

ESG, Financial Constraints, and Green Technology Innovation: Evidence from China with the Moderating Role of Environmental Public Attention

Jiawen Wang^{1*}

¹ Faculty of Finance, City University of Macau, Macao 999078, China

*Corresponding author: Jiawen Wang

Abstract

Against the backdrop of China's "dual-carbon" objectives and ongoing improvements in ESG disclosure standards, green technological innovation has become central to firms' sustainable development. Using a sample of Chinese A-share listed companies, this study examines how ESG performance affects firms' green technology innovation and whether the effect varies across regions and ownership types. To unpack the underlying channels, the analysis incorporates financing constraints as a mediating mechanism and environmental public attention as a moderating factor. The results show that ESG performance is positively associated with green innovation, with pronounced geographic variation and firm-level heterogeneity. The effect is stronger for non-state-owned enterprises than for state-owned enterprises. Financing constraints mediate the ESG–green innovation relationship, suggesting that improved ESG performance can ease funding frictions and thereby support innovation activities. In addition, environmental public attention significantly strengthens the positive effect of ESG on green innovation: in regions with higher public attention to environmental issues, the ESG-innovation linkage becomes more pronounced. Overall, this study contributes to the literature by integrating spatial heterogeneity and public environmental attention into the empirical analysis of ESG-driven green innovation.

Keywords

ESG, green technology innovation, financial constraint, environmental public attention

1. Introduction

Green technology innovation plays a critical role in facilitating the United Nations Sustainable Development Goals and the issue of climate change [1]. Although the world has made tremendous efforts to reduce the effects of climate change, many challenges still remain across the globe, and the situation in Asia seems even more severe [2]. China has put forth the idea for the establishment of an innovation system for market-oriented green technology with the goal of developing and enhancing clean energy, clean production, and energy-saving environmental protection industries [3]. China's efforts demonstrate its commitment to making green innovation integral to its development strategy and to pursuing collaborative as well as industrial innovation. The initiatives have resulted in leaps and bounds in strategic industries such as renewable energy and new energy vehicles.

During the implementation period of China's 14th Five-Year Plan, the nation's ESG development entered a phase of remarkable expansion and maturation. This transformative period witnessed substantial advancements across multiple dimensions such as the establishment of more sophisticated ESG governance frameworks, the accelerated development of comprehensive ESG standards, a notable surge in ESG-oriented investment activities, progressive improvements in corporate ESG management practices, and the continual refinement of ESG rating and assessment methodologies. This comprehensive evolution has fundamentally reshaped the corporate landscape, as Chinese enterprises have progressively deepened their understanding of ESG principles and begun integrating these considerations systematically into their operational strategies and strategic decision-making frameworks. Existing academic research has documented that superior ESG performance can facilitate corporate green innovation through two primary pathways: the signalling mechanism and the resource integration channel [3-6]. The signalling mechanism operates by conveying credible information about corporate sustainability commitments to external stakeholders, thereby reducing information asymmetry. Meanwhile, the resource integration channel functions by improving access to critical resources, including financial capital, human talent, technological capabilities, and collaborative partnerships that are essential for innovation activities.

Nevertheless, green innovation initiatives typically exhibit three distinctive characteristics that present substantial challenges for enterprises. They demand considerable financial investment upfront, higher levels of uncertainty and risk, and require extended development cycles before generating tangible returns. Consequently, corporations pursuing green innovation frequently encounter significant financing constraint bottlenecks that impede their innovation capacity. The capital-intensive nature of green technology development, combined with information asymmetries between firms and external investors, creates barriers to securing adequate funding for long-term sustainability projects. ESG performance can affect corporate green innovation, while results can be diverse and complex. This is mainly attributed to the difference in the nature of companies and unbalanced regional development. Thus, investigating the mechanism of ESG impact on green technology innovation is practically and theoretically meaningful. While most studies prove heterogeneous characteristics, discussions on regional gradient differences and their causes remain relatively broad. This study attempts to enrich current research on ESG and green innovation in emerging markets with a discussion on the role of financing constraints and regional differences and a closer look at the moderating effect of environmental public attention.

The contribution of this research mainly includes three aspects. First, it attempts to broaden the contextual applicability of studies on the relationship between ESG performance and green technology innovation. This provides supplementary empirical evidence based on the Chinese market to inform research in emerging market economies. In addition, it refines the dimensions of heterogeneity analysis, revealing regional gradients and enterprise nature differences, thereby enriching empirical cases in this field. Last, it provides empirical insights from the Chinese market for studies on the effect of financial constraints and environmental public attention.

2. Hypothesis Development

2.1 ESG and green technology innovation

ESG apparently aligns with the “dual carbon” goals. According to signalling theory, companies fulfilling ESG responsibilities can signal high-quality development to stakeholders, alleviate regulatory pressure, reduce public relations risks, and gain external support to improve green technological innovation [7]. Together with stakeholder theory, firms integrating ESG into their business activities can easily increase information transparency and therefore reduce information asymmetry with external stakeholders [8-9]. Overall, strong ESG performance reflects multidimensional positive development, strengthens stakeholder partnerships, sustains resources and promotes green technological innovation. Therefore, this study establishes the following hypothesis:

H1: As a firm’s ESG performance increases, its green technology innovation increases.

2.2 The mediating effect of financial constraints

Good ESG performance conveys positive market signals. In other words, information asymmetry between firms and other stakeholders is reduced. The attraction of capital from investors, financial institutions and government policy incentives offsets financing constraints for the company [10]. Lowering the level of financing constraints allows the company to access sufficient financial capital to undertake green technology innovation activities, thus filling the funding gap and increasing the intensity of green technology innovation [11]. Conversely, companies with low ESG performance face high financing constraints because of amplified information asymmetry, thus hindering green technological innovation activities. Therefore, this study designs the following hypothesis:

H2: ESG performance reduces financial constraints, boosting business green technology innovation.

3. Data and Research Design

This study draws on a panel of Chinese A-share listed firms over the period 2010–2022. Firm-level ESG ratings are obtained mainly from the Sino-Security Index Information Service and iFinD, with complementary financial information collected from the CSMAR and Wind databases. To ensure data quality and improve the reliability of the estimates, this study implements the following procedures: (i) ST and *ST firms are removed; (ii) firms in the financial industry are excluded; (iii) observations with missing key variables are dropped; and (iv) all continuous variables are winsorized at the 1st and 99th percentiles to reduce the impact of outliers.

3.1 Variables

Green innovation (GI) is the dependent variable and sourced from CNRDS database. Following prior research, GI is measured as the natural logarithm of one plus the number of green invention patents. The same calculation method also applies to the alternative dependent variable in robustness checks, defined as the green utility model patent (GIn).

The primary independent variable is ESG performance, proxied by the Sino ESG Score. This composite rating evaluates firms' environmental, social, and governance practices based on publicly disclosed information. In robustness checks, this research employs the Bloomberg ESG Composite Score (ESG_B) as an alternative proxy.

Existing studies find that numerous factors influence corporate green innovation. To reduce omitted variable bias, this study selects the following core variables as controls: firm size (Size), asset structure (Lev), tangible assets (Tan), profitability (Roe), firm age (Age), shareholder ownership (Top1), nature of ownership (Soe) and growth capacity (Grow). Additionally, this study controls for year and firm fixed effects.

3.2 Research Design

To empirically test the hypothesis, the regression model is constructed as follows:

$$GI_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \theta Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

where $GI_{i,t}$ denotes the green innovation of firm i in year t and $ESG_{i,t}$ represents the firm's ESG performance. The term $Controls_{i,t}$ includes firm-level characteristic control variables. This research also includes firm effect μ_i and year λ_t fixed effects.

4. Results

4.1 Descriptive statistics

Table 1 reports the descriptive statistics for 11045 observations. The data reveal that the mean values for green innovation indicators (GI and GIn) are 0.305 and 0.241, respectively. Large standard deviations also indicate a significant uneven distribution and polarization in green innovation output across the sample firms. In contrast, the mean ESG score is 74.589 with a smaller standard deviation, suggesting that overall ESG performance is relatively stable and concentrated. Regarding control variables, state-owned enterprises

account for over half of the sample (53%), the average shareholding of the largest shareholder is 37.5%, and the mean leverage ratio is 47.3%. This reflects that the sample is primarily composed of mature enterprises with relatively concentrated ownership and moderate financial leverage, although significant individual variations remain in terms of profitability (Roe) and growth (Grow).

Table 1. Descriptive Statistics

	N	Mean	SD	Min	Max
GI	11045	0.305	0.705	0	2.996
GIn	11045	0.241	0.593	0	2.639
ESG	11045	74.589	5.383	56.93	84.1
Size	11045	22.499	1.440	17.893	25.596
Lev	11045	0.473	0.199	0.05	0.895
Roe	11045	0.047	0.060	-0.24	0.218
Age	11045	2.446	0.730	0	3.367
Grow	11045	0.184	0.423	-0.574	2.891
Top1	11045	0.375	0.161	0.087	0.752
Soe	11045	0.53	0.499	0	1
Tan	11045	0.227	0.176	0.002	0.687

4.2 Main results

The empirical results presented in Table 2 provide crucial insights into the relationship between corporate ESG and GI. Examining Model (1), which represents the baseline specification incorporating only the core ESG dimensional indicators without additional control variables, this research observes a regression coefficient of 0.00391 for ESG. This coefficient achieves statistical significance at the 1% level, indicating an exceptionally low probability that the observed relationship occurred by random chance. Specifically, the coefficient magnitude suggests that each unit increase in the comprehensive ESG score corresponds to approximately 0.00391 units of enhancement in green innovation metrics. This baseline result establishes a preliminary empirical foundation suggesting that corporate commitment to ESG principles serves as a meaningful driver of sustainable technological advancement. However, the interpretation of Model (1) requires careful consideration of its limitations. Omitting control variables can cause a serious omitted-variable bias. In that case, the link between ESG performance and innovation may not be a true ESG effect. Instead, it may be driven by other unobserved factors. To deepen the research conclusion, model (2) introduces a series of control variables to enhance the robustness of the analysis. In this extended model, the coefficient value of ESG is 0.00341, and its significance level reaches the statistical standard of 1%, indicating that after controlling for other potential influencing factors, ESG performance still has a significant positive effect on GI.

Table 2. Baseline Regression

	(1)	(2)
	GI	GI
ESG	0.00391*** (3.499)	0.00341*** (3.036)
Size		0.02478*** (2.608)
Lev		-0.02086 (-0.464)
Roe		0.12874 (1.452)
Age		0.03356 (1.569)
Grow		-0.00640 (-0.806)
Top1		-0.09564

		(-1.445)
Soe		-0.00847
		(-0.256)
Tan		-0.08844
		(-1.438)
cons	0.01383	-0.52282**
	(0.166)	(-2.338)
N	11045	11045
Firm FE	Y	Y
Year FE	Y	Y
r2	0.74338	0.74391

* All models are set to have firm fixed effects and year fixed effects. t statistics in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. These apply to all regression results in this research.

4.3 Robustness Test

Two methods are adopted in the robustness test. The first method substitutes the core independent variable. The original ESG indicator is replaced with the Bloomberg ESG Composite Score (denoted as ESG_B), while the dependent variable remains the corporate green innovation (GI) indicator (corresponding to Model (1) in Table 3). The regression analysis results reveal a considerably positive coefficient at the 1% significance level, demonstrating the robustness of the baseline model's conclusion. Conversely, the second method substitutes the dependent variable. The GI is substituted by the logarithm of one plus the quantity of green utility model patents (GIn). The core explanatory variable remains the same. Referring to Model 2 in Table 3, ESG is significantly positive at the 5% significance level. This further proves that the core conclusion remains robust after changing the measurement method for GI. Using two alternative indicator substitutions, the robustness checks provide consistent results, confirming that ESG performance is significantly and positively associated with firms' green innovation (GI). This consistency indicates that the core conclusions are highly reliable.

Table 3. Robustness test

	(1)	(2)
	GI	GIn
ESG B	0.00607***	
	(4.925)	
Size	0.02252**	0.01370
	(2.383)	(1.469)
Lev	-0.01984	-0.00976
	(-0.443)	(-0.223)
Roe	0.11716	0.06204
	(1.319)	(0.726)
Age	0.03145	0.05296**
	(1.476)	(2.504)
Grow	-0.00763	-0.00854
	(-0.969)	(-1.122)
Top1	-0.09869	-0.26743***
	(-1.491)	(-3.949)
Soe	-0.00776	-0.00514
	(-0.234)	(-0.164)
Tan	-0.10268*	-0.10403*
	(-1.667)	(-1.822)
ESG		0.00237**
		(2.159)
cons	-0.38530*	-0.24348
	(-1.804)	(-1.092)
N	11045	11045
r2	0.74460	0.66356

5. Additional Discussion

The relationship between ESG performance and corporate green innovation demonstrates considerable complexity and variability in practical contexts. This heterogeneity stems primarily from two sources: fundamental differences in organizational characteristics (such as ownership structure, firm size, industry sector, and development stage) and pronounced disparities in regional economic development levels, institutional environments, and policy support mechanisms across China's vast geographic landscape. The eastern coastal regions, for instance, typically enjoy more developed financial markets, stronger regulatory enforcement, and greater stakeholder awareness compared to central and western regions, potentially leading to differential effects of ESG initiatives on innovation outcomes.

Given these complexities, investigating the mechanisms through which ESG performance influences green technology innovation holds substantial practical and theoretical significance. From a practical standpoint, understanding these mechanisms can guide corporate managers in formulating more effective ESG strategies and help policymakers design targeted interventions to promote sustainable innovation. Theoretically, such investigation enriches the comprehension of how nonfinancial performance dimensions interact with innovation processes in emerging market contexts characterized by institutional transitions and development imbalances.

5.1 Regional differences and enterprise nature

The heterogeneity analysis shown in Table 4 discusses the effect of ESG performance on GI in different groups of samples. To examine the heterogeneity characteristics of the regional differences, eastern, middle and western groups are formed to compare their distinct results. As shown in Table 4, Column (1), the estimated ESG coefficient for firms in the eastern region is 0.00277, which is significant at the 10% level. For the central regional group, the ESG coefficient in Table 4, Column (2) is 0.00237, and it is not significant. These findings can be attributed to the eastern region's advanced marketization and the dense concentration of green innovation resources. Therefore, it allows for the easy alignment of ESG practices with the market's needs for green innovation, resulting in the promotion of GI. Last, in Table 4, Column (3), for the western regional group, the ESG coefficient is 0.006 and has a positive statistical significance at the 5% level. This finding can be explained by the fact that in weaker information environments, ESG is more likely to be recognized as a credible signal for investors and financial institutions. Therefore, firms with better ESG in western area find it easier to gain financial support and facilitate more efficient resource allocation to green innovation activities.

As reported in Column (4), the SOE subsample provides an ESG coefficient of 0.00168, which becomes statistically insignificant. In contrast, in Column (5) for non-SOEs, the ESG coefficient is 0.00429 and remains significant (1% significance level). It is obvious that non-state-owned corporations are subject to stronger competitive pressure from the marketplace, and better ESG performance can be seen as a good signal of firms' reputation.

This evidence highlights an asymmetric effect of ESG, indicating that its ability to foster green innovation is contingent upon the nature of the firm's ownership. It varies across regions and firm types. There is a need for the development of differentiated strategies in future policy initiatives, for example, strengthening the synergetic support mechanisms for ESG and green innovation in central areas.

Table 4 Heterogeneity Analysis Results

	(1) East	(2) Middle	(3) West	(4) State-owned	(5) Non-State-owned
	GI	GI	GI	GI	GI
ESG	0.00277*	0.00237	0.00600**	0.00168	0.00429***
	(1.958)	(0.926)	(2.238)	(0.998)	(2.777)
Controls	Yes	Yes	Yes	Yes	Yes
cons	-0.25902	-0.81138	-0.63117	-0.08024	-1.05677***
	(-0.907)	(-1.497)	(-1.194)	(-0.226)	(-3.373)
N	7535	1939	1571	5859	5186
r2	0.76248	0.72699	0.62660	0.75661	0.73358

5.2 The mediator-financial constraint

This study employs the SA index (absa) as a quantitative measure to assess the severity of corporate financing constraints. The SA index exhibits a positive correlation with challenges of funding availability. Specifically, elevated index values signal more pronounced financing obstacles, reflecting heightened difficulties in accessing credit markets, unfavourable borrowing terms, or restricted cash flow positions that impede innovation investment capacity. The empirical findings documented in Table 5 provide several critical insights into this relationship. The first column of results confirms that ESG performance exerts a statistically significant and positive effect on GI. More importantly, the second column presents compelling evidence regarding the mediating mechanism. The results demonstrate that superior ESG performance substantially alleviates corporate financing constraints, as evidenced by a regression coefficient of -0.00135 that achieves statistical significance at the rigorous 1% level. This reduction translates directly into enhanced capital acquisition capability, improved access to diverse funding sources, and greater financial flexibility to support long-term green innovation projects that typically require patient capital and sustained resource commitment. From a theoretical perspective, corporate ESG commitment functions as a credible signal transmitted to capital markets. This signalling mechanism narrows the information gap between investors and firms, enabling external capital providers to more clearly identify the enterprise's long-term development value, which in turn reduces information friction costs during the financing process.

Specifically, green innovation is typically associated with high barriers, long-term innovation project durations, and high risk. From the resource-based theory, capital, being an important part of a core resource of a firm, suggests that easing funding constraints essentially optimizes and upgrades a firm's resource base. Sufficient capital is necessary for a firm to deliver an end-to-end innovation solution support. In this case, lower financing costs enable firms to enter more advanced and better-equipped areas of low-carbon factor inputs. Accordingly, financing constraints mediate the effect of ESG performance on GI.

Table 5. Financial Constraint (SA Index)

	(1)	(2)
	GI	absa
ESG	0.00341***	-0.00135***
	(3.036)	(-7.957)
Size	0.02478***	-0.02869***
	(2.608)	(-7.803)
Lev	-0.02086	-0.00976
	(-0.464)	(-1.026)
Roe	0.12874	0.04230**
	(1.452)	(2.191)
Age	0.03356	0.02861***
	(1.569)	(6.551)
Grow	-0.00640	0.00374
	(-0.806)	(1.624)
Top1	-0.09564	0.03811**
	(-1.445)	(2.492)
Soe	-0.00847	0.00486
	(-0.256)	(1.096)
Tan	-0.08844	0.00541
	(-1.438)	(0.422)
_cons	-0.52282**	4.46071***
	(-2.338)	(56.550)
N	11045	11045
r2	0.74391	0.96262

5.3 The moderator: environmental public attention

Apart from the internal organizational drivers that promote green innovation, external environmental factors can fundamentally shape and reconfigure the ESG-innovation relationship. This research primarily investigates the moderating effect of public environmental attention on the relationship between corporate ESG performance and green technology innovation outcomes. Public environmental awareness works as a crucial indicator that captures societal preferences regarding ecological sustainability, environmental protection, and responsible corporate behaviour. This collective consciousness reflects not only passive concern but also active engagement with environmental issues that can translate into tangible pressure on corporate actors. In the era of big data, online search behaviour records provide an unprecedented opportunity to capture and quantify the attention that market participants, including consumers, investors, media outlets, and regulatory bodies, direct towards specific environmental events, concerns, and corporate practices. These digital footprints offer real-time insights into evolving preferences, emerging priorities, and behavioural intentions across diverse stakeholder groups. The theoretical rationale underlying this measurement approach posits that search activity reflects genuine interest and concern that can subsequently influence decision-making processes, consumption patterns, and investment choices.

Cities or regions with higher levels of public attention to environmental concerns cultivate an institutional and cultural context wherein firms operating within these areas develop heightened awareness of sustainable development imperatives. This environmental consciousness enlarges reputational risks associated with poor environmental performance, strengthens stakeholder expectations for corporate ecological responsibility, and creates competitive pressures as peer organizations respond to similar societal demands. Consequently, enterprises embedded in such environmentally conscious contexts demonstrate a substantially greater willingness to implement sustainable business practices, allocate resources toward green projects, and integrate environmental considerations into core operational decisions. This enhanced commitment to sustainability, in turn, strengthens the positive impact of ESG initiatives on green innovation outcomes by creating alignment between corporate capabilities (reflected in ESG performance) and external incentives (reflected in public attention).

Following the methodological approach established by Wu et al. [12], this research measures the level of public environmental concern using the Baidu Search Index as a proxy variable. This index aggregates search volume data to construct a quantitative indicator of attention intensity. Specifically, "smog" (雾霾) and "environmental pollution" (环境污染) are selected as the primary keywords for identifying and tracking the level of environmental attention, as these terms capture the most salient and widely discussed environmental concerns within the Chinese context during the study period.

The empirical results presented in Table 6 provide compelling support for the hypothesized moderating effect. The interaction term coefficient for public environmental attention registers at 0.00577, achieving statistical significance at the 5% level. This finding carries important implications. It suggests that in regions or periods characterized by higher levels of public environmental attention, the effect of ESG performance on corporate green innovation is improved. In other words, the marginal impact of improving ESG on innovation output is greater when societal environmental consciousness is more pronounced.

Table 6. The moderating effect of Public Attention (PA)

	(1)
	GI
ESG	0.00349***
	(3.095)
ESG x PA	0.00577**
	(2.366)
Size	0.02457***
	(2.587)
Lev	-0.02151
	(-0.479)
Roe	0.12426
	(1.397)
Age	0.03304

	(1.543)
Grow	-0.00651
	(-0.822)
Top1	-0.09634
	(-1.453)
Soe	-0.00767
	(-0.233)
Tan	-0.09402
	(-1.529)
cons	-0.52208**
	(-2.334)
N	11045
r2	0.74405

6. Conclusion

The empirical evidence presented in this study establishes a robust and statistically significant association between corporate ESG performance and green technology innovation outcomes. Crucially, this relationship exhibits pronounced spatial heterogeneity across China's diverse regional landscape, with enterprises located in the economically developed eastern coastal region deriving the most substantial innovation benefits from their ESG engagement efforts. This geographical disparity likely reflects differences in institutional quality, market maturity, and resource availability that characterize China's uneven development pattern.

Moreover, this analysis reveals that the signalling mechanism through which ESG performance communicates corporate quality and sustainability commitment to external stakeholders among non-state-owned enterprises (non-SOEs). These firms, lacking the implicit government backing enjoyed by state-owned counterparts, gain reputation and resource access advantages from credible ESG signals. Additionally, this research identifies and empirically validates financing constraints as a critical mediating mechanism. Superior ESG facilitates access to capital by reducing information asymmetries, lowering perceived investment risks, and enhancing corporate creditworthiness in the eyes of financial institutions and investors.

Finally, the study demonstrates that environmental public attention works as a significant positive moderator, improving the ESG-innovation relationship when societal environmental consciousness intensifies. These empirical findings reflect several important practical implications for corporate strategy and policy design. Companies across all ownership structures and regions should strategically prioritize ESG practices by systematically integrating environmental, social, and governance principles into their core strategic planning processes rather than treating them as peripheral compliance activities. This recommendation particularly applies to non-state-owned firms confronting severe financing constraints, as enhanced ESG performance offers a viable pathway to alleviating capital access barriers and unlocking innovation potential. Furthermore, enterprises operating in different regional contexts should adopt geographically tailored ESG strategies that account for local institutional characteristics, stakeholder expectations, and development priorities. Eastern enterprises, benefiting from more sophisticated markets and stronger institutional environments, can productively focus on deepening the integration between ESG initiatives and green innovation activities to maximize synergistic benefits. Conversely, firms in central regions should concentrate on foundational capacity building, enhancing internal ESG awareness, establishing systematic ESG management frameworks, and developing organizational capabilities necessary for effective ESG implementation.

Future research can extend this analysis across multiple dimensions. First, research could expand beyond the firm level and explore how ESG collaboration and coordination among supply chain partners generate synergistic impacts on green innovation performance. Second, empirical methodologies could be enriched by leveraging quasi-natural experimental scenarios arising from discrete ESG policy changes or regulatory interventions. This can enable more rigorous causal identification and address potential endogeneity concerns.

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Conflicts of Interest

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