The Impact of ESG Performance on Innovation of Chinese Enterprises

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Abstract: Scholars and practitioners widely discuss the impact of ESG performance on businesses, often linking it to financial performance or company value. However, research on its impact on corporate innovation and stakeholder heterogeneity is lacking. This study uses Chinese A-share listed companies and Shangdao Green Financial Institutions' ESG rating, finding that ESG performance boosts corporate innovation quantity and quality by alleviating financing constraints and reducing agency costs. For enterprise heterogeneity, internal governance enhances ESG's impact on innovation, while external governance by institutional investors does not.

Keyword: ESG performance, corporate innovation, financing constraints, internal and external governance
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1 Research Background

Enterprises, key to economic growth, must boost China's innovation. Exploring corporate innovation and its determinants is vital. Determinants encompass internal factors (size, capacity, financing, governance, equity) and external ones (market structure, government support, industry traits). High investment, risk, and long cycles hinder innovation. ESG performance, crucial for capital market health, reflects a firm's environmental, social, and governance responsibilities. Under sustainable development, enterprises prioritize stakeholder values and expectations in innovation.

Research shows empirical links between CSR and innovation, suggesting complementary strategies[1],. New CSR cultures boost innovation[2],, but some argue overinvestment in CSR may lead consumers to doubt research funds, quality, and business performance.

To explore ESG's impact on corporate innovation and stakeholder heterogeneity, we analyzed Chinese listed firms' 2015-2020 panel data. Using OLS regression with ESG ratings as proxies, we found higher ESG performance boosts both quantity and quality of innovation. Info asymmetry and sustainability theories explain this by easing financing and agency costs. Internal vs. external governance roles differ: institutional investors' attention doesn't help, but CEO duality strengthens the ESG-innovation link.

2 Theoretical Analysis and Research Hypotheses

2.1The Impact of ESG Performance on Corporate Innovation

ESG evaluation guides investors in E, S, and G aspects. Research shows: Environmental disclosure boosts corporate innovation[3],, especially in high-risk industries, fostering green innovation[4],.Corporate Social Responsibility enhances patents and green innovation. Central enterprise board & equity balance pilots also promote innovation investment. From a sustainable perspective, high ESG performance enhances corporate innovation by reducing info asymmetry, financing constraints[5-6],, agency costs, strengthening innovation capabilities, focusing on long-term development, and promoting innovation.

Hence, ESG strategies can motivate corporate innovation. Isabel et al. (2018) found that innovation reduces energy consumption, enhances service quality, and meets stakeholder needs [7],. Based on the above analysis, this article proposes the following hypotheses:

Assumption 1 (H1): ESG performance has a positive impact on corporate innovation output.

2.2 The Intermediary Role of Financing Constraints

Modern corporate financing theory explains higher external financing costs due to info asymmetry and agency problems. Signal theory states that disclosing non-financial info reduces asymmetry, enhances transparency, increases participation, and curbs opportunism. CSR shapes a positive image, boosts reputation, reduces perceived risk, improves credit ratings and valuations, attracts investors[8-9],, and expands financing channels. High ESG performance sends positive signals, gains stakeholder support, reduces market pressure, and lowers equity costs, leading to high credit ratings, easy external capital access, reduced financing costs, eased financial pressure, and ensured R&D funds. Thus, financing constraints mediate between ESG performance and corporate innovation output.Based on the above analysis, this article proposes the following hypotheses:

Assumption 2 (H2): Financing constraints mediate the relationship between ESG performance and firm innovation output.

2.3 The Intermediary Role of Agency Costs

Enterprise innovation faces long cycles and high uncertainty, challenging management incentives. Fulfilling social responsibility alleviates these concerns, promotes innovation risks, and drives exploratory innovation. Research shows that managing social responsibility can reduce agency costs to drive corporate innovation [10],. Thus, improving CSR not only mitigates agency costs but balances social responsibility with shareholder interests, suggesting agency costs mediate between ESG performance and corporate innovation output.Based on the above analysis, this article proposes the following hypotheses:

Assumption 3 (H3): Agency costs mediate between ESG performance and firm innovation output.

2.4 The Heterogeneous Role of Internal Governance and External Governance

Based on the aforementioned theoretical analysis, Stakeholders influence corporate innovation, and ESG practices reduce risks, gaining stakeholder support. In China's capital market, institutional investors emphasize long-term value, influencing internal governance and external supervision. Higher institutional shareholding leads to stronger ESG performance and innovation efficiency. Therefore, the following hypothesis is proposed:

Assumption 4 (H4): Compared to companies with low institutional shareholding, companies with high institutional shareholding have a stronger impact on ESG performance and corporate innovation.

3 research design

3.1 Sample Selection and Data Sources

This article takes the ESG rating of A-share listed companies as the research object, using the financial data of Shangdao Green Finance Company from 2015 to 2020 as the sample, and the rating score reflects the ESG performance. Data processing includes: removing companies with high operational volatility (such as finance and insurance), ST/ST * companies, and companies with missing data; The data comes from the commercial GF-ESG rating (including ESG reports, social responsibility reports, etc.) and CSMAR financial database included in the Wind database, and the patent data comes from CNIPA and is manually organized. After 1% truncation of continuous variables, 1070 company year samples were obtained.

3.2 Sample Definition

3.2.1 ESG Performance

This article uses SynTaoGF ESG evaluation data to evaluate corporate ESG performance, which was internationally recognized by Bloomberg in 2021. SynTaoGF is the first ESG rating agency in China to sign the PRI, be recognized by CBS, and receive international authoritative praise. Its evaluation system consists of 127 items, divided into 10 levels (A+ to d), decreasing in order. This article converts the values to 1-9. The research sample consists of ESG data from the Shanghai and Shenzhen 300 Index from 2015 to 2020, aiming to explore the relationship between ESG performance and corporate performance.

3.2.2 Control Variable

We have controlled for innovative explanatory factors to avoid the impact of ESG performance. The control variables include company growth, profitability, and debt paying ability. Corporate governance includes the shareholding ratio of the largest shareholder (TOP1), the proportion of independent directors (IDR), the size of the board of directors (Board), CEO duality (DUAL), internal decision-making level (IC), external governance level (lnsHold), operating period (AGE), and corporate attributes (Soe). The virtual variables are set to 1 for state-owned enterprises and 0 for non-state-owned enterprises. Simultaneously adopting the new version of the "Classification Guidelines for Chinese Listed Companies" and controlling IND FE with YEAR FE. The variable definitions are detailed in Table 1.

Table 1 sample definition

Variable	Symbol	Description
Innovation quality	LnoPatent	Natural logarithm of the sum of the invented quantities
ESG grade	ESG	According to the quotient GF-ESG, the score is divided from low to high from 1 to 9
Profitability	Growth	Current operating revenue growth rate
Profit rate	Roa	Current profit margin on total assets
Debt ratio	Lev	Ratio of total liabilities to total assets
The largest shareholder shareholding ratio	TOP1	The ratio of the number of shares held by the largest shareholder to the total number of shares
Board structure	IDR	The ratio of independent directors to the directors
Board size	Board	The number of board members
Company age	AGE	The natural logarithm of the number of years a company goes public
Equity attributes	Soe	For virtual variables, 1 for state-owned enterprises and 0 for non-state-owned enterprises
CEO duality	DUAL	Virtual variable, the chairman concurrently general manager is 1, otherwise it is 0
Share ratio of institutional investors	InsHold	The number of shares held by institutional investors is divided by the total number of shares
Risk control ability	IC	Internal control indicators of the Dibo database
Financing constraints	FC	Calculated by the model (4) and (5)
Agency cost	OER	Operating rate = management rate + sales rate
Industry	IND FE	Industry fixed effect
Age	YEAR FE	Industry fixed effect

3.3 Model Selection

This article sets up regression model (1) to test the impact of ESG performance on corporate innovation, in order to test hypothesis 1.

The specific regression model is as follows:

$$\mathrm{Patent}_{i,t}(\mathrm{InoPatent}_{i,t}) = a_0 + a_1\mathrm{ESG}_{i,t} + a_i\Sigma\mathrm{Controls}_{i,t} + a_3\mathrm{YEAR}_{i,t} + a_4\mathrm{IND}_{i,t} + \varepsilon_{i,t} \quad (1)$$

In the formula, $\mathrm{ESG}_{i,t}$ represents the ESG rating obtained by company i in t, and Patent represents the company's green patent. Among them, t represents the number of green innovation patents of the enterprise, a is the coefficient value, $\mathrm{Controls}$ is the control variable, and $\varepsilon_{i,t}$ is the residual. This article uses a regression model that controls for time and industry fixed effects (according to the 2012 China Securities Regulatory Commission standards), and employs robust standard error and enterprise level error clustering to address issues related to heteroscedasticity and time series.

ESG performance evaluates corporate environmental, social, and governance responsibilities, and high performance influences capital information acquisition through specific pathways, thereby promoting innovation. Based on the theoretical analysis in this article and the assumption of intermediary efficiency, the following models (2) and (3) were established, focusing on how ESG promotes corporate innovation by reducing financing constraints and alleviating agency problems. The median is the mediator variable, and this article sequentially tests the coefficients β_1 and δ_2.

$$Median_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \sum\beta_j Controls_{i,t} + \mu YEAR + \eta ind \quad (2)$$

$$Patent_{i,t} = \delta_0 + \delta_1 ESG_{i,t} + \delta_2 Median_{i,t} + \sum \delta_j Controls_{i,t} \quad (3)$$

This article uses the FC index to measure corporate financing constraints. We established models (4) and (5) based on Gu to measure the degree of corporate financing constraints:

$$P(QUFC = 1|Z_{i,t}) = \frac{eZ_{i,t}}{1 + eZ_{i,t}} \quad (4)$$

$$Z_{i,t} = \alpha_0 + \alpha_1 size_{i,t} + \alpha_2 lev_{i,t} + \alpha_3 (CASHDIV/ta)_{i,t} + \alpha_4 MB_{i,t} + \alpha_5 (NWC/ta)_{i,t} \quad (5)$$

The calculation process of the financing constraint variable FC is as follows:

Firstly, we standardize the annual scale, years, and cash dividend payout ratio of the enterprise, and establish a financing constraint dummy variable QUFC based on this: when the relevant mean of the enterprise is higher than the third percentile, QUFC is 0, and vice versa, it is 1.

Secondly, to accurately quantify financing constraints, we use a Logit model to fit the annual financing constraint probability FC of the enterprise, with values ranging from 0 to 1. The larger the value, the heavier the constraint. The model considers factors such as the cash dividends (CASHDIV), total assets (ta), net working capital (NWC), and pre-tax profit (EBIT) announced by the enterprise in the current year.

Finally, through the Logit regression analysis of model (1), the probability p of annual financing constraints for enterprises is obtained, and the financing constraint indicator FC is defined to directly reflect the degree of constraints.

4 Empirical Result Analysis

4.1 Multi Descriptive Statistics

The descriptive statistical results in Table 2 show that the average ESG score of the sample companies is 4.305, with a variance of 1.105, indicating that their average ESG level is between B - and B. The mean of Patent is 2.166, with a standard deviation of 2.261, indicating significant differences in innovation output. SynTaoGF chose Shanghai and Shenzhen 300 Index companies for rating considerations, therefore, the companies generally have high levels of investment institution shareholding and risk control. The statistics of other control variables are consistent with existing research.

In addition, this article analyzed the correlation of the data and studied its correlation coefficient. The results showed that there is a significant positive correlation between ESG and corporate innovation, with a coefficient of 0.7, which preliminarily proves the results of this article.

Table 2 descriptive statistics

Variables	N	Mean	Stand Deviation	Min	Max
ESG	1070	4.305	1.105	2	7
Patent	1070	2.166	2.261	0	7.595
InoPatent	1070	1.450	1.889	0	6.974
IC	1070	680.7	150.8	0	886.5
InsHold	1070	65.34	20.48	11.61	96.11
ROA	1070	0.0647	0.0567	-0.0445	0.238
LEV	1070	0.513	0.0192	0.0868	0.895

4.2 Multiple Linear Regression Results

4.2.1 ESG Performance and Corporate Innovation

Table 3 reports the regression results of ESG performance and corporate innovation, using cluster robust standard error to control for heteroscedasticity. (1) Column (4) controls for industry fixed effects and time fixed effects, while columns (2), (3), (5), and (6) add other control variables that may affect the innovation level of the enterprise. The results indicate that ESG performance has a significant promoting effect on corporate innovation. Taking column (3) as an example, the coefficient of ESG is 0.3367, which is significantly negative at the 1% level, indicating that the increase in ESG performance has significantly increased the patent application volume of the enterprise; The coefficient of ESG is 0.3062, which is significantly negative at the 1% level, indicating that the increase in ESG performance has significantly increased the number of invention patent applications for enterprises. Economically speaking, the improvement of ESG performance resulted in a 33.67% and 31% increase in the natural logarithm of patent applications and invention patent applications, respectively.

This result indicates that, under the premise of their own development and external environmental needs, enterprises have the motivation to improve the quality of research and technological innovation, release signals of sustainable development, and win the support of the public and investors. Assumption 1 has been validated.

Table 3 Linear regression results

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	Patent	Patent	InoPatent	InoPatent	InoPatent
ESG	0.3845***	0.4693***	0.3367***	0.3883***	0.3960***	0.3062***
	(6.58)	(7.70)	(5.79)	(7.41)	(7.59)	(6.10)
IC		0.0015***	0.0012**		0.0011***	0.0010**
		(3.60)	(3.20)		(3.42)	(3.26)
InsHold		-0.0155***	-0.0064		-0.0146***	-0.0077*
		(-3.69)	(-1.68)		(-4.53)	(-2.49)
ROA		5.6452***	5.3896***		0.7771	0.9865
		(3.52)	(3.83)		(0.60)	(0.85)
DUAL		-0.1123	-0.0425		-0.1989	-0.1422
		(-0.71)	(-0.31)		(-1.54)	(-1.23)
SOE		-0.2949	-0.3172*		-0.0258	-0.0130
		(-1.75)	(-2.04)		(-0.18)	(-0.09)
Cons	1.6889***	-2.5598**	-3.2666***	-0.5232	-1.8456**	-3.4717***
	(3.54)	(-3.17)	(-3.77)	(-1.19)	(-2.72)	(-4.42)
YEAR FE	Yes	No	Yes	Yes	No	Yes
IND FE	Yes	No	Yes	Yes	No	Yes
N	1070	1070	1070	1070	1070	1070
r2	0.2802	0.1018	0.3318	0.2319	0.1017	0.3012

4.2.2 The Intermediary Effect of Financing Constraints

The empirical results of measuring corporate financing constraints using the FC index as a mediator variable are reported in columns (1) and (2) of Table 4. (1) The results of the column indicate that in the regression of ESG to FC, the ESG coefficient is -0.0075, which is significantly negative at the 10% level, indicating a significant negative correlation between ESG rating and financing constraints. This suggests that good ESG performance of a company can reduce financing costs, decrease the degree of information asymmetry, and alleviate the financing constraints faced by the company. In column (2), after adding the mediator variable, the ESG coefficient is 0.287, significant at the 1% level, and the FC coefficient is significantly negative. After considering financing constraints, although the impact of ESG ratings on corporate innovation is still positive, the impact coefficient has decreased from 0.3367 in column (3) of Table 3 to 0.287 in column (2) of Table 4, and the corresponding t-value has decreased from 5.79 to 5.00, indicating that the addition of financing constraints has reduced the impact of ESG ratings on corporate innovation. According to Wen et al.'s research[11], further Sobel tests were conducted. The Sobel value is 0.0138 and the Z value is 1.739, significant at the 5% level. There is a mediating effect of financing constraints on the driving effect of ESG ratings on corporate innovation. In other words, the higher the ESG rating, the more funds companies will invest, easing financing constraints and expanding the sources of funding for technological innovation activities. The mediating effect accounts for 21% of the total effect. Financing constraints have a certain intermediary effect and significant economic significance.

Table 4 Regression results of mediation effect

	(1)	(2)	(3)	(4)
	FC	Patent	OER	Patent

ESG	-0.00724* (-2.45)	0.287*** (5.04)	0.0144* (1.99)	0.309*** (5.47)
FC		-2.272*** (-3.37)		
OER				-0.394* (-1.97)
IC	-0.0000239 (-0.95)	0.000870* (2.34)	0.00000335 (0.09)	0.000925* (2.43)
DUAL	0.00401 (0.65)	-0.0228 (-0.17)	0.000118 (0.01)	-0.0318 (-0.23)
GROWTH	-0.0118 (-1.56)	-0.202 (-1.31)	0.0476** (3.03)	-0.156 (-1.01)
SOE	-0.0130* (-2.11)	-0.450** (-2.80)	-0.0655** (-3.02)	-0.446** (-2.75)
TOP1	0.000378 (1.55)	-0.00229 (-0.48)	0.00106 (1.34)	-0.00273 (-0.56)
INDEP	-0.00117** (-2.89)	0.0382*** (3.46)	-0.00297** (-3.23)	0.0397** (3.57)
BOARD	-0.00115 (-0.88)	0.134*** (3.79)	-0.00809* (-2.50)	0.133*** (3.71)
YEAR FE	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes
N	1070	1070	1070	1070
r2	0.443	0.330	0.217	0.324
F	23.47	42.50	39.39	44.59

4.2.3 The Intermediary Effect of Agency Costs

This article focuses on the agency conflict between management and shareholders, namely the first type of agency cost, which is a key variable for evaluating the internal governance efficiency of a company and reflects the degree of improvement in corporate governance. Drawing on Zhen's research[12] we selected the operating expense ratio (including management expense ratio and sales expense ratio) as a measure of agency costs.

Column (3) of Table 4 shows that in the regression analysis between ESG and agency costs, the ESG coefficient is 0.0144 and negative at the 10% significance level, indicating that an increase in ESG rating helps to reduce agency costs. Furthermore, in column (4), when introducing agency cost as a mediator variable, the ESG coefficient is significantly positive (0.309, 1% level), while the agency cost coefficient is significantly negative (-0.394, 10% level), indicating that agency cost plays a mediating role between ESG and corporate innovation.

To verify this mediating effect, we conducted a Sobel test. The results showed that the Sobel value was -0.0096 and the Z value was -1.366, which were significant at the 5% significance level. This indicates that agency costs play a partial mediating role in the driving process of ESG ratings on corporate innovation, accounting for 14.56% of the total effect and having significant economic significance.

4.2.4 Testing The Heterogeneity Effect of External Governance

To verify H4, we determined the 33% and 67% percentiles based on analysis, divided the samples into high and low groups, and used model (1) to perform group regression. The results are shown in Table 5 (1) - (4). (1) Column (3) shows the regression results of the high shareholding group, while columns (2) and (4) show the low shareholding group. Comparison shows that both ESG ratings and corporate innovation levels are significant. In terms of innovation level, the coefficient of the low shareholding group is 0.4277, and the coefficient of the high shareholding group is 0.2709. The Chow test p-value is 0.060, indicating a difference in ESG ratings between the two groups. The innovation effect of ESG ratings is more pronounced in the low shareholding group, indicating that although the high institutional shareholding ratio strengthens supervision, ESG ratings have not further promoted innovation, which is contrary to expectations. Through a review of previous work, studies have shown that institutional investors below a certain threshold promote innovation, while those above it inhibit it. Empirical evidence shows that under high institutional shareholding ratios, a good ESG rating does not necessarily promote innovation. The higher the proportion of institutional shareholding, the better the effect. Beyond the limit, although a company's good ESG brings external resources, it does not promote innovation.

Table 5 Heterogeneity test of external governance

	(1)	(2)	(3)	(4)
	Patent		InoPatent	
	High	Low InosHold	High	Low InosHold

	Inshold		Inshold	
ESG	0.2709**	0.4277***	0.2062**	0.4176***
	(3.26)	(3.71)	(2.97)	(3.93)
IC	0.0016**	0.0004	0.0012*	0.0007
	(2.68)	(0.53)	(2.27)	(1.00)
ROA	1.0117	4.9846*	-6.4773**	2.8012
	(0.42)	(2.12)	(-3.14)	(1.44)
DUAL	-0.0666	-0.1727	-0.3488	-0.0733
	(-0.26)	(-0.78)	(-1.90)	(-0.37)
GROWTH	0.2353	-0.8057*	0.0278	-0.7098
	(0.89)	(-2.54)	(0.12)	(-2.48)
SOE	-1.0081***	0.5427	-0.3132	0.6386*
	(-4.08)	(1.77)	(-1.50)	(2.21)
TOP1	0.0397***	-0.0209*	0.0312***	-0.0242**
	(5.35)	(-2.18)	(4.69)	(-2.92)
INDEP	0.0583***	0.0548**	0.0300*	0.0586***
	(3.53)	(2.65)	(2.04)	(3.37)
BOARD	0.2308***	0.0003	0.1662**	-0.0345
	(3.78)	(0.00)	(3.21)	(-0.55)
_cons	-5.6959***	-2.3321	-3.5602**	-4.1053**
	(-4.59)	(-1.40)	(-3.08)	(-2.96)
YEAR FE	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes
N	356	357	356	357
r2	0.4048	0.4702	0.3335	0.4534
ρ value	0.060		0.024	

5 Robustness Analysis

5.1 Replace The Explained Variable

The core explanatory variables for SynTaoGF ESG rating measurement. The robustness test uses the Huazhong ESG Rating (ESG2), which has 26 indicators and is evaluated based on industry weighted averages. It is divided into C-AAA levels and assigned 1-9 values. Table 6 (1) and (2) show that the ESG2 coefficients (0.3304 and 0.2811) are positive at a significance level of 1%, verifying the robustness of the baseline results. Sustainability observed through patent applications. Conduct robustness tests on model (1) with 1-cycle and 2-cycle delays. Table 6 (3) and (5) show the F. with a one cycle lag Patent and F The coefficients of InoPaint are 0.3935 and 0.3198, both significantly positive at the 1% level, indicating that ESG rating can improve the innovation level of the following year.

Table 6(4) and (6) show the two period lag of F Patent and F The coefficients of InoPaint are 0.4268 and 0.3443, respectively, which are also significantly positive at the 1% level, verifying the existence of a certain degree of time lag in patent applications. Overall, ESG ratings can effectively promote future innovation of enterprises, and the conclusion is robust.

Table 6 robustness analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	InoPatent	F.Patent	F2.Patent	F.InoPatent	F2.InoPatent
ESG2	0.3304***	0.2811***	0.3935***	0.4268***	0.3198***	0.3443***
	(5.88)	(6.27)	(6.37)	(6.17)	(6.25)	(6.04)
InsHold	0.0002	-0.0012	0.0006	-0.0008	-0.0022	-0.0042
	(0.04)	(-0.45)	(0.13)	(-0.15)	(-0.68)	(-1.12)
IC	0.0009*	0.0007*	0.0009*	0.0001	0.0010**	0.0007
	(2.32)	(2.42)	(2.25)	(0.20)	(3.06)	(1.83)
ROA	4.6625***	0.3079	6.3050***	9.3880***	1.6603	4.0860*
	(3.45)	(0.28)	(3.86)	(4.71)	(1.21)	(2.42)
DUAL	-0.0038	-0.1048	0.0218	-0.0705	-0.0483	-0.0599
	(-0.03)	(-0.95)	(0.14)	(-0.37)	(-0.36)	(-0.38)
GROWTH	0.0247	-0.0470	0.0773	0.0073	0.0174	-0.0795
	(0.15)	(-0.35)	(0.43)	(0.04)	(0.11)	(-0.44)
AGE	0.0137	0.0151	0.0228	0.0413**	0.0209*	0.0316*
	(1.41)	(1.86)	(1.94)	(2.85)	(2.10)	(2.56)
SOE	-0.4628**	-0.1309	-0.4970**	-0.5395*	-0.1533	-0.2100
	(-2.99)	(-0.96)	(-2.70)	(-2.45)	(-0.93)	(-1.07)
TOP1	0.0014	-0.0033	0.0022	0.0035	-0.0022	0.0010
	(0.30)	(-0.82)	(0.40)	(0.52)	(-0.45)	(0.16)

INDEP	0.0405**	0.0316***	0.0375**	0.0246	0.0282**	0.0210
	(3.73)	(3.37)	(3.04)	(1.73)	(2.60)	(1.70)
BOARD	0.1503***	0.1235***	0.1410***	0.0988	0.1227***	0.1084*
	(4.34)	(4.13)	(3.36)	(1.95)	(3.30)	(2.39)
_cons	-4.8988***	-4.9411***	-5.3043	-4.9968***	-5.8042***	-6.7070***
	(-5.22)	(-6.18)	(-5.10)	(-3.55)	(-6.47)	(-6.54)
YEAR FE	Yes	Yes	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1070	1070	803	589	803	589
r2	0.3570	0.3445	0.3694	0.3801	0.3536	0.3628

5.2 Lagged Explanatory Variable

To reduce the bidirectional causal effect, the model introduces ESG ratings lagged by one or two cycles as explanatory variables. Columns (1) and (3) of Table 7 show that the lagged ESG (ESG t-1) coefficients are significantly 0.3809 and 0.3018, both of which are significantly positive at the 1% level, confirming the robustness of the benchmark regression results. Columns (2) and (4) of Table 7 reveal that the ESG rating coefficients for the lagged two periods are 0.3436 and 0.2831, respectively, which are also significantly positive at the 1% level, further strengthening the robustness of the benchmark regression. The results show that ESG has a positive impact on innovation in the next year, and the lag coefficient reflects the patent application time and lag effect, which is consistent with existing research. Overall, the benchmark regression results are robust.

Table 7 Lagged explanatory variable

	(1)	(2)	(3)	(4)
	Patent	InoPatent	F.Patent	F2.InoPatent
ESG	0.2857***	0.2838***	0.2797***	0.3006***
	4.07	3.38	4.58	4.14
ESGt-1	0.3809***		0.3018***	
	(6.15)		(5.99)	
ESGt-2		0.3436***		0.2831***
		(4.16)		(4.93)
_cons	-6.1302***	-7.3636***	-6.1845***	-7.5995***
	(-6.16)	(-6.18)	(-6.46)	(-7.21)
YEAR FE	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes
N	803	589	803	589
r2	0.3803	0.3979	0.3623	0.3730

5.3 Instrumental Variable Method

Referring to the Benlemlih and Bita methods[13], the average ESG rating (AV-ESG) of all listed companies in the province where the company is located is selected as the instrumental variable to address endogeneity issues. Due to the ESG rating of the company being indirectly influenced by other companies in the same province and not directly related to innovation behavior, two-stage least squares (2SLS) analysis is used. The first stage regression shows the results of the first stage in column (2) of Table 8, where Anderson Rubin Wald's F-value is 17.9573, which meets the criteria for weak instrumental variable testing and proves the validity of the variable. The second stage regression, as shown in column (3), shows an ESG coefficient of 0.4025, which is negative at a significance level of 10%. This result strongly supports the conclusion that ESG ratings promote corporate innovation and validates its robustness.

Table 8 Instrumental variable method

	(1)	(2)	(3)
	OLS	First Stage	Second Stage
ESG	0.3367***		0.4025*
	(5.79)		(2.46)
AV_ESG	0.0012**	0.9218***	
	(3.20)	(14.05)	
IC	-0.0064	0.0010***	0.0008
	(-1.68)	(5.61)	(1.75)
InsHold	5.3896***	-0.0058***	-0.0031
	(3.83）	(-3.38)	(-0.78)
ROA	2.8436***	-1.5079*	5.3055***
	(6.20)	(-2.41)	(3.65)

LEV	-0.0425	-0.2577	3.1577***
	(-0.31)	(-1.27)	(6.76)
DUAL	-0.1653	-0.0336	-0.0253
	(-1.08)	(-0.54)	(-0.18)
GROWTH	0.0038	0.0064	-0.1688
	(0.40)	(0.09)	(-1.01)
AGE	-0.3172*	0.0184***	-0.0021
	(-2.04)	(4.16)	(-0.20)
SOE	-0.0026	0.4178***	-0.4711**
	(-0.53)	(6.39)	(-2.75)
TOP1	0.0396***	0.0018	-0.0030
	(3.53)	(0.86)	(-0.64)
INDEP	0.1261***	0.0155***	0.0395***
	(3.53)	(3.45)	(3.75)
BOARD	0.3367***	0.0183	0.1360***
	(5.79)	(1.26)	(4.08)
_cons	-3.2666***	-0.3527	-4.8474**
	(-3.77)	(-0.51)	(-3.13)
YEAR FE	Yes	Yes	Yes
IND FE	Yes	Yes	Yes
N	1070	1070	1070
r2	0.3318	0.3491	0.3215
F	41.3670	17.9573	

6 Conclusions and Policy Recommendations

6.1 Conclusion

With global ESG investment growing, regulatory agencies, investors, and companies are increasingly focused on ESG. Many companies integrate ESG into key decisions. While ESG performance measures sustainable development, its effectiveness is debated, especially in developing countries. This study proposes a framework linking ESG performance to innovation through resources and governance, supporting prior research. Using Chinese A-share firms and Shangdao ESG ratings, panel data regression shows ESG significantly boosts innovation quantity and quality by easing financial constraints and agency costs, with higher ESG performance yielding greater effects.

6.2 Suggestion

We propose the following suggestions for corporate ESG practices and regulatory strategies:

Firstly, companies should deepen ESG practices, enhance ratings, improve disclosure, and increase investment to boost performance, reputation, reduce agency costs, ease financing constraints, and enhance investment efficiency. Integrate ESG concepts into products, training, and projects to promote high-quality development. Strengthen disclosure to help stakeholders understand ratings, support long-term development, and enhance core competitiveness and long-term value.

Secondly,regulatory authorities should improve regulations supporting corporate ESG practices, strengthen listed companies' ESG disclosure systems, build a green finance system aligned with domestic and foreign standards, regulate corporate behavior, enhance market transparency, and provide accurate investor information.

Finally, improve the capital market system, optimize mechanisms, ensure effective ESG information transmission, reduce information asymmetry, lower allocation friction, solve financing problems, stimulate innovation, and pave the way for high-quality economic development.

7 Limitations and Future Research Directions

This study has certain limitations and requires further research.

This study has limitations and needs further research. Firstly, it uses a single-dimensional ESG measurement, ignoring the multi-dimensionality of E, S, and G. The study employed China's authoritative green finance rating but lacked individual scores, limiting its evaluation of specific ESG aspects of listed companies. Therefore, it doesn't conclusively determine ESG's impact on corporate innovation. Future studies should use multidimensional ESG performance. Secondly, the study focuses on China. Future research can broaden topics and compare results with developed countries. Finally, future researchers can adapt the model to include the pandemic and test COVID-19's impact on ESG and innovation.

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