

# A Study on the Impact of ESG Rating Disclosure on Corporate Green Innovation

Ruopeng Wang<sup>1,\*</sup>, Ziyi Rong<sup>2</sup>

<sup>1</sup> Pratt Risk Engineering, Duke University, Durham, North Carolina, United States

<sup>2</sup> Software Engineering, Beijing - Dublin International College at BJUT

\* Corresponding Author Email: rw319@duke.edu

**Abstract.** By building a regression model, this study examines the effect of corporate ESG on green innovation. It also looks at how corporate transparency and the level of internal monitoring influence this relationship. It has been discovered that there is a strong correlation between a company's ESG ratings and its commitment to green innovation, and that companies with high ESG ratings are more likely to do so. Additionally, the level of corporate internal oversight and transparency play a helpful moderating function in this relationship, and stronger internal oversight and greater transparency can further foster the growth of green innovation. Additionally, the relationship between ESG ratings and green innovation is mediated, respectively, by business reputation, R&D expenditure, and financial restrictions. A deeper understanding of the effects of ESG in various contexts is made possible by heterogeneity analysis, which demonstrates that state-owned enterprises and larger companies are likely to be positively impacted by ESG ratings. Both the results of the robustness test by substituting explanatory variables technique and the approach using instrumental variables corroborate the conclusions made in this research. This study offers crucial information about how ESG impacts corporate green innovation, which greatly encourages the formulation of corporate sustainability and green innovation policies.

**Keywords:** Component, Moderating effect, Mediating effect, ESG Rating, Enterprise Green Innovation.

## 1. Introduction

In the past decades, the global society and economy have faced many serious challenges, such as climate change, resource shortage, environmental pollution, social inequality, etc. These issues have attracted widespread attention from all walks of life, promoting the awareness and pursuit of sustainable development. As an important part of socio-economic activities, enterprises' role in facing these challenges cannot be ignored.

In this setting, green innovation has emerged as one of the key tactics used by businesses to overcome obstacles and achieve sustainable development. It helps enterprises meet the needs of the market and society but also helps to enhance their competitiveness, reduce risks, and open up new market opportunities for them. At the same time, the ESG framework provides companies with a comprehensive way to assess their sustainability performance, which helps them better manage their relationships with stakeholders and enhance their social reputation and corporate value.

Green innovation is the software or hardware innovation for green products and their related processes, aiming to carry out economic activities while reducing negative impacts on the environment and providing conditions for sustainable development. The difference between green and ordinary innovation mainly lies in reducing environmental pollution, saving resources, and having a favorable environmental impact. Meanwhile, the fundamental purpose of green innovation is the same as ordinary innovation, which is to improve economic efficiency and increase revenue. Enterprises adopt green innovation not only to comply with governmental norms and respond to governmental appeals but also to improve their market competitiveness and generate sustainable income.

ESG includes Environmental, Social, and Governance. Environmental assessment focuses mostly on determining if businesses have taken action to safeguard the environment and how much

safeguarding the environment is present in their economic operations. Due to the attention paid to environmental issues in recent years, the environmental factor is usually the most concerned in the ESG assessment. Social refers to the accomplishment of corporate social responsibility, which is a prerequisite for the moral standing of businesses and is an essential component of their voluntarily accepted behavior. Social responsibility requires corporate management to contribute to social development while pursuing economic benefits. Governance refers to the company's self-regulation, which mainly focuses on the checks and balances between the owners and operators of the company.

Numerous studies have investigated the connection between green innovation and corporate ESG scores. Some scholars point out that green innovation has a moderating effect on the ESG effect. In North American listed companies, green innovation has a moderating effect on the improvement of ESG ratings and market valuation, and there is a beneficial correlation between strong ESG performance and enterprises' market capitalization. Environmental uncertainty may reduce firms' ESG ratings. Green innovation plays a mediating role in this regard. It helps to mitigate the adverse effects of environmental uncertainty, which means that firms can better cope with fluctuations in the external environment and improve the stability of their ESG ratings by strengthening green innovation. The mediating role of green innovation is also reflected in helping to achieve a close alignment between digital transformation strategies and corporate ESG ratings. Some literature also points out that ESG ratings can promote green innovation, while green innovation also plays a vital role in improving firms' ESG ratings.

To summarize, the existing literature has made some significant findings. However, there are still some limitations, such as the limited scope of the research sample, restricted geographic applicability, and data availability. Therefore, this study explores the relationship and influence mechanism between green innovation and corporate ESG ratings, not only theoretically, it can enrich and deepen the theoretical system about sustainability, innovation management and corporate social responsibility, and provide new academic research in related fields with a new Not only in theory, it can enrich and deepen the theoretical system about sustainability, innovation management and CSR, and provide new perspectives and theoretical frameworks for academic research in related fields; but also in practice, it can provide guidance for enterprises to formulate more forward-looking and strategic green innovation and ESG strategies, to better plan and integrate sustainability goals, and to enhance their competitiveness and sustainability performance.

## **2. Theoretical analysis and research hypotheses**

### **2.1. The direct impact of corporate ESG performance on green innovation**

In recent years, academic research on enterprise green innovation has focused on the analysis and study of green innovation factors. In terms of the influence of green system on enterprise green innovation, at the beginning of the 20th century, "Porter's hypothesis" proposed that some appropriate environmental policies and systems can effectively enhance the enthusiasm of enterprises to carry out technological innovation, and Yalabik et al. proposed that in the case of enterprises facing the double yards of customer reduction due to environmental pollution and government regulation, enterprises will increase their investment in environmental protection technology and reduce the amount of emissions [1]. In terms of the influence of market factors on enterprise green innovation, enterprises can use the market mechanism to optimize their green technology, lower the risk of technological innovation and promote the efficient utilization of resource allocation. Therefore, in the process of enterprise green innovation, enterprises need the support of government policies, funds and other aspects. According to stakeholder theory, when an enterprise pursues value maximization, its ESG rating can have an impact on the activities of stakeholders, thus promoting the enterprise's green innovation.

This paper proposes:

H1: ESG ratings positively contribute to firms' green innovation.

## **2.2. The moderating role of corporate internal oversight on green innovation**

In the company's internal management system, the supervisory board holds the power to review the legitimacy of the duties of the company's managers, which includes monitoring the operation and investment strategies of the board of directors and the management team [2]. A good ESG rating represents a superior level of corporate governance and creates an environment conducive to the supervisory board's performance of its functions, thus facilitating its supervisory functions and promoting the innovation process of corporate green technology. High ESG-rated companies have a robust corporate governance structure, which reduces agency conflicts and information asymmetry, enabling the supervisory board to access the company's internal information more quickly, and to effectively assess and adjust the decisions of the board of directors and management. This further helps enterprises to avoid problems such as moral hazard and adverse selection in the decision-making process, making wise choices for long-term business growth and encouraging the real use of green technology innovation.

This paper proposes:

H2: Corporate internal oversight has a positive moderating role in the relationship between ESG and green innovation.

## **2.3. The moderating effect of corporate information transparency on green innovation The moderating role of corporate internal oversight on green innovation**

Information transparency of a company is the extent and truthfulness with which a company publicizes and discloses its operations and finances for stakeholders to assess and make decisions. Increased information transparency helps to identify and assess green innovation initiatives, and investors are able to gain a deeper understanding of companies when they are more open with information [3]. This in-depth knowledge helps reduce the difficulty of assessing green innovation uncertainty and supports decision-making in the face of information imbalance. At the same time, increased transparency of information helps predict green innovation outcomes. Recipients of the company's information will have a clearer grasp of the complete green innovation process while maintaining checking on the program to make sure it is heading in the direction of investor interests, which will ultimately contribute to the effective implementation of corporate green innovation. Moreover, companies with high ESG ratings are more willing to hire professional auditors or accountants in the industry to further improve the transparency of the company's audit information and accounting information [4]. External audit can be regarded as a reliable and high-quality information disclosure, which provides shareholders with relevant information to enable them to make investment decisions and supervise their investment targets, thus promoting investors' investment in enterprises with green innovation, and at the same time, helping enterprises to reduce the burden of supervision, lowering the incentive to give up green innovation because of their own high regulatory costs. Increased transparency of accounting information helps to reduce uncertainty and information asymmetry, thus reducing the rate of return required by investors for investment, reducing the financing burden of invested enterprises, alleviating financing constraints [5], and promoting enterprises to carry out green innovation.

This paper proposes:

H3: Corporate information transparency has a positive moderating role in the relationship between ESG and green innovation.

## **2.4. Mediating effects of corporate reputation The moderating role of corporate internal oversight on green innovation**

Enterprises undertaking green innovation need to be supported by resources in terms of technological know-how, finance and specialized talent. Higher ESG ratings indicate that an enterprise emphasizes its sustainability and green economic development and is able to effectively take on social responsibility and make a positive impact on environmental, social and governance aspects. As a result, such an enterprise is more likely to be recognized by key stakeholders such as

society at large, investors and the government, thus enhancing its corporate reputation. Good corporate reputation can be aided by attracting and retaining professional talent, provide the intellectual capital needed for enterprises to carry out green innovation, and improve the efficiency of enterprises to carry out green innovation [7].

This paper proposes:

H4: Corporate reputation has a mediating effect in the relationship between ESG and green innovation.

### **2.5. Mediating effects of firms' R&D investment**

Enterprise R&D investment can realize enterprise green innovation by improving the utilization of enterprise natural resources and reducing pollutant emissions [8]. R&D investment in corporate green innovation can be regarded as a long-term investment, which is characterized by large input costs, long transformation cycles, and uncertain returns. In the absence of external regulation, companies often tend not to promote green innovation in order to reduce their expenditures, which may be detrimental to the public interest. However, ESG ratings increase the transparency of information and internalize the potential external risks faced by firms, thus raising their awareness of their responsibilities and thus motivating them to engage in green innovation. As a result, firms will be more proactive in increasing their R&D investment in green innovation in pursuit of long-term benefits.

This paper proposes:

H5: Firms' R&D investment has a mediating effect in the relationship between ESG and green innovation.

### **2.6. Mediating effects of corporate finance constraints**

Due to its high input cost, long payback period and uncertainty, enterprises need to invest sufficient funds when engaging in green innovation. Enterprises often choose external financing behaviors to raise sufficient funds when carrying out green innovation [9]. According to principal-agent theory, the information asymmetry of enterprises often leads to the problem of financing constraints faced by enterprises. Investors' distrust and lack of understanding of enterprises make enterprises need to pay larger financing costs when they engage in external financing. In this case, the enterprise ESG rating can be used as the enterprise information reference to increase the information transparency of the enterprise and alleviate the problem of information asymmetry. high ESG rating sends a signal to investors that the enterprise is operating well and attracts investors to invest in the enterprise [10]. Therefore enterprises with higher ESG ratings tend to receive favor from investors, their financing costs will be lower, and they face less financing constraints.

This paper proposes:

H6: Corporate financing constraints re the mediating effect in the relationship between ESG and green innovation.

Based on the above research assumptions, the theoretical model of this paper is shown in Figure 1 below.

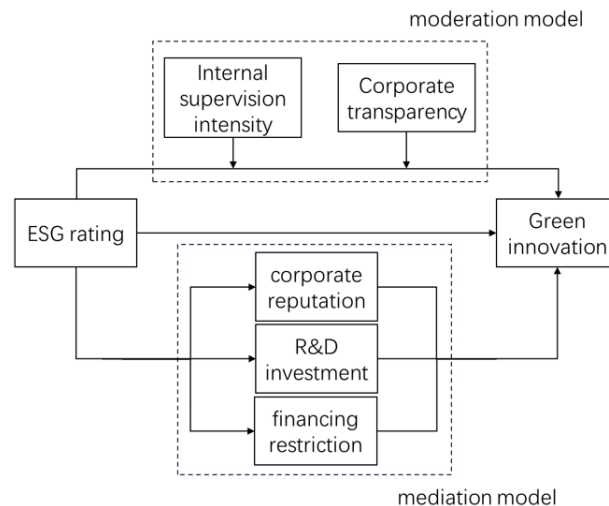


Figure 1. Example of a ONE-COLUMN figure caption

### 3. Research design

#### 3.1. Sample selection and data sources

This paper uses A-share listed companies from 2010 to 2021 as a sample to investigate the relationship between corporate ESG ratings and corporate green innovation. The CSMAR is the primary source of the financial information used in this article, green innovation-related data from CNRDS, and ESG rating from WIND. 24,509 observations are included after preprocessing.

#### 3.2. Definition of variables

**Explained variables.** Referring to the practice of Yu Zhimai [11], the company's green innovation level (*gi\_gain*) is the explanatory variable.

**Explanatory variables.** The explanatory variable of this paper is corporate ESG rating (*esg*). According to the WIND database Chinese certificates ESG ratings and referring to Xilongsheng et al. [12], the ESG rating results C-AAA are assigned a value of 1-9.

**Moderating variables.** Internal oversight intensity (*is*) draws on the study of Ren Guangqian et al. [13], using the number of supervisors in the year of the enterprise as an indicator to measure the internal oversight of the enterprise. Enterprise transparency (*lnatt*) directly using the CSMAR of listed company transparency indicators, the transparency of listed companies in the evaluation results of "excellent, good, passing, failing" were assigned a value of 4-1.

**Mediating variables.** The measure of financing constraint (*sa*) is relatively mature, among which the following more common measurement models exist investment-cash flow sensitivity model, KZ index model, Cleary multivariate discriminant model, FC index model, Size Age index model, and so on. In this paper, we refer to Wang's study [14] and choose the Size Age index model to measure the degree of financing constraints of Chinese listed firms. Corporate R&D investment (*rd*) Based on the listed companies' R&D investment projects in CSMAR database and referring to the practice of Huang [15], the current year's listed companies' R&D investment is used to measure the corporate R&D investment (*rd*) index. Corporate reputation (*RD*) refers to the study of Zhou et al. [16] to measure corporate reputation by corporate intangible assets, which is processed by adding and taking the natural logarithm of intangible assets.

**Control variables.** This paper selected return on assets (*roa*), gearing ratio (*lev*), financial leverage (*df1*), firm size (*size*), current ratio (*liqr*), quick ratio (*qr*), cash ratio (*cashr*), equity multiplier (*em*), the proportion of the top ten shareholders' shareholding (*topten*) as control variables. And industry (*industry*) and year (*year*) dummy variables are set to control the effect of industry and time on the regression results. Specific variable definitions are listed in Table 1.

**Table 1.** List of variable definitions

Variable type	Variable name	Variable symbol	definition
explanatory variable	Level of green innovation	gi_gain	Ln (number of green inventions independently acquired by the company in the year + number of green utility models independently acquired by the company in the year + number of green inventions jointly acquired by the company and other entities in the year + number of green utility models jointly acquired by the company and other entities in the year + 1)
explanatory variable	ESG rating	esg	Assign the CSI ESG rating results C-AAA to 1-9, respectively.
moderator variable	Intensity of internal oversight	is	Number of supervisors in the enterprise during the year
	Corporate transparency	lnatt	According to the disclosure of the Shenzhen Stock Exchange and Shanghai Stock Exchange, the evaluation results of the transparency of listed companies "excellent, good, pass, fail" are assigned as 4-1 respectively.
intermediary variable	Financing constraints	sa	$SA = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age$ Size: natural logarithm of the total asset size of the enterprise Age: Years of experience of the enterprise = number of years of observation (current year's statistical cut-off date) - time of establishment of the enterprise (year)
	R&D investment	rd	Ln (firms' R&D investment for the year + 1)
	Corporate Reputation	reput	Ln (corporate intangibles + 1)
control variable	return on assets	roa	Net profit/total assets
	gearing	lev	Total liabilities/total assets
	financial leverage	df1	(Net profit + income tax expense + finance costs) / (Net profit + income tax expense)
	Enterprise size	size	Ln (Total total assets of listed companies at the beginning of the year + 1)
	current ratio	liqr	Current assets/current liabilities
	quick ratio	qr	(Current assets - inventories)/current liabilities
	cash ratio	cashr	Closing balance of cash and cash equivalents/current liabilities
	equity multiplier	em	Total assets/total owners' equity
	Year fixed effects	year	Annual dummy variables
industry fixed effect	industry	Industry dummy variables	

### 3.3. Modeling

In order to test the impact of corporate ESG ratings on corporate green innovation, this paper sets the following regression model (1) and benchmark regression model (2):

$$gi\_gain_{it} = \beta_0 + \beta_1 esg_{it} + \sum year + \sum industry + \varepsilon_{it} \quad (1)$$

$$gi\_gain_{it} = \beta_0 + \beta_1 esg_{it} + \alpha Controls_{it} + \sum year + \sum industry + \varepsilon_{it} \quad (2)$$

Where “gi\_gain” is the green innovation, esg is the firm's ESG rating, “Controls” is the control variable,  $\varepsilon$  is the random error term,  $\beta_0$  is the intercept term,  $\beta_{11}$  is the coefficient of the direct effect of the firm's ESG rating on the green innovation, and  $\alpha$  is the effect of the control variable on the firm's ESG rating.

Based on the above analysis of the moderating mechanism, model (3) and model (4) were constructed to test the moderating effects of internal supervision intensity, corporate transparency in the relationship between corporate ESG ratings and green innovation, respectively.

$$gi\_gain_{it} = \beta_0 + \beta_{21}esg_{it} + \beta_{22}is_{it} + \beta_{22}is_{it} \times esg_{it} + \alpha Controls_{it} + \sum year + \sum industry + \varepsilon_{it} \tag{3}$$

$$gi\_gain_{it} = \beta_0 + \beta_{31}esg_{it} + \beta_{32} \ln att_{it} + \beta_{33} \ln att_{it} \times esg_{it} + \alpha Controls_{it} + \sum year + \sum industry + \varepsilon_{it} \tag{4}$$

In this case, ESG ratings, internal supervision intensity, and corporate transparency were centered.  $\beta_{23}$  is the moderating effect,  $\beta_{33}$  is the moderating effect. “is” is the strength of firms' internal supervision, and “lnatt” is firms' transparency.

## 4. Empirical results and analysis

### 4.1.Descriptive statistical analysis

The mean value of ESG ratings of enterprises is 4.206, standard deviation indicates that there are obvious differences in the level of ESG ratings of Chinese enterprises, and the unbalanced development is characterized by different enterprises. The minimum value of green innovation level is 0, and the maximum value is 6.879, which demonstrates that there also exists a significant gap; at the same time, the median value of green innovation level is 0, and the average value is 0.741, which indicates that a larger proportion of Chinese listed enterprises do not pay attention to the development of corporate green innovation, and the overall degree of development of green innovation of Chinese listed enterprises is poor (Table 2).

**Table 2.** Descriptive statistics of the main variables

Variable	N	Mean	p50	SD	Min	Max.
gi_gain	24509	0.741	0	1.057	0	6.879
esg	24509	4.206	4	1.085	1	8
is	24509	3.463	3	1.017	0	12
lnatt	24509	3.078	3	0.609	1	4
sa	24509	-3.780	-3.786	0.270	-5.646	-2.109
rd	24509	17.86	17.84	1.499	13.62	21.92
reput	24509	18.61	18.55	1.659	14.01	23.26
roa	24509	0.0560	0.0460	0.0790	-0.0190	7.446
lev	24509	0.387	0.376	0.195	0.00800	1.065
df1	24509	1.345	1.062	0.981	0.434	7.791
size	24509	21.95	21.76	1.331	19.51	26.14
liqr	24509	2.850	1.849	2.959	0.425	18.77
qr	24509	2.341	1.413	2.728	0.265	17.19
cashr	24509	1.026	0.448	1.692	0.0350	11.04
em	24509	1.882	1.601	0.911	1.050	6.490
topten	24509	60.18	61.46	14.84	24.66	90.71

### 4.2.Regression analysis

The fixed effects regression results are shown in Table 3. Model (1) is analyzed only for the key explanatory variable corporate ESG ratings and corporate green innovation level. In model (2),

control variables are added for regression analysis. In model (3) and (4), model (2) is used as the baseline regression, and the moderator variable and the cross-multiplier term between it and the key explanatory variable enterprise ESG rating are further added, and the independent variables and the moderator variables are centered, eliminating the effect of multicollinearity of the variables on the regression results.

**Table 3.** Table of regression analysis results

	(1)	(2)	(3)	(4)
	<b>gi_gain</b>	<b>gi_gain</b>	<b>gi_gain</b>	<b>gi_gain</b>
esg	0.132***	0.074***	0.075***	0.073***
	(22.028)	(14.232)	(14.392)	(13.481)
roa		-0.066	-0.064	-0.097*
		(-1.370)	(-1.392)	(-1.836)
lev		0.669***	0.659***	0.678***
		(8.517)	(8.394)	(8.637)
dfi		-0.045***	-0.043***	-0.043***
		(-6.523)	(-6.209)	(-6.249)
size		0.382***	0.382***	0.377***
		(58.920)	(57.957)	(58.083)
liqr		-0.039***	-0.040***	-0.039***
		(-3.726)	(-3.771)	(-3.718)
qr		0.049***	0.049***	0.050***
		(4.156)	(4.195)	(4.189)
cashr		0.010*	0.010*	0.009*
		(1.882)	(1.873)	(1.747)
em		-0.056***	-0.052***	-0.056***
		(-3.566)	(-3.341)	(-3.579)
topten		-0.000	-0.000	-0.000
		(-0.638)	(-0.718)	(-0.751)
is			-0.014**	
			(-2.118)	
interaction_esg_is			0.029***	
			(5.170)	
lnatt				0.042***
				(4.489)
interaction_esg_lnatt				0.029***
				(3.826)
_cons	0.186***	-8.050***	-8.001***	-8.066***
	(7.478)	(-57.145)	(-57.087)	(-57.373)
Industry	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	24509	24509	24509	24509
R-squared	0.223	0.411	0.412	0.412

t statistics in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

From model (1) and model (2) in Table 3, it can be seen that the regression coefficient of ESG rating on the level of green innovation of enterprises is significantly positive, and the regression coefficient still maintains a high level of significance after adding control variables for regression analysis, which indicates that the higher the ESG rating of the enterprise, the stronger the level of green innovation of the enterprise, and the hypothesis 1 (H1) is supported.

Model (3) in Table 3 verifies that corporate internal oversight intensity has a moderating role in the above relationship. The regression coefficients of its cross-multiplier term with corporate ESG ratings show that there is a significant positive moderating effect of corporate internal supervision intensity on the relationship between corporate ESG ratings and corporate green innovation, which suggests that stronger corporate internal supervision intensity can drive corporations to carry out more efficient green innovation, and Hypothesis 2 (H2) is valid.

Model (4) in Table 3 verifies that corporate transparency has a moderating role in the above relationship. The regression coefficients of its cross-multiplier term with corporate ESG ratings show that there is a significant positive moderating effect of corporate transparency on the relationship between corporate ESG ratings and corporate green innovation, which suggests that there exists an opportunity for corporations to obtain sufficient funding at low cost when they have stronger corporate transparency, and that sufficient financial support makes corporations have stronger incentives to independently choose to increase their corporate green innovation behaviors and to improve corporate green innovation efficiency, hypothesis 3 (H3) is supported.

### 4.3. Robustness tests

This paper employs a variety of robustness tests, period including the replacement of the explanatory variables method to test the conclusions, the results of which are shown in Table 4 below, and the instrumental variables method, the results of which are shown in Table 5 below.

#### 1) Replacement of explanatory variables

This paper replaces green innovation acquisition with green innovation application. The regression results of model (5), indicates the robustness of the conclusion.

**Table 4.** Replacement of explanatory variables results

	(5)
	<b>gi_apply</b>
esg	0.101***
	(17.005)
_cons	-9.842***
	(-64.330)
Controls	Yes
Industry	Yes
Year	Yes
Observations	24509
R-squared	0.432

#### 2) Instrumental variables method

This paper adopts the instrumental variable method for robustness testing. Considering that firms' ESG ratings have a certain lagged response in the capital market, and that the improvement of ESG ratings in the early period can lay a good foundation for ESG ratings in the later period, this paper selects the lagged one-period ESG ratings (L1.esg) as the instrumental variable. regression results in Table 5 indicate the conclusion is robust. According to the Anderson LM statistic, the probability of under-identification of instrumental variables is 0, which strongly rejects the original hypothesis, i.e., there is no problem of under-identification of instrumental variables; the Cragg-Donald Wald F statistic is 1308.669 and is well above the critical value of 10% (16.38), i.e., there is no problem of weakly instrumental variables, and the instrumental variables are chosen reasonably; as the instrumental variable number is equal to the number of endogenous explanatory variables, there is no over-identification, so there is no need for over-identification test. In summary, the regression using the instrumental variable method is reasonable, and the regression results of the instrumental variable method are consistent with the benchmark regression results.

**Table 5.** Instrumental variable regression results

VARIABLES	first esg	second gi_gain
L.esg	0.269*** (36.18)	
esg		0.131*** (5.97)
Anderson LM		1207.667***
Cragg-Donald Wald F		1308.669
Industry	Yes	Yes
Observations	18,523	18,523
R-squared		0.153

**4.4.Mechanism analysis and testing**

1) A test of the mediating mechanism of corporate reputation

Wen Zhonglin's mediation effect test method is consulted in this article [17] to test the mediation mechanism of corporate reputation. The regression results of corporate ESG ratings, corporate reputation on corporate green innovation are demonstrated in columns (1)-columns (3) in Table 6 below. As seen in column (3), the coefficient of corporate reputation on corporate green innovation is significantly positive, and judging from the stepwise regression method, it can be observed that there is a positive mediation effect of corporate reputation. Further, this paper adopts the Sobel test and the self-sampling method (Bootstrap) to further test the mediating mechanism. The Sobel test method yields a coefficient value of Goodman-1 (Aroian) of 0.00245381 ( $Z=6.001$ ,  $p=0$ ), indicating that the coefficient is significantly positive at the 1% level, thus confirming the existence of the mediating mechanism of corporate reputation. In addition, the Sobel test also yields that among the mediating mechanisms of corporate reputation, the indirect effect accounts for 3.326% of the total effect. Through the self-sampling method (Bootstrap), it can be obtained that the confidence interval of the indirect effect does not contain 0 (LLCI=0.00160, ULCI=0.00303), which indicates that the importance of the indirect effect and the indirect impact's value of 0.00245. The results show that the self-sampling method also verifies the existence of the mediating mechanism of corporate reputation. In summary, ESG ratings of enterprises can promote enterprises to carry out green innovation by enhancing corporate reputation, and Hypothesis 4 (H4) is supported.

**Table 6.** Test results of corporate reputation mechanism

	(1) gi_gain	(2) reput	(3) gi_gain
esg	0.074*** (0.005)	0.045*** (0.006)	0.071*** (0.005)
reput			0.055*** (0.006)
_cons	-8.050*** (0.141)	-2.391*** (0.140)	-7.919*** (0.140)
year	Yes	Yes	Yes
Observations	24509	24509	24509
R-squared	0.411	0.687	0.414

2) A test of the mediating mechanism of corporate R&D investment

This paper refers to Wen Zhonglin's mediation effect test method [17], which also tests the mediation mechanism of corporate R&D investment. The regression results are demonstrated in columns (1)-column (3) in Table 7 below. As seen in column (3), the coefficient of corporate R&D investment on corporate green innovation is significantly positive, which can be judged from the stepwise regression method that there is a positive mediating effect of corporate R&D investment.

Further, this paper adopts the Sobel test and the self-sampling method (Bootstrap) to further test the mediation mechanism. The Sobel test yields a coefficient value of Goodman-1 (Aroian) of 0.01446848 ( $Z=13.66$ ,  $p=0$ ), thus confirming the existence of the mediating mechanism of the impact of corporate R&D investment. In addition, the Sobel test also concludes that among the mediating mechanisms of firms' R&D investment, the indirect effect accounts for 19.613% of the total effect. Through the self-sampling method (Bootstrap), the confidence interval of the indirect effect does not contain 0 (LLCI=0.0122, ULCI=0.0157). The results show that the self-sampling method also verifies the existence of the mediating mechanism of enterprises' R&D investment.

**Table 7.** Mechanism of R&D investment by enterprises

	(1)	(2)	(3)
	<b>gi_gain</b>	<b>rd</b>	<b>gi_gain</b>
esg	0.074*** (0.005)	0.093*** (0.006)	0.059*** (0.005)
rd			0.156*** (0.006)
_cons	-8.050*** (0.141)	0.008 (0.147)	-8.051*** (0.138)
Observations	24509	24509	24509
R-squared	0.411	0.607	0.431

### 3) A test of the mediating mechanism of financing constraints

This paper refers to Wen Zhonglin's mediation effect test method [17] to test the mediation mechanism of financing constraints as well. The regression results are demonstrated in columns (1)-columns (3) in Table 8 below. As seen in column (3), the coefficient of corporate financing constraints on corporate green innovation is significantly positive, and judging from the stepwise regression method, it can be concluded that financing constraints have the mediating effect of positive transmission. Further, this paper adopts the Sobel test and the self-sampling method (Bootstrap) to further test the mediation mechanism. The Sobel test yields a coefficient value of Goodman-1 (Aroian) of 0.00662391 ( $Z=8.596$ ,  $P=0$ ), thus confirming that there is an intermediation mechanism effect of financing constraints. In addition, the Sobel test also yields that among the mediating mechanisms of financing constraints, the indirect effect accounts for 8.980% of the total effect. Through the self-sampling method (Bootstrap), it can be obtained that the confidence interval of the indirect effect does not contain 0 (LLCI=0.00460, ULCI=0.00835). The results show that the self-sampling method also establishes the existence of the mechanism that mediates financial limitations.

**Table 8.** Results of the financial constraints mechanism test

	(1)	(2)	(3)
	<b>gi_gain</b>	<b>sa</b>	<b>gi_gain</b>
esg	0.074*** (0.005)	0.013*** (0.001)	0.067*** (0.005)
sa			0.491*** (0.027)
_cons	-8.050*** (0.141)	-4.166*** (0.044)	-6.005*** (0.153)
Observations	24509	24509	24509
R-squared	0.411	0.291	0.422

## 4.5.Heterogeneity analysis

### 1) Heterogeneous analysis of the nature of ownership

For the nature of enterprise ownership, compared with non-state-owned enterprises, state-owned enterprises often need to assume more social responsibilities and obligations, but state-owned enterprises often do not have excessive performance pressure, and do not need to think too much about

profit maximization, which makes state-owned enterprises have the ability to build a sustainable development of the production mode. And then because SOEs tend to have more adequate financial support, SOEs are more inclined to engage in green innovation behaviors. The impact of ownership nature on firms' ESG ratings and green innovation is demonstrated in Table 9 below. Further this paper tests whether there is a significant difference in the coefficient between the two groups by bdiff method (Vardiff=-0.03389, p=0.002). The findings from the experiment suggest the difference is substantial at 1% level.

**Table 9.** Table of results of the analysis of the heterogeneity of ownership properties

	(1)	(2)	(3)
	<b>gi_gain</b>	<b>gi_gain</b>	<b>gi_gain</b>
esg	0.0738***	0.0909***	0.0571***
	(14.23)	(8.81)	(9.44)
_cons	-8.0495***	-10.1688***	-6.2933***
	(-57.14)	(-39.57)	(-34.05)
Observations	24509	7441	17063
R-squared	0.411364	0.498374	0.340625
Adj. R-squared	0.41	0.49	0.34
within-R-squared	0.26	0.30	0.18
Adj. within-R-squared	0.2588445	0.3035955	.01800561
Vardiff		-0.03386690213123	
P-value		0.002	

## 2) Heterogeneity analysis of enterprise size

In terms of firm size, larger firms tend to have more financial support than smaller ones, and larger firms will be more interested in long-term sustainability. In this case, large firms are more willing to invest in green innovations that support long-term sustainability. The impact of firm size on firms' ESG ratings and green innovation is demonstrated in Table 10 below. Columns (2) and (3) in Table 10 report the impact of ESG ratings on firms' green innovation for large and small firms, respectively, and from the regression results, it can be seen that the coefficients of ESG ratings of large firms on firms' green innovation are significantly larger than the coefficients of ESG ratings of small firms on firms' green innovation. Further this paper tests whether there is a significant difference in the coefficient between the two groups by bdiff method (Vardiff=-0.0459, p=0). The findings from the experiment suggest that the difference is substantial at a 1% level.

**Table 10.** Results of the analysis of firm size heterogeneity

	(1)	(2)	(3)
	<b>gi_gain</b>	<b>gi_gain</b>	<b>gi_gain</b>
esg	0.0738***	0.0854***	0.0395***
	(14.23)	(10.46)	(6.66)
_cons	-8.0495***	-11.3167***	-3.9600***
	(-57.14)	(-42.43)	(-16.43)
Observations	24509	12250	12254
R-squared	.411364	.457544	.199197
Adj. R-squared	0.41	0.45	0.19
within-R-squared	0.26	0.24	0.05
Adj. within-R-squared	.2588445	.238849	.0471552
Vardiff		-0.045918005801624	
P-value		0	

## 5. Conclusions and Recommendations

### 5.1. Research Conclusion

Based on stakeholder theory, this paper studies the impact of corporate ESG ratings on green innovation. The results show that ESG ratings significantly positively impact corporate green innovation. The robustness test ensures the robustness of the findings. In addition, benchmark regression results indicate that enhancing corporate internal oversight and corporate transparency can improve the efficiency of green innovation. Further research using the mediation effect test finds that ESG performance affects corporate green innovation through corporate reputation, R&D investment, and financing constraints. Heterogeneity analysis reveals that effect of ESG performance on corporate green innovation is more significant in state-owned and larger enterprises.

### 5.2. Insights and Suggestions

From the enterprise level, when formulating enterprise development strategies, they should fully realize the promotion effect of ESG disclosure on green innovation. First, firms should uphold the concept of sustainable development and implement the idea of ecological environmental protection in their economic activities. Second, enterprises should consciously fulfill their social responsibilities, help social development, and enhance their reputation. A good reputation can reduce the cost of enterprise financing and help enterprises obtain more strategic resources, thus providing more favorable conditions for enterprise green innovation. Third, enterprises can improve their internal governance and supervision and enhance transparency. This is conducive to enterprises making longer-term decisions and more beneficial to the company's development.

It should improve the ESG rating disclosure system from the government level, build an environment conducive to corporate ESG construction, and formulate relevant laws and regulations.

From an investor's perspective, when choosing investment targets, the information that can be referred to is the financial and economic performance and the relevant information disclosed by ESG ratings. This can better help investors manage investment risks and make longer-term investment plans.

### 5.3. Limitation

Although the CSI ESG rating combines China's national conditions and capital market characteristics with international mainstream methodologies and practical experience, there are only nine levels in its ESG rating. Compared with other ESG rating methods, such as Bloomberg ESG Rating and Shangdao Ronglv ESG Rating, CSI's ESG rating is roughly divided into grades, and companies under the same rating may have more excellent performance differences. Subsequent research can improve the measurement method of corporate ESG ratings. Second, for different industries, the role of ESG on green innovation and how there may be differences in subsequent research can be further refined by the research industry to improve the impact of corporate ESG in different industries on green innovation mechanisms.

## 6. Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

## 7. References

- [1] S. Chouaibi and J. Chouaibi, "Social and ethical practices and firm value: the moderating effect of green innovation: evidence from international ESG data", *International Journal of Ethics and Systems*, vol. 37, Jul. 2021, pp.442-465, doi: 10.1108/IJOES-12-2020-0203.

- [2] Q.Q. Zhao, X.T. Li, S.Q. Li, “Analyzing the Relationship between Digital Transformation Strategy and ESG Performance in Large Manufacturing Enterprises: The Mediating Role of Green Innovation”, MDPI, vol. 15, pp.1-20, doi: 10.3390/su15139998.K. Elissa, “Title of paper if known,” unpublished.
- [3] J.C. Li, G.H. Lian, A. Xu (2023) “How do ESG affect the spillover of green innovation among peer firms? Mechanism discussion and performance study”, *Journal of Business Research*, vol. 158, Jan. 2023, pp.1-10, doi: 10.1016/j.jbusres.2023.113648.M. Young, *The Technical Writer’s Handbook*. Mill Valley, CA: University Science, 1989.
- [4] B. Yalabik, R.J. Fairchild, “Customer, regulatory, and competitive pressure as drivers of environmental innovation”. *International Journal of Production Economics*, 2011, 131 (2): pp.519-527, doi: 10.1016/j.ijpe.2011.01.020.
- [5] Z. Fang, X. Kong, A. Sensoy, et al, “Government's awareness of environmental protection and corporate green innovation: A natural experiment from the new environmental protection law in China”, *Economic Analysis and Policy*, vol.70, Jun.2021, pp.294-312, doi: 10.1016/j.eap.2021.03.003.
- [6] Y. Xia, J. Hou, H. Huang, et al, “Exploring the Impact of Firm Transparency on Green Innovation Legitimacy: Empirical Evidence from Listed Companies in China”, *Sustainability*, 2023, 15 (13): 10104.
- [7] Y.Y. Li. “Accounting Robustness, ESG Disclosure and Financing Constraints”, Shenyang University, 2022.
- [8] P.W. Roberts, G.R. Dowling. “Corporate reputation and sustained superior financial performance [J]”, *Strategic management journal*, 2002, vol. 23 (12), pp.1077-1093.
- [9] J. Zhang, G. Liang, T. Feng, et al. “Green innovation to respond to environmental regulation: how external knowledge adoption and green absorptive capacity matter? *Business Strategy and the Environment*”, 2020, vol. 29 (1), pp.39-53.
- [10] X. Xiang, C. Liu, M. Yang. “Who is financing corporate green innovation?”, *International Review of Economics & Finance*, 2022, vol.78, pp.321-337.
- [11] Z.M. Yu. ““Words from the heart” or “words from the heart”: does management tone signal green innovation?”, *Foreign Economics and Management*, 2022, vol. 44 (06), pp.18-33.
- [12] L.S. Xi, Y. Wang. “Corporate ESG disclosure and stock price crash risk”, *Economic Issues*, 2022 (08), pp.57-64.
- [13] G.Q. Ren, R. Xu, Y.X. Li. “Structural characteristics and supervisory effectiveness of state-owned holding and supervisory board”, *Economic system reform*, 2019 (02), pp.156-163.
- [14] R.I. Wang. “Management governance, environmental accounting disclosure and financing constraints”, *Finance and Accounting Newsletter*, 2021 (03), pp.73-76.
- [15] X.X. Huang. “Research on the impact of ESG rating disclosure on corporate green innovation [J]”, *National Circulation Economy*, 2023 (14), pp.69-74.
- [16] L.P. Zhou, Y. Chen, Y.J. Jin. “An empirical study on the relationship between corporate social responsibility and financial performance--an analytical explanation based on the perspective of corporate reputation”, *Jiangsu Social Science*, 2016 (03), pp.95-102.
- [17] Z.L.O. Wen, J. Fang, J.Y. Xie et al. “A methodological study of domestic mediation effects”, *Advances in Psychological Science*, 2022, 30 (08), pp.1692-1702.