

Empirical research on the effect of environmental, social and governance (ESG) rating on green innovation of Chinese A-share listed companies

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Abstract

Purpose – China's economy is now focused on high-quality, green growth. The Environmental, Social and Governance (ESG) framework assesses corporate sustainability across ESG dimensions, balancing economic value with sustainability. Green innovation integrates economic performance with social and environmental responsibilities, aligning with ESG. However, the impact of ESG evaluation on promoting corporate green innovation has been rarely studied.

Design/methodology/approach – To deeply explore the relationship between ESG evaluation and corporate green innovation, this study uses a set of panel data from 732 Chinese A-share listed companies from 2014 to 2022 to run fixed-effect regressions. The one-year lagged data of green innovation is used to deal with potential endogeneity issue.

Findings – The study shows that ESG evaluation significantly enhances green innovation. Through heterogeneity analysis of equity nature (state-owned enterprises and non-state-owned enterprises), it is found that the effect of ESG evaluation on green innovation is more pronounced in state-owned enterprises. Further research indicates that ESG evaluation significantly promotes green innovation overall by guiding firms to increase their innovation investment.

Originality/value – To the best of the authors' knowledge, this study is among the first to examine ESG evaluation's impact on corporate green innovation in Chinese A-share companies, by exploring research and development investment as a mediator and corporate equity nature as a moderator, addressing key gaps in the literature.

Keywords ESG rating, Equity nature heterogeneity, Green innovation, Chinese companies

Paper type Research paper

1 Introduction

With the rapid development of the global economy and the drive of high energy consumption, the ecological environment faces continuous deterioration challenges, and the concept of "green sustainable development" has become increasingly prominent. Currently, China's economy has entered a new stage of high-quality development. Promoting green development is not only a necessary requirement for achieving high-quality development but also an important path for building a "Beautiful China" (Zhang and Chen, 2023).



The Chinese Government has explicitly stated the need to improve fiscal, financial, investment, pricing policies and standard systems that support green development, develop green low-carbon industries, perfect the market-based allocation system for resource and environmental elements and accelerate the research, development and promotion of advanced energy-saving and carbon-reduction technologies (Liu and Lyu, 2022; Tan and Zhu, 2022). In this context, it is crucial to optimize institutional design and policy incentives to encourage companies to proactively participate in green innovation and inject new momentum into green development.

Companies play a crucial role in achieving coordinated economic, environmental and social development through green innovation, which integrates economic performance with corporate social responsibility and environmental objectives (Tolliver *et al.*, 2021; Takalo and Tooranloo, 2021; Khan and Liu, 2023). As green innovation aligns inherently with Environmental, Social and Governance (ESG) principles, ESG evaluation internalizes social and environmental responsibilities into corporate value maximization, driving transformation and development (Xu *et al.*, 2021). The ESG framework, proposed by the United Nations, addresses the challenge of achieving balanced sustainable development (Zhou *et al.*, 2023; Lee, 2024). ESG evaluation has been shown to reduce capital costs, enhance corporate value and leverage governance advantages to mitigate environmental risks (Wang *et al.*, 2023; Mohy-ud-Din, 2024). However, studies on whether ESG evaluation promotes green innovation remain scarce (Mukhtar *et al.*, 2023). Furthermore, ownership structure significantly influences technological innovation, suggesting the need to explore how ownership heterogeneity moderates the ESG–green innovation relationship (Wright, 2017; Wang and Sun, 2022).

This study aims to address two critical questions:

- Q1. Does ESG evaluation significantly promote green innovation among Chinese A-share listed companies?
- Q2. How does corporate equity heterogeneity moderate the relationship between ESG evaluation and green innovation?

By answering these questions, this research seeks to fill existing gaps in the literature, provide empirical evidence for China's green sustainable development and offer references for the government to formulate and implement innovation-driven high-quality development policies.

This study's unique contribution lies in its systematic analysis of the relationship between ESG evaluation and corporate green innovation, focusing particularly on the moderating effect of equity heterogeneity and the mediating role of research and development (R&D) investment. Using panel data from 732 Chinese A-share listed companies between 2014 and 2022, combined with fixed-effect (FE) regression models, this study provides robust empirical evidence. It not only addresses gaps in the current literature but also offers theoretical support for companies to implement ESG principles and enhance innovation capabilities, while providing valuable insights for policymakers to guide corporate green transformation effectively.

2 Literature Review and Hypotheses

Neoclassical economic theory posits that the ultimate goal of a firm is to maximize its value (Gordon, 1992). This objective drives firms to constantly seek ways to enhance their competitiveness and market position. Continuous innovation is seen as a key pathway for firms to improve their sustainable development capabilities and achieve long-term growth and excess profits (Amore *et al.*, 2013). Through continuous innovation, firms can make

significant progress in technological advancement, product improvement and market expansion, thereby standing out in fierce market competition (Broadstock *et al.*, 2020). However, continuous innovation is a long-term and complex process of learning and accumulation, involving substantial inputs of human, material and financial resources. These inputs are very costly, with future returns so uncertain, not to mention the immediate benefits; all of which greatly dampens enthusiasm for innovation (Di-Simone *et al.*, 2022). In the process of seeking existing benefits, companies are prone to investing in short-term projects with cycles that involve less risk and faster results. Typical examples include marketing activities, short-term financing and product improvement involving investment. Such short-term behaviors may bring some economic returns in the short run but often result in insufficient core competitiveness and hinder sustainable development (Hughes *et al.*, 2021). It is then that the contradiction between long-term growth and excess profits, innovation and seeking immediate benefits may trap firms in this dilemma and finally unbalance long-term development against short-term gains.

Green innovation, as a distinct form of innovation, goes beyond traditional innovation by emphasizing not only economic benefits but also social responsibility and environmental protection (Chen, 2008). While traditional innovation focuses primarily on improving product performance and market competitiveness, green innovation extends this focus to include efficient resource utilization and environmental pollution reduction (Chavira *et al.*, 2023). For instance, green innovation encompasses improvements in energy efficiency, the application of cleaner production technologies and the exploration of circular economy models (Shamzuzoha *et al.*, 2022). Studies have shown that green innovation not only enhances a firm's long-term competitiveness in the market but also promotes sustainability across the supply chain by reducing carbon emissions and conserving resources (Yang *et al.*, 2024). Moreover, green innovation is particularly transformative for traditional manufacturing processes, as it integrates digital and intelligent technologies to significantly lower production costs, increase efficiency and minimize environmental impacts (He *et al.*, 2024). Therefore, exploring the drivers of green innovation and its relationship with ESG evaluation holds significant theoretical value and provides practical insights for developing targeted policies and strategies for both firms and governments.

The long-term pursuit of corporate value maximization, regardless of environmental and social responsibilities, has resulted in continuous ecological degradation and unsustainable economic and social development. With the aggravation of global environmental problems and improvements in awareness of social responsibility, this type of corporate practice aiming solely at economic interests has been increasingly criticized and questioned (Chen *et al.*, 2023; Lee *et al.*, 2024). The performance evaluation of enterprises with regard to ESG organically unites the benefits in economic terms, environmental responsibility and social responsibility from an internal perspective. It internalizes environmental and social responsibilities and puts forward new ideas and methods for realizing coordinated, sustainable corporate development and ecological protection (Zheng *et al.*, 2022; Jin and Lei, 2023). Research (Zheng *et al.*, 2022; Jin and Lei, 2023) shows that ESG evaluation or ESG advantages can not only enhance the market value of firms but also improve financial performance and investment returns. For example, implementing sound environmental management measures can reduce operating costs and improve resource utilization efficiency; actively fulfilling social responsibility can enhance brand image and market competitiveness. In addition, ESG performance is positively correlated with the quantity and quality of innovation outputs, helping to improve innovation quality and efficiency (Hang *et al.*, 2023; Yu *et al.*, 2024).

However, despite its growing importance, research on ESG evaluation and corporate green innovation remains limited and inconsistent. Some studies suggest a significant positive relationship between ESG performance and innovation activities (Liu and Lyu, 2022; Wang *et al.*, 2023), while others argue that this relationship is nonlinear (Broadstock *et al.*, 2020; Yang *et al.*, 2024). In addition, existing research (Zhang and Jin, 2022; Liu and Xu, 2024) has largely overlooked how the heterogeneity of corporate equity nature [e.g. state-owned enterprises (SOEs) vs non-state-owned enterprises (non-SOEs)] moderates the impact of ESG evaluation on green innovation. Moreover, although prior studies acknowledge the role of R&D investment in driving innovation (Xu *et al.*, 2021; Jin and Lei, 2023), few have explored its mediating effect in the context of ESG-driven green innovation. These gaps highlight the need for further investigation into the mechanisms through which ESG evaluation promotes green innovation and how specific firm characteristics, such as equity heterogeneity, influence this relationship.

To address these gaps, this study explores the relationship between ESG evaluation and green innovation among Chinese A-share listed companies, focusing on two key aspects: the moderating role of corporate equity heterogeneity and the mediating role of R&D investment. By doing so, this research not only provides empirical evidence on the effectiveness of ESG evaluation in driving green innovation but also uncovers the mechanisms through which it operates, offering practical insights for both policymakers and corporate managers.

Corresponding policies and systems aimed at encouraging firms to engage in green innovation have been introduced by the government, with a view to guiding innovative practices in environmental protection and resource conservation through policy guidance and support. For example, it provides various incentives, such as tax breaks, R&D subsidies and technical support, to influence firms' investments in green technology R&D and applications (Xu *et al.*, 2021; Zhang, 2023). The public also assumes the role of an important supervisor in green transformation and development regarding environmental responsibility in firms through consumer-choice-induced awareness, supervision brought about by public opinion and the activities of social organizations. More importantly, firms can use ESG advantages to gain more investor support and, at the same time, policy, funding and resource support from the government, thus decreasing green innovation costs and dispersing innovation risks (Cao *et al.*, 2024). Particularly under heavy investment pressure, investors are increasingly valuing ESG performance in general as a major indicator in assessing the long-term investment value and risks of firms. Accordingly, good ESG performance may increase the attractiveness of more investment funds and enhance market reputation and competitiveness, thereby increasing the exuberance and success rate of green innovation. As such, the *H1* is proposed:

H1. ESG rating has a positive effect on green innovation in Chinese firms.

The current research into how ESG evaluation would affect green innovation in Chinese companies is likely to be divided due to firm heterogeneity. One important heterogeneity factor is the difference in equity nature: SOEs versus non-SOEs. As a rule, SOEs enjoy prominent advantages in resource acquisition, policy support and social responsibility. These advantages help SOEs to make full use of government policies, funds and resources in implementing ESG evaluation issues, thereby mobilizing green innovation more comprehensively (Zhang and Jin, 2022). Entailing their hegemonic position in the economic and social systems at home, SOEs often receive broader and deeper policy inclinations and support measures. For example, environmental subsidies for SOEs could be plentiful in number, together with technology R&D funds and tax incentive policies. Much of the cost

and risk of green innovation can, therefore, be reduced with this support, which helps to raise their passion and efficiency in pursuing green innovation (Liu and Xu, 2024). Furthermore, as SOEs are more under pressure from society and politics to meet the requirements of social and environmental responsibilities, they will be more proactive in actively responding to ESG evaluation needs for corporate image and social recognition considerations in contrast to private enterprises.

In contrast, non-SOEs are relatively in a disadvantageous position in resource acquisition and policy support, hence bringing about a less pronounced ESG evaluation impact on green innovation compared with SOEs (Zhang and Jin, 2022). Non-SOEs are more driven by pressures of market competition and have to focus more on short-term economic benefits and market improvements, probably investing less in green innovation as compared to those firms with ESG evaluation (Liu and Xu, 2024). Given the lack of sufficient policy support and resource guarantee, non-SOEs may be confronted with more serious financial pressure and risk when promoting green innovation, which will affect their motivation and reality. Therefore, considering differences in ownership, one can appreciate that ESG evaluation has different impacts on the green innovation of different enterprise types. Based on this, the H2 is proposed:

- H2. The impact of ESG evaluation on green innovation varies by ownership. Compared to non-state-owned enterprises, ESG evaluation has a stronger positive effect on the green innovation of state-owned enterprises.

3 Research design

3.1 Sample selection and data sources

This study investigates the impact of ESG performance on green innovation by using a panel data set of Chinese A-share listed companies [1] on the Shanghai and Shenzhen Stock Exchanges from 2014 to 2022. The selected period ensures data availability and reflects recent developments in China's ESG disclosure practices and green innovation policies, including the implementation of the "13th Five-Year Plan" and the announcement of the "Dual Carbon" targets. ESG data before 2014 are relatively scarce and inconsistent, which makes 2014 a practical starting point.

To ensure the reliability of the sample, several exclusion criteria are applied. Companies in the financial industry (e.g. banks, securities and insurance firms) are excluded due to their distinct financial structures and ESG evaluation frameworks. Firms under Special Treatment (ST) [2], delisted firms and companies with missing values for key variables, such as ESG scores, green patents, or leverage, during the observation period are also removed. After applying these criteria, the final sample comprises 6,588 firm-year observations from 732 listed companies, spanning diverse industries, ownership types and regions.

This study uses data from three key sources:

- (1) ESG ratings: Obtained from Bloomberg, which uses a standardized framework covering 21 topics and 122 subindicators across ESG dimensions. Bloomberg ESG scores are widely adopted in both academic and professional research due to their transparent methodology, broad coverage and consistent evaluation criteria. In the Chinese context, Bloomberg provides comprehensive ESG data for A-share companies, facilitating comparability across firms and years. This credibility and granularity make Bloomberg scores particularly suitable for longitudinal panel analysis.

- (2) Green patent data: Collected from the China Research Data Service Platform, which classifies green patents into invention and utility models in alignment with international definitions of green innovation.
- (3) Financial and governance data: Extracted from the China Stock Market & Accounting Research (CSMAR) database, which offers extensive firm-level financial and governance indicators widely used in empirical research on Chinese listed companies.

3.2 Variable definitions

The dependent variable in this study is corporate green innovation. Given the broad nature of innovation and the lack of a universally accepted metric for green innovation, this study adopts the total number of authorized green patents as a proxy, following prior research (Zhang and Chen, 2023; Zhu and Yang, 2024). Green patents are defined as those reflecting innovations in areas such as environmental protection, energy efficiency, emission reduction and resource recycling. This indicator provides an objective measure of a firm's actual achievements in green technology. To account for the time lag between patent application and authorization, a one-period lag [3] is applied to green patent data. This approach better captures the temporal relationship between ESG performance and subsequent innovation outcomes. More importantly, the use of lagged green innovation helps to mitigate potential endogeneity concerns, such as reverse causality and omitted variable bias, thereby enhancing the robustness of the empirical analysis.

The key explanatory variable is the Bloomberg ESG rating, which reflects a firm's performance in ESG dimensions. The ESG score is derived from 21 primary topics and 122 subindicators and ranges from 0 to 100. A higher score denotes stronger performance in sustainability-related practices. Bloomberg ESG ratings have been widely adopted in academic research due to their methodological transparency and data availability (Zhang and Chen, 2023; Zhu and Yang, 2024).

The moderating variable in this study is the firm's ownership nature. Drawing on Zhang and Jin (2022) and Lian *et al.* (2023), a dummy variable is constructed: firms are coded as 1 if state-owned, and 0 otherwise. This enables an examination of whether ESG performance influences green innovation differently between SOEs and non-SOEs, and helps to identify the moderating effect of ownership structure.

Several control variables are included to account for firm-specific heterogeneity:

- Firm size (SIZE) represents the natural logarithm of total assets and is a key determinant of innovation capacity. Larger firms often possess more financial and human resources to support innovation but may also face structural inertia and managerial complexity that can hinder innovation flexibility (Lian *et al.*, 2023).
- Tobin's Q is used as a proxy for market valuation and growth expectation. Firms with higher Tobin's Q are typically more motivated to invest in innovation to sustain competitive advantage, though they may also be influenced by short-term performance pressures that could limit long-term innovation investments (Lian *et al.*, 2023).
- Financial constraint (FC) reflects a firm's difficulty in obtaining external financing. While financial constraints may restrict green R&D spending, they can also compel firms to use their limited funds more efficiently, potentially enhancing innovation output (Zhang and Liu, 2023).

- Leverage is measured as the debt-to-asset ratio and serves as a contemporaneous indicator of financial structure. Excessive leverage can reduce the resources available for innovation, while moderate leverage may stimulate firms to pursue innovation as a means of improving profitability and repayment capacity (Liu and Lyu, 2022).
- Liquidity, measured by the current ratio (CUR), indicates the firm's short-term solvency. Higher liquidity may facilitate investment in innovation, though overly high liquidity might suggest underutilization of current assets (Zhang and Jin, 2022).
- Total asset turnover (TAR) captures operational efficiency. Efficient use of assets may generate more internal funds for innovation, though it can also lead to operational strain that limits innovation space (Zhang and Jin, 2022).
- Ownership concentration indicates the distribution of shares among major shareholders. While concentrated ownership may improve decision-making efficiency and innovation focus, it may also reduce diversity in strategic inputs (Lian et al., 2023).
- Board independence (BOI) is measured by the proportion of independent directors. A more independent board is often linked to better governance and innovation oversight, though excessive independence may slow down strategic responsiveness (Liu and Lyu, 2022).

3.3 Establishment of research model

Drawing on prior empirical studies (Lian et al., 2023; Zhang and Chen, 2023), this research adopts a panel data regression framework to examine the effect of ESG performance on corporate green innovation. The data set includes multiyear (2014–2022) and multifirm (732 listed companies) observations, capturing both cross-sectional and temporal variation. Such a structure makes panel modeling especially appropriate, as it allows the control of unobserved firm-specific heterogeneity and time-fixed effects. This approach helps mitigate omitted variable bias and enhances the internal validity of the estimated relationships (Zhang and Chen, 2023). In addition, the multiperiod design facilitates an analysis of dynamic changes, enabling the investigation of ESG's long-term impact on firms' innovation behavior (Lian et al., 2023).

To further address potential endogeneity, particularly reverse causality between ESG performance and innovation outcomes, this study uses lagged ESG scores as explanatory variables. This design ensures temporal sequencing between predictor and outcome, improving causal inference and reducing simultaneity bias. A Hausman specification test is conducted to determine the appropriate estimation strategy, with results supporting the use of the FE model over the random effects (RE) alternative. Consequently, the FE model is used to control for time-invariant firm characteristics. Moreover, robust standard errors clustered at the firm level are applied to correct for potential heteroskedasticity and serial correlation, thereby reinforcing the robustness and reliability of the regression estimates.

In order to test *H1*, the following model equation (1) is established:

$$GI_{i,t+1} = \alpha + \beta_1 LnESG_{i,t} + \beta_2 \sum Control + \varepsilon_{i,t} \tag{1}$$

To test *H2*, the following model equation (2) is established, using the interaction term of ESG rating (LnESG) and equity nature (EQN) to test the moderating effect of equity nature:

$$GI_{i,t+1} = \alpha + \beta_1 LnESG_{i,t} + \beta_2 EQN_{i,t} + \beta_3 LnESG_{i,t} * EQN_{i,t} + \beta_4 \sum Control + \varepsilon_{i,t} \quad (2)$$

Variable definitions are displayed in Table 1.

4 Empirical results

4.1 Descriptive statistics

Table 2 reports the statistical descriptions of the main variables. The logarithm of the ESG evaluation has a minimum value of 2.376, a maximum value of 4.265, an average value of 3.358 and a standard deviation of 0.282, indicating low volatility. The minimum value of corporate green innovation is 0, and the maximum value is 7.052 (original value being 1,154 items), with an average value of 1.103 and a standard deviation of 1.323, indicating significant differences in green innovation among companies. The statistical descriptions of the other variables also reflect their levels to a certain extent. In addition, this research performed winsorize treatment on three variables: Tobin's Q (TOBQ), financial leverage (FIL) and current ratio (CUR). This treatment limits the effect of extreme values in the data by transforming the extreme values to reduce their influence. In this winsorizing process, the technique adjusts the lowest 5% of the observations to the 5th percentile value and the highest 5% of the observations to the 95th percentile value.

4.2 Unit root test

Table 3 reports the unit root test results for green innovation and ESG evaluation. Because this study uses short panel data, Fisher Augmented Dickey-Fuller (ADF) and Im, Pesaran, and Shin (IPS) methods were used to perform unit root tests on green innovation and ESG evaluation, respectively.

Table 1. Variable definitions

Category	Variable name	Symbol	Definitions
Dependent variable	Green innovation	GI_{t+1}	Natural logarithm of (total number of green patents grants + 1) Green patents including both green invention patents and green utility model patents
Independent variable	ESG rating	LnESG	Natural logarithm of Bloomberg ESG rating of Chinese-listed firms
Moderating variable	Equity nature	EQN	If the sampling firm is state-owned, EQN = 1; otherwise, if the sampling firm is non-state-owned, EQN = 0
Controlling variables	Firm size	SIZE	Natural logarithm of firm total assets
	Tobin's Q	TOBQ	Total market value/total asset value
	Financial constraints	FC	The size-age index constructed by Hadlock and Pierce (2010) : $SA = -0.737 * Size + 0.043 * Size^2 - 0.040 * Age$
	Financial leverage	FIL	FIL = Total liabilities/total assets
	Current ratio	CUR	CUR = Current assets/current liabilities
	Total asset turnover	TAR	TAR = Business revenue/total assets
	Ownership concentration	OWC	OWC = sum of the top ten largest shareholders' holding percentage
	Board independence	BOI	BOI = number of independent directors/total number of people in the board

Source(s): [Hadlock and Pierce, 2010](#); [Liu and Lyu, 2022](#); [Zhang and Jin, 2022](#); [Lian et al., 2023](#); [Zhang et al., 2023](#); [Zhang and Chen, 2023](#)

Table 2. Descriptive statistics to variables

Variable	Mean	Median	Maximum	Minimum	Std. dev.	Observations
GI_{t+1}	1.103	0.693	7.052	0.000	1.323	6,588
LnESG	3.358	3.363	4.265	2.376	0.282	6,588
EQN	0.585	1.000	1.000	0.000	0.493	6,588
SIZE	23.306	23.220	28.502	16.161	1.280	6,588
TOBQ	1.812	1.456	4.569	0.900	0.982	6,588
FC	-3.846	-3.865	-2.109	-4.732	0.268	6,588
FIL	0.500	0.513	0.814	0.157	0.189	6,588
CUR	1.646	1.345	4.546	0.448	1.044	6,588
TAR	0.650	0.529	8.601	0.003	0.555	6,588
OWC	0.579	0.584	0.975	0.133	0.155	6,588
BOI	0.375	0.364	0.800	0.200	0.058	6,588

Note(s): GI_{t+1} = the one-year lagged green innovation, LnESG = natural logarithm of ESG rating, EQN = equity nature, SIZE = firm size, TOBQ = Tobin's Q, FC = financial constraints, FIL = financial leverage, CUR = current ratio, TAR = total asset ratio, OWC = ownership concentration, BOI = board independence

Source(s): Created by the authors

Table 3. Unit root test

Variable	Fisher ADF test		IPS test	
	Statistic	p-value	Statistic	p-value
GI_{t+1}	1,282.87***	0.005	-1.418*	0.078
LnESG	5,252.43***	0.000	-105.93***	0.000

Note(s): GI_{t+1} = the one-year lagged green innovation, LnESG = natural logarithm of ESG rating,

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

Source(s): Created by the authors

The ADF test results show that they are all significant at the 1% level. Meanwhile, the IPS test results are significant at the 10% level. As such, both green innovation and ESG evaluation are stationary series, strongly rejecting the existence of unit roots.

4.3 Baseline regressions

Table 4 presents the baseline regression results examining the effect of ESG evaluation on corporate green innovation using pooled ordinary least squares regression (OLS), fixed effects (FE) and random effects (RE) models. Across all specifications, ESG rating is positively and significantly associated with green innovation, with coefficients significant at the 0.1% level. These findings offer robust empirical support for *H1*, which posits a positive relationship between ESG evaluation and corporate green innovation. This result aligns with prior studies such as Wang and Sun (2022) and Zhu and Yang (2024), which also suggest that firms with higher ESG performance are more likely to engage in innovation activities aligned with environmental and social objectives. The positive link underscores the role of ESG as an internalized mechanism that not only enhances corporate responsibility but also stimulates sustainable innovation practices.

In terms of control variables, corporate green innovation is significantly positively correlated with the company's asset size (SIZE), market value (TOBQ) and financing constraints (FC). Conversely, green innovation is significantly negatively correlated with the

Table 4. Regression of green innovation and ESG rating

Variables	Pooled-OLS model	Dependent variable: GI_{t+1}	
		Fixed-effect model	Random-effect model
LNESG	0.898*** (0.057)	0.232*** (0.066)	0.532*** (0.047)
SIZE	0.387*** (0.017)	0.263*** (0.026)	0.439*** (0.020)
TOBQ	0.073*** (0.018)	0.054*** (0.016)	0.046*** (0.014)
FC	0.648*** (0.062)	0.869*** (0.151)	-0.167 (0.089)
FIL	-0.040 (0.114)	-0.251* (0.122)	-0.314** (0.117)
CUR	-0.107*** (0.020)	-0.029 (0.019)	-0.029 (0.018)
TAR	0.049 (0.026)	0.041 (0.033)	0.117*** (0.030)
OWC	-1.035*** (0.098)	-0.216 (0.125)	-0.450*** (0.115)
BOI	0.046 (0.246)	0.155 (0.220)	0.233 (0.216)
Constant	-7.814*** (0.503)	-2.351* (0.993)	-11.331*** (0.566)
Hausman test	Chi-square statistic = 76.523***, $p < 0.001$. Fixed-effect model used		
R-square	0.260	0.818	0.191
F-statistics	256.379***, $p < 0.001$	35.157***, $p < 0.001$	172.484***, $p < 0.001$

Note(s): Dependent variable: GI_{t+1} = the one-year lagged green innovation, independent variable: LnESG = natural logarithm of ESG rating. Controlling variables: SIZE = firm size, TOBQ = Tobin's Q, FC = financial constraints, FIL = financial leverage, CUR = current ratio, TAR = total asset ratio, OWC = ownership concentration, BOI = board independence. Standard errors are in brackets. Periods included: 9. Cross sections include: 732. Total panel observations: 6,588. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source(s): Created by the authors

company's current ratio (CUR), financial leverage (FIL) and ownership concentration (OWC). The correlation between green innovation and asset turnover ratio (TAR) and board independence (BOI) is not significant. These results indicate that different corporate characteristics have varying impacts on green innovation, which needs to be considered when formulating policies and corporate strategies.

4.4 Corporate equity nature heterogeneity analysis

SOEs constitute the backbone of China's national economy and typically serve broader political and social functions beyond profit maximization. In contrast, non-SOEs are more market-oriented and efficiency-driven. To examine the heterogeneity in the ESG–innovation relationship across ownership types, this study classifies firms into SOEs (EQN = 1) and non-SOEs (EQN = 0) following the ownership structure definitions in the CSMAR database.

An interaction term between ESG rating and ownership type is constructed, and the results are reported in Table 5. The coefficient of the interaction term is positive and statistically significant at the 0.1% level in both FE and RE models. This finding indicates that ESG evaluation has a stronger positive effect on green innovation in SOEs compared to non-SOEs, providing empirical support for *H2*. These results are consistent with Lian *et al.* (2023), who argue that SOEs are more responsive to national strategic goals such as green development. Moreover, the governance structure and public accountability of SOEs may amplify the influence of ESG practices on innovation. In contrast, non-SOEs may prioritize short-term returns, thereby limiting the extent to which ESG evaluation drives green innovation.

4.5 Robustness test

To verify the stability of the impact of ESG evaluation on corporate green innovation, this study uses the variable substitution method for robustness testing. Patent applications are the

Table 5. Corporate equity nature heterogeneity analysis

Variables	Pooled-OLS model	Dependent variable: GI_{t+1}	
		Fixed-effect model	Random-effect model
LNESG	0.748*** (0.084)	0.085 (0.077)	0.317*** (0.063)
EQN	-0.756* (0.343)	-0.616** (0.231)	-0.961*** (0.229)
LNESG*EQN	0.262* (0.102)	0.248*** (0.066)	0.341*** (0.067)
SIZE	0.383*** (0.017)	0.282*** (0.026)	0.449*** (0.020)
TOBQ	0.082*** (0.018)	0.059*** (0.016)	0.052*** (0.014)
FC	0.657*** (0.062)	0.823*** (0.151)	-0.179* (0.089)
FIL	-0.044 (0.114)	-0.249* (0.122)	-0.312** (0.116)
CUR	-0.108*** (0.020)	-0.031 (0.019)	-0.032** (0.018)
TAR	0.046 (0.026)	0.039 (0.033)	0.111*** (0.030)
OWC	-1.098*** (0.099)	-0.253* (0.126)	-0.523*** (0.116)
BOI	-0.050 (0.247)	0.139 (0.221)	0.174 (0.216)
Constant	-7.214*** (0.536)	-2.583** (0.995)	-10.943*** (0.572)
Hausman test	Chi-square statistic = 78.150***, $p < 0.001$. Fixed-effect model used		
R-square	0.262	0.819	0.196
F-statistics	212.645***, $p < 0.001$	35.225***, $p < 0.001$	145.329***, $p < 0.001$

Note(s): Dependent variable: GI_{t+1} = the one-year lagged green innovation, independent variable: LnESG = natural logarithm of ESG rating, moderating variable: EQN = equity nature, controlling variables: SIZE = firm size, TOBQ = Tobin's Q, FC = financial constraints, FIL = financial leverage, CUR = current ratio, TAR = total asset ratio, OWC = ownership concentration, BOI = board independence. Standard errors are in brackets. Periods included: 9. Cross sections include: 732. Total panel observations: 6,588. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source(s): Created by the authors

precursor to patent grants, and applications do not necessarily result in grants. According to the 2022 annual report released by the China National Intellectual Property Administration (CNIPA), the number of invention patent applications in China in 2022 was 1.619 million, while the number of invention patents granted was 798,000, with a grant rate of 49.3%. This indicates that less than half of the patent applications were granted. Although most patent applications were not granted in the same year, the number of patent applications still reflects the innovation capability of enterprises. Therefore, this study replaces the number of granted green patents (GI_{t+1}) with the number of green patent applications (GIA_{t+1}) and conducts empirical analysis.

The robustness test results reported in Table 6 (Model 1–Model 3) show that corporate green innovation is positively related with ESG evaluation, and this effect is significant at the 0.1% level. This indicates that improvements in ESG evaluation significantly enhance corporate green innovation. Therefore, the impact of ESG evaluation on corporate green innovation is significant and stable, supporting H1. However, in Model 3, the coefficient of the interaction term between equity nature and ESG evaluation is positive but not significant, indicating that H2 is not supported in the robustness test.

4.6 Further empirical tests

R&D investment is the driving force and source of innovation activities and is a key factor in corporate innovation. Innovation is a continuous accumulation process, characterized by long-term and high-risk, requiring significant resources, especially substantial R&D funding (Xu et al., 2021; Zhu and Yang, 2024). Therefore, companies need to obtain a large amount of internal and external funds to support long-term innovation activities. The ESG concept is

Table 6. Robustness test

Variables	Dependent variable: GIA_{t+1}		
	Model (1)	Model (2)	Model (3)
LNESG	0.251*** (0.057)	0.251*** (0.057)	0.239*** (0.067)
EQN		0.078 (0.058)	0.010 (0.201)
LNESG*EQN			0.020 (0.058)
SIZE	0.099*** (0.022)	0.100*** (0.022)	0.102*** (0.023)
TOBQ	0.057*** (0.014)	0.058*** (0.014)	0.058*** (0.014)
FC	0.106 (0.130)	0.102 (0.130)	0.099 (0.131)
FIL	−0.095 (0.106)	−0.096 (0.106)	−0.096 (0.106)
CUR	0.000 (0.016)	0.001 (0.016)	0.000 (0.016)
TAR	0.035 (0.028)	0.035 (0.028)	0.035 (0.028)
OWC	−0.100 (0.108)	−0.087 (0.191)	−0.093 (0.109)
BOI	0.070 (0.190)	0.085 (0.191)	0.080 (0.191)
Constant	−2.212* (0.859)	−2.313** (0.863)	−2.310** (0.863)
Hausman test (Chi-sq. statistic)	66.563***, $p < 0.001$	67.116***, $p < 0.001$	70.129***, $p < 0.001$
	Fixed-effect used	Fixed-effect used	Fixed-effect used
R-square	0.795	0.795	0.795
F-statistics	30.212***, $p < 0.001$	30.178***, $p < 0.001$	30.134***, $p < 0.001$

Note(s): Dependent variable: GIA_{t+1} = the one-year lagged green innovation (total number of green patents applications), independent variable: $LnESG$ = natural logarithm of ESG rating, moderating variable: EQN = equity nature, controlling variables: $SIZE$ = firm size, $TOBQ$ = Tobin's Q, FC = financial constraints, FIL = financial leverage, CUR = current ratio, TAR = total asset ratio, OWC = ownership concentration, BOI = board independence. Method: cross-section-fixed and year-fixed effects. Standard errors are in brackets. Periods included: 9. Cross sections include: 732. Total panel observations: 6,588. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source(s): Created by the authors

essentially a green development concept with sustainable development as its fundamental goal. It can influence corporate innovation investment in two ways: First, ESG evaluation is highly endorsed by the government and widely accepted by the public, which compels companies to increase their R&D investment, directly driving corporate innovation from within. Second, a high ESG evaluation projects a positive corporate image externally, attracting more external resource support and long-term investments, thereby providing companies with ample external funds to carry out innovation activities, indirectly promoting corporate innovation. Existing research (Wang *et al.*, 2023; Rauf *et al.*, 2024) also shows that fulfilling ESG responsibilities can promote increased R&D investment by companies. From the above analysis, it can be seen that ESG evaluation directly or indirectly generates an expansion effect on R&D investment, influencing corporate innovation through continuous increases in R&D investment. Based on this, it can be considered that R&D investment plays a mediating role in the process of ESG evaluation affecting corporate green innovation. In other words, ESG evaluation impacts corporate green innovation through the intrinsic mechanism of increasing R&D investment.

To test this intrinsic mechanism, following the experience of existing research, a mediation effect model is constructed as shown in equations (3) and (4):

$$LnRD_{i,t} = \alpha + \beta_1 LnESG_{i,t} + \beta_2 \sum Control + \varepsilon_{i,t} \quad (3)$$

$$GI_{i,t+1} = \alpha + \beta_1 LnESG_{i,t} + \beta_2 LnRD_{i,t} + \beta_3 \sum Control + \varepsilon_{i,t} \quad (4)$$

Table 7 presents the empirical results of the mediation test. ESG evaluation is found to have a significant positive effect on corporate green innovation, with a coefficient significant at the 1% level. After incorporating R&D investment as a mediating variable, the coefficient of ESG on green innovation decreases from 0.232 to 0.190 but remains statistically significant at the 1% level. Meanwhile, the coefficient of R&D investment is positive and significant at the 0.1% level. These results indicate that R&D investment partially mediates the relationship between ESG evaluation and green innovation, providing support for the proposed theoretical pathway. This finding is consistent with prior research (e.g. Wang *et al.*, 2023; Zhu and Yang, 2024), which suggests that ESG practices can foster innovation by enhancing firms' internal resource allocation and increasing their commitment to long-term R&D. The mediating role of R&D highlights the internal mechanism through which ESG contributes to sustainable innovation outcomes.

5 Discussions and conclusions

5.1 Discussions

How to internalize corporate social and environmental responsibilities as integral parts of corporate value, practice ESG principles to promote the national innovation-driven development strategy and achieve green and sustainable development has become a major issue faced by both the state and enterprises. Numerous studies have examined the impact of ESG evaluation on corporate value, financial performance and investment and financing aspects, but few scholars have explored the impact of ESG evaluation on corporate green

Table 7. Mediating effect of R&D investment

Variables	Dependent variable: GI_{t+1}		
	Model (1)	Model (2)	Model (3)
LnESG		0.232*** (0.066)	0.190** (0.066)
LnRD			0.128*** (0.012)
SIZE	0.273*** (0.026)	0.263*** (0.026)	0.173*** (0.027)
TOBQ	0.058*** (0.016)	0.054*** (0.016)	0.047** (0.016)
FC	0.855*** (0.151)	0.869*** (0.151)	0.830*** (0.149)
FIL	-0.279* (0.122)	-0.251* (0.122)	-0.136 (0.122)
CUR	-0.031 (0.019)	-0.029 (0.019)	-0.021 (0.019)
TAR	0.043 (0.033)	0.041 (0.033)	0.011 (0.032)
OWC	-0.208 (0.125)	-0.216 (0.125)	-0.162 (0.124)
BOI	0.191 (0.220)	0.155 (0.220)	0.093 (0.218)
Constant	-1.874 (0.985)	-2.351* (0.993)	-2.631** (0.985)
Hausman test (Chi-sq statistic)	115.914***, $p < 0.001$	76.523***, $p < 0.001$	80.435***, $p < 0.001$
	Fixed-effect used	Fixed-effect used	Fixed-effect used
R-square	0.818	0.818	0.822
F-statistics	35.119***, $p < 0.001$	35.157***, $p < 0.001$	35.897***, $p < 0.001$

Note(s): Dependent variable: GI_{t+1} = the one-year lagged green innovation, independent variable: LnESG = natural logarithm of ESG rating, mediating variable: LnRD = natural logarithm of R&D investment, controlling variables: SIZE = firm size, TOBQ = Tobin's Q, FC = financial constraints, FIL = financial leverage, CUR = current ratio, TAR = total asset ratio, OWC = ownership concentration, BOI = board independence. Method: cross-section-fixed and year-fixed effects. Standard errors are in brackets. Periods included: 9. Cross sections include: 732. Total panel observations: 6,588. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source(s): Created by the authors

innovation and its internal mechanisms from the perspective of equity nature heterogeneity. This study empirically studies the impact of ESG evaluation on corporate green innovation using green innovation data and ESG evaluation data from 732 Chinese listed companies from 2014 to 2022. The research findings are as follows:

First, there is a significant positive correlation between corporate green innovation and ESG evaluation, meaning that an improvement in ESG evaluation positively impacts and significantly enhances corporate green innovation. As such, *H1* is supported. This finding is consistent with the works of [Wang and Sun \(2022\)](#) and [Zhu and Yang \(2024\)](#), which have also reported that positive ESG performance contributes to strengthen green innovation of Chinese companies. Corporate social and environmental responsibilities have become crucial components influencing corporate value, closely tied to a company's long-term survival and development in the market. Companies shall not only satisfy shareholders' interests but also consider the needs of other stakeholders such as employees, consumers, communities and the environment ([Wang and Sun, 2022](#)). This study found a significant positive correlation between corporate green innovation and ESG evaluation, indicating that the implementation of ESG principles helps enhance corporate green innovation levels. Good ESG performance are favorable to companies establish a better brand image and reputation, thereby attracting more resources and support, including recognition and resources from investors, customers and the government. These resource advantages can be translated into investments in R&D and innovation, thereby enhancing a company's innovation capability ([Cao et al., 2024](#); [Zhu and Yang, 2024](#)). However, it is also necessary to recognize that ESG evaluation may involve various factors, including overall corporate strategy, resource allocation and external environment. Merely improving ESG evaluation is not enough to fully drive corporate green innovation; companies also need to comprehensively plan and continuously improve internal management, technology R&D and market expansion ([Hang et al., 2023](#); [Yu et al., 2024](#)). This integrated effort ensures that ESG principles truly become a driving force for corporate innovation, promoting green and sustainable development.

Second, regarding the analysis of corporate ownership heterogeneity, the positive impact of ESG evaluation on green innovation is more significant in SOEs compared to non-SOEs. In this sense, *H2* is supported. This finding is similar with [Zhang and Jin \(2022\)](#) and [Liu and Xu \(2024\)](#) which also reveal Chinese SOEs are more capable to promote green innovation than non-SOEs. However, this finding differs to [Wan et al. \(2024\)](#) and [Zhu and Yang \(2024\)](#), which argue that the green innovation promotion effect of ESG is more powerful in non-SOEs. From the perspective of corporate equity nature, this study found that the positive impact of ESG evaluation on green innovation is significantly stronger in SOEs compared to non-SOEs. This phenomenon can be explained by the differences in resource acquisition and policy support between SOEs and non-SOEs. It is naturally easier for SOEs to respond to and implement ESG policies because they enjoy the added advantages of resource acquisition, policy support and fulfilling their social responsibilities ([Zhang and Jin, 2022](#); [Wang et al., 2023](#)). Therefore, due to government policy inclination and resource support in green innovation implementation, an SOE is likely to receive more financial subsidies, technical support and market access opportunities. In addition, under the unique ownership structure of SOEs, the pressure and expectations in social and environmental responsibilities are more significant; therefore, the impact of ESG evaluation improvement on prompt green innovation would be even sharper ([Lian et al., 2023](#); [Liu and Xu, 2024](#)). This result shows that SOEs have the advantage of resource acquisition and policy support in their establishment, whereas non-SOEs are relatively at a disadvantage in these two factors. While competing, non-SOEs rely heavily on flexibility and market acumen but might not enjoy

policy support or resource acquisition to the same extent, which could affect their performance in green innovation. This further explains the impact of corporate ownership nature, demonstrating its significant effect on green innovation ability.

Third, increased R&D investment plays an important mediating role in the process by which the evaluation of ESG influences corporate green innovation. It means that a heightened ESG evaluation would increase corporate innovation willingness and behavior through larger R&D investments, hence increasing the extent of corporate green innovation. The finding is close to [Zhu and Yang \(2024\)](#), which further warns that the positive effect of ESG performance on green innovation in Chinese firms is mediated by R&D investment. It can thus be said that R&D investment plays a very significant role in mediating the process by which ESG evaluation affects corporate green innovation, therefore underlining the fact that resource investment is very important in the innovation process ([Wang et al., 2023](#)). Innovation is a long-term process that requires significant resource input and unremitting endeavor. Therefore, the increase in investment in R&D would create better motivating circumstances for ESG evaluation to enhance corporate innovation willingness and behavior to foster green innovation development. R&D investment, as a key variable, enhances innovation capabilities and improves the efficiency of allocating resources within organizations, which will magnify the impact of ESG evaluation on green innovation ([Lian et al., 2023](#); [Zhu and Yang, 2024](#)). This conclusion might set a milestone in corporate innovation processes for delivering on ESG-based evaluation, with the implication that increased R&D investment likely correlates with improved innovation outcomes. In the process of increasing investment in R&D, enterprises should not only obtain funds but also train and introduce innovative talents, establish perfect management systems for R&D, strengthen cooperation with research institutions and universities and further improve R&D efficiency and the conversion rate of innovation achievements ([Wu et al., 2024](#)). Thus, companies can better use resource advantages brought about by ESG evaluation to foster the growth of green innovation. In summary, ESG evaluation significantly promotes the level of corporate green innovation through the rising mechanism of R&D investment.

5.2 Concluding remarks and contributions

This study empirically examines the relationship between ESG evaluation and corporate green innovation, using panel regression and mediation analysis to explore both direct and indirect pathways. The results demonstrate that ESG evaluation significantly promotes green innovation not only through direct influence on firm behavior but also indirectly via increased R&D investment. Furthermore, the effects vary across ownership types, with SOEs showing stronger ESG–innovation linkages than non-SOEs.

Building on these findings, this study contributes to the literature in three key ways. First, it provides robust empirical evidence on the causal linkage between ESG evaluation and green innovation within the context of Chinese A-share listed firms. While existing literature has addressed ESG and innovation separately, few studies have directly examined their causal connection in a longitudinal setting.

Second, by incorporating ownership structure as a moderating factor, this research highlights how institutional and policy contexts shape the ESG–innovation relationship. The comparative analysis between SOEs and non-SOEs enriches the understanding of organizational heterogeneity in sustainability strategies, responding to calls for more nuanced examinations of firm-specific factors in ESG research.

Third, the study identifies R&D investment as a key mediating mechanism through which ESG evaluation enhances green innovation. This insight not only clarifies the internal transmission pathway but also aligns with recent literature emphasizing the strategic

integration of ESG and innovation agendas (e.g. Wang *et al.*, 2023; Zhu and Yang, 2024). The proposed mediation framework offers a foundation for future theoretical and empirical exploration of ESG-driven innovation processes.

5.3 Practical implications

Based on the empirical findings, this study offers several practical recommendations for enhancing the impact of ESG evaluation on green innovation in China. First, the Chinese Government should continue improving the national ESG evaluation framework to ensure its reliability, consistency and relevance. A well-designed and transparent ESG rating system can not only increase corporate awareness of environmental and social responsibilities but also embed sustainability into firms' long-term innovation strategies. Integrating ESG criteria into broader national goals, such as innovation-driven development and green transformation, requires coordinated policy design, implementation guidance and performance monitoring. Expanding ESG coverage to a wider range of enterprises will amplify the collective impact on sustainable development.

Second, external governance institutions, including regulatory agencies and auditing bodies, should strengthen their supervisory role over corporate ESG performance, especially for large SOEs. Regular and independent audits can ensure that ESG disclosures are both meaningful and verifiable. Publishing standardized ESG performance reports would promote transparency, enhance public trust and motivate firms to pursue genuine innovation rather than symbolic compliance.

Third, more targeted support should be provided to small and medium-sized enterprises (SMEs) to enable them to leverage ESG evaluation for innovation. Given their limited resources but strong adaptability, SMEs require differentiated incentives, such as tax relief, funding support or technical assistance, to participate in ESG-aligned innovation activities. Such policy interventions can unlock innovation potential in under-resourced firms and broaden the overall effectiveness of ESG-driven green innovation.

5.4 Research limitations and suggestions to the direction of future works

While this study provides meaningful insights into the relationship between ESG evaluation and green innovation, several limitations warrant future investigation. First, the sample period spans from 2014 to 2022, which may not fully capture the long-term dynamics of ESG-driven innovation. Although this timeframe reflects recent ESG developments in China, it may overlook lagged effects and structural changes that emerge over extended periods. Future research could extend the temporal scope or adopt rolling window methods to explore evolving ESG–innovation linkages over time.

Second, this study focuses primarily on ownership structure as the source of firm-level heterogeneity. While ownership is an important institutional dimension, it may not fully explain the variance in ESG responsiveness. Future research could incorporate additional moderating variables, such as firm size, life cycle stage, industry characteristics or regional regulatory environments. A multidimensional heterogeneity approach could help policymakers and practitioners better target interventions toward firms most responsive to ESG incentives.

Third, the analysis emphasizes R&D investment as the mediating channel between ESG evaluation and green innovation. However, other internal and external factors, such as corporate culture, managerial incentives, environmental regulation or market competition, may also influence this relationship. Future studies could explore alternative or complementary mechanisms to build a more holistic understanding of how ESG principles

translate into innovation outcomes. A broadened mediation framework would deepen both theoretical insight and practical applicability in ESG research.

In summary, this study provides empirical evidence that ESG evaluation significantly enhances green innovation among Chinese A-share listed companies, both directly and indirectly through R&D investment. The heterogeneity analysis further reveals that the effect is stronger in SOEs, reflecting institutional differences in resource access and policy alignment. These findings not only reinforce the strategic value of ESG practices in innovation management but also contribute to the growing literature on sustainability-oriented corporate transformation. As ESG frameworks continue to evolve globally and nationally, further research is encouraged to expand on these insights and support the development of more effective, innovation-driven ESG policies.

Notes

- [1.] A-shares are shares of mainland Chinese companies denominated in Renminbi (RMB) and primarily available to domestic investors, although foreign access has expanded through programs like the Stock Connect. In contrast, other types of shares, such as B-shares and H-shares, are traded in foreign currencies like USD or HKD and are typically accessible to international investors outside mainland China.
- [2.] ST companies are companies that have been flagged by the stock exchange due to financial or operational abnormalities. These companies often face stricter regulatory scrutiny and higher risks, making them less suitable for this study.
- [3.] Thus, in this study, the green innovation data is from 2014 to 2022, and data of other variables are from 2013 to 2021.

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