How do ESG dimensions drive corporate green technology innovation? — The mediating effect of financing constraints

Abstract: This paper uses A-share listed companies in China from 2012 to 2022 as a sample to deconstruct the impact of ESG on green innovation from multiple dimensions and verify the mediating effect of financing constraints. The study finds that: (1) the environmental (E) and social (S) dimensions significantly promote green technology innovation, while the governance (G) dimension has no significant effect; (2) financing constraints partially mediate the relationship between the environmental dimension and green innovation, but are not significant in the social and governance dimensions. This provides a theoretical basis and practical insights for policymakers to construct precise incentive mechanisms and for enterprises to optimize ESG resource allocation.

Keywords: ESG; corporate green innovation; financing constraints

I. Introduction

As the world's largest carbon-emitting economy, China has continuously strengthened incentives for green technology research and development since proposing the "dual carbon" goals. However, enterprises still face the dual dilemma of "insufficient innovation motivation" and "tightening funding constraints." This contradiction highlights the urgency of exploring mechanisms that drive green innovation. In this context, the Environmental, Social, and Governance (ESG) system has gradually become a strategic tool for guiding corporate green transformation due to its multidimensional quantitative assessment of sustainable development capabilities. However, how does ESG performance translate into green innovation performance? Is there dimensional heterogeneity in its mechanisms? Answering these questions is not only related to the effectiveness of corporate ESG practices but also holds significant value for policymakers in constructing precise incentive mechanisms.

Existing research indicates that ESG performance can promote innovation through channels such as alleviating corporate financing constraints, increasing R&D investment, and mitigating managerial myopia. However, there are still three limitations in related studies: first, most literature treats ESG as a holistic concept, neglecting the heterogeneous mechanisms of the environmental (E), social (S), and governance (G) dimensions. Second, regarding the mediating mechanisms of ESG's impact on green innovation, existing studies often focus on external resource acquisition (such as government subsidies and investor attention) but pay little attention to financing constraints as a key transmission path. Especially in the context of structural discrimination in China's credit market, whether ESG performance can release green R&D funds by alleviating financing constraints requires empirical evidence. Third, the perspective of heterogeneity analysis is relatively singular, lacking a systematic examination of the moderating effects of industry attributes, property rights nature, and regional marketization levels, leading to insufficient adaptability of policy recommendations.

To address the above research gaps, this paper uses A-share listed companies in China from 2012 to 2022 as a sample and conducts analysis from three levels: "dimension deconstruction — mechanism identification —

contextual adaptation." First, based on resource-based theory and stakeholder theory, it reveals the differentiated impact of E, S, and G dimensions on corporate green innovation performance. Second, it introduces financing constraints as a mediating variable to analyze the specific path through which ESG performance promotes green innovation by alleviating external financing limitations. Finally, it explores the heterogeneous characteristics of ESG effects in conjunction with industry nature, enterprise property rights, and regional marketization levels.

II. Literature Review and Hypothesis Development

(1) ESG Performance and Green Technological Innovation

The concept of ESG originates from Socially Responsible Investment (SRI) and sustainable development theory, with its core focus on promoting long-term value creation for enterprises through the measurement of non-financial performance across three dimensions: Environmental, Social, and Governance [2] . In recent years, the impact of ESG performance on technological innovation has gradually become a research hotspot, but there is still no consensus on the mechanisms linking it to green innovation (i.e., the development of environmentally friendly technologies).

1. Overall Perspective: The Innovation Incentive Effect Driven by ESG

Mainstream research suggests that ESG performance can promote green technological innovation through multiple pathways. Based on resource-based theory, ESG practices can accumulate intangible resources (such as policy support and stakeholder trust), providing external legitimacy and internal resource foundations for enterprises' green technology R&D [3] . For example, Han Ling [4] found that companies with high ESG ratings are more likely to receive government green subsidies, thereby reducing innovation costs; Yang Jie [5] pointed out that ESG information disclosure attracts long-term investors by alleviating information asymmetry, providing stable funding support for high-risk green R&D.

2. Dimensional Deconstruction: The Differentiated Pathways of E, S, and G

Environmental Responsibility (E) and Green Innovation: The Porter Hypothesis suggests that strict environmental regulations can compel companies to upgrade their technology through the "innovation compensation" effect [6In line with this logic, the fulfillment of corporate environmental responsibilities (such as pollution reduction and investment in clean technologies) may directly drive the output of green patents. Empirical research shows that companies with a high level of environmental information disclosure significantly increase their applications for green patents [7], but such studies often focus on the direct impact of environmental performance and do not fully reveal the indirect path through which it promotes innovation by reallocating resources.

Social responsibility (S) and green innovation: Stakeholder theory emphasizes that fulfilling social responsibilities helps build a trust network between companies and employees, suppliers, and communities, thereby reducing cooperation friction and promoting knowledge spillover [8]. For example, Ran Rong [9] found that good corporate social responsibility performance can significantly promote the output of corporate green technology innovation by providing more redundant resources; however, some studies have pointed out that social responsibility information disclosure can be used by companies to cover up issues in their operations [10]. This controversy indicates that the impact of social responsibility on green innovation may exhibit non-linear characteristics or situational dependence.

Governance effectiveness (G) and green innovation: Agency cost theory suggests that optimizing governance structures (such as enhancing board independence and executive compensation incentives) can alleviate

management's short-sighted behavior and ensure the long-term resource investment required for green innovation [11]. Cai Jun [12] confirmed based on data from Chinese listed companies that corporate ESG information disclosure has a positive and significant effect on corporate green technology innovation, but his research did not distinguish the differentiated impact of governance mechanisms on different types of innovation. Furthermore, the promoting effect of governance improvement on green innovation may be constrained by the external institutional environment (such as the level of regional marketization), and this moderating effect has not been sufficiently discussed.

Based on the above discussion, this paper proposes the following hypotheses:

H1a: The fulfillment of environmental responsibilities (E) significantly promotes corporate green innovation performance.

H1b: The fulfillment of social responsibilities (S) significantly promotes corporate green innovation performance.

H1c: The enhancement of governance effectiveness (G) significantly promotes corporate green innovation performance.

(2) The mediating role of financing constraints

1. Financing constraints are a core obstacle to corporate green innovation. Compared to general innovation, green technology innovation often requires more investment, carries higher risks, and has a broader impact.ESG performance mainly promotes corporate green technology innovation by alleviating corporate financing constraints [13]. Showcasing the achievements of enterprises in environmental performance, social responsibility fulfillment, and internal governance can effectively reduce agency problems [14] and enhance the willingness of potential partners to cooperate. ESG information disclosure reduces information asymmetry between investors and enterprises, thereby enhancing financial institutions' risk assessment capabilities for green projects [15].

2. Existing literature has preliminarily verified the mitigating effect of ESG on financing constraints [16], but there are two limitations: First, the dimensional heterogeneity of the intermediary mechanism has been overlooked. For example, environmental responsibility (E) may directly obtain policy-based low-interest loans through environmental technology certification, while governance effectiveness (G) attracts equity financing by improving financial transparency, leading to fundamentally different paths for alleviating financing constraints. Second, existing studies often use a single financing constraint indicator (such as the KZ index), failing to reflect the channel differentiation effect between equity financing and debt financing, which may result in biased estimates of the intermediary effect.

III. Research Gap and Hypotheses

Based on the existing literature, this paper identifies the following research gaps: First, the differentiated impact mechanism of ESG dimensions (E/S/G) on green innovation performance has yet to be clarified; second, the mediating role of financing constraints may exhibit dimensional heterogeneity, but relevant empirical evidence is lacking; third, the effectiveness of ESG may be moderated by contextual factors such as industry attributes and property rights, necessitating heterogeneity analysis to enhance the policy adaptability of conclusions.

Furthermore, each dimension of ESG may indirectly drive green innovation by alleviating financing constraints, but the intensity of its effects varies:

H2a: Financing constraints mediate the relationship between environmental responsibility (E) and green

innovation.

H2b: Financing constraints mediate the relationship between social responsibility (S) and green innovation.

H2c: Financing constraints mediate the relationship between governance effectiveness (G) and green innovation, and the mediating effect is weaker than that of dimensions E and S.

IV. Research Design

(1) Sample and Data

This study selects data from Chinese A-share listed companies from 2012 to 2022 as the test sample. To ensure the accuracy of the research results, the sample data has been processed as follows: (1) Financial industry enterprises were excluded. The main reason is that although financial enterprises have a large amount of capital flow, they do not create actual wealth themselves. Therefore, there are significant differences in accounting standards between financial and non-financial enterprises, and the relevant indicators are not comparable. If they are not excluded, it will affect the research results. (2) We also excluded ST and *ST sample enterprises from the statistical year. These enterprises are specially treated and have certain financial issues or other anomalies that may lead to inaccurate research conclusions, so they are excluded. (3) We also excluded sample enterprises with missing relevant data. (4) Finally, this paper includes 12,034 company-year sample observations. This paper performs 1% and 99% winsorization on continuous variables and uses STATA 17.0 to complete data processing and regression analysis.

(2) Variable Setting

1. Dependent Variable: Green Technology Innovation (EnvrPat).

In this study, green technology innovation (EnvrPat) is used as the dependent variable, referencing the number of green invention patent applications + the number of green utility model applications + 1, taking the natural logarithm as suggested by Wang Xin [16] and Xu Jia [17].

2. Independent Variables: E, S, G Sub-scores (Huazheng ESG Rating)

In this study, the mediating variable is ESG. Based on other research, the Huazheng ESG rating is chosen to measure ESG performance. This system is adapted from mainstream international ESG evaluation systems and is suitable for the Chinese market. The rating is characterized by high data availability, frequent updates, and broad coverage. This indicator has gained wide recognition and application in academia and among industry professionals. The nine performance levels of ESG are ranked as "C, CC, AAA" arranged in descending order from 1 to 9 for corporate ESG performance ranking.

3. Mediating Variable: Financing Constraints (SA Index).

Currently, there are multiple indicators for measuring financing constraints in the academic field. This study references the research of Liu Mengkai et al. [18] and uses the SA index model to measure financing constraints. The SA index is considered to have strong exogeneity compared to other indicators, making it a better measure of corporate financing constraints.

4. Control Variables:

This study controls for several factors that may affect corporate green technology innovation: firm age (Age), firm

growth (Growth), ownership concentration (Top1), cash flow ratio (Cash), board size (Board), dual role (Dual), audit opinion (Audit), and firm size (Size) as control variables. The definitions of the variables are shown in Table 1.

Table 1 Variable Definitions

Variable Type	Variable Name	Variable Symbol	Variable Definition
Dependent Variable	Green Technology Innovation	EnvrPat	Ln(Number of Green Invention Patent Applications + Number of Green Utility Model Applications + 1)
Independent Variable	E, S, G Sub-scores	E/S/G	Huazheng ESG Rating
Intermediary Variable	Financing Constraints	SA	The smaller the value, the greater the financing constraints faced by the enterprise
Control Variable	Enterprise Age	Age	Statistical Year - Year of Establishment
	Enterprise Size	Size	Natural logarithm of total assets
	Enterprise growth potential	Growth	This year's operating income / last year's operating income - 1
	Cash flow ratio	Cashflow	Net cash flow from operating activities / total assets
	Board size	Board	Number of board members, take the natural logarithm
	Dual	Dual	The combination of the Chairman and General Manager roles is 1; otherwise, it is 0.
	Equity Concentration	Top1	The percentage of shares held by the largest shareholder.

V. Model Construction

As shown in Model (1), this study fixed the annual and industry effects in the regression to determine the impact of ESG on corporate green technology innovation to verify H1. Based on Model (1) and drawing on the research of Wen Zhonglin et al. [19], we further constructed Mediating Effect Model 2 and Model 3 to verify H2.

$$\mathrm{EnvrPat}_{i,t} = \alpha_0 + \alpha_1 \mathrm{ESG}_{i,t} + \alpha_2 \mathrm{Controls}_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} (1)$$

$$\mathrm{EnvrPat}_{i,t} = \alpha_0 + \alpha_1 \mathrm{ESG}_{i,t} + \alpha_2 \mathrm{Controls}_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} (1)$$

$$SA_{i,t} = \gamma_0 + \gamma_1 \mathrm{ESG}_{i,t} + \gamma_2 \mathrm{Controls}_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} (2)$$

$$\mathrm{EnvrPat}_{i,t} = \beta_0 + \alpha_1 \mathrm{ESG}_{i,t} + \beta_2 SA_{i,t} + \beta_3 \mathrm{Controls}_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} (3)$$

In which, EnvrPat is the dependent variable, ESG is the independent variable, SA is the mediating variable, and Controls is the set of control variables, while the symbols represent the control for year and industry, and ε is the error term.$\sum Year \sum Industry \varepsilon_{i,t}$

VI. Empirical Analysis

(1) Descriptive Statistics

Table 2 shows the descriptive statistics of the relevant variables. Among them, the maximum value of corporate green technology innovation is 4.762, and the minimum value is 0, indicating a significant gap in corporate green technology innovation among enterprises. The maximum value of corporate financing constraints is -3.154, the minimum value is -4.488, and the average value is -3.854, suggesting that financing constraint issues

exist among enterprises and need to be addressed and improved. The maximum value of ESG performance is 8, and the minimum value is 1, indicating a large disparity in ESG performance among enterprises. Additionally, the average value is 4.229, indicating that the average ESG rating of enterprises is above grade "B." To avoid multicollinearity, a VIF test was conducted on the existing variables; the VIF values of each variable are all less than 2, indicating that there is no significant multicollinearity issue in the data.

Table 2 Descriptive Statistical Analysis

Variable	Sample Size	Mean	Standard Deviation	Minimum	Maximum Value
EnvrPat	12034	0.889	1.184	0.000	4.762
ESG	12034	4.229	1.029	1.000	8.000
SA	12034	-3.854	0.254	-4.488	-3.154
Size	12034	22.507	1.284	20.199	26.440
Growth	12034	0.357	0.891	-0.634	6.028
CashFlow	12034	0.051	0.065	-0.134	0.238
Dual	12034	0.241	0.427	0.000	1.000
FirmAge	12034	2.958	0.314	1.946	3.555
Board	12034	2.140	0.197	1.386	2.890
Top1	12034	0.342	0.145	0.090	0.741

(2) Correlation Analysis

The results of the correlation analysis are shown in Table 3. There is a significant positive correlation between ESG performance and corporate green technology innovation, which means that when a company's ESG performance level is higher, its performance will also improve. The positive correlation between financing constraints, ESG performance, and corporate green technology innovation also indicates that ESG can enhance corporate green technology innovation by alleviating financing constraints.

Table 3 Correlation Analysis

Variable Name	EnvrPat	ESG	SA	Size	Growth	CashFlow	Dual	FirmAge	Board	Top1
EnvrPat	1									
ESG	0.140***	1								
SA	0.0830***	0.0798***	1							
Size	0.414***	0.230***	0.0144	1						
Growth	-0.0404***	0.0233**	-0.00842	0.0327***	1					
CashFlow	0.0102	0.0931***	-0.0130	0.0533***	-0.0971***	1				

Dual	-0.0270***	-0.0366***	0.0797***	-0.163***	-0.0328***	-0.0153*	1		
FirmAge	0.0403***	-0.00728	-0.879***	0.226***	0.0283***	0.0170*	-0.107***	1	
Board	0.0791***	0.0383***	-0.0125	0.239***	-0.0220**	0.0437***	-0.197***	0.0723***	1
Top1	0.0141	0.0630***	0.179***	0.172***	0.0356***	0.0782***	-0.0839***	-0.135***	0.0358***	1

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

(3) Benchmark regression results

The regression results for E, S, and G dimensions are shown in Table 4.

Environmental Dimension (E): In column (1), only E and the corporate technological innovation variable were added, with time and industry effects being fixed. The E coefficient was found to be significantly positive at the 1% level (=0.198, p<0.01), indicating that for every 1 unit increase in environmental performance, the number of green technological innovations increases by 0.198 units, showing a high level of economic significance.αAfter adding control variables in column (2), the E coefficient decreased to 0.019 but remained significant at the 1% level (=0.091, p<0.01), suggesting that some effects may be transmitted through control variables (such as firm size and firm growth), but the direct effect of E remains robust. This supports the hypothesis H1a.α

Social Dimension (S): In column (3), only S and the corporate technological innovation variable were added, with time and industry effects being fixed. The S coefficient was found to be significantly positive at the 1% level (=0.086, p<0.01). After adding control variables in column (α4) the coefficient significantly decreased to 0.024, only significant at the 5% level (=0.024, p<0.05), indicating weaker economic significance. However, the hypothesis H1b still holds.α

Governance Dimension (G): In column (5), only G and the corporate technological innovation variable were added, with time and industry effects being fixed. The G coefficient was found to be significantly positive at the5% level (=0.051, p<0.51). After adding control variables in column (α6), the coefficient further decreased to 0.012 and was significant, indicating that the hypothesis H1c does not hold.

Table 4 E, S, G Dimension Regression Coefficient Significance

Variable	E		S		G	
	(1)	(2)	(3)	(4)	(5)	(6)
EnvrPat	0.198***	0.091***	0.086***	0.024**	0.051**	0.012
	(6.33)	(4.30)	(5.28)	(2.14)	(2.14)	(0.80)
Control Variable	Not controlled	Controlled	Not controlled	Controlled	Not controlled	Controlled
_cons	0.483***	-8.340***	0.494***	-8.712***	0.612***	-8.795***
	(7.52)	(-6.93)	(6.60)	(-7.02)	(4.73)	(-6.99)
Individual Fixed Effects	YES	YES	YES	YES	YES	YES

Year Fixed Effects	YES	YES	YES	YES	YES	YES
N	12034	12034	12034	12034	12034	12034
R^2	0.298	0.428	0.274	0.422	0.264	0.421

$^{*}p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

(4) Mediating effect test.

Mediating effect test of E, S, and G dimensions is shown in the table.5.

Environmental dimension (E): The total effect is significant at the 1% level (=0.091, p<0.01), the mediating path is significant at the 1% level (=0.006, p<0.01), and the direct effect remains significant at the 1% level, but the coefficient decreases by 4.4% (=0.087, p<0.01). E partially mediates its promotion of green technological innovation by alleviating financing constraints, with the mediating effect accounting for 4.4% ((0.091-0.087)/0.091). That is, for every 1 unit increase in the E score, there is an indirect increase of 0.004 units in green patents through alleviating financing constraints. Hypothesis H1a is supported.$\alpha\alpha\alpha$

Social dimension (S): The total effect is significant at the 5% level (=0.024, p<0.05), but the mediating path is not significant, meaning that hypothesis H2b is not supported. The impact of S on green innovation does not pass through financing constraints.α

Governance dimension (G): The total effect is not significant, the mediating path is significant at the 1% level, but the direct effect remains not significant. That is, G can indirectly promote innovation by alleviating financing constraints, but the direct effect is suppressed. Thus, hypothesis H2c is not supported.

Table 5 Mediating effect analysis

Variable	(1) EnvrPat	(2) SA	(3) EnvrPat
E	0.091***	0.006***	0.087***
	(4.30)	(3.55)	(4.23)
SA			0.727*
			(1.85)
S	0.024**	0.000	0.024**
	(2.14)	(0.24)	(2.11)
SA			0.782*
			(1.92)
G	0.012	0.005***	0.008
	(0.80)	(3.94)	(0.58)
SA			0.778*
			(1.94)
Control Variable	Controlled	Controlled	Controlled
Individual Fixed Effects	YES	YES	YES
Industry Fixed Effects	YES	YES	YES
N	12034	12034	12034

(5) Robustness Test

For the robustness test, we refer to Xu Jia [17] and choose the ratio of the number of green utility model patent applications to the total number of patent applications in that year, RatioEnvrUtyPat, replacing the explanatory variables. We select Peng Bo's ESG to replace Huazheng's ESG, namely, berge, bergs, and bergg, which respectively replace E, S, and G.Additionally, the sample period is adjusted to 2017-2022.

Replace the explained variable, after replacing the green innovation indicator from the number of green patents (EnvrPat) to the proportion of green patents (RatioEnvrUtyPat), the coefficient of the environmental dimension (E) is 0.003 (t=2.66), which is significant at the 1% level, indicating that a 1-unit increase in ESG environmental performance corresponds to a 0.3 percentage point increase in the proportion of green patents. Although the absolute value of the coefficient is relatively small, the direction is consistent with the benchmark model, confirming the robust promoting effect of the environmental dimension on green innovation.

Replace explanatory variables (peng_Bo ESG replaces Huazheng ESG)

Environmental dimension (E): After using the peng_Bo ESG environmental score (berge), the coefficient is 0.006 (t=1.88), significant at the 10% level, consistent in direction with the benchmark model (positive), but the significance level decreases. This indicates that there are differences in the effects of the environmental dimension under different ESG rating systems, possibly due to differences in indicator construction methods (such as data sources and weight allocation), but the core conclusion still supports the positive effect of environmental performance on innovation.

Social dimension (S): After replacing with the peng_Bo social score (bergs), the coefficient is 0.009 (t=2.28), significant at the 5% level, which is a decrease from the benchmark model's 0.028 (t=2.25), but the significance remains. This indicates that the positive effect of the social dimension is robust across indicators, but its economic significance is weaker, requiring theoretical explanation for its limited practical impact.

Governance dimension (G): After replacing with the peng_Bo governance score (bergg), the coefficient is -0.001 (t=-0.20), still not significant, consistent with the benchmark model results (original G coefficient 0.007, t=0.47). This further verifies that the governance dimension has no significant impact on green innovation, and the conclusion is robust.

Sample interval adjustment, the results in column (3) support the above conclusions.

Table 6 Robustness Test

Variable	(1) RatioEnvrUtyPat	(2) EnvrPat	(3) EnvrPat
E	0.003***		0.084***
	(2.66)		(5.28)
berge		0.006*	
		(1.88)	
S	0.000		0.028**
	(0.06)		(2.25)
bergs		0.009**	
		(2.28)	
G	-0.001		0.007
	(-0.71)		(0.47)
bergg		-0.001	
		(-0.20)	
Control Variable	Controlled	Controlled	Controlled
Individual Fixed Effects	YES	YES	YES
Industry Fixed Effects	YES	YES	YES

(6) Endogeneity Test

1. Use the lagged explanatory variable.

Environmental Dimension (L.E): The coefficient of the lagged E score is 0.0893*** (t=11.18), which is highly consistent with the benchmark model result (0.091***), confirming that the positive impact of environmental performance on green innovation has temporal persistence and is not affected by reverse causality.

Social Dimension (L.S): The coefficient of the lagged S score is 0.0176*** (t=3.10), which is a decrease compared to the benchmark model (0.024**), but the significance level has increased to 1%. This indicates that the impact of social performance has a lag effect, and its statistical robustness has strengthened, but the economic significance has further weakened, possibly because social investments (such as employee welfare) require a longer time to translate into innovative outputs.

Governance Dimension (L.G): The coefficient of the lagged G score is 0.0111 (t=1.54), which remains insignificant and is consistent with the benchmark regression results.

Table 7 Lagged Explanatory Variables

Variable	(1) L.E	(1) L.S	(1) L.G
EnvrPat	0.0893***	0.0176***	0.0111
	(11.1793)	(3.1009)	(1.5398)
Control Variable	Controlled	Controlled	Controlled
_cons	-7.6776***	-7.9136***	-7.9949***
	(-31.0249)	(-31.9321)	(-32.0250)
Control Variable	Controlled	Controlled	Controlled
Individual Fixed Effects	YES	YES	YES
Industry Fixed Effects	YES	YES	YES
N	10940	10940	10940
R^2	0.427	0.420	0.420

2. Instrumental Variable Method

This paper selects the average ESG of other companies in the same industry for the same year as the instrumental variable (mean1) to address the endogeneity issue.

The coefficients of the instrumental variable (mean1) for E, S, and G scores are all significant at the 1% level, and the F-values far exceed the empirical threshold of 10 (E: 39.918; S: 173.830; G: 75.534), indicating a strong correlation between the instrumental variable and the endogenous explanatory variables, thus ruling out the weak instrument problem. After controlling for endogeneity, the coefficients of E, S, and G on green innovation (EnvrPat) are 0.238*, 0.082*, and 0.157*, respectively, all significant at the 10% level, consistent with the baseline model. This indicates that the positive effect of the environmental dimension (E) is the most robust, supporting the core conclusion that "environmental investment directly drives innovation." Although the impacts of the social (S) and governance (G) dimensions are weaker, the increase in statistical significance (5% significance for S compared to the baseline model, and non-significance for G) suggests that their effects may be obscured by omitted variables or reverse causality.

Table 8 Instrumental Variable Analysis Table

Variable	(1)	(2)	(1)	(2)	(1)	(2)

	E	EnvrPat	S	EnvrPat	G	EnvrPat
mean1	0.350***		1.012***		0.532***	
	(6.32)		(13.18)		(8.69)	
	E	0.238*	S	0.082*	G	0.157*
		(1.80)		(1.81)		(1.79)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Individual Fixed Effects	YES	YES	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES	YES	YES
N	12028	12028	12028	12028	12028	12028
F	39.918	404.273	173.830	408.919	75.534	397.208

(8) Conclusion

1. Differentiated impacts of ESG across dimensions: Environmental responsibility (E) significantly promotes green technology innovation through a dual pathway of directly driving green patent output and alleviating financing constraints; social responsibility (S) has a positive effect on innovation, but the effect is weaker and does not transmit through financing constraints; the enhancement of governance effectiveness (G) has no significant impact on green innovation, possibly because governance optimization focuses more on resource allocation efficiency rather than innovation incentives.

2. Mediating effect of financing constraints: Only the environmental dimension indirectly promotes innovation by alleviating financing constraints, with a mediating effect accounting for 4.4%, indicating that there is dimensional heterogeneity in the financial transmission mechanism of ESG.

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