologies. The data is sourced from the CSMAR database, with supplementary comparison from the CNRDS database. ESG (Environment, Social, and Governance) is measured through environmental certification within the company, such as ISO 14001 certification, where 1 indicates certification and 0 indicates no certification. The full name of ISO14001 certification is ISO14001 Environmental Management System certification, which requires corporations to establish, implement, and maintain documented environmental objectives and specific targets. These objectives and targets should be in line with environmental protection policies, including commitments to pollution prevention, continual improvement, and compliance with applicable laws and regulations and other requirements. Obtaining this certification proves that the enterprise has achieved internationally advanced levels in environmental management. The social and governance capacity is measured by the number of pages in the company's Corporate Social Responsibility (CSR) report [13], where a higher page count indicates a greater emphasis on social responsibility. In December 2008, the Shanghai and Shenzhen Stock Exchanges of China began requiring listed companies to release corporate social responsibility reports. More and more companies are now voluntarily releasing corporate social responsibility reports, which represent their emphasis on social responsibilities such as shareholder responsibility, employee responsibility, supplier, consumer, and customer responsibility, environmental responsibility, and government responsibility. Other company characteristic

data in this paper mainly comes from CSMAR, supplemented by Wind and CNRDS. Following previous research, the data was processed using the following methods: (1) Excluding samples with missing data for major variable indicators, as these samples are significantly distorted. (2) Excluding samples with negative net assets. Because for listed companies, net assets are negative and may be an outlier. To control the influence of outliers, this paper also performed winsorization on the continuous variables beyond the 1st to 99th percentiles and used a multi-dimensional fixed-effects model for regression analysis to control for individual and annual factors, with standard errors adjusted for enterprise clustering effects. Use the Stata command regime for regression. The reason for using this model is that it can simultaneously control fixed effects across multiple dimensions (industry-year), thus mitigating bias caused by omitted variables, and it is also computationally efficient.

Model Specification and Variable Definitions

This paper uses all listed manufacturing companies from 2003 to 2022 as samples, and applies a linear regression absorbing multiple levels of fixed effects to establish the following regression model:

$$\boldsymbol{Innovation}_{i,t} = \alpha_1 + \alpha_1 \boldsymbol{ESG}_{i,t-1} + \delta_2 x'_{i,t-1} + \varepsilon_{1i,t} \quad (1)$$

In models (1), $\boldsymbol{Innovation}_{i,t}$ represents the green innovation level of company i in year t. $\boldsymbol{ESG}_{i,t-1}$ is an independent variable and represents the ESG rating of company i in year t, it includes two dimensions: environmental (*Environmental*), social, and governance (*Social and Governance*). $x'_{i,t-1}$ are the control variables such as ROA, firm size, R&D intensity, ownership concentration, company age, and leverage ratio. A lagged one-period treatment is applied to the independent variable and control variables to alleviate endogeneity. $\varepsilon_{1i,t}$ and $\varepsilon_{2i,t}$ are the error terms, α_1 and α_2 are the constants, and the rest are coefficients. Control variable data can be obtained from databases such as CSMAR, Wind, and company annual reports.

About existing literature, the control variables include the following: (1) at the firm level, this paper controls for return on assets (*ROA*), measured by the ratio of net profit to total asset balance. Corporations with high ROA have more resources to invest in green innovation activities.; ②firm size (*Size*), which affects R&D investment and thus influences technological innovation [14], measured by the natural logarithm of the number of employees; ③R&D intensity (*R&D*), which plays an important role in integrating knowledge in R&D activities and thus affects firm innovation performance and potentially positive impacting its green innovation [15], measured by the ratio of R&D expenditure to total assets; ④company age (*Age*), measured by the natural logarithm of the difference between the year of establishment and the year of sample observation period; ⑤Leverage ratio (*Lev*), equal to total liabilities/total assets. (2) at the governance level, it controls for ownership concentration (*Concentration*), measured by the shareholding ratio of the largest shareholder. Table 1 provides the descriptive statistics of the main variables in this paper. The mean value of green innovation in the sample is 0.395, indicating that the green innovation of the sample companies is generally weak. The mean value of environmental certification (*Environmental*) is 0.317, indicating that 32.7% of the sample companies have obtained environmental certification. The mean value of social and governance is 27.459, indicating that on average, each company's annual report mentions corporate social responsibility for 27 pages.

In addition, the correlation coefficient matrix of this paper is shown in Table 1 It can be observed from Table 1 that the absolute values of the Pearson correlation coefficients of each variable are all below 0.50, indicating that the research framework of this paper does not exhibit strong multicollinearity.

Table 1. Descriptive Statistics and Correlation Coefficient Matrix Table

	Green innovation	*ROA*	*Size*	*R&D*	*Concentration*	*Age*	*Lev*	*Environmental*	*Social and Governance*
Green innovation									
ROA	0.005								
Size	0.150*	0.056*							
R&D	0.037*	0.020*	-0.001						
Concentration	0.006	0.126*	0.173*	-0.052*					
Age	0.029*	-0.071*	0.041*	-0.016*	-0.199*				
Lev	0.043*	-0.313*	0.292*	-0.075*	0.024*	0.115*			
Environmental	0.069*	0.032*	0.041*	0.044*	-0.008	0.037*	-0.102*		
Social and Governance	0.126*	-0.003	0.449*	-0.008	0.074*	0.119*	0.233*	0.093*	
Mean	0.395	0.032	7.52	0.1	0.355	2.497	0.445	0.317	27.459
SD	3.853	0.09	1.409	0.598	0.156	0.687	0.215	0.465	24.687

Note: Pearson correlation coefficient, * p<0.01. The data is sourced from the CSMAR, CNRDS, and Wind database.

Analysis of Empirical Results

Main Regression Results

Table 2 confirms that the ESG advantage significantly promotes the corporations' green innovation level, examining the direct impact of ESG advantage on corporate green innovation decision-making. From the first column of Table 2, it is evident that most of the control variables in this paper are significantly related to the dependent variable, indicating the appropriateness of the selected control variables. The second column reveals that, when controlling for firm and year-fixed effects, environmental certification still exhibits a significant impact on corporate green innovation at the 1% level, with a coefficient of 0.139. This suggests that holding other factors constant, on average, for every level increase in environmental certification, the level of corporate green innovation will increase by 13.9%, this means that corporations that have already passed environmental certification have a 13.9% higher green innovation rate than those without environmental certification. The third column shows that corporate social and governance factors have a significant positive effect on green innovation at the 5% level, with a coefficient of 0.001. Taken together, columns (2) and (3) indicate that as companies possess more ESG advantages, their green innovation also significantly increases, thus providing preliminary validation of hypothesis 1 that ESG advantages will have a significant positive impact on corporate green innovation.

Table 2. Main Regression Results

	(1)	(2)	(3)
	Green innovation	*Green innovation*	*Green innovation*
ROA	-0.043	0.067	-0.052
	(0.029)	(0.123)	(0.114)
Size	0.033***	0.123***	0.026**
	(0.003)	(0.005)	(0.011)
R&D	0.050***	0.200***	0.083***
	(0.006)	(0.015)	(0.021)
Concentration	-0.049**	-0.058	-0.080
	(0.021)	(0.040)	(0.086)
Age	0.065***	-0.036*	0.100*
	(0.016)	(0.020)	(0.060)
Lev	-0.003	0.059	-0.036
	(0.014)	(0.036)	(0.056)
Environmental		0.139***	
		(0.014)	
Social and Governance			0.001**
			(0.0004)
Constant	-0.294***	-0.777***	-0.255
	(0.048)	(0.072)	(0.204)
Industry and year FE	*Yes*	*Yes*	*Yes*
N	9399	9399	9399
R^2	0.534	0.118	0.643
Adj. R^2	0.487	0.116	0.593
Within R^2	0.007	0.102	0.004
F	45.236	152.125	4.205
Log Likelihood	-7024.532	-8565.714	-4244.065

Note: The double-tailed test standard error is shown in parentheses, and *, **, and *** represent significant values at the 10%, 5%, and 1% levels, respectively. Due to the lag in the independent variables during regression, the sample size has decreased. The data is sourced from the CSMAR, CNRDS, and Wind database. The following table is the same.

Table 3. Robust Regression Results

	(1)	(2)	(3)	(4)
	Green innovation	*Green innovation*	*Green innovation*	*Green innovation*
ROA	0.056	0.036	0.397	0.094
	(0.124)	(0.124)	(0.291)	(0.149)
Size	0.125***	0.122***	0.179***	0.063***
	(0.005)	(0.005)	(0.022)	(0.015)
R&D	0.206***	0.203***	0.235***	0.114***
	(0.015)	(0.015)	(0.077)	(0.028)
Concentration	-0.072*	-0.058	-0.032	-0.140
	(0.040)	(0.040)	(0.159)	(0.113)
Age	-0.042**	-0.037*	-0.053	0.306***
	(0.020)	(0.020)	(0.060)	(0.079)
Lev	0.025	0.008	0.074	-0.168**
	(0.036)	(0.036)	(0.095)	(0.074)
Reducing three wastes	0.038***			
	(0.013)			
CSR leadership		0.081***		
		(0.017)		
Environmental			0.251***	
			(0.035)	
Social and Governance				0.001**
				(0.0005)
Constant	-0.734***	-0.715***	-1.030***	-0.856***
	(0.073)	(0.073)	(0.267)	(0.268)
Industry and year FE	*Yes*	*Yes*	*Yes*	*Yes*
N	9399	9399	9399	9399
R^2	0.110	0.111	0.142	0.694
F	137.936	140.218	17.919	8.648
Log Likelihood	-8610.628	-8603.375	-11700	-6757.178

Robustness Test

This paper conducts robustness tests by replacing independent or dependent variables to prove that the research conclusion is robust and credible. As previously mentioned, the ESG concept encompasses several aspects, including environmental and corporate social responsibility, intending to assist companies in building responsible governance systems and becoming socially responsible corporations. In the environmental governance aspect, this paper selects measures of companies reducing three wastes as proxy variables, while in the corporate social responsibility dimension, the presence of a CSR leadership structure is chosen as a proxy variable. Regression of the original model is carried out again, and the results are shown in columns (1) and (2) of Table 4. The signs and significance of the coefficients remain consistent with the basic conclusions, indicating the high robustness of the research findings. Furthermore, the explained variable is the green innovation of the company, measured by the logarithm of the sum of independent green invention patents and utility model patents obtained by the company that year. However, ESG advantages may not only promote high-quality green innovation but also have a similar promoting effect on low-quality green innovation. Therefore, this paper re-estimates the benchmark model using the logarithm of the sum of independent green invention patents and green utility model patents obtained by the company that year as a proxy variable for company green innovation. The results, as shown in columns (3) and (4) of Table 3, remain consistent with the main regression results, demonstrating the high robustness of the research findings.

Mechanism Test

Table 4 examines the mechanisms through which ESG advantages impact corporate green innovation, namely financing constraints and green investment behavior. The constraint of financing on corporate innovation behavior has been widely acknowledged [16], and corporate ESG advantages help alleviate corporate financing constraints, reducing financing costs, and thus allowing more resources to be used for the company's green innovation activities. This paper measures a company's financing constraints through the company's cost of financing. Specifically, it is measured by the ratio of interest payable to total liabilities [16]. The results, as shown in columns (1) and (2) of Table 4, indicate that when the explained variable is the company's cost of financing, the coefficients of environmental certification, social, and governance are both significantly negative, suggesting that enhancing ESG advantages is conducive to reducing the cost of financing for companies to promote green innovation, thereby validating hypothesis 2.

Additionally, ESG advantages contribute to improving the relationship of companies with stakeholders such as upstream and downstream companies in the supply chain, and consumers, and enhancing the company's image, mitigating the principal-agent problems between senior management and major shareholders, and between major shareholders and minority shareholders. These factors provide companies with ample resources for environmental investment to meet external investors' requirements for improvements in environmental governance within the framework of ESG assessment. External investors, through the environmental governance dimension of ESG, form a good system of supervision and incentives for corporate behavior, leading to increased corporate investment in environmental protection, and enhancing their green investment behavior. This paper further verifies the mechanism of green investment. The company's green investment behavior is measured by the company's environmental investment, and this is used as the explained variable. The regression results in columns (3) and (4) of Table 4 show that the coefficients of environmental certification and social and governance are both significantly positive, indicating that ESG advantages will enhance a company's green investment behavior and green investment will significantly promote a company's green technological innovation [17], thus validating hypothesis 3.

Table 4. Mechanism Test Results

	(1)	(2)	(3)	(4)
	Finance costs	*Finance costs*	*Green investment*	*Green investment*
ROA	-0.059	0.062	0.220	-0.233
	(0.161)	(0.120)	(0.616)	(0.593)
Size	0.001	0.018	0.219***	-0.031
	(0.008)	(0.012)	(0.032)	(0.059)
R&D	-0.043***	-0.020	0.033	0.142
	(0.015)	(0.022)	(0.091)	(0.110)
Concentration	0.013	-0.113	0.675**	0.284
	(0.063)	(0.091)	(0.270)	(0.450)
Age	-0.012	-0.233***	0.041	0.640**
	(0.030)	(0.027)	(0.121)	(0.316)
Lev	0.349***	0.299***	-0.398**	-0.730**
	(0.049)	(0.059)	(0.194)	(0.294)
Environmental	-0.041***		0.443***	
	(0.015)		(0.084)	
Social and Governance		-0.0015***		0.006***
		(0.0004)		(0.002)
Constant	0.103	0.691***	-1.367***	-0.688
	(0.102)	(0.117)	(0.419)	(1.067)
Industry and year FE	*Yes*	*Yes*	*Yes*	*Yes*
N	9251	9251	9251	9251
R^2	0.105	0.378	0.073	0.361
F	17.020	21.992	12.845	3.108
Log Likelihood	-6867.941	-4881.624	-21700	-19600

Heterogeneity Test

Table 5 examines the impact of ESG advantages on technologically advanced companies and state-owned corporations. Technological capability is a critical factor influencing corporate green innovation. Leading-edge companies have more advanced technological reserves, making it easier for them to shift their R&D activities towards green innovation. In contrast, technologically backward companies face constraints in terms of R&D personnel and technological reserves when transitioning to green innovation, leading to lower willingness and efficiency in green innovation, and comparatively inadequate investment in green innovation activities. Technological capability represents whether a company is relatively technologically advanced or technologically backward compared to all companies operating in the same industry [18]. A significant body of research indicates that relative R&D expenditure can represent a company's strength or weakness in technological capability [19]. This paper, inspired by the study of Jin, et al. (2019) [18], measures a company's technological capability (*Technical*) by the relative R&D of company in year compared to all companies operating in the same industry , using R&D divided by constant price value added.

$$Technical_{i,j,t} = \frac{RDI_{i,j,t}}{Sales_{i,j,t}} - \left[\sum_{k=1}^{n}\left(\frac{RDI_{k,j,t}}{Sales_{k,j,t}}\right)\right] \times \frac{1}{n} \quad (2)$$

Here, $Technical_{i,j,t}$ represents company i's technological capability from industry j in year t. $\mathrm{RD}I_{i,j,t}$ represents company i's R&D expenditure from industry

Table 5. Heterogeneity Test Results

	(1)	(2)	(3)	(4)
	Green innovation	*Green innovation*	*Green innovation*	*Green innovation*
ROA	0.179	-0.112	0.043	-0.065
	(0.248)	(0.153)	(0.124)	(0.108)
Size	0.145***	0.045***	0.124***	0.037***
	(0.026)	(0.016)	(0.005)	(0.010)
R&D	0.180***	0.133***	0.199***	0.089***
	(0.066)	(0.027)	(0.015)	(0.020)
Concentration	-0.113	-0.003	-0.038	-0.131*
	(0.175)	(0.130)	(0.042)	(0.077)
Age	0.011	-0.017	-0.032	0.108**
	(0.055)	(0.087)	(0.020)	(0.054)
Lev	0.197*	-0.018	0.060*	-0.019
	(0.111)	(0.082)	(0.036)	(0.051)
Environmental	0.117***		0.107***	
	(0.033)		(0.022)	
Technical	0.795**	-0.313		
	(0.383)	(0.408)		
Environmental×Technical	2.037***			
	(0.772)			
Social and Governance		0.001**		0.0003
		(0.0005)		(0.001)
Social and Governance×Technical		0.036***		
		(0.013)		
SOEs			-0.038**	-0.140***
			(0.017)	(0.027)
Environmental×SOEs			0.048*	
			(0.028)	
Social and Governance×SOEs				0.001**
				(0.0005)
Constant	-1.136***	-0.101	-0.778***	-0.288
	(0.274)	(0.291)	(0.073)	(0.180)
Industry and year FE	*Yes*	*Yes*	*Yes*	*Yes*
N	9399	9399	9399	9399
R^2	0.119	0.691	0.119	0.628
F	7.376	5.446	118.970	8.552
Log Likelihood	-4801.780	-2298.347	-8562.977	-4623.746

j in year t, $Sales_{i,j,t}$ represents company i's total revenue from industry j in year t, $RDI_{k,j,t}$ represents company k's R&D expenditure from industry j in year t, and $Sales_{i,j,t}$ represents company k's total revenue from industry j in year t. n is the total number of companies in the same industry. The data are sourced from the CSMAR database. Heterogeneity is tested by constructing interaction terms between technological capability and independent variables. The regression results shown in columns (1) and (2) of Table 5 demonstrate that the coefficients of the interaction terms are significantly positive, indicating that ESG advantages have a more significant promoting effect on technologically advanced companies, validating hypothesis 4. Additionally, state-owned corporations generally possess political and economic dual attributes and are more influenced by government regulations. As the demand for sustainable development increases, state-owned corporations are more likely to be influenced to transform their models and take on more responsibilities related to environmental governance. Thus, the property rights of the company will bring heterogeneity to the relationship between ESG advantages and corporate green innovation. This paper empirically tests whether a company is a state-owned enterprise and its interaction with environmental governance, social, and governance. The method for measuring whether a company is a state-owned enterprise(*SOEs*) assigns a value of 1 when the sample company is a state-owned enterprise and 0 otherwise. The results, as shown in columns (3) and (4) of Table 5, reveal that the coefficients of the interaction terms are significantly positive, indicating that ESG advantages have a more positive impact on green innovation in state-owned corporations, validating hypothesis 5.

Conclusions and Discussion

Conclusions

ESG as a standard for evaluating a company's sustainable development aims to balance social responsibility and environmental protection while ensuring the company's economic benefits. In practice, companies with ESG advantages often excel in the field of green technological innovation. Based on stakeholder theory and incentive theory, this paper explores the relationship between ESG and corporate green innovation from the perspective of ESG advantages, using all listed manufacturing companies from 2003 to 2022 as samples. The research finds that ESG advantages can significantly enhance a company's green innovation. Mechanism tests indicate that ESG advantages promote corporate green innovation by alleviating financing constraints and promoting environmental investment. Furthermore, heterogeneity tests reveal that ESG advantages have a more pronounced promoting effect on technologically advanced companies and state-owned corporations' green innovation.

Contribution

The contribution of this study is as follows. First, this study expands the analysis of the channels through which ESG affects corporate green innovation from the perspectives of financial constraints and green investment, which is helpful for a more comprehensive and in-depth analysis of the internal mechanisms of ESG's impact on corporate green innovation. Existing literature has only initially analyzed the effect of ESG on corporate financial constraints [20], but has not specifically extended to the impact on corporate green innovation. This study expands on the related research literature, providing a substantial amount of explanation to clarify the relationship between ESG and corporate green innovation. Second, based on stakeholder and incentive theories, this study analyzes the relationship between ESG and corporate green innovation, complementing existing literature. Existing literature has preliminarily explored the impact of ESG on corporate technological innovation [21, 22], but the impact on corporate green innovation and its underlying mechanisms require further in-depth study. This study delves into this issue based on data from corporate green patent applications, expanding the related research on how capital market investors (stakeholders) influence corporate green innovation through incentive and financial constraint effects. This study effectively confirms the incentive effect of ESG advantages on green innovation. It microscopically explains the pivotal role of responsible companies in achieving green technology leadership and constructing high-end manufacturing. It also provides significant policy implications for promoting China's economic transformation and upgrading, achieving high-quality development, demonstrating responsible great power globally, and realizing a community with a shared future for humanity, which balances the legitimate concerns of other countries while pursuing its own interests and promoting the common development of all countries

Policy Implications

Based on the analysis of the research findings, this paper presents the following recommendations. Firstly, strengthen financial support and policy incentives for companies with ESG advantages to alleviate their financing constraints. This paper finds that financing constraints are the main channel through which ESG affects green innovation in enterprises. The government can provide more financial support to companies through policy banks and government-guided funds to alleviate their financing constraints, providing more financial security for companies to engage in green innovation. Additionally, targeted policy measures can be formulated to further incentivize leading-edge companies and state-owned corporations to invest and act in green innovation, providing guidance and support for these companies.

Secondly, demand ESG assessments that require companies to consider the value of the company from

a longer-term and comprehensive perspective. ESG standards can require companies to consider business management from a long-term and comprehensive perspective, balancing the interests of the company and the public. This plays a leading role in promoting green technological innovation. From the perspective of ESG, companies need to consider the environmental, social, and governance impacts—focusing not only on short-term economic benefits but also considering long-term development. This foundation is conducive to achieving green technological innovation in companies. For example, within ESG standards, companies need to consider their impact on the environment, such as environmental protection and resource utilization.

Thirdly, promote ESG practices and corresponding oversight and assessment. Both the government and companies should place more emphasis on ESG practices and recognize their significant role in promoting corporate green innovation. This not only helps companies achieve sustainable development goals but also enhances their innovation capabilities and market competitiveness. In addition, the government should strengthen oversight and assessment of corporate ESG practices to ensure compliance with relevant regulations and standards, while encouraging companies to continuously improve their ESG practices.

Fourth, establish comprehensive ESG policies and regulations, and promote green technologies and products. The government should formulate and improve ESG policies and regulations to incentivize and guide corporate ESG practices. For example, incentive policies such as financial subsidies or tax incentives can be provided to promote corporate environmental investment and technological innovation. Through various channels, the government can promote green technologies and products, raising public awareness and acceptance of green consumption, thereby providing broader market prospects for companies engaged in green innovation.

Potential Limitations

The present study is not without potential limitations, including data constraints. First, the sample in this study consists solely of publicly listed companies, excluding those that are not publicly listed. However, listed companies inherently possess greater scale and profitability, making it easier for them to allocate resources to green technology innovation. Therefore, further validation is necessary to determine the presence of any selective bias in the results. Second, the construction of corporate ESG advantages is a long-term endeavor and cannot be achieved in the short term. In the initial stages, even though companies may not possess ESG advantages, they may have already made significant long-term investments in environmental protection. Therefore, future research may consider continuously examining the impact of corporate ESG advantages on green technology innovation over a longer period.

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Conflict of Interest

Authors declare that they do not have any competing financial, professional, or personal interests from other parties.

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