ESG and green Innovation

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Abstract:

In recent years, with the growing emphasis on environmental protection and sustainable development in society, comprehensive green transformation has emerged as a prominent trend in economic and social development. This transformation not only enables enterprises to achieve sustainable development but also captivates the attention of an increasing number of investors. By analyzing the panel data of listed companies between 2011 and 2021, we found that outstanding ESG performance plays a pivotal role in promoting green technology innovation among enterprises. Within this process, financing constraints serve as a crucial intermediary. This research outcome offers valuable references for promoting green development initiatives among enterprises, enhancing the disclosure system of social responsibility information, and optimizing the efficiency of capital market allocation..

Keywords: ESG, financing constraints, green innovation, enterprise development

1. Introduction

ESG, which stands for Environment, Society, and Governance, has emerged as a pivotal concept in investment. It serves not only as an investment strategy but also as a method for evaluating the overall condition of a company, encompassing various aspects such as environmental impact, social responsibility, and corporate governance. The government, regulatory agencies, and industry associations have recognized the significance of ESG and have introduced policies requiring listed companies to disclose more ESG information. These measures aim to prod companies to enhance their ESG performance and steer investors towards considering ESG investment. Investors are increasingly concerned about the ESG performance of companies, as it not only impacts their long-term development but also has bearing on the overall well-being of society. Excellent ESG performance can enhance a company's credibility, boost brand value, and bolster market competitiveness. The public's response will also directly influence the economic value of enterprises, as consumers increasingly prioritize corporate social responsibility and environmental actions. Green innovation is key to achieving competitive advantages and facilitating low-carbon economic transformation for enterprises. Green technology innovation not only helps enterprises reduce costs and enhance efficiency but also enables the development of new markets and business models. As an essential means of green and low-carbon transformation for enterprises, it plays a pivotal role in safeguarding the environment and promoting sustainable development. However, financing constraints may affect the relationship between ESG and green innovation. Enterprises facing financing pressure may have limited investment in ESG and green technology due to funding shortages. To foster the green development of enterprises, it is imperative to address the issue of financing constraints and provide more financial support and policy guarantees for enterprises.

2. Literature review

Combing the existing literature, we find that many scholars have paid attention to the impact of corporate ESG responsibility fulfillment. First of all, corporate ESG performance promotes the disclosure of more environmental information and improves the information transparency with stakeholders. Darnall et al. (2022) [1] and An et al. (2023)[2] argued that a high ESG score not only provides investors with incremental information on the current risks of enterprises, but also helps to reduce investors' expectations on the future development risks of enterprises, thus reducing information asymmetry. Secondly, corporate ESG performance can reduce the cost of debt financing and equity financing by reducing the information asymmetry with creditors and equity holders. Raimo et al. (2021) [3] and Tang (2022) [4] found that the higher the transparency of ESG information disclosure, the lower the cost of debt financing. Finally, corporate ESG performance can comprehensively improve financial performance and market value by easing financing constraints. Xie et al. (2019) [5] and Yu et al. (2018) [6] empirically proved that higher ESG transparency can positively affect the Tobin's Q value of enterprises. Meanwhile, Zheng et al. (2022) [7] According to the research of Tan and Zhu (2022) [8] and the observations of other scholars, ESG ratings have a positive impact on the increase of green innovation in enterprises. However, there is currently little research on the impact of corporate ESG responsibility on technological innovation. Therefore, we analyzed the data from 2011 to 2020 and found some interesting results.

3. Theoretical analysis and research hypotheses

3.1 The impact of ESG performance on green innovation in enterprises

Green technology innovation with the core pursuit of achieving green development, can inject internal impetus into the sustainable development of China's economy and society. Taking the initiative in green and low-carbon management can indirectly improve economic performance (Ren, 2012) and gain higher competitive advantages for enterprises (Mcadam & Keogh, 2010).

There exists a social contract between enterprises and stakeholders, which dictates how enterprises should operate and behave. If a company violates this contract, it will face questions about the legitimacy of its operations, leading to litigation risks and public pressure. Institutional investors, as important stakeholders of enterprises, have a supervisory responsibility for corporate behavior. They demand that companies actively fulfill social expectations and industry standards to ensure that their actions comply with ethical and legal requirements. Under the pressure of the capital market, enterprises have the motivation to make more proactive environmental management decisions using green innovative technologies. This is because these decisions can meet the universally recognized values and ethical standards of investors, thereby obtaining higher market evaluations and protecting the company's image and reputation. Better fulfillment of social responsibility will help companies maintain more stable cooperative relationships with stakeholders. This kind of cooperative relationship can bring more resources and opportunities to enterprises, which is conducive to continuously obtaining the resources needed to promote technological innovation. At the same time, actively carrying out innovation activities can also enhance the competitive advantage of enterprises, enabling them to stand invincible in the fierce market competition. Therefore, the company has the motivation to fulfill its social responsibility and promote environmental protection and governance. This can not only meet the expectations of stakeholders but also further deepen the connection between the company and stakeholders. By fulfilling social responsibility, companies can gain more support and trust, making it easier to access the resources needed for technological innovation. Ultimately, this will help enhance the company's overall strength and give it a competitive advantage in the market.

H1: Under the same conditions, excellent ESG performance can drive green technology innovation in enterprises.

3.2 Impact of ESG performance on financial constraints

On the other hand, Qiu and Yin's (2019) study found that companies with better environmental and corporate governance performance can effectively reduce financing costs. The study also pointed out that the quality of ESG information disclosure has a significant impact on the financing cost of enterprises. Based on signal transmission theory, excellent ESG performance of enterprises is seen as an implicit contract that helps to transmit positive signals to the outside world. This type of signal can win the support and recognition of stakeholders, establish a good corporate social responsibility image, strengthen communication with stakeholders, and enhance corporate reputation (Du et al., 2011). This helps fund providers to have stronger confidence in the strength of the enterprise, while also reducing decision-making risks for creditors and investors. Therefore, companies with good reputations are more likely to be favored by external investors, thereby reducing the cost of external financing and bringing convenience to financing for the enterprise.

H2: Reducing financing constraints can be achieved by improving the ESG performance of enterprises.

3.3 The impact of ESG performance on green technology innovation in enterprises: the mediating role of financial constraints

According to Schumpeter's innovation theory, the ability to obtain funds plays a crucial role in the technological innovation of enterprises and provides economic support for their green transformation and upgrading. Numerous studies have shown that the lengthy investment process required to convert "new knowledge" into commercialization often makes it difficult for investors to distinguish the advantages and disadvantages of a project compared to investing in tangible or short-term assets. Technological innovation requires huge amounts of funding and high income uncertainty (Altomonte et al., 2016). Due to the popularization of ESG standards, excellent ESG performance can be reflected in the stock market through financial performance, which makes professional institutional investors more inclined to engage in socially responsible investments (Wang and Chen, 2017). Therefore, on the basis of improving ESG performance, enterprises can obtain more financial support, thereby expanding the funding sources for green technology innovation activities.

H3: Excellent ESG performance can alleviate financial constraints and promote sustainable development of enterprises.

4. Research design

4.1 Model Design

In order to test Hypothesis 1, the following model is constructed:

$$GI_{it} = \beta_0 + \beta_1 * ESG_{it} + X * Controls_{it} + \mu_i + \delta_t + \epsilon_{it} (1) \quad (1)$$

Where denotes the level of green technology innovation of enterprise i in period t, is the intercept term, is the coefficient of ESG, X is the coefficient matrix of control variables, Controls is the matrix of control variables, and is the random disturbance term. $GI_{it} \beta_0 \beta_1 \mu_i \delta_t \epsilon_{it}$ If >0 and significant, Hypothesis 1 is valid. $valid . \beta_1$

In order to test Hypotheses 2 and 3, the following model is constructed:

$$COD_{it} = \alpha_0 + \alpha_1 * ESG_{it} + X * \text{ Controls }_{it} + \mu_i + \delta_t + \epsilon_{it}$$

$$GI_{it} = \eta_0 + \eta_1 * ESG_{it} + \eta_2 * COD_{it} + X * \text{ Controls }_{it} + \mu_i + \delta_t + \epsilon_{it} \quad (2)\ (3)$$

Denotes the financing cost of firm i in period t in (2). COD_{it} X is the coefficient matrix of control variables; Controls is the matrix of control variables; in addition, and are introduced to control the influence of industry and year factors; ϵ_it is the random disturbance term. $\mu_i \delta_t$ If <0 and significant, it indicates that the better the enterprise ESG performance is, the lower the financing cost will be, so Hypothesis 2 is established. α_1 On this basis, if it is significant, it is a partial intermediary; η_1 If it is not significant, it is considered as complete mediation. η_2 If <0 and significant, and >0 but less than that in Model (1), Hypothesis 3 is established. established. $\eta_1 \beta_1$

4.2 Definition of Variables

Table 1 Variable definition table

Variable types	Variable name	Variable symbol	Specific way of definition
Explanatory variables	ESG performance	ESG	The benchmark regression is based on ESG evaluation data developed by Bloomberg. In the robustness test, the ESG score of Huazheng is used as the proxy variable of ESG performance.
Explained variable	Green technology innovation	GI	Measure the total number of green patent applications, green invention and utility model patents used in green innovation, and calculate the logarithm of the number of green patent applications of listed companies. Robustness testing uses green innovation efficiency and the number of green innovation technology citations as indicators.
Mediating variable	Financing costs	COD	COD1 is the financial expenses/total liabilities of the enterprise at the end of the period; The final COD2 is calculated based on the formula (interest expenses+ commission expenses +other financial expenses)/total liabilities

Control variables	Age of business	Age	Current year of business - year of establishment
	Separation rate of two rights	Seperation	(Percentage of control - Percentage of ownership)/percentage of control
	Market-to-book ratio	MB	Market value of the company over book value
	Proportion of state-owned shares	State	The proportion of state-controlled shares in all shares
	Ownership concentration	Top1	Shareholding ratio of the largest shareholder
	Proportion of independent directors	Indep	Number of independent directors/board of directors
	Enterprise size	Size	Take the logarithm of the total assets of the business
	Two jobs in one	Dual	One if the chairman and general manager are the same person and zero otherwise

4.3 Sample and Data

This paper selects Chinese listed enterprises from 2011 to 2021 as the initial sample, and further does the following screening work: (1) eliminate the samples of ST and ST* in the current year; (2) eliminating the missing values; (3) Companies in the financial industry are proposed.

5 Empirical results

5.1 Descriptive statistics

In Table 2, the variance of Bloomberg ESG is relatively high, indicating significant differences in ESG performance among different companies. This difference can be attributed to differences in the company's emphasis on ESG, investment of resources, and implementation strategies. In contrast, the variance of green innovation is relatively small, and after logarithmic processing, the differences between the data are reduced. This may be because green innovation is a relatively new field, and most companies are actively exploring and practicing it, so the differences between data are relatively small.

Table2 Descriptive statistics

VarName	Obs	Mean	SD	Min	Median	Max
Bloomberg ESG	33956	32.05	9.97	9.09	30.2082	68.92
Hua Zheng ESG	33956	4.62	1.05	0.75	4.75	7.75
Age	33956	18.68	5.96	2	19	42
State	33956	0.04	0.12	0	0	0.88
size	33956	23.98	1.56	19.54	23.71	28.55
MB	33956	1.77	1.34	0.64	1.37	27.34
Top1	33956	37.81	16.33	3.62	36.17	89.09
Dual	33956	0.19	0.39	0	0	1
Seperation	33956	5.31	8.17	7.64	0	44.99
Indep	33956	38.17	6.72	23.08	36.36	80

GI1	33956	1.28	1.52	0	0.69	7.23
GI2	33956	1.03	1.39	0	0.69	7.14
GI3	33956	0.76	1.14	0	0	5.99
SOE	33956	0.59	0.49	0	1	1
COD1	33956	0.01	0.02	0.16	0.01	0.07
COD2	33956	0.02	0.01	0	0.02	0.07
Num	33956	23.36	156.93	1.00	3	7039
GI_efficiency	33897	0.06	0.07	0	0.04	0.20
hhi	33956	0.12	0.11	0.0210	0.08	1

In Table 3, there is a significant positive correlation between ESG and GTI, which is in line with our expectations. ESG and GTI are both indicators for measuring corporate sustainability and social responsibility, and their positive correlation indicates that companies that perform well in ESG performance often also make contributions to green innovation. This further confirms the close connection between ESG and green innovation, and provides strong support for our research on company sustainability and social responsibility.

Table3 Phase relation table

	ESG	GI1	GI2	GI3	Age	State	size
ESG	1						
GI1	0.221***	1					
GI2	0.244***	0.968***	1				
GI3	0.184***	0.884***	0.783***	1			
Age	0.168***	-0.021***	-0.00800	-0.032***	1		
State	-0.039***	0.00500	0.010*	0.010*	-0.054***	1	
size	0.557***	0.246***	0.260***	0.262***	-0.068***	0.114***	1
MB	-0.121***	-0.072***	-0.060***	-0.108***	-0.024***	-0.121***	-0.388***
Top1	0.124***	0.00400	0.00400	0.031***	-0.257***	0.217***	0.356***
Dual	-0.014**	0.079***	0.080***	0.085***	-0.044***	-0.100***	-0.143***
Seperation	-0.049***	-0.062***	-0.077***	-0.046***	0.155***	-0.049***	-0.123***
Indep	0.129***	-0.00400	0	0.00400	-0.220***	0.00800	0.292***
	MB	Top1	Dual	Seperation	Indep		
MB	1						
Top1	-0.157***	1					
Dual	0.162***	-0.156***	1				
Seperation	0.00200	0.072***	-0.011**	1			
Indep	-0.068***	0.186***	0.040***	-0.122***	1		

注 :***, **, * means statistically significant at 1%, 5%, and 10%, respectively.

5.2 Benchmark Regression

In order to test Hypothesis 1, this paper uses the two-way fixed effect model for regression. Table 4 reports the regression results. Columns (1) - (3) show the regression results of ESG on overall GTI, inventive GTI and utility model GTI, respectively. The coefficient of enterprise size (size) is positive, indicating that the larger the company is, the stronger the GTL capability is.

Table 4 Benchmark regression

	GI1	GI2	GI3
Bloomberg ESG	0.0185 * * *	0.0183 * * *	0.0089 * * *
	(0.002)	(0.002)	(0.001)
Age	0.0083 * * *	0.0052 * * *	0.0055 * * *
	(0.002)	(0.002)	(0.001)
State	0.1070	0.0698	0.0943 *
	(0.075)	(0.064)	(0.055)
size	0.2191 * * *	0.1929 * * *	0.1488 * * *
	(0.011)	(0.010)	(0.009)
MB	0.0038	0.0102 * *	0.0024
	(0.005)	(0.005)	(0.003)
Top1	0.0009	0.0010 *	0.0006
	(0.001)	(0.001)	(0.000)
Dual	0.0443 *	0.0515 * *	0.0408 * *
	(0.024)	(0.021)	(0.018)
Seperation	0.0010	0.0016	0.0013
	(0.001)	(0.001)	(0.001)
Indep	0.0031 * *	0.0023	0.0010
	(0.002)	(0.001)	(0.001)
_cons	4.7018 * * *	4.3364 * * *	3.1808 * * *
	(0.249)	(0.226)	(0.192)
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	10629	10629	10629
Adj. R^2	0.303	0.283	0.281

Note: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively; The figures in parentheses are t values, the same below.

5.3 Mechanism Test

Table5 shows the regression results of the mechanism analysis. The first column displays the regression results of ESG performance on the cost of corporate debt financing. The coefficient of ESG is significantly negative, indicating that better ESG performance can reduce corporate financing costs, and hypothesis 2 has been validated. On the basis of benchmark regression, columns (2), (3), and (4) respectively add the cost of corporate debt financing, and the financing cost coefficient is significantly positive, indicating that reducing financing costs can enhance the green technology innovation of enterprises. Meanwhile, the coefficient of ESG is significantly positive and smaller than the coefficient in the benchmark regression, indicating that good ESG performance of enterprises can not only directly promote GGI, but also promote GGI by reducing financing costs. This validates hypothesis 3.

Table5 Mediating effect

	(1)	(2)	(3)	(4)
	COD1	GI1	GI2	GI3
Bloomberg ESG	0.0002 * * *	0.0182 * * *	0.0180 * * *	0.0087 * * *
	(0.000)	(0.002)	(0.002)	(0.001)
COD1		1.3570 * * *	1.3640 * * *	0.6954 * * *
		(0.291)	(0.258)	(0.193)
Age	0.0003 * * *	0.0079 * * *	0.0048 * * *	0.0052 * * *
	(0.000)	(0.002)	(0.002)	(0.001)
State	0.0042 * *	0.1128	0.0756	0.0972 *
	(0.002)	(0.075)	(0.064)	(0.055)
size	0.0034 * * *	0.2237 * * *	0.1975 * * *	0.1512 * * *
	(0.000)	(0.011)	(0.010)	(0.009)
MB	0.0024 * * *	0.0006	0.0070	0.0040
	(0.000)	(0.005)	(0.005)	(0.003)
Top1	0.0002 * * *	0.0012 * *	0.0013 * *	0.0008 *
	(0.000)	(0.001)	(0.001)	(0.000)
Dual	0.0027 * * *	0.0407 *	0.0479 * *	0.0389 * *
	(0.001)	(0.024)	(0.021)	(0.018)
Seperation	0.0001 * * *	0.0009	0.0014	0.0012
	(0.000)	(0.001)	(0.001)	(0.001)
Indep	0.0001 * *	0.0030 *	0.0022	0.0010
	(0.000)	(0.002)	(0.001)	(0.001)
_cons	0.0582 * * *	4.7807 * * *	4.4157 * * *	3.2213 * * *
	(0.007)	(0.251)	(0.228)	(0.194)
Ind FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	10629	10629	10629	10629
Adj. R^2	0.184	0.304	0.285	0.281

5.4 Heterogeneity analysis

This paper conducts grouped regression according to whether the enterprise is a state-owned enterprise, whether it belongs to the manufacturing industry, and the degree of industry competition. The results are shown in Table 6, Table7and Table8. It can be seen that the coefficient of state-owned enterprises is smaller than that of non-state-owned enterprises, that of manufacturing enterprises is smaller than that of non-manufacturing enterprises, and that of companies with less market competition is smaller than that of companies with more market competition, indicating that companies that are non-state-owned enterprises, non-manufacturing enterprises or companies with more market competition have better ESG performance to promote green technology innovation.

Table6 Heterogeneity analysis - Grouping of enterprise nature

	(1)	(2)	(3)	(4)	(5)	(6)
	GI1-Not-SOE	GI1-SOE	GI2-Not-SOE	GI2-SOE	GI3-Not-SOE	GI3-SOE
Bloomberg ESG	0.0233 * * *	0.0141 * * *	0.0225 * * *	0.0145 * * *	0.0108 * * *	0.0074 * * *
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age	0.0139 * * *	0.0126 * * *	0.0085 * * *	0.0113 * * *	0.0097 * * *	0.0053 * *
	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
State	0.0900	0.1416 *	0.0868	0.1138	0.0548	0.0823
	(0.217)	(0.080)	(0.188)	(0.069)	(0.163)	(0.059)
size	0.2076 * * *	0.2283 * * *	0.1769 * * *	0.2039 * * *	0.1514 * * *	0.1491 * * *
	(0.018)	(0.015)	(0.017)	(0.014)	(0.015)	(0.011)
MB	0.0096	0.0101	0.0138 * *	0.0182 * *	0.0012	0.0035
	(0.006)	(0.009)	(0.006)	(0.009)	(0.004)	(0.006)
Top1	0.0025 * * *	0.0015 *	0.0025 * * *	0.0016 *	0.0013 * *	0.0008
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dual	0.0779 * * *	0.0674	0.0930 * * *	0.0638	0.0412 * *	0.0611
	(0.028)	(0.048)	(0.024)	(0.043)	(0.021)	(0.038)
Seperation	0.0009	0.0035 * *	0.0015	0.0023	0.0006	0.0008
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Indep	0.0019	0.0060 * * *	0.0024	0.0054 * * *	0.0024	0.0024
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
_cons	4.6057 * * *	4.6366 * * *	4.1604 * * *	4.2706 * * *	3.3059 * * *	3.1377 * * *
	(0.429)	(0.337)	(0.393)	(0.308)	(0.341)	(0.255)
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	5230	5396	5230	5396	5230	5396
Adj. R^2	0.286	0.360	0.256	0.347	0.268	0.327

Table7 Heterogeneity analysis - Whether it is a manufacturing group

	(1)	(2)	(3)	(4)	(5)	(6)
	GI1-manufacturing	GI1-Not-manufacturing	GI2-manufacturing	GI2-Not-manufacturing	GI3-manufacturing	GI3-Not-manufacturing
Bloomberg ESG	0.0190 * * *	0.0208 * * *	0.0192 * * *	0.0196 * * *	0.0094 * * *	0.0103 * * *
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Age	0.0118 * * *	0.0067 * * *	0.0067 * * *	0.0059 * * *	0.0088 * * *	0.0033 *
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
State	0.3084 * *	0.0033	0.2569 * *	0.0191	0.1736 *	0.0749

	(0.131)	(0.088)	(0.112)	(0.077)	(0.100)	(0.064)
size	0.3095 * * *	0.1144 * * *	0.2724 * * *	0.1009 * * *	0.2119 * * *	0.0743 * * *
	(0.016)	(0.013)	(0.015)	(0.012)	(0.013)	(0.009)
MB	0.0075	0.0102	0.0152 * *	0.0120 * *	0.0014	0.0041
	(0.007)	(0.006)	(0.006)	(0.006)	(0.004)	(0.004)
Top1	0.0032 * * *	0.0020 * * *	0.0030 * * *	0.0017 * * *	0.0030 * * *	0.0025 * * *
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dual	0.0613 * *	0.0068	0.0784 * * *	0.0087	0.0546 * *	0.0103
	(0.031)	(0.030)	(0.027)	(0.027)	(0.024)	(0.019)
Seperation	0.0022	0.0014	0.0032 * *	0.0010	0.0014	0.0028 * * *
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Indep	0.0002	0.0065 * * *	0.0011	0.0058 * * *	0.0011	0.0030 *
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
_cons	6.5636 * * *	2.6241 * * *	6.0633 * * *	2.3852 * * *	4.4374 * * *	1.7601 * * *
	(0.362)	(0.301)	(0.333)	(0.265)	(0.288)	(0.213)
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6229	4400	6229	4400	6229	4400
Adj. R^2	0.283	0.319	0.264	0.321	0.265	0.293

Table8 Heterogeneity analysis - Grouping of industry competition degree

	(1)	(2)	(3)	(4)	(5)	(6)
	GI1-low-hhi	GI1-high-hhi	GI2-low-hhi	GI2-high-hhi	GI3-low-hhi	GI3-high-hhi
Bloomberg ESG	0.0125 * * *	0.0307 * * *	0.0128 * * *	0.0293 * * *	0.0036 * *	0.0200 * * *
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Age	0.0071 * * *	0.0103 * * *	0.0036 *	0.0083 * * *	0.0059 * * *	0.0045 *
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
State	0.0482	0.3733 * * *	0.0407	0.2575 * *	0.0568	0.3491 * * *
	(0.093)	(0.125)	(0.080)	(0.109)	(0.068)	(0.095)
size	0.1995 * * *	0.2471 * * *	0.1738 * * *	0.2221 * * *	0.1347 * * *	0.1671 * * *
	(0.014)	(0.017)	(0.013)	(0.015)	(0.011)	(0.012)
MB	0.0089	0.0073	0.0152 * *	0.0003	0.0007	0.0072
	(0.006)	(0.008)	(0.006)	(0.007)	(0.004)	(0.006)
Top1	0.0019 * * *	0.0001	0.0017 * * *	0.0004	0.0012 * *	0.0000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dual	0.0218	0.0908 * *	0.0304	0.0936 * * *	0.0255	0.0779 * *
	(0.029)	(0.041)	(0.026)	(0.035)	(0.021)	(0.032)

Seperation	0.0011	0.0037 * *	0.0006	0.0044 * * *	0.0002	0.0031 * *
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
Indep	0.0045 * *	0.0002	0.0040 * *	0.0012	0.0012	0.0006
	(0.002)	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)
_cons	4.0537 * * *	5.7303 * * *	3.7037 * * *	5.3688 * * *	2.7200 * * *	3.8810 * * *
	(0.325)	(0.375)	(0.295)	(0.338)	(0.253)	(0.282)
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6886	3741	6886	3741	6886	3741
Adj. R^2	0.249	0.397	0.221	0.394	0.219	0.369

5.5 Robustness test

To ensure the accuracy and reliability of our empirical research conclusions, we have adopted various testing methods to validate our results. Firstly, we used debt financing cost as a mediator variable and found a significant negative correlation between ESG score and financing cost, which further confirms the positive impact of ESG on corporate debt financing cost. Secondly, we considered potential endogeneity issues and improved the accuracy of the estimation through instrumental variable processing methods. In addition, we also used the Huazheng ESG score as an alternative measurement method for explanatory variables, as well as the measurement methods for green innovation efficiency and GTI patent citation frequency as explanatory variables, to verify the robustness of our conclusions in different contexts. In all regression results, the ESG score coefficient showed a significant positive correlation, while the financing cost coefficient showed a negative correlation, further confirming the reliability of our conclusion. Therefore, we can be confident that corporate ESG performance has a positive impact on the cost of debt financing.

Table9 Robustness test: Replacing explanatory variables

	(1)	(2)	(3)
	GI1	GI2	GI3
Hwa Zheng ESG	0.0940 * * *	0.0795 * * *	0.0433 * * *
	(0.009)	(0.008)	(0.006)
Age	0.0079 * * *	0.0049 * * *	0.0053 * * *
	(0.002)	(0.002)	(0.001)
State	0.0749	0.0481	0.0802
	(0.076)	(0.066)	(0.056)
size	0.2453 * * *	0.2217 * * *	0.1617 * * *
	(0.011)	(0.010)	(0.009)
MB	0.0052	0.0121 * * *	0.0017
	(0.005)	(0.005)	(0.003)
Top1	0.0010 *	0.0010 *	0.0007
	(0.001)	(0.001)	(0.000)
Dual	0.0571 * *	0.0621 * * *	0.0466 * * *
	(0.024)	(0.021)	(0.018)
Seperation	0.0013	0.0018 *	0.0014 *
	(0.001)	(0.001)	(0.001)

Indep	0.0040 * *	0.0030 * *	0.0014
	(0.002)	(0.001)	(0.001)
_cons	5.1755 * * *	4.8212 * * *	3.4098 * * *
	(0.254)	(0.232)	(0.195)
Ind FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	10629	10629	10629
Adj. R^2	0.301	0.278	0.279

6 Conclusion

This study uses empirical data from 2015 to 2019 and explores the impact of ESG performance on green technology innovation in enterprises based on information asymmetry, signal transmission, and sustainable development theories. We conducted empirical evidence analysis on A-share listed companies in the Shanghai and Shenzhen stock markets by reducing financial constraints. Specifically, superior ESG performance can significantly stimulate the company's innovation in green technology. By examining indirect effects, we aim to uncover the reciprocal relationship between financial constraints and this process. After correcting data, adjusting process metrics, and considering potential internal issues, the aforementioned conclusion remains valid. This study has significant practical implications for the lifelong exploration of the relationship between enterprise ESG and the company's innovation path of Cuilv Technology.

References:

[1] Darnall N, Ji H, Iwata K, et al. Do ESG reporting guidelines and verifications enhance firms' information disclosure? [J]. Corporate Social Responsibility and Environmental Management, 2022, 29(5): 1214-1230.

[2] An J, Zhang C Q, Gao L, et al. Do ESG Scores Have Incremental Information Value on the Primary Bond Market? — Evidence from China[J]. Frontiers in Environmental Science, 10: 2585.

[3] Raimo N, Caragnano A, Zito M, et al. Extending the benefits of ESG disclosure: The effect on the cost of debt financing[J]. Corporate Social Responsibility and Environmental Management, 2021, 28(4): 1412-1421.

[4] Tang H. ESG performance, Investors' Heterogeneous Beliefs, and Cost of Equity Capital in China[J]. Frontiers in Environmental Science, 2022: 2421.

[5] Xie J, Nozawa W, Yagi M, et al. Do environmental, social, and governance activities improve corporate financial performance? [J]. Business Strategy and the Environment, 2019, 28(2): 286-300.

[6] Yu E P, Guo C Q, Luu B V. Environmental, social and governance transparency and firm value[J]. Business Strategy and the Environment, 2018, 27(7): 987-1004.

[7] Zheng M, Feng G F, Jiang R A, et al. Does environmental, social, and governance performance move together with corporate green innovation in China? [J]. Business Strategy and the Environment, 2022.

[8] Tan Y, Zhu Z. The effect of ESG rating events on corporate green innovation in China: The mediating role of financial constraints and managers' environmental awareness[J]. Technology in Society, 2022, 68: 101906.