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Article

An empirical study on green innovation and ESG information disclosure of listed companies in China

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Abstract: Lately, there is a progressive assimilation of sustainable and green development principles into the collective conscience of individuals. Companies have received considerable attention from all sectors of life when it comes to the environment, society and governance (ESG). This study uses a bidirectional fixed effects model to investigate the influence and the mechanism of green innovation on company ESG information, using a research sample composed of data from the A-share listed companies in China spanning the period from 2011 to 2021. The findings indicated that green innovation exerted a substantial positive influence on ESG information disclosure, and the effect was more substantial, especially in mature and declining companies. Financing constraints and analysts' attention played a mediating role between green innovation and ESG information disclosure. The results of heterogeneity analysis showed that green innovation played a more significant role in promoting ESG information disclosure among state-owned companies, large-scale companies, manufacturing companies and heavy pollution companies. Furthermore, implementing green development policies had facilitated the reinforcement of the promotion impact of ESG information disclosure through green innovation. Additionally, the instrumental variable method was employed to conduct a robustness test. This study enhances the understanding of the theoretical framework about green innovation and the disclosure of ESG information, and offers valuable insights for advancing the sustainable development of companies.

Keywords: A-share listed companies in China; green innovation; company ESG information disclosure; analysts' attention; financing constraints

1. Introduction

Currently, all perspectives of life in society have shown unprecedented attention to issues such as controlling environmental pollution, fulfilling social responsibility and the internal governance of companies. With the acceleration of the global integration process and the deepening of the market economy, the world has shown an unparalleled focus on sustainable development. International efforts like the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development have been enacted to tackle address pressing environmental challenges. In China, since the 18th National Congress of the Communist Party of China, great importance has been highly attached to the construction of an ecological civilization. Consequently, the concept of green and sustainable development has emerged as a prominent trend in the ongoing economic progress. In 2020, China formally announced the ambitious "Double carbon" target, with the objective of peaking carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060. This target is becoming a driving force behind the 14th Five-Year Plan, which emphasizes the need to expedite the comprehensive green transformation of economic and social development. As a result,

the principles of sustainable development and corporate social responsibility rooted in ESG principles have garnered significant attention and recognition from companies worldwide.

With the growing popularity of the sustainable development concept, the need for stakeholder ESG information is increasing (Huang, 2021). Under the above background, as a "direct window" for external observation of ESG behavior, the research on ESG information disclosure has attracted much attention (Zheng and Xu, 2018). Existing literature primarily concentrates on the quality of ESG information disclosure (Xie and Zhou, 2022), the relationship between ESG information disclosure and ESG performance (Bissoondoyal-Bheenick et al., 2023; Khan, 2022), as well as the examination of economic consequences and influencing factors analysis.

For the economic consequences of ESG disclosure, ESG development may affect corporate resource acquisition (Zeng and Chen, 2023), corporate resource allocation (Li and Li, 2023), and production behaviours (Fang and Hu, 2023; Xi and Zhao, 2022). Moreover, the factors that influence corporate ESG disclosure have also been explored from both macro and micro perspectives. While environmental regulatory tools' impact on corporate ESG disclosure has been an existing macro studying perspective, studies from a micro perspective typically focus on corporate governance and ownership characteristics. The use of an environmental protection tax serves as a powerful tool for market-based environmental regulation. By converting external impacts, such as corporate emissions, into internal costs for businesses, it incentivizes them to prioritize emissions management as a future development goal, increase green investments, and improve their overall ESG performance (Wang et al., 2021). Whereas study of ESG disclosure is multifaceted. While policymakers focus on overarching regulations, scholars tend to take a more granular approach for examining corporate governance and ownership characteristics. This includes corporate management, board, all of which impact ESG disclosure. For example, CEO and ESG executive positions can promote such disclosure, while management tenure can have a dampening effect. Board size, activeness, and female representation can facilitate ESG disclosure (Qureshi et al., 2020). Other factors, such as public perception of ESG (Liu et al., 2023), digitalization (Bidatian et al., 2023; Fang et al., 2023), environmental uncertainty (Wang et al., 2023), and external monitoring mechanisms (Chen et al., 2022), also play important roles in ESG disclosure. Overall, whether viewed from a macro or micro perspective, ESG disclosure is an important and complex issue. It is evident that ESG disclosure, a crucial aspect of capital market reform, has been extensively researched by scholars. Nevertheless, there remains a notable shortage of emphasis on the impact of green innovation, a pivotal pathway for development, on ESG information disclosure's quality among listed companies. Diverging from conventional innovation, green innovation encompasses both knowledge and environmental innovation, thereby amalgamating the concepts of green and innovation to foster a mutually beneficial outcome that encompasses economic, environmental, and social advantages (Sun et al., 2021). In the era of high-quality economic development, companies aspiring for more efficient and sustainable progress will inevitably accord greater significance to ESG information disclosure. Consequently, pursuing such objectives profoundly influences the extent of companies' ESG information disclosure practices.

Enterprises across the globe are navigating the twin challenges of environmental changes and economic growth, highlighting the need for sustainable development strategies that enable harmonious coexistence between companies and the environment (Li et al., 2019). Chinese companies—the key players in the emerging market, must not only adhere to the requirements of green economy development, but also proactively address environmental challenges through sustainable strategies. However, Chinese companies have struggled with creating new economic growth opportunities while also improving environmental outcomes for a long time. Stakeholders, including governments and consumers, now recognize eco-innovation's importance as a core strategy for realizing corporate sustainability goals (Huang and Li, 2017). The existing literature has addressed the topic of green innovation extensively. Ge (2019) focuses on heavily polluting companies and demonstrates that green technological innovation alleviates financing constraints not only directly, but also significantly enhances the relationship between carbon information disclosure's quality and financing constraints. Song et al. (2021) examine green technology innovation's effect on Chinese manufacturing companies operating within the global value chain, revealing a U-shaped relationship through empirical testing. Mensah et al. (2019) establish the importance of green innovation capability in enhancing urban green total factor productivity. However, at present, there is still relatively limited literature that directly links green innovation to ESG information disclosure. Relevant research mainly includes as below: Xu (2019) believes that green innovation has become a necessary management activity for companies under the current national economic system and industrial transformation and upgrading. Continuous green innovation can help companies obtain sustainable competitive advantages in the harsh market environment, affecting the motivation of companies' environmental information disclosure. Zhai et al. (2022) discovered that the improved ESG performance had a substantial influence on fostering enhanced corporate green innovation by conducting a zero-inflated Poisson regression analysis on publicly traded manufacturing firms in China. Li et al. (2023) employed panel data regression of China's A-share listed companies from 2011 to 2021 to identify a noteworthy spillover effect of ESG performance on eco-innovation. This effect was achieved by mitigating financing constraints and promoting environmental awareness among peer companies.

In summary, academia has initiated a wealth of research on green innovation and ESG disclosure, which provides a valuable reference. However, these studies show the subsequent deficiencies: Firstly, the majority of past studies primarily examine the influence of ESG information disclosure on green innovation, with limited studies exploring the reciprocal relationship and underlying mechanisms of ESG information disclosure from the view of green innovation. Secondly, the role and influence of funding constraints and analysts attention on the connection between green innovation and ESG disclosure are rarely examined in current literature. In light of these gaps, this study employs a two-way fixed effects model to empirically examine the correlation between eco-innovation and ESG information disclosure, utilizing information extracted from the CSMAR database for China's A-share listed companies from 2011 to 2021.The primary contributions of this paper can be concluded as follows: Firstly, it examines green innovation's influence on companies'

ESG information disclosure, and also investigates variations in this impact across different life cycles. This not only enhances the existing research but also expands the research scope in this area. Secondly, the paper delves into the mediating mechanism of eco-innovation and ESG information disclosure by considering factors such as financing constraints and analysts' attention, thereby deepening the depth of investigation. Thirdly, the fifth section of the paper explores the correlation between eco-innovation and company ESG information disclosure through a comprehensive analysis of various contextual factors, including property rights, pollution, company size, industry type, and policy environment. As a result, this research offers valuable recommendations and practical guidance to enhance ESG information disclosure's quality of companies.

The paper consists of several sections. The theoretical analysis and research hypotheses are presented in the second section. The third section details the data collection and methodology employed in the study. Moving forward, the fourth section entails the analysis of empirical findings. Subsequently, the fifth section explores heterogeneity through robustness testing. Finally, the final section concludes the study and offers recommendations according to the research findings.

2. Theoretical analysis and research hypothesis

2.1. Green innovation and company ESG information disclosure

ESG information disclosure's quality is predominantly influenced by three core factors: environmental management, social responsibility, and corporate governance. Existing research has demonstrated that corporate governance (Barros et al., 2022) and environmental regulatory policies (Cai and Zhou, 2022) exert an influence on ESG information disclosure's quality.

Green innovation, a crucial factor in achieving corporate green development goals, encompasses the enhancement of product design through environmentally friendly products or processes that mitigate the negative environmental impact throughout the product life cycle (Huang and Li, 2017) or attain sustainable objectives (Li et al., 2018). Green innovation can also reduce the energy consumption of products, research and develop new recyclable materials, optimize recycling and remanufacturing processes, and help companies to establish a green identity (Yu et al., 2016). Under the trend that environmental protection is increasingly paid attention to, reducing pollution penalties and establishing a green identity can effectively improve corporate environmental and social responsibility performance, promote sustainable development and improve corporate governance level (Xie and Zhu, 2021). Furthermore, as the momentum for corporate green technology innovation intensifies, there will be a marked enhancement in their ESG performance. Successful technological innovation can not only reduce production costs and improve product composition, but also drive product upgrades, thereby augmenting both the environmental and economic performance of the enterprise. This enhancement extends beyond the economic domain, as it also propels regional entities to adopt technological advancements and product improvements, which in turn creates employment opportunities, enhances job quality, and amplifies the social benefits of the enterprise. This holistic approach ensures the attainment of the dual economic and

social objectives embedded within ESG standards. Consequently, enterprises embark on substantial strides in technological innovation, thereby imbuing their ESG performance with profound significance. Within a conducive environment, enterprises will perpetually innovate and progress, thereby better serving societal needs, fostering industrial advancement, and achieving sustainable development. This positive feedback loop will emerge as the fundamental driving force for future corporate growth. As a result, the correlation between eco-innovation and ESG information disclosure has become more apparent.

According to the market theory, in the product and service market, companies actively engage in green innovation practices to establish competitive differentiation, stimulate demand in new markets, gain favor with environmentally conscious consumers, increase market share and thereby improve financial performance (Xie et al., 2019), and attain a state of mutually beneficial economic efficiency and companies' environmental conservation efforts (Li and Xiao, 2020). Therefore, the more companies focus on their green innovation practices, the more they will get the attention of consumers and investors in enhancing their green innovation capabilities, and the more they pay attention to ESG disclosure, which is closely linked to their ecological development, thereby fostering sustainable development. Based on this, the first hypothesis is proposed.

Hypothesis 1: Green innovation contributes to promoting the company ESG information disclosure quality.

2.2. Green innovation's impact on company ESG information disclosure based on lifecycle

Under life cycle theory, companies are divided into different stages. Companies with different life cycles exhibit very different financial characteristics, organizational characteristics and production methods (Dickinson, 2011), The variations in different lifecycle stages will give rise to discrepancies in green innovation's effect on ESG information's quality.

During the growth phase, to expand the enterprise's scale and enhance its financing capacity, the enterprise may introduce professional managers and the principal-agent problem begins to emerge, with power mainly concentrated in the hands of a few managements. As a result, companies in this phase focus on manufacturing, scale expansion and operational management. The substantial investment in green innovation, coupled with long-term returns and high-performance pressure, contributes to a challenge where executives manipulate corporate information disclosure to pursue short-term financial rewards. As a consequence, corporate ESG information disclosure's quality is affected. During maturity phase, companies undergo optimizations in organizational structure and governance mechanisms, while their production and operational methods, as well as profitability levels, attain a certain degree of stability (Li and Tan, 2019). These surplus funds enable companies to pursue green transformations and embrace low-carbon development. During the recession, companies become less growth-oriented and flexible, lack the ambition to explore new areas, and their corporate systems become rigid. Management is more willing to focus on the ESG disclosure quality to reduce

business risks and maintain its reputation. Therefore, considering the stage characteristics in companies based on the different life cycles, this paper raises hypothesis H2.

Hypothesis 2: When an enterprise is in different stages of life cycle, green innovation's impact on ESG information disclosure is different.

2.3. Green innovation, financing constraints and company ESG disclosure

According to the resource dependence theory, the investment in environmental and social responsibility will inevitably occupy part of the fund for most companies. When facing other projects with more economically beneficial, they will likely be forced to abandon investment in environmental and socially responsible aspects, thus affecting the overall return efficiency of the company (Bhandari and Javakhadze, 2017). Hence, in pursuit of stable returns, certain companies are compelled to compromise on enhancing the quality of ESG information disclosure.

The current research results show a correlation between green technology innovation and financing constraints, and this correlation is bidirectional, with green technology innovation providing significant relief to firms' financing constraints (Zhang et al., 2020). The alleviation of financing constraints can further increase the motivation for green technology innovation, and improve and maintain good environmental and social performance (Lin and Ma, 2022). In addition, the development of green innovation expands and enriches corporate financing channels. It not only improves the external corporate governance environment, but also gives executives the opportunity and possibility to earn more compensation simultaneously (Gu and Zhai, 2021). This also motivates the management to take more account of shareholders' rights and interests, focus on the refined corporate management and the ability of sustainable development in the investment decision-making processes for gradually improving the ESG disclosure quality, and plan ESG into the overall development strategy (Shu and Zhang, 2020), for improving the corporate governance system. Building upon this, this study proposes research assumptions.

Hypothesis 3: Enhancing green innovation capability helps facilitate ESG information disclosure by easing financing constraints.

2.4. Green innovation, analysts' attention and company ESG information disclosure

Analysts assume a critical role in monitoring and facilitating information transfer between companies and external stakeholders. Their attention significantly influences ESG information disclosure's quality of a company. Analysts conduct in-depth research on companies to evaluate projects objectively by leveraging their expertise. The evaluation findings are disseminated through investment rating reports and other channels, which bridges the information gap between investors and companies. The quality of ESG disclosure acts as a deterrent against managerial misconduct, and analysts' attention serves as a mediator in this relationship. This effect is particularly evident in companies characterized by lower transparency, lower institutional ownership, and voluntary ESG information disclosure (He et al., 2022). In recent

years, prompted by national policies, companies have increasingly prioritized green innovation practices, and those with stronger green innovation capabilities tend to attract greater analysts' attention. Drawing on signaling theory, companies with high analysts' attention exhibit enhanced information transparency and reduced information asymmetry, ultimately leading to improved ESG information disclosure quality. This, in turn, establishes a foundation for high-quality enterprise development. Drawing on these premises, this paper presents its research hypotheses.

Hypothesis 4: Analysts' attention has a positive mediating effect on the relationship between green innovation and ESG information disclosure.

3. Data and methods

3.1. Sample and data sources

Given the substantial gaps in enterprise data prior to 2010 in China, this study extensively references existing literature and narrows its focus to data from 2010 onwards. Additionally, to address the challenge of data consistency, it utilizes a sample comprising all companies listed on China's A-share market from 2011 to 2021. Firstly, the financial data of these listed companies were collected and organized. The ESG disclosure index was obtained from the dataset sourced from Bloomberg, while all other data were collected from the CSMAR database. For ensuring the accuracy and dependability of the data, strict sample selection principles were followed: (1) Omitting companies with significant missing variable data; (2) excluding companies with operational irregularities in ST and *ST categories; (3) considering the unique characteristics of the financial industry, excluding companies in this sector. To mitigate the impact of outliers, this study applied a winsorization technique, excluding data points beyond the 1st and 99th percentiles. Consequently, a final sample of 1354 listed companies was obtained.

3.2. Definition of variables

1) Dependent variable: ESG information disclosure of companies (ESG)

Prominent ESG ratings in both China and abroad include the ESG Green Rating developed by the Green Finance Organization of the Industrial and Commercial Bank of China (Green Finance Group of the Industrial and Commercial Bank of China, 2017). Other notable ESG evaluation systems for listed companies include those proposed by the China Securities Investment Fund Association, China Securities ESG rating, Social Value Investment Alliance's ESG rating for sustainable development, Shang Dao Rong Green's ESG rating, Thomson Reuters' ESG score, and Bloomberg's ESG disclosure score. Among these, previous studies often utilize Bloomberg's ESG disclosure score to assess companies' ESG disclosure levels. Therefore, drawing from the study undertaken by Buchanan et al. (2018) and Yuan et al. (2022), the paper adopted Bloomberg's ESG disclosure rating to measure the ESG disclosure's level. Bloomberg's ESG disclosure rating evaluates ESG disclosure's level based on relevant information disclosed by companies. The evaluation index system comprises three primary indicators, twenty secondary indicators, and 120 tertiary indicators, which spans from 0 to 100. A higher score indicates a higher level of ESG disclosure.

2) Independent variable: Green innovation (GI)

Green innovation (GI) is calculated as the logarithm of the cumulative count of self-generated green innovations applied by companies within a specific year and the count of independently applied ecological utility models in the subsequent year. The use of green patents serves as a measure of a company's green innovation performance. While it may not directly quantify the market value of corporate green innovation, it indirectly reflects the level of activity and research and development (R&D) capability in the company's business management process (Jiang and Tan, 2020). Building upon the research conducted by Ai et al. (2020) and Wang et al. (2022), this study emphasizes applications' quality for green inventions rather than the granted amount. This choice is driven by the time lag involved in the patent granting process, which may not capture the timely participation of green innovation. Therefore, using the sum of independently applied and granted green inventions' quantity plus one, the results are logarithmically transformed to measure the company's level of green innovation.

3) Mediating variables: Financing constraints (SA) and analysts' attention (analyst)

Following the approach of Zhai et al. (2022), this study utilizes the absolute magnitude of the SA index to quantify corporate financing constraints. A higher the SA index's absolute value indicates a more pronounced level of financial constraint experienced by the company. Additionally, inspired by the work of Li et al. (2016), the number of analyst teams focusing on the company in the current year is chosen as a measure of analysts' attention. A higher number indicates increased attention and interest from analysts towards the company.

4) Control variables

Considering various factors that may impact corporate ESG disclosure, based on the full reference of previous research (Xu et al., 2022), the selected control variables include company market value, equity concentration, gearing ratio, board size, return on total assets and total asset turnover ratio. Further information showed in **Table 1**.

Table 1. Summary of variable definition.

Variables	**Description**	**Symbol**	**Definition**
Independent variable	ESG information disclosure	ESG	Bloomberg ESG Information Disclosure Score
Dependent variable	Green innovation	GI	The number of green inventions independently applied for by the company in the current year and the number of green utility models independently applied for in the current year shall be taken as the logarithm after +1
Mediating variable	Financing constraints	SA	Absolute value of SA index
	Analysts' attention	Analyst	Number of analyst teams focusing on the enterprise during the year
Control variable	Company market value	Mvc	Equity market value + debt market value
	Equity concentration	Thr	Sum of the shareholdings of the top ten shareholders
	Gearing ratio	Lev	Total liabilities/total assets
	Board size	Bs	Number of directors
	Return on total assets	ROA	Net profit/total assets balance
	Turnover of total assets	ATO	Closing balance of operating income/total assets

3.3. Methodology and model building specification

1) Benchmark regression model

In order to test the influence of green innovation on company ESG information disclosure, this paper adopts the two-way fixed effects model to control the year and the industry and build the following econometrics model:

$$\mathrm{ESG}_{it} = \alpha_0 + \alpha_1 \mathrm{GI}_{it} + \alpha_2 \mathrm{Controls}_{it} + Y_{\mathrm{eart}} + I_{\mathrm{ndi}} + \varepsilon_{it} \quad (1)$$

where GI represents green innovation, ESG represents ESG information disclosure, Controls represents control variables, *t* represents year, *i* represents sample companies, I_{ndi} and Y_{eart} represent industry and year fixed effects, respectively, and ε is a random error term.

2) Mediating effect model

To facilitate the process of examine the mediating impact of financial constraints and analysts' attention, this study formulates model Equations (2) and (3) based on model Equation (1).

The specific inspection model is as follows:

$$M_{it} = \beta_0 + \beta_1 \mathrm{GI}_{it} + \beta_2 \mathrm{Controls}_{it} + Y_{\mathrm{eart}} + I_{\mathrm{ndi}} + \varepsilon_{it} \quad (2)$$

$$\mathrm{ESG}_{\mathrm{it}} = \gamma_0 + \gamma_1 \mathrm{GI}_{it} + \gamma_2 M_{it} + \gamma_3 \mathrm{Controls}_{it} + Y_{\mathrm{eart}} + I_{\mathrm{ndi}} + \varepsilon_{it} \quad (3)$$

where *M* is the intermediate variable, the other variables are consistent with the above. Using the research methods of Ai et al. (2020), Wen and Ye (2014) for reference, the step-by-step method is adopted to analyze the mediating effect. Firstly, the coefficients α_1, β_1 and γ_2 in model Equations (1)–(3) are tested in turn. If the coefficients α_1, β_1 and γ_2 are all significant, the mediating effect holds; If at least one coefficient does not show statistical significance, the bootstrap method is applied to test further. The mediating effect holds if the result is notable; otherwise, there is no mediating effect. Secondly, the coefficient γ_1 in the model Equation (3) is tested. If it is significant, it indicates local mediation; otherwise, it is complete mediation. Finally, the symbols of γ_1 and $\beta_1\gamma_2$ are compared. If they have the same symbol, both positive or negative, they belong to partial mediating effect, and the ratio of mediator effects to total utility is $\beta_1\gamma_2/\alpha_1$. If the symbol is different, positive or negative, it belongs to the masking effect, and the mediating effect's proportion is $|\beta_1\gamma_2/\gamma_1|$.

4. Analysis of empirical results

4.1. Descriptive statistics

Table 2 provides descriptive statistics for the primary variables. The mean value of ESG is 26.857, with a maximum value of 51.373, indicating a relatively low overall quality of ESG disclosure among the sampled companies. The standard deviation of 7.816 reflects the variability in ESG disclosure quality across companies. The average value of green innovation (GI) is 0.741. Due to industry-specific disparities, the number of green patent applications varies significantly, ranging from 0 to 4.127, with a standard deviation of 1.050, denoting the diversity in green innovation endeavors. The mean value of financing constraint (SA) is 3.793, ranging from a minimum of 3.241 to a maximum of 4.396, suggesting that sampled companies generally encounter financing constraints, albeit with variation. Analysts' attention ranges from 1 to 44, with an average of 9.378 companies followed by analyst teams and a standard

deviation of 9.569. Additionally, the statistical outcomes of the control variables exhibit varying degrees of variability.

Table 2. Descriptive statistical analysis results.

Variables	*N*	Mean	P50	Sd	Min	Max
ESG	10,354	26.857	26.747	7.816	11.157	51.373
GI	10,354	0.741	0	1.050	0	4.127
SA	10,354	3.793	3.792	0.239	3.241	4.396
Analyst	10,354	9.378	6	9.569	1	44
Mvc	10,354	1.291	6.021	2.111	5.731	1.471
Thr	10,354	59.389	60.570	14.585	24.970	89.380
Lev	10,354	0.406	0.396	0.202	0.050	0.865
Bs	10,354	8.513	9	1.594	5	14
ROA	10,354	0.043	0.042	0.059	−0.230	0.196
ATO	10,354	0.612	0.519	0.405	0.091	2.448

4.2. Correlation analysis

The results of the correlation analysis performed to assess multicollinearity among the indicators are presented in **Table 3**. The table presents the correlation coefficients between the dependent variable (ESG), independent variable (GI), control variables, and mediating variables, with significance levels of 1%, 5% and 10%. The correlation coefficient between ESG information disclosure's quality and green

Table 3. Correlation analysis.

	ESG	GI	SA	Analyst	Mvc	Thr	Lev	Bs	ROA	ATO
ESG	1.000									
GI	0.267***	1.000								
SA	0.252***	−0.042***	1.000							
Analyst	0.112***	0.154***	−0.071***	1.000						
Mvc	0.372***	0.297***	−0.030***	0.353***	1.000					
Thr	0.013	−0.069***	−0.223***	0.062***	0.037***	1.000				
Lev	0.048***	0.206***	0.162***	−0.019***	0.328***	−0.142***	1.000			
Bs	−0.005	0.065***	0.029***	0.055***	0.182***	−0.032***	0.160***	1.000		
ROA	0.031***	−0.041***	−0.072	0.330***	0.046***	0.248***	−0.387***	−0.017***	1.000	
ATO	0.018*	0.001	0.033***	0.090***	0.016**	0.024***	0.168***	0.024***	0.109***	1.000

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

innovation is 0.267, exhibiting statistical significance at a 1% level. This finding

indicates a positive correlation, suggesting that enhancing green innovation capabilities can substantially enhance ESG information disclosure's quality. This result provides preliminary support for the hypothesis 1. The correlation coefficients between the remaining variables all exhibit values lower than 0.7, indicating the non-existence of multicollinearity problems.

4.3. Analysis of regression results

1) Benchmark regression analysis

A two-way fixed effects model was chosen for the multiple regression analysis, controlling for the effects of year and individual, and the results are shown in **Table 4**. Column (1) in **Table 4** presents the results of investigating the direct relationship between company green innovation and ESG information disclosure. The estimated regression coefficient is 0.239, indicating statistical significance at the 1% level, indicating that an increase of 1% in the level of green innovation possibly promote corporate ESG disclosure's quality by 0.239%, thus further signifies that an improvement in green innovation capability enhances the quality of company ESG information disclosures significantly. Regarding control variables, company market capitalization, equity concentration and return on total assets have a significant positive relationship with corporate ESG information disclosure. The coefficient of corporate market capitalisation is significantly positive with a coefficient of 3.361, implying the well-developed companies have higher ESG disclosure quality. It may depend on the advanced production facilities, high-quality labour force and efficient management system acquired by the better-developed companies. The coefficient of equity concentration is significantly positive at 0.021, indicating that the higher the equity concentration is, the better ESG disclosure quality is. Moreover, the significantly positive coefficient of return on total assets at 3.056, imposes a significant positive contribution to ESG disclosure. All other control variables are also largely consistent with the mainstream literature.

Table 4. Benchmark regression results.

Variables	ESG	E	S	G
GI	0.239*** (3.99)			
GI		0.497*** (4.38)		
GI			0.344*** (5.81)	
GI				0.158*** (2.83)
Mvc	3.361*** (19.35)	5.781*** (17.52)	3.811*** (22.17)	7.871*** (2.71)
Thr	0.021*** (3.46)	0.042*** (3.67)	0.009 (1.50)	0.024** (2.41)
Lev	−2.161*** (−4.27)	−1.411 (−1.46)	−0.888 (0.52)	−5.166*** (−6.12)
Bs	−0.028 (−0.64)	−0.117 (−1.38)	−0.133*** (−3.01)	0.166** (2.24)

Table 4. (*Continued*).

Variables	ESG	E	S	G
ROA	3.056*** (2.83)	9.511*** (4.62)	2.282** (2.13)	−2.333 (−1.30)
ATO	−0.288 (−1.24)	−0.553 (−1.25)	−0.156 (−0.68)	−0.312 (−0.81)
Cons	19.940*** (12.73)	4.092*** (2.85)	9.521*** (6.15)	49.806*** (19.06)
Industry	Control	Control	Control	Control
year	Control	Control	Control	Control
N	10,354	10,219	10,292	10,347
Adj-R^2	0.7087	0.3954	0.3418	0.7229
F	605.93	160.62	128.54	649.40

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

Furthermore, for examining green innovation's impact on the three ESG dimensions, this thesis conducts regression analyses with each dimension as an explanatory variable. The outcomes of these regressions are presented in **Table 4**, columns (2)–(4). The results indicate a noteworthy positive correlation between green innovation and all three ESG dimensions. Specifically, green innovation has the most substantial effect on the environment, followed by social responsibility and corporate governance.

2) Impact of green innovation on ESG information disclosure based on lifecycle perspective

Drawing upon the findings of the aforementioned study, the sample variables are categorized into different stages by using the life cycle theory and employing Dickinson's (2011) cash flow combination method. The classification comprises three stages of growth, maturity, and decline, which are determined based on the associations, both positive and negative, among operating cash flows, investment cash flows, and financing cash flows.

To delve deeper into the analysis, a two-way fixed effects model is employed. **Table 5** shows the impact of current green innovation on company ESG disclosure under different life cycles. In particular, green innovation's influence on ESG disclosure is not significant for companies in the growth stage. Mainly because companies in this stage of rapid expansion, with high profitability as their priority, are less inclined to prioritize their focus on green innovation. In contrast, during the maturity stage, green innovation is found to have a significant and positive correlation with company ESG disclosure at a 5% level of significance, with a correlation coefficient 0.213, indicating the companies with better green innovation capabilities place more emphasis on the ESG disclosure quality. In the recessionary period, green innovation is still positively associated with ESG disclosure at the level of 10%, with a correlation coefficient of 0.306. This indicates that green innovation still positively influences ESG disclosure in this recessionary period, but the coefficient and significant level have decreased compared to the mature period.

Table 5. Regression results of green innovation to company ESG information disclosure based on lifecycle perspective.

Variables	**ESG**		
	Growth stage (1)	**Mature stage (2)**	**Recession stage (3)**
GI	0.079 (0.45)	0.213** (2.30)	0.306* (1.94)
Mvc	3.791*** (9.54)	2.871*** (11.09)	2.181*** (4.84)
Thr	0.061*** (3.06)	0.015* (1.67)	0.020* (1.68)
Lev	−0.673 (−0.45)	−3.372*** (−4.19)	−3.055*** (−3.10)
Bs	0.192 (1.26)	0.034 (0.50)	−0.004 (−0.05)
ROA	1.706 (0.51)	3.615** (2.13)	3.649* (1.67)
ATO	0.546 (0.79)	−0.164 (−0.46)	−0.496 (−1.16)
Cons	10.388*** (3.00)	18.161*** (7.33)	24.235*** (9.56)
Industry	Control	Control	Control
Year	Control	Control	Control
N	1758	4930	3384
Adj-R^2	0.7007	0.7168	0.7071
F	76.38	267.18	170.13

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

3) Mediating effects of financing constraints

The stepwise regression analysis was performed using the aforementioned model to examine financial constraints' mediating role in the association between eco-innovation and the quality of corporate ESG disclosure. The regression results are shown in **Table 6**. In column (1), a statistically significant positive correlation between eco-innovation and ESG disclosure is observed. The regression coefficient of green innovation and ESG disclosure is 0.239 and significant at the level of 1%. It indicates that an increase of 1% in green innovation may drive up the corporate ESG disclosure quality by 0.239%. Thus, this is consistent with previous findings. Subsequently, the mediating variable of financing constraint is introduced for empirical testing, and column (2) demonstrates that green innovation exhibits a significant negative impact on financing constraint, indicating that green innovation's advancement can mitigate the issue of financial constraints encountered by companies. The coefficient for green innovation is −0.003, which is significantly negative at the level of 1 percent. Lastly, in column (3), the coefficients for green innovation and financing constraint are 0.215 and −3.607, respectively, both passing the significance test. Furthermore, the coefficient of green innovation decreases from 0.239 to 0.215, with positive signs of both γ_1 and $\beta_1\gamma_2$ exhibiting positive signs, which provides conclusive evidence of a partial mediating effect of financing constraints, and the mediating effect is 4.5% of the total effect. These results align with the expectations of hypothesis 3, suggesting

that the enhancement of green innovation can enhance ESG information disclosure's quality by alleviating financing constraints. Further, it proves that financing constraints have a mediating effect between green innovation and corporate ESG disclosure.

Table 6. Intermediary effects of financing constraints.

Variables	**ESG** **(1)**	**SA** **(2)**	**ESG** **(3)**
GI	0.239*** (3.99)	−0.003*** (−7.58)	0.215*** (3.59)
SA			−3.607*** (−3.85)
Mvc	3.361*** (19.35)	−1.791*** (−101.33)	2.851*** (12.99)
Thr	0.021*** (3.46)	−0.001*** (−36.10)	0.016*** (2.63)
Lev	−2.161*** (−4.27)	0.078*** (24.39)	−2.179*** (−4.31)
Bs	−0.028 (−0.64)	0.002*** (5.90)	−0.031 (−0.70)
ROA	3.056*** (2.83)	0.104*** (15.24)	3.338*** (3.09)
ATO	−0.288 (−1.24)	0.001 (0.81)	−0.237 (−1.02)
Cons	19.940*** (12.73)	3.593*** (317.25)	33.198*** (8.77)
Industry	Control	Control	Control
Year	Control	Control	Control
N	10,354	10,354	10,354
Adj-R^2	0.7087	0.8882	0.7092
F	605.93	4838.98	590.86

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

4) Mediating effect of analysts' attention

To assess analysts' attention's mediating effect on the correlation between eco-innovation and company ESG disclosure, regression analysis was conducted, and the results are presented in **Table 7**. In column (1), the analysis investigates whether the development of eco-innovation enhances ESG information disclosure. The regression coefficient of green innovation and ESG disclosure is 0.239 and significant at the level of 1%. It indicates that a 1% increase in green innovation may drive up corporate ESG disclosure quality by 0.239%. Thus, the finding supports the notion that green innovation positively influences ESG information disclosure, consistent with previous findings.

Then, for column (2), where analysts' attention serves as the independent variable, the regression coefficient for green innovation remains significantly positive with a significance level of 1%. The regression coefficient is 0.551, indicating that a 1% increase in green innovation could give rise to a 0.551% increase in analyst attention, which further indicates a significant and positive relationship between green

innovation and analysts' attention.

Table 7. Mediating effect of analysts' attention.

Variables	**ESG (1)**	**Analysts' attention (2)**	**ESG (3)**
GI	0.239*** (3.99)	0.551*** (7.18)	0.148*** (2.95)
Analyst			0.034*** (5.28)
Mvc	3.361*** (19.35)	1.671*** (36.30)	3.851*** (12.04)
Thr	0.021*** (3.46)	−0.002 (−0.28)	0.013** (2.03)
Lev	−2.161*** (−4.27)	2.429*** (4.42)	−2.904*** (−5.19)
Bs	−0.028 (−0.64)	0.037 (0.61)	0.008 (0.16)
ROA	3.056*** (2.83)	38.188*** (30.44)	−0.530 (−0.43)
ATO	−0.288 (−1.24)	1.126*** (4.03)	−0.078 (−0.32)
Cons	19.940*** (12.73)	7.524*** (3.63)	18.716*** (9.88)
Industry	Control	Control	Control
Year	Control	Control	Control
N	10,354	10,354	10,354
Adj-R^2	0.7087	0.7788	0.7127
F	605.93	95.15	453.27

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

Lastly, in column (3), the coefficients for eco-innovation and analysts' attention are 0.148 and 0.034, respectively, both passing the significance test. Notably, the coefficient for green innovation decreases from 0.239 in column (1) to 0.148 in column (3). Both γ_1 and $\beta_1\gamma_2$ have positive signs, which provides compelling evidence of a partial mediating effect of analysts' attention, and the mediating effect is 7.8% of the total effect.

These empirical results align with hypothesis 4, which posits that companies with stronger green innovation capabilities attract greater attention, consequently enhancing the quality of their ESG disclosure.

5. Heterogeneity test and robustness test

5.1. Heterogeneity test

Considering that the effect of companies due to the different nature of property rights, size, industry, the nature of pollution, and the national green development policy, this study is based on the fixed effects model to carry out the heterogeneity analysis. The specific content is as follows:

1) Heterogeneity analysis based on property rights

Since green innovation creates more significant social benefits and corresponds with national strategic planning, guidance on state-owned companies' strategic decisions is essential for national strategic planning promotion. This study hypothesizes that the role of green innovation in promoting ESG disclosure will be more significant among state-owned enterprises (SOEs). To test this hypothesis, the sample was divided into state-owned and non-state-owned companies, and group comparisons were performed, adhering to the methodology of Chen et al. (2022) and Wang et al. (2014). The nature of ownership was coded as 1 for state-owned companies and 0 for non-state-owned companies. **Table 8** presents the regression results. In column (1), state-owned enterprises exhibit a coefficient of 0.312 for green innovation (GI). In column (2), non-state-owned companies display a coefficient of 0.151 for GI. The coefficient for green innovation is significant at the 1% level only in state-owned enterprises. Non-state-owned enterprises demonstrate significance at the 10% level. These findings suggest that green innovation has a more substantial effect on ESG disclosure in state-owned enterprises compared to non-state-owned enterprises, supporting the prediction that the role of green innovation in promoting ESG disclosure is more critical among SOEs.

Table 8. Results of heterogeneity analysis based on property rights nature, different size and industry nature.

Variables	**State-owned companies (1)**	**Non-state-owned companies (2)**	**Large-size (3)**	**Small-size (4)**	**Manufacturing (5)**	**Non-manufacturing (6)**
GI	0.312*** (3.76)	0.151* (1.72)	0.221*** (3.28)	0.073 (0.50)	0.278*** (3.44)	0.232** (2.57)
Mvc	2.651*** (10.64)	3.791*** (15.20)	2.671*** (14.72)	9.081*** (5.24)	3.651*** (15.75)	2.091*** (8.15)
Thr	0.016* (1.72)	0.033*** (3.54)	0.007 (0.93)	0.033*** (2.70)	0.030*** (3.54)	0.026*** (2.71)
Lev	−2.735*** (−3.65)	−0.874 (−1.19)	−2.722*** (−4.08)	−2.759*** (−3.06)	−3.499*** (−5.10)	−0.821 (−1.03)
Bs	−0.008 (−0.15)	0.016 (0.21)	0.009 (0.19)	−0.064 (−0.63)	0.002 (0.04)	−0.007 (−0.12)
ROA	2.979* (1.74)	1.672 (1.16)	2.243* (1.68)	−0.112 (−0.06)	−0.119 (−0.08)	4.604*** (2.73)
ATO	0.098 (0.32)	−0.779** (−2.13)	−0.089 (−0.33)	0.329 (0.66)	−0.049 (−0.15)	−0.504 (−1.50)
Cons	24.183*** (11.11)	13.739*** (5.87)	19.923*** (9.06)	18.992*** (9.14)	20.084*** (14.38)	14.938*** (4.85)
Industry	Control	Control	Control	Control	Control	Control
Year	Control	Control	Control	Control	Control	Control
N	5162	4685	7973	2099	5911	4161
Adj-R^2	0.7457	0.6731	0.7166	0.5913	0.7192	0.7044
F	387.73	229.69	505.47	62.09	644.21	274.52

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

2) Heterogeneity analysis based on different company size

This paper also makes an empirical test according to the different company sizes. Building upon the studies by Huang et al. (2022) and Zhang and Lu (2022), this study

divides the sample based on company size using dummy variables. Companies surpassing the median are assigned a value of 1, whereas those falling below the median are assigned a value of 0. The regression outcomes for the various size groups are displayed in **Table 8**. In column (3) of **Table 8**, the coefficient for eco-innovation (GI) is 0.221, and it is statistically obvious at the 1% significance level. However, in column (4), the coefficient for GI is 0.073, and it is found to be statistically insignificant. These findings suggest that green innovation's impact on ESG disclosure is more pronounced in larger companies compared to smaller ones. This may be due to large companies' competitive strength, unobstructed access to capital, and strong resource background, making them more capable of green innovation.

3) Heterogeneity analysis based on industry nature

By incorporating industry classification variables and drawing insights from Xu et al. (2022), this study employed grouped regressions to investigate industry variations' impact on companies' heterogeneous behavior. The outcomes are displayed in **Table 8**, specifically in column (5), and it displays the regression outcomes for the manufacturing group, indicating a coefficient of 0.278 for green innovation (GI), which exhibits statistical significance at the 1% level. In contrast, column (2) exhibits the regression results for the non-manufacturing sector, with a coefficient of 0.232 for GI at the significant level of 5%. The corresponding coefficients for green innovation (GI) indicate that it has a more significant role in augmenting ESG disclosure within the manufacturing sector. This disparity can be attributed to the greater difficulty of implementing green innovation in the non-manufacturing sector, where companies often encounter higher technical barriers.

4) Heterogeneity analysis based on pollution properties

The disparities in pollution levels across companies can also lead to variations in green innovation's influence on ESG information disclosure. Heavily polluting companies become a focal point for green development initiatives. Seeking to enhance their social image and gain consumer recognition, these companies tend to place more emphasis on green development, consequently improving quality level of ESG information disclosure. Based on the data obtained from the CSMAR database pertaining to heavily polluting companies, and drawing insights from the studies proceeded by Wang et al. (2023) and Wang and Yang (2022), the sample was divided into two groups: highly polluting and non-highly polluting, for conducting group-based testing. A value of 1 was assigned to companies classified as heavily polluting, while a value of 0 was assigned to non-heavily polluting ones. The findings are displayed in **Table 9**. Column (1) displays the regression outcomes for the heavily polluting group, revealing a coefficient of 0.459 for green innovation (GI), which is statistically significant at the 1% level. On the other hand, column (2) presents the regression results for the non-heavily polluting group, with a coefficient of 0.132 for GI, statistically significant at the level of 10%, which indicates that green innovation contributes more significantly to the quality of ESG disclosure for heavily polluting companies. The heavily polluting companies with more attention from the government and the public are more likely to be subject to environmental regulatory instruments.

Table 9. Results of heterogeneity analysis based on pollution and policy background.

Variables	**Heavy pollution (1)**	**Non-heavy pollution (2)**	**≤2016 (3)**	**>2016 (4)**
GI	0.459*** (3.69)	0.132* (1.94)	0.058 (0.65)	0.292*** (3.42)
Mvc	4.941*** (10.76)	2.811*** (15.33)	2.101 (1.00)	7.721*** (6.92)
Thr	0.015 (1.17)	0.024*** (3.46)	0.011 (1.29)	0.032*** (2.68)
Lev	−3.630*** (−3.12)	−1.440** (−2.50)	−1.913*** (−2.75)	−2.898*** (−3.07)
Bs	−0.161* (−1.70)	0.033 (0.65)	0.071 (1.12)	0.008 (0.11)
ROA	−1.045 (−0.44)	2.684** (2.21)	−0.246 (−0.18)	0.177 (0.15)
ATO	−0.191 (−0.43)	−0.444 (−1.58)	−0.399 (−1.31)	−0.004 (−0.01)
Cons	19.234*** (8.44)	19.457*** (12.29)	22.714*** (10.03)	27.601*** (8.79)
Industry	Control	Control	Control	Control
Year	Control	Control	Control	Control
N	2439	7633	5024	5048
Adj-R^2	0.7368	0.7061	0.5784	0.4505
F	276.81	436.94	178.35	116.19

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

5) Heterogeneity analysis of policy effects based on green development

The "Guiding opinions on establishing a green financial system" were jointly released on 31 August 2016 by institutions such as the Bank of China, the Ministry of Finance, and seven other ministries and commissions. This significant policy document serves as a guide to promote and encourage increased investment from social capital into green development initiatives, and also advocate for the full implementation of the principles of green development. Consequently, the implementation of these guiding opinions is assumed to provide stronger support from financial institutions to facilitate green development and result in a more substantial valuation for such endeavors. This paper takes the promulgation of the Guiding Opinions as the event point and divides the entire sample into two sub-samples based on Lin and Li (2023): the pre-event sample (2010–2016), assigned a value of 0, and the post-event sample (2016–2021), assigned a value of 1, to investigate whether the further promotion of green innovation has achieved the significant results.

In columns (3) and (4) from **Table 9**, a notable difference is observed in impact of the green innovation on company ESG information disclosure before and after the introduction of the guidance. Before its implementation, the coefficient of green innovation (GI) in column (3) is 0.058, indicating a positive but insignificant relationship. However, after the implementation, the coefficient of GI in column (4) is 0.292, which is significant at the 1% level. This suggests that the financial support provided for corporate green development has yielded promising results. The findings

in columns (3) and (4) of **Table 9** further suggest that as the policy framework for financial support in green development continues to improve, corporate green innovation's impact on their ESG information disclosure becomes more pronounced.

5.2. Robustness test

The paper chooses the instrumental variables approach, explanatory variables replacement, and the bootstrap method to conduct the robustness test for ensuring the robustness and reliability of the results.

1) Instrumental variables approach

Endogeneity is usually caused by the causal relationship between explanatory variables and explained variables, the omission of variables in the model, and the error in sample selection, etc. Thus, the potential endogenous problems in this paper may come from the two-way causality. Green innovation can provide intellectual support for companies' ESG information disclosure, and companies with better ESG information disclosure quality can also adversely affect eco-innovation to some extent.

Table 10. Instrumental variables method.

Variables	**One-stage regression GI**	**Two-stage regression ESG**
GI_{i-1}	0.587*** (40.87)	
GI_{i-2}	0.286*** (19.04)	
GI		1.630*** (17.35)
Cons	0.046*** (3.82)	23.917*** (40.49)
Controls	Yes	Yes
Industry	Control	Control
Year	Control	Control
N	7913	7913
Adj-R^2	0.7123	0.6309
Sargan test	0.9794	0.9868

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

Building upon the research conducted by Ullah et al. (2022), Yu et al. (2022), and Li et al. (2021), the research aims to examine the benchmark model by introducing a combination of lagged first-order term (GI_{i-1}) and lagged second-order term (GI_{i-2}) of green innovation as instrumental variables. By doing so, the intention is to mitigate the potential endogeneity issue and enhance the findings' robustness. The findings are displayed in **Table 10**, including the first-stage regression analysis results. These results show a significant and positive correlation between the instrumental variables and green innovation. Additionally, the second-stage regression analysis results reveal a notable and positive association between green innovation and the outcome variable, aligning with the earlier findings. The Sargan test can judge whether the selection of instrumental variables is reasonable. Because the Sargan test's *P* value is large, the original hypothesis of "all instrumental variables are valid" can be accepted, which

shows that instrumental variables selected in regression analysis are valid. Consequently, even after addressing the potential issue of endogeneity, hypothesis 1 remains supported.

2) Heckman two-stage model

To address potential sample selection bias in the quality of corporate ESG information disclosure, this study applies the Heckman two-stage model for robustness testing of the previously established research conclusions.

The decision of whether a firm receives an ESG rating is subject to the self-selection behavior of rating agencies, which introduces sample selection bias impacting the assessment of corporate ESG performance. To mitigate the endogeneity issue stemming from this sample self-selection, the Heckman two-stage model is utilized to examine the relationship between green innovation and corporate ESG performance. Adopting the methodology of Pan and Guo (2023), this study defines a dummy variable, ESGDUM, which takes the value of 1 if a firm receives a Bloomberg ESG rating and 0 otherwise. The ESGDUM variable serves as the dependent variable, while the ratio of the number of other listed companies in the same industry that have received an ESG rating to the total number of firms in that industry (ESGMean) is employed as the exclusion restriction variable. Probit regression is conducted with ESGDUM as the dependent variable, alongside ESGMean and control variables such as firm market value. After computing the inverse Mills ratio (IMR), it is incorporated into model Equation (1) for the second-stage regression. The results of the Heckman two-stage regression are presented in **Table 11**. In the second stage, column (2) indicates that, after controlling for industry and year fixed effects, the coefficient of the IMR is significantly positive at the 1% level, and the coefficient of green innovation is also significantly positive at the 1% level. This suggests that, after addressing the endogeneity potentially arising from the self-selection issue of ESG ratings, green innovation remains significantly positively correlated with corporate ESG performance, thereby validating hypothesis H1.

Table 11. Test results of Heckman two-stage.

Variables	**ESGDUM** **(1)**	**ESG** **(2)**
GI		0.213*** (13.52)
ESGMean	2.265*** (3.98)	
IMR		0.384*** (5.52)
Cons	10.246*** (3.27)	12.315*** (8.67)
Controls	Yes	Yes
Industry	No	Yes
Year	No	Yes
N	28,258	10,354
Adj-R^2	0.6309	0.7055

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

3) Explanatory variables replacement

The above hypotheses were tested for robustness by a variable substitution approach. According to the study of Huang and Chen (2022), Xu and Cui (2020), the explanatory variable, green innovation, was tested empirically with the number of green inventions independently applied by companies annually as a new explanatory variable, while other variables remained unchanged. As shown in **Table 12**, there exists a consistent and statistically significant positive correlation between green innovation and ESG, with a significance level of 1%. These findings align in conjunction with the previous test results; these findings further strengthen the reliability of the estimation for hypothesis 1.

Table 12. Regression results of alternative interpretive variables.

Variables	**ESG**
GI	0.283*** (4.18)
Mvc	3.361*** (19.31)
Thr	0.021*** (3.42)
Lev	−2.133*** (−4.22)
Bs	−0.029 (−0.67)
ROA	3.064*** (2.84)
ATO	−0.289 (−1.25)
Cons	19.989*** (12.76)
Industry	Control
Year	Control
N	10,354
Adj-R^2	0.7088
F	606.07

Note: ***, ** and * are significant at 1%, 5% and 10%, respectively.

4) Bootstrap method

This study additionally employs the bootstrap method to reevaluate the hypotheses 3 and 4, namely the mediating effects of financing constraints and analysts' attention. Drawing upon the research conducted by Wen and Ye (2014) and Wan et al. (2020), it is posited that a significant mediating or direct effect is established when the 95% confidence interval does not include zero. However, regarding the computing power of the econometric software, only the time effect is fixed in this section.

As can be seen in **Table 13**, for "Green innovation-financing constraints-ESG", the mediating and direct effects are [−0.099, −0.011] and [1.085, 1.348] at 95% confidence intervals respectively. 95% deviation-corrected confidence intervals are [−0.098, −0.021] and [1.086, 1.349]. All the aforementioned results, excluding the zero values, affirm the validity of hypothesis 3, thereby confirming the existence of

financing constraints' mediating effect on the association between green innovation and ESG information disclosure.

Table 13. Bootstrap test results of SA.

	Observed Coef.	**Bootstrap Std. Err.**	***P* [95% Conf. Interval]**		**BC [95% Conf. Interval]**	
Indirect effect	−0.056	0.022	−0.099	−0.011	−0.098	−0.021
Direct effect	0.241	0.067	1.085	1.348	1.086	1.349

As seen in **Table 14**, the mediating and direct effects for "Green innovation-analysts' attention-ESG" are [0.008, 0.034] and [0.439, 0.655], at the 95% confidence intervals, respectively. 95% deviation-corrected confidence intervals are [0.008, 0.035] and [0.391, 0.636]. It can be concluded that none of the above contains 0, which means that hypothesis 4 still holds. The results demonstrate the existence of analysts' attention's mediating effect on the connection between eco-innovation and ESG disclosure.

Table 14. Bootstrap test results of analysts' attention.

	Observed Coef.	**Bootstrap Std. Err.**	***P* [95% Conf. Interval]**		**BC [95% Conf. Interval]**	
Indirect effect	0.021	0.007	0.008	0.034	0.008	0.035
Direct effect	0.249	0.007	0.439	0.655	0.391	0.636

6. Conclusions and recommendations

The 20th National Congress Report in China highlights the importance of adopting sustainable practices and pursuing harmonious coexistence between humans and nature. This vision entails comprehensive green transformation and the collective effort to promote green development across all sectors of society. It is widely advocated for companies to protect the ecological environment, assume social responsibility, and enhance governance. To enhance ESG information disclosure's quality, considerable attention has been given to ESG indices.

This study empirically investigates the correlation between green innovation and ESG information disclosure. It also investigates the mediating mechanisms involving financing constraints and analysts' attention. The findings indicate a significant positive effect of green innovation on corporate ESG disclosure, particularly among companies in the maturity and decline stages of their life cycles. Moreover, financing constraints and analysts' attention act as mediators between green innovation and corporate ESG disclosure.

Moreover, this study examines variations in the enabling green innovation's effect on corporate ESG disclosure across different factors such as corporate ownership, size, industry nature, pollution level, and policy context. The results reveal that promoting eco-innovation has a more pronounced impact on ESG information disclosure among state-owned, large-scale, manufacturing, and highly polluting companies. Additionally, with the support of green development policies, green innovation's positive impact on corporate ESG disclosure is enhanced.

Notably, the robustness tests conducted in this study confirm the validity and reliability of the research findings.

First of all, this paper enriches the literature on green innovation's impact on company ESG information disclosure and provides a certain theoretical basis. Meanwhile, the conclusions of the study also offer many inspirations for company practice. Specifically, at the company level, the following measures are proposed. Firstly, the findings highlight the positive green innovation's impact on competitiveness and ESG information disclosure. Therefore, companies are encouraged to prioritize and invest in green innovation initiatives to enhance their competitive edge. By incorporating environmental protection practices into their operations, companies can align with the increasing demand for high-quality development, thereby gaining government support, fostering consumer loyalty, and establishing a favorable corporate image. In addition, companies should know that green innovation is not only a means to meet regulatory requirements but also an opportunity to address environmental challenges and contribute to sustainable development proactively. Embracing green innovation as an intrinsic aspect of their business strategy can lead to long-term success and create positive environmental and social impacts. Furthermore, companies are advised to engage in transparent and comprehensive ESG information disclosure. By effectively communicating their environmental, social, and governance practices, companies can build trust with stakeholders, attract responsible investors, and enhance their reputation in the market. Overall, the findings underscore the strategic importance of green innovation in improving competitiveness, attracting support, and building a positive corporate identity. Implementing these recommendations can position companies favorably in the evolving landscape of sustainable business practices. Therefore, companies should fully understand and position their green innovation strategies in sustainable management, consider green innovation as a new core competitiveness source, and seize the enormous development opportunities brought by green transformation. Investing in green innovation can create healthy competition among corporations and encourage more eco-friendly practices. This, in turn, can lead to improved ESG performance and help maintain a competitive edge in the industry. Besides, companies should build a high-quality of board decision-making system, enhancing the independence, standardizing the remuneration structure, increasing the proportion of institutional investors' shareholding and simultaneously improving board directors' independence to further strengthen the supervision power. To further promote ESG responsibilities, public awareness should be raised, and financial institutions, analysts, and the media should apply reputational pressure through external monitoring.

At for the government level, ESG-related regulators should accelerate the process of enhancing the ESG information disclosure and monitoring systems of listed companies and fostering a continuous improvement of ESG assessment techniques by third-party organizations. Build an ESG rating system with Chinese characteristics, enable ESG ratings to play a soft regulatory part in the market effectively, and promote the "establishment of a market-driven green innovation system." This will drive companies to actively take in green innovation initiatives and contribute to the attainment of the "Double Carbon" objective so that humans and nature can live harmoniously. Moreover, the government should make a clear distinction between

rewards and penalties for different ESG performances. Companies with high ESG ratings should be rewarded with certain preferential policies and material incentives, such as encouraging commercial banks to set up green funds, granting interest reductions and more exemptions, and accepting green channels, increasing green credit, and also implementing preferential tax policies. However, for companies with negative fulfillment of ESG responsibilities, penalties should be proposed more, such as setting a higher penalty for environmental violations and levying additional environmental taxes. Establishing an effective constraint mechanism to enhance corporate ESG information disclosure's quality voluntarily.

This paper carries both significance and limitations. Firstly, it contributes by examining corporate green innovation's impact on ESG information disclosure at the micro level. To advance this research area, future studies could broaden the scope by investigating additional factors that affect ESG disclosure from various angles. Secondly, regarding the heterogeneity analysis, this study categorizes dividing the sample into industries with high pollution intensity and industries with low pollution intensity, as well as manufacturing and non-manufacturing sectors. However, further disaggregation and examination of specific industries within these categories remain unexplored, presenting an avenue for further investigation and testing. Expanding the research to encompass a broader range of factors and conducting in-depth analyses within specific industries would provide a more comprehensive understanding of the complexities surrounding ESG disclosure and its relationship with corporate green innovation. The promotion of smart tax construction is an active endeavor in China. To this end, the country should utilize modern information technologies like big data, cloud computing, artificial intelligence, and blockchain to intelligently transform the existing tax collection and management system. This transformation should aim to establish a platform for the sharing of tax-related information between the government and enterprises, expand the scope of supervision of the Golden Tax Project to include more non-tax businesses, and create a tax risk identification and early warning system through the use of data analysis technology. The implementation of these measures will enhance the quality of the corporate information environment, mitigate agency conflicts, and encourage enterprises to increase capital investment in areas like environmental protection, social responsibility, and corporate governance to achieve high-quality development.

While the aforementioned paper offers valuable insights, it is not without limitations. Firstly, it tests the relationship between eco-innovation and corporate ESG (environmental, social, and governance) performance through financing constraints and analysts' attention. Future studies could delve into other mechanisms of action for a more thorough and comprehensive analysis. Secondly, the research focuses on analysing green innovation's impact on the ESG disclosure of Chinese listed companies at the micro level. Future studies should explore the influencing factors of ESG disclosure from a broader scope, such as expanding to other countries and regions. Furthermore, the paper conducts heterogeneity analysis by categorizing the sample into heavy and non-heavy pollution sectors, encompassing both manufacturing and non-manufacturing industries. However, it does not delve into further industry-specific subdivisions. Subsequent research endeavors could delve deeper into this domain, conducting thorough exploration and testing within specific industries.

Finally, this paper measures green innovation's level through the number of green invention applications and green patent applications, owing to data availability. Future research could measure green innovation's level through other means to examine its impact on corporate ESG disclosure.

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