Received: 19 August 2023 | Revised: 23 December 2023 | Accepted: 2 January 2024

DOI: 10.1002/bse.3692

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

ESG ratings and green innovation: A U-shaped journey towards sustainable development

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Funding information
National Natural Science Foundation of China, Grant/Award Numbers: 71721001, 72371256; Excellent Young Team Project Natural Science Foundation of Guangdong Province of China, Grant/Award Number: 2023B1515040001

Abstract

This study examines the relationship between corporate ESG ratings and green innovation based on data from Chinese A-share listed companies for the period between 2011 and 2022. The findings suggest a "U"- shaped relationship between ESG ratings and green innovation. Companies with lower ESG ratings (referred to as "bad" companies) tend to focus on improving their corporate governance and operational conditions, often at the expense of green innovation. However, as companies improve their ESG ratings, they increasingly view green innovation as a key growth area. This relationship is particularly evident in companies with low profitability and high operational risks. Additionally, we explore the impact of corporate ESG ratings on different types of green patents. The study finds that "bad" companies can mitigate the negative impact on green innovation through collaborative efforts, while non-inventive green innovations, they benefit from independent research and development. Furthermore, the study examines the role of government subsidies and executive compensation in influencing this relationship. The results show that government subsidies can both positively and negatively affect green innovation, depending on the company's operational status and ESG rating. The results provide valuable insights for companies, investors, and policymakers regarding the significant role of ESG scores in promoting green innovation and suggest strategies to enhance corporate sustainability performance.

KEYWORDS

ESG ratings, government subsidy, green innovation, sustainable development

1 | INTRODUCTION

In recent years, the concept of Environmental, Social, and Governance (ESG) has experienced rapid growth and widespread acceptance globally, particularly in developed countries (Daugaard, 2020). Numerous institutional investors and fund managers now consider ESG factors

Abbreviations: CDP, Carbon Disclosure Project; ESG, Environmental, social, and Governance; GRI, Global Reporting Initiative standards; KPIs, Key Performance Indicators; SFDR, Sustainable Finance Disclosure Regulation; TCFD, Task Force on Climate-related Financial Disclosures.

as integral components of their investment decision-making process (Broadstock et al., 2021; Gillan et al., 2021). They recognize that, in addition to yielding long-term financial returns, incorporating ESG factors can manage potential risks and exert a positive impact on society and the environment. Moreover, regulatory bodies have played a pivotal role in propelling the development of ESG (Drempetic et al., 2020; Gillan et al., 2021; Zhai et al., 2022). For instance, the European Union's Sustainable Finance Disclosure Regulation (SFDR) mandates financial market participants to disclose how their products interact with ESG factors. This legislation not only enhances transparency but also drives the industry's focus toward sustainable investment. Under regulatory impetus, various industry standards and rating systems have emerged, such as the Global Reporting Initiative (GRI) standards, the Carbon Disclosure Project (CDP), and recommendations from the Task Force on Climate-related Financial Disclosures (TCFD).

In contrast, China, though a latecomer in ESG ratings with its first ESG ratings appearing only in 2015 (Broadstock et al., 2021), is rapidly catching up, particularly in terms of government impetus and policy formulation. Many policies have been implemented to promote the disclosure of ESG information and the construction of rating systems. For example, in September 2018, the China Securities Regulatory Commission revised the "Corporate Governance Guidelines for Listed Companies," establishing a basic framework for ESG information disclosure in China for the first time. In December 2020, the "Environmental Information Legal Disclosure System Reform Plan" approved by China's Central Comprehensive Reform Commission proposed that by 2025, a mandatory environmental information disclosure system will be essentially formed. In May 2022, the State-owned Assets Supervision and Administration Commission of the State Council issued the "Plan to Improve the Quality of Central Enterprises Holding Listed Companies," explicitly requiring central enterprises holding listed companies to implement new development concepts and explore establishing a comprehensive ESG system. Besides, Chinese enterprises face dual pressures of economic transformation and sustainable development. The impact mechanism of ESG ratings on Chinese enterprises' development differs from developed countries and needs further exploration.

In recent years, China's economy has transitioned from a high-speed growth stage to a high-quality development stage (Zhou et al., 2020). As a new development concept, high-quality development, characterized by innovation, greenness, coordination, openness, and sharing, provides an important guarantee for sustainable economic development and forms a global development consensus. For enterprises, how to achieve green and sustainable development has become a focus of attention. As environmental issues become increasingly severe, enterprises also face green transformation pressures from the government, all sectors of society, and even consumers. Green innovation, as a type of innovation, helps enterprises achieve green transformation, improve resource utilization efficiency, and reduce pollution emissions through the development of green technology, green products, and services (Zheng et al., 2023). Green innovation is not only crucial for the sustainable development of enterprises themselves but also an important measure for enterprises to undertake environmental responsibilities and promote green development. Therefore, how enterprises carry out green innovation activities and what factors affect enterprises' green innovation is worth in-depth exploring.

Contemporary research has extensively explored the intricate relationships between financial markets, corporate governance, policy and regulation, corporate finance, and stock performance, with corporate Environmental, Social, and Governance (ESG) practices. From a financial market perspective, Alda (2019) discovered that companies holding a larger share of pension funds are more likely to employ renewable energy and disclose environmental information. Barros et al. (2022) observed that mergers and acquisitions have no significant impact on ESG ratings in the year of transaction completion, but they play a pivotal role in enhancing ESG performance in the subsequent year. Tampakoudis and Anagnostopoulou (2020) found that acquirers' ESG performance improves following the acquisition of targets with previously poor performance. Apergis et al. (2022) revealed a correlation between superior ESG ratings and lower costs of unsecured debt in the initial bond market. Barros et al. (2023) identified a close link between higher ESG ratings and the likelihood of higher dividend payments, the stability of payout amounts, and shareholder returns from dividend yields.

In terms of corporate governance, Bravo and Reguera-Alvarado (2019) found a positive correlation between gender diversity in audit committees and the quality of voluntary ESG reporting. De Masi et al. (2021) noted that a critical mass of female board members positively impacts every component of ESG ratings. Eccles et al. (2013) posited that focusing on issues most "substantial" to shareholder value in products, processes, and business models, coupled with significant innovation in these areas, could concurrently elevate financial and ESG performance. Gebhardt et al. (2023) discovered that implementing ESG Key Performance Indicators (KPIs) within internal management systems enhances ESG performance.

From a policy and regulatory standpoint, Zhang et al. (2023) found that interruptions in environmental subsidies significantly positively impact corporate ESG performance. Meng et al. (2023) indicated that collusion between national entities and corporations exacerbates air pollution by hindering ESG fulfillment, with a more pronounced effect in heavily polluting enterprises than in industrial firms. In terms of corporate finance, Conca et al. (2021) established a positive relationship between strict environmental and social information disclosure and corporate profitability. Dmuchowski et al. (2023) observed a positive correlation between ESG factors and corporate financial performance, more pronounced over a longer term. Sandberg et al. (2023) found that higher ESG ratings are associated with better asset return on assets (ROA) and return on equity (ROE). He, Ding et al. (2023) noted that ESG ratings significantly reduce corporate risk-taking, while Tarulli et al. (2023) found that higher levels of disclosure effectively reduce corporate financial burdens.

Regarding stock performance, Tamayo-Torres et al. (2019) identified a positive relationship between the governance dimension and Tobin's Q, a negative and significant relationship with the social dimension, and an insignificant relationship with the environmental dimension. Zhou et al. (2022) demonstrated that improvements in listed companies' ESG performance enhance their market value, with a distinct mediating effect of financial performance. Additionally, operational capabilities serve as a crucial mediating pathway through which ESG performance affects company market value.

In addition, a multitude of studies have delved into the relationship between corporate ESG and innovation. Eccles et al. (2013) suggest that by concentrating on issues of paramount importance to shareholder value and pioneering substantial innovations in products, processes, and business models to prioritize these issues, it is feasible to simultaneously enhance financial and ESG performance. Engle et al. (2020) employed third-party ESG ratings to simulate a company's climate risk exposure, finding notable performance in innovating within and outside the hedge sample in response to climate news. He, Zhao and Zheng (2023) discovered that the innovation compensation effect can exponentially augment the impact of environmental protection tax law on corporate ESG. Li et al. (2023) observed that focal companies' ESG in their industry possesses a significant green innovation spillover effect, achieved by alleviating financing constraints and enhancing environmental enforcement awareness among peer companies. Liu and Zhang (2023) identified that managerial myopia could negatively influence ESG engagement through corporate innovation. Long et al. (2023) noted that an enhancement in national ESG performance significantly fosters green innovation. Wang et al. (2023) found that companies covered by ESG rating agencies saw a significant 3.9% increase in green innovation output, primarily reflected in the growth of green invention patents. Wu et al. (2023) discovered a positive correlation between the shared ESG activity preferences among clustered institutional investors and corporate low-carbon innovation. Zheng et al. (2023) found a long-term bidirectional co-movement between ESG performance and corporate green innovation output.

Existing research often assumes a linear relationship between corporate ESG and various variables. However, some studies argue that the impact of corporate ESG is not merely a straightforward linear relationship. For instance, Broadstock et al. (2019) found that advanced ESG policies and disclosure levels correlate positively with a company's ecological efficiency, but only up to a certain point, beyond which the effect becomes "neutral," demonstrating a clear pattern of diminishing marginal returns in ESG performance. Kumar et al. (2022) discovered a significant inverted U-shaped relationship between corporate sustainability performance, its reporting practices, and financial performance. Long et al. (2023) observed that improvements in environmental and governance performance significantly promote green innovation yet in countries with weaker green innovation capabilities, enhancements in social performance reduce green innovation output. Conca et al. (2021) identified a negative impact between company market value and governance disclosure practices, with a negative and significant relationship between the social dimension and Tobin's Q. Bhandari et al. (2022) found that the relationship between sustained competitive advantage and ESG footprint is concave.

Previous literature has unveiled a predominantly positive correlation between corporate ESG and a myriad of factors. Studies also highlight a generally positive association between innovation and the impact of ESG. However, some research indicates that, in certain instances, corporate ESG might yield adverse effects. Particularly noteworthy is the near absence of exploration into the potential negative effects of ESG scoring on green innovation, suggesting a certain void in research. Notably, current literature lacks an analysis of the negative impacts of corporate ESG scoring on green innovation, especially a thorough examination of under what circumstances ESG scoring might produce positive effects and in what conditions negative effects might be observed. Therefore, we aim to bridge this gap by conducting a comprehensive investigation into the complex relationship between corporate ESG scoring and green innovation, particularly delving into the potential fluctuations across different stages of ESG scoring. Such scholarly endeavors will contribute to a more nuanced and comprehensive understanding of how ESG ratings influence corporate green innovation, thereby offering invaluable insights for academic research and practical application in related fields.

This study contributes significantly to the current literature in several ways. Firstly, this study uncovers a positive U-shaped relationship between a company's ESG (Environmental, Social, and Governance) rating and its green innovation, highlighting how "bad" companies focus on improving corporate governance to enhance their ESG scores while "good" companies invest heavily in green innovation as part of their growth strategy. Secondly, the study analyzes the relationship between corporate ESG ratings and various types of green patents, revealing that "bad" companies can mitigate the negative impacts of ESG development on green inventive innovations through collaboration while realizing the positive effects of ESG ratings on green innovation through independent research and development. Thirdly, by differentiating between profitability and operational risks, the research finds that the positive U-shaped relationship between a company's ESG rating and green innovation predominantly exists in groups with low profitability and high operational risks, suggesting that companies with lower ESG ratings tend to focus their resources on strengthening corporate governance. Lastly, the study delves into the impact of government subsidies and corporate executive compensation levels on the ESG-green innovation relationship, discovering that excessive subsidies can lead to an inverted U-shaped relationship, indicating the need for balanced subsidy strategies to encourage green innovation effectively.

The remainder of this paper is organized as follows: Section 2 reviews the existing theories on the impact of corporate ESG on green innovation and proposes the theory and research hypotheses of this paper. Section 3 describes the empirical research design, including data sources and sample processing, model setting and variable definition, and descriptive statistics and analysis. Section 4 presents and analyzes the empirical results, including the benchmark and endogeneity treatment. Section 5 provides further analysis, including ESG sub-item research, heterogeneity analysis, and moderating mechanisms analysis. Finally, Section 6 summarizes the research conclusions, policy implications, limitations, and scope for future research. The appendix shows the robustness test results.

2 | THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

2.1 | The impact of ESG ratings on green innovation performance

Viewed through the lens of ESG, within the paradigm of neoclassical theory, acompany's obligation is to maximize profits through the lawful and ethical use of resources, conceiving any other activities that obstruct the maximization of shareholder value as unacceptable (Xu et al., 2021). Concurrently, neoclassical theory postulates that the returns from ESG activities will not surpass their costs (Friedman, 2007). ESG embodies a company's comprehensive considerations in sustainability, social responsibility, and governance, typically viewing environmental investments or social responsibility activities exceeding the statutory minimum standards as generating additional costs, thus diminishing corporate value. Indeed, as noted by (Kim & Lyon, 2015), "The entire environmental regulation paradigm is built on the idea that firms must be forced into environmental improvements, as they would otherwise find these improvements expensive or unprofitable and hence would not undertake them voluntarily." Conversely, modern corporate theory often posits that ESG can contribute to a company's long-term development. For instance, Stakeholder Theory proposes that companies should create value not only for shareholders but also for all stakeholders, encompassing employees, consumers, local communities, natural resources, and environmental resources (Freeman, 1984). According to this theory, companies should consider environmental initiatives when crafting business strategies, thereby obtaining long-term economic benefits from competitive advantages.

From a green innovation perspective, neoclassical theory suggests that green innovation involves more investment and a longer return period and that investment returns do not exceed their costs, thereby discouraging more green innovation investments. However, modern corporation theory posits that due to the more significant investment, longer return period, externalities caused by the two attributes of "innovation" and "green," and greater risk involved with green innovation investment compared to fixed asset investment, green innovation investment could impede short-term business performance and make managers reluctant to invest in green innovation and disclose green innovation information (Zhai et al., 2022). However, green innovation investment could benefit long-term business performance, and companies need to overcome managerial short-sightedness and actively invest in green innovation.

Existing theories suggest that a company's development of ESG ratings can promote green innovation in the company. Firs, based on Stakeholder Theory and Signal Transmission Theory, good corporate ESG performance helps shape corporate image and reputation (Barnea & Rubin, 2010; Flammer, 2015), social responsibility reports provide non-financial information, reducing information asymmetry between investors and managers (Cui et al., 2018), alleviate financing constraints, broaden sources of funds (Lenz et al., 2017), thus laying the foundation for the development of green innovation. Secondly, from the perspective of Resource Dependence Theory, ESG is essentially an investment rather than a cost, bringing positive returns for employees, investors, and other stakeholders (Claessens, 2006), demonstrating good social responsibility performance helps attract excellent human resources to participate in productive activities (Barnea & Rubin, 2010; Kostant, 1999), thereby promoting the company's green innovation.

While green innovation is paramount for a company's sustainable development, given its long-term process, high uncertainty, and expensive transitional costs (Berrone et al., 2013), companies face a critical decision-making juncture in addressing environmental conservation challenges. This decision entails choosing between directly purchasing existing green technology equipment on the market or investing in proprietary research and development to seek innovative solutions. Firstly, acquiring ready-made green technology equipment can bring immediate environmental benefits to a company, while reducing the uncertainties and resource consumption inherent in the R&D process. However, this approach might restrict the company's capacity for independent innovation in green technology and the establishment of long-term competitive advantages. Secondly, in-house development of green technologies requires substantial initial investment and entails greater risks, yet it could endow the company with more enduring competitive advantages and deeper market insights. Finally, due to the positive externalities of green innovation, companies engaging in such activities cannot reap all the benefits, allowing competitors to replicate or benefit from the innovations at a lower cost (Nie et al., 2021). Therefore, companies must meticulously weigh the short-term and long-term benefits (risk-adjusted) of both options, as well as their affordability.

We delve into the relationship between a company's Environmental, Social, and Governance (ESG) scoring and green innovation, particularly considering how the company's current status—distinguished as "good" companies (with higher ESG ratings) versus "bad" companies (with lower ESG ratings)—affects this relationship.

For "good" companies, which generally have achieved commendable operational performance and possess relatively stable financial conditions, previous investments in fixed assets and conventional innovation have been successful. Yet, facing evolving market developments and fierce competition, further traditional investments may no longer yield significant returns. Thus, these companies need to identify new growth avenues, with green innovation emerging as a pivotal potential area. By investing in green technologies and sustainable development projects, these firms can not only realize positive Net Present Value (NPV) but also enhance their market recognition and level of sustainable development.

Conversely, "bad" companies, possibly grappling with operational difficulties and financial challenges, may find that investments in green innovation carry substantial risks, with benefits requiring a longer time to materialize and offering limited immediate improvements to the enterprise. Additionally, due to prevalent information asymmetry and moral hazards between enterprises and investors, investors approach the disclosure of green innovation projects with caution, leading to higher financing costs and restricted R&D investment funds (Hoffmann & Kleimeier, 2021). This scenario is more acute in "bad" companies, and given that their primary task often involves stabilizing operational conditions, they are more inclined to invest directly in fixed assets and conventional innovation, aiming to achieve positive NPV and improve company performance. Therefore, investing in green innovation may not be a strategic choice for these "bad" companies in the short term.

In summary, the influence of ESG scoring on green innovation essentially represents a balancing act between costs and benefits. For "bad" companies, can reap benefits from fixed assets and conventional innovation by improving management levels and enhancing governance capabilities, thereby accumulating capital. However, for these companies, the high costs and uncertain risks associated with green innovation mean that in the process of enhancing ESG, the costs of green innovation may outweigh its benefits. On the other hand, for "good" companies, the decision to invest in green innovation is more definitive, as they have recognized that returns on investments in other areas are diminishing and that green transformation and innovation are key trends for future development, with benefits greatly exceeding the costs. For "bad" companies, while there may be a need to focus on improving operational conditions in the short term, from a long-term perspective, as these companies improve and transition to "good" companies, they should consider incorporating green innovation into their strategic planning to achieve long-term sustainable development goals. Ultimately, the role of ESG scoring in promoting corporate green innovation will be influenced by the company's own conditions and long-term strategic planning. This differentiated strategy reflects the complexity and diversity of enterprises in addressing environmental challenges and pursuing sustainable development. Therefore, we propose the following hypothesis:

> **Hypothesis 1.** In companies with low ESG ratings, the development of ESG scoring will reduce their level of green innovation, while in companies with high ESG ratings, the development of ESG scoring will enhance their green innovation level. In other words, there is a positive "U" shaped relationship between a company's ESG scoring and green innovation.

2.2 | The impact of ESG on various green patents

In prior research and practice, green innovation has been categorized into two major types: inventive green innovation (such as green patent technology) and non-inventive green innovation (like utility model patents) (Wang et al., 2023; Xu et al., 2021). Typically, inventive green innovations significantly enhance a company's technological sophistication and production efficiency, playing a pivotal role in sustainable corporate development (Fang et al., 2017; Quan et al., 2021). However, compared to non-inventive green innovation, inventive green innovations usually require greater financial investment, accompanied by higher research and development complexity and risk.

Especially for "bad" companies facing operational challenges, striving to improve their ESG ratings and rectify company management issues becomes critical. In this context, developing non-inventive green innovations emerges as an effective strategy to meet environmental protection standards amidst the pressure to do so. Despite their lower technological content, non-inventive green innovations, with their relatively lower R&D difficulty and risk, can effectively reduce financial inputs, thereby positively impacting the improvement of company operations. Hence, "bad" companies might prefer to allocate resources to develop such innovations to comply with legal and regulatory requirements.

For "good" companies, which have already achieved commendable operational performance, there is greater flexibility in terms of green innovation. These companies, in the process of developing their ESG ratings, will increase their investment in green innovation, not only fostering the growth of inventive green innovation but also promoting non-inventive green innovation. The technological and production efficiency advantages of inventive green innovations may further consolidate these companies' market-leading positions, aligning with their long-term sustainable development strategies.

Green innovation can be further subdivided into independent green innovation and collaborative green innovation. In the realm of inventive green innovation, "bad" companies may find it challenging to independently undertake green innovations. However, through collaboration with "good" companies, they can leverage their partners' technology and resources to achieve higher investment returns. This collaborative approach helps mitigate the challenges these companies face in improving their ESG ratings. For "excellent" companies, despite their technological and resource advantages, collaboration might diminish their role in enhancing ESG ratings through green innovation, as the contributions from partners may be minimal.

In the case of non-inventive green innovation, given the lower R&D complexity, companies might perceive the costs and complexities of collaboration as unnecessary, hence preferring independent innovation. For "bad" companies, operational challenges and resource constraints may lead them to reduce collaboration in this field. In contrast, "good" companies, with their strong reputation and robust R&D capabilities, are more likely to engage in collaborative efforts in non-inventive green innovation to achieve a broader market impact. Therefore, the following hypotheses are proposed:

> **Hypothesis 2.** There is a positive "U" shaped relationship between a company's ESG rating and both independent and collaborative inventive green innovation. For inventive green innovation, companies with low ESG ratings can mitigate the negative impact of their ESG ratings on the level of green inventive innovation through collaboration; for non-inventive green innovation, low ESG rating companies can achieve a positive impact on green innovation levels through independent R&D.

> **Hypothesis 3.** The relationship between a company's ESG rating and independent non-inventive green innovation is not a positive "U" shape, but it is a positive "U" shape with collaborative non-inventive green innovation.

3 | RESEARCH DESIGN

3.1 | Data source and sample processing

Given the limitations of ESG and corporate green patent data, we select Chinese A-share companies listed on the Shanghai and Shenzhen stock exchanges from 2011 to 2022 as the sample for research. The data on corporate green innovation is obtained by matching the research data of green invention patents and utility model patents issued by the China National Intellectual Property Administration with the green patent data of listed companies in the CNRDS database. The green patent data mainly comprises four categories: independently obtained green invention patents, independently obtained green utility model patents, collaboratively obtained green invention patents, and collaboratively obtained green utility model patents. The ESG data is derived from Bloomberg's Environmental, Social, and Corporate Governance database. All other data is sourced from the CSMAR database.

To ensure the accuracy of the data, the following selection criteria were applied: (1) exclusion of the financial and real estate industries; (2) exclusion of companies that have been delisted or suspended from listing within one year of their listing, exclusion of companies listed on the Beijing Stock Exchange, exclusion of ST-type companies; (3) exclusion of corporate values with negative operating income and total assets; (4) exclusion of observations with missing independent and dependent variables; (5) for the missing values of Control variables, the interpolation method (extrapolation) is used to supplement them. Eventually, 1,330 companies were obtained, resulting in 10,348 company-year observations.

3.2 | Model specification and variable definition

In order to examine the impact of ESG performance on the level of corporate green innovation, we construct the following model:

$$GI_{i,t+1} = \alpha_0 + \alpha_1 ESG_{i,t} + \alpha_2 ESGPF_{i,t} + \gamma Controls_{i,t} + \sum\nolimits_t Year_t + \sum\nolimits_i Individual_i + \varepsilon_{i,t} \quad (1)$$

Where the subscripts i and t represent the sample individual and the year respectively.

Dependent Variable ($GI_{i,t+1}$). The dependent variables in this study include five indicators: the number of green patents obtained ($Green\_GET_{i,t+1}$), reflecting the overall green innovation level of the company; the number of green invention patents obtained independently ($Green\_GET^{I,NU}_{i,t+1}$), reflecting the level of high-quality green innovation autonomously by the company; the number of green invention patents obtained collaboratively ($Green\_GET^{I,U}_{i,t+1}$), reflecting the general level of green innovation autonomously by the company; the number of green utility model patents obtained collaboratively ($Green\_GET^{NI,NU}_{i,t+1}$), reflecting the level of high-quality green innovation cooperatively by the company; the number of green utility model patents obtained collaboratively ($Green\_GET^{NI,U}_{i,t+1}$), reflecting the general level of green innovation cooperatively by the company. In order to control the lag impact of ESG on corporate green innovation and the endogeneity caused by reverse causality, the explained variables in this study are forward-shifted by one period.

Independent Variables ($ESG_{i,t}$, $ESGPF_{i,t}$). $ESG_{i,t}$ is the Bloomberg ESG rating of the company i in year t, and $ESGPF_{i,t}$ is the square of the Bloomberg ESG rating of company i in year t. Currently, Bloomberg collects about 300 data points from approximately 11,000 companies in 63 countries. By screening publicly available information sources, Bloomberg assesses the extent to which each company discloses its Environmental, Social, and Governance (ESG) activities. Bloomberg's data points are weighted according to their importance and come from company reports, such as CSR reports, annual reports, and corporate websites, thus reflecting the range of information disclosed to investors. Based on the collected data points, and adjusted according to industry conditions, Bloomberg estimates that the disclosure score ranges from 0.1 (lowest) to 100 (highest).

The independent variables $ESG_{i,t}$ and $ESGPF_{i,t}$ represent a company's ESG metrics. $ESG_{i,t}$ is the Bloomberg ESG rating for company i in year t, while $ESGPF_{i,t}$ is the square of the Bloomberg ESG rating for company i in year t. The Bloomberg ESG rating is a composite index designed to evaluate a company's performance in three critical areas: environment, social, and governance. In terms of environmental aspects, the score considers factors such as energy use, waste management, and emission control. These metrics reflect a company's commitment and efficiency in environmental practices and resource management. The social score encompasses areas like labor standards, product responsibility, and community engagement. This segment assesses the company's impact and contributions to its employees, customers, and the communities in which it operates. The governance score focuses on various aspects of corporate governance, including the diversity and independence of the board, executive team compensation policies, and the company's transparency and shareholder rights. Importantly, Bloomberg's ESG scoring not only considers a company's disclosure of information in these key areas but also measures its actual performance.[1] Therefore, this scoring provides a comprehensive perspective to assess a company's overall performance in environmental, social, and governance aspects.

Control Variables ($Controls_{i,t}$). Following Wang et al. (2023), we control for company size (Size), company leverage (Lev), company return on assets (ROA), company revenue growth rate (Growth), company long-term asset ratio (PPE), company operating net cash ratio (CFO), company age (Age), largest shareholder shareholding

[1] In the methodology and domain information of the Bloomberg ESG rating, it is mentioned that "If any input field value is missing, the company receives the lowest score among all possible scenarios." Furthermore, the Bloomberg scoring explanation also states, "In general, field scoring is determined from guidance provided by Bloomberg research on best practices, corporate governance frameworks, and industry practitioners. Typically, the guidance takes the form of a best or worst governance practice. Categories are mapped to numerical values, so that best practices attain a score of 7 and up and worst practices attain scores of 3 and below, with significant ground in between." This implies that the Bloomberg score is a comprehensive index encompassing various indicators' disclosure and performance. The scoring system effectively integrates an assessment of both the company's transparency in reporting its activities and the substantive quality of these actions, thereby offering a nuanced and detailed evaluation of a company's commitment and effectiveness in environmental, social, and governance aspects.

ratio (Top1), and Tobin's Q value of the company (TobinQ). In order to control for the impact of individual and macroeconomic conditions on the level of corporate innovation, we also control for individual (Individual) and year (YEAR) fixed effects. ε represents the random error term. Table 1 defines and calculates the main variables.

3.3 | Descriptive statistics and analysis

The present treatise conducts a comprehensive descriptive statistical analysis of the primary variables. To illustrate, the mean values for the independent green invention patents obtained in the subsequent year (F1.Green_GET^{I,NU}), collaborative green non-invention patents acquired in the following year (F1.Green_GE^{TI,U}), joint green invention patents gained in the year after (F1.Green_GET^{NI,NU}), and cooperative green non-invention patents earned in the next year (F1.Green_GET^{NI,U}) are respectively 0.4444, 0.8295, 0.1814, and 0.2580. Viewed through the prism of independent research and development (R&D) versus collaborative R&D, enterprises predominantly tend to favor the independent development of green patents. This indicates a potential involvement of core technologies and key innovations in the field of green technology, suggesting that companies are inclined towards independent R&D to safeguard and control their intellectual property rights.

Assessing the enterprise's R&D in invention and non-invention patents, it is observable that firms are currently more engaged in the development of non-invention green patents. This underscores that businesses, in the process of green technology innovation, place a greater emphasis on improvements and applications based on pre-existing technology. This approach allows for a swift response to market demand, propelling sustainable development objectives, while accentuating technology's practicality, thereby satisfying the equilibrium between societal environmental demands and business strategy more effectively. The average value for ESG (Environmental, Social, and Governance) stands at 28.4675, indicating that the majority of enterprises exhibit a certain degree of concern and performance in environmental, social, and governance aspects. The standard deviation of ESG is 8.96, ranging from a minimum of 9.91 to a maximum of 68.92, reflecting considerable variances in ESG performance among different enterprises. Some companies might display a heightened sense of responsibility and enthusiasm concerning environmental, social, and governance aspects, while others need to further elevate their performance (Table 2).

4 | EMPIRICAL RESULTS AND DISCUSSION

4.1 | Baseline regression results[2]

Table 3 presents the baseline regression results of the impact of a company's ESG rating on its overall level of green innovation. In Table 3, we employed three groups of regressions: the first column represents the double-fixed effect model without the inclusion of control variables; the second column denotes the random effects model excluding control variables (with the exception of year dummy variables); and the third column signifies the double-fixed effect model incorporating control variables.

Based on the analysis results in Table 3, we observed that in columns 1, 2, and 3, the ESG coefficient is significantly negative, while the coefficient of ESGPF (ESG rating squared) is significantly positive. This indicates a positive U-shaped relationship between a company's ESG rating and green innovation, thereby validating our Hypothesis 1. This suggests that "bad" companies (those with lower ESG ratings) reduce green innovation in the process of improving their ESG ratings, whereas "good" companies (those with higher ESG ratings) increase green innovation.

We speculate that this may be due to the fact that green innovation often requires a longer investment and payback period, as well as carries higher risk (Li et al., 2023; Wang et al., 2023). "Bad" companies, facing significant operational pressures, tend to adopt measures that can immediately improve their operational conditions. This leads to a preference for directly acquiring relevant equipment to meet environmental regulatory requirements rather than resolving environmental issues through prolonged research and development. This tendency reflects the practical needs of "bad" companies to respond to regulatory pressures in the short term and also reveals a predilection for quick solutions rather than investing in long-term R&D and innovation. While this approach may swiftly meet current regulatory demands, it could limit the company's long-term development potential in environmental technologies and sustainable growth. Furthermore, this strategy may lead to an over-reliance on external technology, neglecting the cultivation of internal R&D capabilities and technological innovation. In the long run, this might impact the company's competitiveness in the market, especially in today's context where environmental standards are continually rising, and green technology is increasingly important. Therefore, companies should balance short-term adaptation with long-term sustainable development strategies when considering meeting environmental regulatory requirements, and find an appropriate balance between internal R&D and external technology acquisition. This will ensure compliance with environmental regulations while laying a solid foundation for the company's future development.

In contrast, "good" companies, typically having achieved commendable operational performance and possessing relatively stable financial conditions, have the capacity to bear the costs required for green innovation. For these companies, green innovation is not only a new point of return growth but also an important pathway to achieve high-quality and sustainable corporate development. Therefore, in their efforts to enhance their ESG ratings, these companies adopt a positive attitude towards green innovation, investing substantial funds in green R&D to improve the level of corporate green innovation.

Additionally, referencing the research method of (Yu et al., 2021), we used the regression results of the third column in Table 3 to visualize the impact of companies' ESG rating on green innovation in Figure 1. In this figure, we estimated the turning point of

[2]To make the coefficients of the regression results more aesthetically pleasing, the dependent variable is multiplied by 100 before performing the regression.

TABLE 1 Main variables and definitions.

Abbr.	Variable name	Calculation method
Green_GET	Green patent acquisition	Natural log of the total number of green patents obtained by the company in the following year +1
Green_GET^{I,NU}	Independent Acquisition of Green Invention Patents	Natural log of the total number of independent green invention patents obtained by the company in the following year +1
Green_GET^{NI,NU}	Independent Acquisition of Green non-invention Patents	Natural log of the total number of independent green utility model patents obtained by the company in the following year +1
Green_GET^{I,U}	Cooperative Acquisition of Green Invention Patents	Natural log of the total number of collaborative green invention patents obtained by the company in the following year +1
Green_GET^{NI,U}	Cooperative Acquisition of Green non-invention Patents	Natural log of the total number of collaborative green utility model patents obtained by the company in the following year +1
ESG	ESG performance	ESG performance of the company in the current year
Size	Company size	Natural log of the book value of the company's assets at the end of the current year
Lev	Company leverage	The ratio of total liabilities to total assets of the company at the end of the current year
ROA	Company return on assets	After-tax net profit/total assets of the company at the end of the current year
Growth	Company revenue growth rate	The ratio of the company's operating income at the end of the current year to the operating income at the end of the previous year
PPE	Company Long-term asset ratio	The ratio of fixed assets to total assets of the company at the end of the current year
CFO	Company operating net cash ratio	The ratio of operating net cash flow to total assets of the company at the end of the current year
Age	Company age	Number of years the company has been listed
Top1	Largest shareholder ownership ratio	The ratio of the shares held by the largest shareholder of the company to the circulating shares
TobinQ	Company Tobin's Q value	The ratio of the company's stock market value at the end of the year to total assets

TABLE 2 Descriptive statistics.

Variable	Sample size	Mean	Std	Min	Max
F1.Green_GET	10,348	1.1130	1.3249	0.0000	7.0519
F1.Green_GET^{I,NU}	10,348	0.4444	0.8543	0.0000	6.4754
F1.Green_GET^{NI,NU}	10,348	0.8295	1.1284	0.0000	6.2086
F1.Green_GET^{NI,U}	10,348	0.1814	0.5821	0.0000	6.6758
F1.Green_GET^{NI,U}	10,348	0.2580	0.7021	0.0000	5.7557
ESG	10,348	28.4675	8.9615	9.9085	68.9166
ESGPF	10,348	890.6996	599.4098	98.1784	4749.4980
Age	10,348	18.3593	5.8543	1.0000	54.0000
Size	10,348	23.1628	1.3119	19.5234	28.6365
Lev	10,348	0.4628	0.1946	0.0075	1.2796
ROA	10,348	0.0486	0.0643	−0.5563	0.6042
PPE	10,348	0.2378	0.1778	0.0000	0.9709
CFO	10,348	0.0633	0.0716	−0.4630	0.7255
Top1	10,348	37.1555	16.3196	3.3900	89.9900
STAFF	10,348	7.5289	1.3519	1.9459	13.1095
TobinQ	10,348	2.4681	2.3333	0.5439	34.0092

the company's ESG rating to be 21.6, with the change value of green innovation at the turning point being −0.2284. Figure 1 clearly shows that most of our sample companies are located to the right of the turning point (77.23% of the samples are on the right side of the turning point). In our study, the average (median) ESG rating of our sample companies is 27.3564 (28.4675), indicating that for most sample companies, improving the ESG rating helps to promote green innovation. It is noteworthy that most previous literature studying the relationship between ESG and green innovation did not consider the quadratic term of ESG, which might explain why most previous ESG studies concluded a positive linear relationship (Xu et al., 2021).

TABLE 3 Baseline regression of the impact of a company's ESG rating on its overall green innovation.

Items	(1) F.Green_GET	(2) F.Green_GET	(3) F.Green_GET
ESG	−1.8811**	−2.0632***	−2.1152***
	(0.8082)	(0.7810)	(0.8043)
ESGPF	0.0504***	0.0494***	0.0490***
	(0.0116)	(0.0115)	(0.0116)
Age		−1.6024***	5.5271***
		(0.5077)	(0.6679)
Size		35.1275***	28.8244***
		(2.5800)	(3.3827)
Lev		6.6265	−7.1864
		(11.1569)	(12.7547)
ROA		3.9672	2.5985
		(19.3676)	(20.3536)
PPE		−6.5869	2.6341
		(12.9234)	(16.2242)
CFO		−11.9829	−5.6050
		(13.8454)	(14.1998)
Top1		−0.2226	−0.2391
		(0.1516)	(0.2089)
STAFF		0.4382	0.4098
		(1.1206)	(1.2771)
TobinQ		0.1798	0.5559
		(0.5721)	(0.5970)
Year fixed	YES	YES	YES
Individual fixed	YES	NO	YES
Constant	72.9872***	−690.7873***	−634.3863***
	(11.8732)	(57.7356)	(75.2353)
Observations	10,348	10,348	10,348
R-squared	0.2346	0.2535	0.2554

Note: The standard errors clustered at the firm level are reported in parentheses, ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels. The same applies below.

In summary, according to the analysis of Table 3, we conclude that there is a positive U-shaped relationship between a company's ESG rating and green innovation. This finding deepens our understanding of the complex relationship between green innovation and a company's ESG rating and highlights the phenomenon of "inferior" companies potentially suppressing green innovation in the process of improving their ESG ratings.

Table 4 presents the baseline regression results of the impact of a company's ESG rating on individual green patents. In Table 4, we employ four groups of regressions: the first column represents the regression result of the influence of a company's ESG rating on independent green invention patents; the second column denotes the regression result of the effect of a company's ESG rating on independent non-invention green patents; the third column signifies the regression result of the impact of a company's ESG rating on collaborative green invention patents; and the fourth column illustrates the regression result of the effect of a company's ESG rating on collaborative non-invention green patents.

Initially, from the table, it is evident that the ESG coefficients in Columns 1 and 3 are −2.3143 and −2.2190, respectively, while the coefficients for ESGPF are 0.0458 and 0.0374, respectively. This indicates a positive U-shaped relationship between a company's ESG rating and both independent and collaborative green inventive patents. The smaller ESG coefficient in Column 1 compared to Column 3, and the larger ESGPF coefficient in Column 1 than in Column 3, validate Hypothesis 2. Furthermore, it is observable that the ESG coefficients in Columns 2 and 4 are negative. While the ESG coefficient in Column 2 is not significant, the coefficient in Column 4 is. The ESGPF coefficients in both Columns 2 and 4 are significantly positive, thereby validating Hypothesis 3. Finally, this phenomenon also indicates that the development of "good" companies' ESG ratings has a positive impact on all levels of green patents.

However, for "inferior" companies, the promotional effect of developing ESG ratings on the level of green patents exists only in independent non-inventive patents, while it is inhibitory for other patents. This disparity suggests that "bad" companies, in the process of improving their ESG ratings, often focus more on the balance of costs and benefits. Due to limited resources and significant operational pressures, these companies may be unwilling or unable to bear high R&D costs. Consequently, they tend to invest in non-inventive patents, which are less expensive and more practical. This strategic choice reflects the real challenges and constraints these companies face in enhancing their environmental protection, social responsibility, and governance structures.

4.2 | Endogeneity issue

The baseline regression advances the dependent variable by one period, which can to some extent solve the endogeneity caused by reverse causality. To further address potential endogeneity in the model, we attempt to construct instrumental variables. Following (Breuer et al., 2018), we use industry ESG performance as an instrumental variable for a company's ESG rating. Table 5 provides the second-stage regression results of the two-stage instrumental variable method. As with the baseline regression, we advance the dependent variable by one period to avoid the lagging effect of ESG ratings on corporate green innovation. Firstly, the Kleibergen-Paap rk LM statistic, Kleibergen-Paap rk Wald F statistic, and Hansen J statistic in each column of Table 5 indicate that there are no issues of under-identification, weak instrumental variables, or over-identification. Secondly, the magnitude and significance of the ESG and ESGPF coefficients in each column of Table 5 do not differ significantly from the baseline regression, indicating that the conclusions drawn from the baseline regression remain correct after dealing with endogeneity issues.

We have also incorporated the Generalized Method of Moments (GMM) model to estimate the impact of a company's ESG ratings on

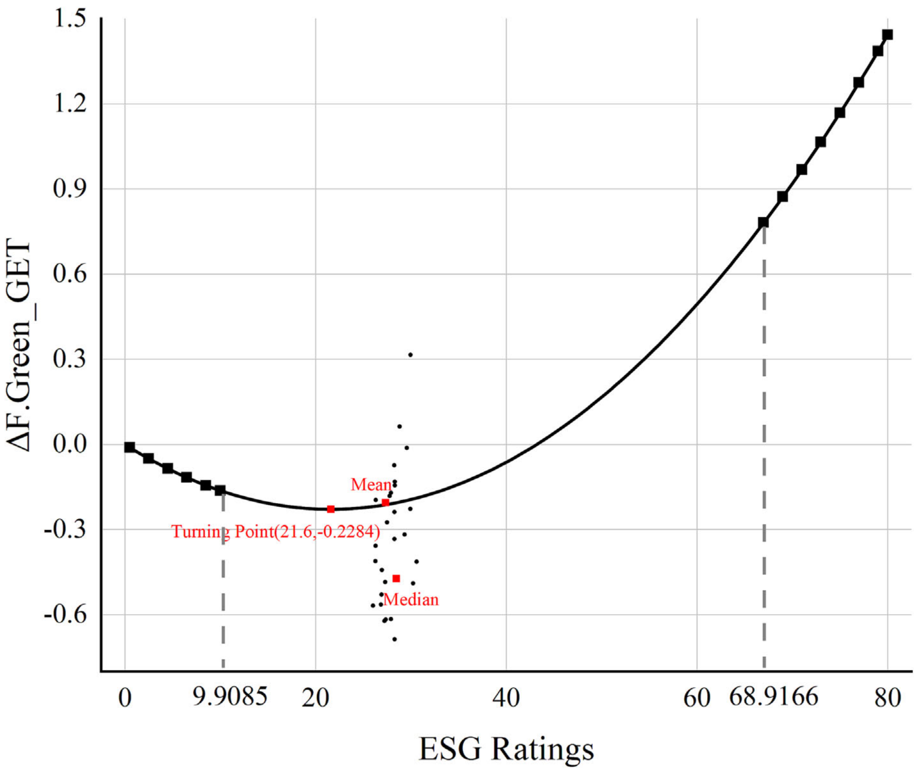

FIGURE 1 The impact of companies' ESG rating on green innovation. *Source*: Authors' own elaboration. Our dataset comprises annual observations of individual companies spanning from 2011 to 2022, covering 1,330 companies in China. These 27 points represent the average ESG ratings of all companies divided by province and the corresponding change in green innovation with the fluctuation in average ESG ratings (calculated based on the column 3 model, with the specific formula being $\triangle F.Green\_GET = -0.021152ESG + 0.000490ESG^2 + u$, where u represents the average of residuals for each province in the column 3 model). In our sample, the lowest ESG rating observed is 9.9085, while the highest is 68.9166.

green innovation. The regression results are displayed in Table 6. It is noteworthy that, in comparison to the baseline regression, the signs and significance levels of the ESG and ESGPF coefficients in each column of Table 5 remain substantially unchanged. This finding indicates that the conclusions drawn from the baseline regression still hold true after addressing endogeneity using the GMM model. This further fortifies our research outcomes, ensuring their robustness.

To enhance the robustness of our study and further substantiate our findings, we implemented three measures. Firstly, we gauged a firm's capability for green innovation by substituting the original green innovation metric with the number of green patent applications. Secondly, considering that elevating ESG (Environmental, Social, and Governance) scores assists companies in establishing a responsible social image and garnering public trust, there is a motivation for listed companies to exaggerate their ESG performance. This could mislead rating agencies and result in inaccurate scores. To address this issue, we utilized the Huazheng ESG rating as the core explanatory variable and reran the regression model to mitigate misunderstandings due to ESG disclosure quality issues.

Moreover, most empirical studies attempting to identify U-shaped relationships typically introduce a nonlinear (usually quadratic) term into the standard linear regression model. If this term is significant and the estimated turning point falls within the data range, a U-shaped relationship can be inferred. However, Lind and Mehlum (2010) argued that this criterion might be overly lenient. The model could erroneously generate turning points and U-shaped relationships when the actual relationship is convex and monotonic. Testing for U-shaped relationships is more intricate, as the null hypothesis requires the relationship to increase (or decrease) on one side of a specific interval and decrease (or increase) on the other. For such a complex null hypothesis, standard testing methods may not be suitable. Therefore, we drew upon Lind and Mehlum's (2010) framework based on Sasabuchi (1980) to test the U-shaped and inverted U-shaped relationships between two variables, using the u-test command. Uttest offers a precise methodology to examine the existence of a U-shaped (or inverted U-shaped) relationship over an interval. Following this logic, we tested the U-shaped relationships in our baseline regression, as shown in Tables A1, A2, and A3 (see Appendix). All models in these tables demonstrate a nonlinear relationship between a company's environmental disclosure and its external equity costs.

5 | FURTHER DISCUSSION: THE CAUSE OF THE U-SHAPED RELATIONSHIP BETWEEN CORPORATE ESG AND GREEN INNOVATION

5.1 | The impact of various sub-items of corporate ESG on green innovation

Firstly, corporate ESG ratings are composed of E, S, and G. Is the U-shaped relationship between corporate ESG ratings and green innovation consistent across all scores, or is it caused by a particular indicator? Could this reflect the underlying logic of why companies improve their ESG ratings? To answer this, we regress E, S, and G separately against green innovation, using the following model:

$$GI_{i,t+1} = \beta_0 + \beta_1 X_{i,t} + \beta_2 XPF_{i,t} + \delta Controls_{i,t} + \sum_t Year_t + \sum_i Individual_i + \tau_{i,t} \quad (2)$$

TABLE 4 Baseline regression of the impact of a company's ESG rating on individual green patents.

Items	(1) F.Green_GET^{I,NU}	(2) F.Green_GET^{NI,NU}	(3) F.Green_GET^{I,U}	(4) F.Green_GET^{NI,U}
ESG	−2.3143***	−1.3872	−2.2190***	−2.7070***
	(0.6361)	(0.8613)	(0.4868)	(0.7468)
ESGPF	0.0458***	0.0364***	0.0374***	0.0464***
	(0.0097)	(0.0127)	(0.0077)	(0.0113)
Age	2.5125***	4.0623***	1.7168***	2.4024***
	(0.4892)	(0.6407)	(0.3461)	(0.4349)
Size	16.2455***	21.1895***	7.7305***	6.6408***
	(2.6993)	(3.1466)	(1.8033)	(2.0427)
Lev	−6.6887	−7.8544	−7.0283	−1.3472
	(7.7402)	(11.8419)	(5.5759)	(7.9087)
ROA	−36.3059***	10.7156	−6.8722	18.7129*
	(13.9321)	(20.0020)	(9.3049)	(10.6744)
PPE	−4.7387	10.4083	−1.8779	−0.1503
	(9.2456)	(14.8934)	(9.1331)	(12.1030)
CFO	−5.7154	−4.0610	−2.5695	−5.1744
	(10.6826)	(13.3389)	(6.5048)	(7.8978)
Top1	−0.1056	−0.4069**	0.2047*	−0.0245
	(0.1552)	(0.1926)	(0.1221)	(0.1421)
STAFF	0.6431	−0.1729	1.1004	−0.3632
	(1.0036)	(1.2939)	(0.7143)	(0.8385)
TobinQ	0.1487	0.6184	−0.0039	0.3559
	(0.3789)	(0.5344)	(0.2218)	(0.2694)
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−345.3180***	−461.6461***	−173.4432***	−133.4492***
	(59.6682)	(70.5406)	(40.5678)	(47.4085)
Observations	10,348	10,348	10,348	10,348
R-squared	0.1351	0.1859	0.0715	0.0802

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE 5 Regression of a company's ESG rating on green innovation levels: instrumental variable method.

Items	(1) F.Green_GET	(2) F.Green_GET^{I,NU}	(3) F.Green_GET^{I,U}	(4) F.Green_GET^{NI,U}
ESG	−4.3919**	−4.7390***	−4.5132***	−4.1381***
	(1.9416)	(1.3776)	(0.9804)	(1.2445)
ESGPF	0.0869***	0.0588***	0.0611***	0.0720***
	(0.0248)	(0.0179)	(0.0128)	(0.0164)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Kleibergen-Paap rk LM	320.131	1325.209	1325.209	1325.209
Kleibergen-Paap rk Wald F statistic	240.082	3895.377	3895.377	3895.377
Hansen J statistic	0.000	0.000	0.000	0.000
Observations	10,316	10,316	10,316	10,316
R-squared	0.2524	0.1215	0.0620	0.0759

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE 6 Regression of a company's ESG rating on green innovation levels: GMM model.

VARIABLES	(1) F.Green_GET	(2) F.Green_GET^{I,NU}	(3) F.Green_GET^{I,U}	(4) F.Green_GET^{NI,U}
ESG	−10.2519***	−6.4726***	−6.5825***	−7.5681***
	(2.3785)	(1.8029)	(1.2395)	(1.4756)
ESGPF	0.1573***	0.0813***	0.0837***	0.1093***
	(0.0298)	(0.0225)	(0.0156)	(0.0192)
Age	−6.5583	5.0289	6.7214***	2.0525
	(4.2730)	(3.3173)	(2.4158)	(2.8570)
Size	29.4411***	18.9867***	9.5059***	7.2313***
	(2.5822)	(1.9341)	(1.3264)	(1.5588)
Lev	−10.1752	−13.3247**	−11.6732**	−3.6004
	(9.5727)	(6.3252)	(4.5319)	(5.7725)
ROA_interp	−3.1302	−34.6871***	−7.2370	15.7067
	(16.6229)	(12.0863)	(8.2093)	(9.5682)
PPE_interp	6.5193	−2.4820	0.3671	2.1957
	(11.2738)	(7.8217)	(5.8798)	(7.2282)
CFO_interp	−5.5142	−6.0698	−2.7595	−5.1569
	(12.5455)	(9.8622)	(6.0852)	(7.4780)
Top1_interp	−0.2341	−0.0956	0.2118***	−0.0209
	(0.1424)	(0.1038)	(0.0753)	(0.0933)
STAFF_interp	0.5633	0.7228	1.1835**	−0.2714
	(0.9201)	(0.7439)	(0.4798)	(0.5744)
TobinQ	0.4098	0.3536	0.0843	0.2942
	(0.4870)	(0.3166)	(0.1851)	(0.2316)
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Kleibergen-Paap rk LM	199.564	199.564	199.564	199.564
Kleibergen-Paap rk Wald F statistic	130.94	130.94	130.94	130.94
Hansen J statistic	0	0	0	0
Observations	10,316	10,316	10,316	10,316
R-squared	0.2338	0.1149	0.0387	0.0585

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

In equation (2), $X_{i,t}$ includes three indicators: E score, S score, and G score. $XPF_{i,t}$ contains three indicators: the square of the E score, the square of the S score, and the square of the G score. Other variables are consistent with model (1). The regression results are shown in Tables 7, 8, and 9.

The E coefficient in each column of Table 7 is not significant, while the EPF coefficients are all significantly positive, indicating that the E score has a positive impact on various green innovation patents and does not result in a U-shaped relationship. This may be due, on the one hand, to the fact that "green" is a fundamental concept of the new development paradigm, and the Chinese government has implemented various environmental regulations to strengthen ecological civilization (Jiang et al., 2021). Under the pressure of external regulations and legitimacy, companies face constraints from environmental regulations and social demands. As such, expected pollution control costs and production costs increase, encouraging companies to improve their environmental performance and thereby enhance their green innovation capabilities.

On the other hand, environmental pollutants represent resource waste in the production process. Emphasizing environmental responsibility is consistent with sustainable development principles, guiding companies to reduce environmental emissions, save energy, and improve resource use efficiency (Aras & Crowther, 2008). Therefore, emphasizing environmental protection will foster appropriate environmental management practices, promote the development of green innovation, and increase pollution prevention efforts.

In Table 8, only the Social (S) coefficient in the third column is significantly negative, while the coefficients in the other columns are not significant. At the same time, the Social Positive Factor (SPF) coefficients in all columns are significantly positive. This indicates a U-shaped relationship between the social score and the level of joint innovation invention patents, but a positive impact on green

TABLE 7 Regression of the impact of E score on various green patent indicators.

Items	(1) F.Green_GET	(2) $F.Green\_GET^{I,NU}$	(3) $F.Green\_GET^{I,NU}$	(4) $F.Green\_GET^{NI,U}$
E	0.219	−0.199	−0.228	−0.149
	(0.245)	(0.206)	(0.158)	(0.219)
EPF	0.0137**	0.0139***	0.0116***	0.0117**
	(0.00550)	(0.00484)	(0.00399)	(0.00562)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−660.9***	−386.8***	−199.2***	−165.6***
	(73.86)	(59.53)	(41.47)	(45.84)
Observations	10,348	10,348	10,348	10,348
R-squared	0.255	0.129	0.066	0.074

Note: ***, **, and *respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE 8 Regression of the impact of S score on various green patent indicators.

Items	(1) F.Green_GET	(2) $F.Green\_GET^{I,NU}$	(3) $F.Green\_GET^{I,NU}$	(4) $F.Green\_GET^{NI,U}$
S	−0.285	−0.874*	−0.975***	−1.001*
	(0.649)	(0.503)	(0.347)	(0.523)
SPF	0.0336**	0.0464***	0.0316***	0.0416***
	(0.0163)	(0.0139)	(0.00968)	(0.0138)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−692.3***	−390.8***	−217.6***	−178.1***
	(74.69)	(59.39)	(40.74)	(45.49)
Observations	10,348	10,348	10,348	10,348
R-squared	0.250	0.131	0.063	0.073

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE 9 Regression of the impact of G score on various green patent indicators.

Items	(1) F.Green_GET	(3) $F.Green\_GET^{I,NU}$	(6) $F.Green\_GET^{I,NU}$	(7) $F.Green\_GET^{NI,U}$
G	−1.529**	−1.755***	−1.406***	−1.718***
	(0.733)	(0.626)	(0.430)	(0.567)
GPF	0.0135**	0.0165***	0.0122***	0.0143***
	(0.00631)	(0.00545)	(0.00383)	(0.00480)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−680.6***	−364.3***	−178.2***	−142.9***
	(76.96)	(62.10)	(39.74)	(45.41)
Observations	10,348	10,348	10,348	10,348
R-squared	0.247	0.126	0.062	0.070

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

innovation in other cases. This may be because, in joint innovation, the social score may have a suppressing effect on "bad" companies. For example, these companies may have different motives in joint innovation. They may focus more on short-term benefits and tend to obtain more resources or technologies through cooperation rather than truly commit to a common innovation goal. These differences in motives can lead to misalignment of goals among partners and thus affect the progress of joint innovation projects. Therefore, in this case, an increase in the social score may suppress the level of joint green invention patents.

However, in other cases, positive social performance may encourage companies to invest more resources in environmental innovation, enhance the level of green innovation, and thus promote a positive relationship between environmental score and green innovation. In summary, these findings emphasize the complex interactions between different types of companies and motives in joint innovation and the important role of social scoring in shaping corporate innovation behavior.

In Table 9, the coefficients for G (Governance) in each column are significantly negative, while the coefficients for GPF are significantly positive. This indicates that the impact of improving corporate governance scores on the level of green innovation presents a U-shaped relationship. This phenomenon may be due to the characteristics of green innovation, such as long cycles, large investments, significant externalities, and high risks. Faced with poor business conditions, "bad" companies may prefer to prioritize resources to improve corporate governance levels to respond to internal and external pressures and challenges. This leads to relatively fewer resources being allocated to green innovation, a field that requires a longer time for returns. Therefore, to some extent, the improvement in governance scores suppresses these companies' enthusiasm for green innovation.

In summary, according to the above conclusions, the U-shaped relationship between ESG ratings and the level of green innovation is mainly due to the G score. We infer that "bad" companies improve ESG ratings mainly by improving the corporate governance score. To verify this inference, we differentiate ESG, E, S, and G, and conduct a descriptive analysis based on the inflection point (21.5917) of the U-shaped relationship between ESG ratings and the impact on total green innovation patents, as shown in Table 10.

From Table 10, it can be seen that when ESG < 21.5917, the average values of DESG, DE, DS, and DG are −0.3035, −0.1149, 0.6124, and −1.5764, respectively, indicating that the change in DESG is mainly caused by DG. When ESG > =21.5917, the average values of DESG, DE, DS, and DG are 2.3720, 2.5353, 0.7438, and 2.7806, respectively, indicating that the change in DESG is mainly caused by DE and DG. In summary, when below the inflection point, companies mainly improve ESG ratings by enhancing G scores; when above the inflection point, it is mainly due to E and G scores, and the contribution of E score is only 0.2453 less than the G score, which well verifies that "bad" companies improve ESG ratings primarily by improving the level of corporate governance.

TABLE 10 Descriptive analysis of DESG, DE, DS, and DG.

Items	Obs	Mean	Std. dev.	Min	Max
ESG < 21.5917					
DESG	1718	−0.3035	2.7403	−13.3890	11.5702
DE	1701	−0.1149	2.4698	−29.8701	14.7992
DS	1718	0.6124	3.1335	−21.0526	19.2982
DG	1718	−1.5764	6.8703	−39.8555	25.4666
ESG > =21.5917					
DESG	7,272	2.3720	4.0203	−11.2665	32.4415
DE	7,270	2.5353	7.0990	−25.9438	61.1598
DS	7,272	0.7438	4.0340	−26.7231	30.8646
DG	7,272	2.7806	8.5830	−42.2336	54.8766

5.2 | Heterogeneity analysis of corporate ESG on green innovation

To further explore the rationality of the "bad" company logic, we also use the return on assets to represent the profitability of the company, and the debt ratio to represent the operating risk of the company for heterogeneity analysis. Specifically, the median return on assets within the sample is used for division; companies below the median are defined as the low-profitability group and those above the median are defined as the high-profitability group. Then, the ESG rating is used to regress on the total level of green innovation patents; the median debt ratio within the sample is used for division, companies below the median are defined as the low operational risk group, and those above the median are defined as the high operational risk group. Then, the ESG rating is used to regress the total level of green innovation patents. The regression results are shown in Table 10.

In Table 11, the ESG coefficients in columns 1 and 4 are significantly negative, and ESGPF is significantly positive, while the ESG coefficients in columns 2 and 3 are not significantly negative. This indicates that the U-shaped relationship between ESG ratings and green innovation only exists in the low-profit group and high-operational risk group, which suggests that the U-shaped relationship between ESG ratings and green innovation is indeed caused by "bad" companies.

5.3 | Analysis of moderating mechanisms

We delve into the challenges faced by companies with low ESG ratings in enhancing their ratings, particularly focusing on how to mitigate, or even reverse, the adverse effects on green innovation output while improving their ESG ratings. It posits that government subsidies could be pivotal in addressing this challenge. Firstly, subsidies provide the crucial financial support needed for firms to engage in green innovation and transformation (Hu et al., 2021). For those companies investing in clean technology or improving production processes to reduce their carbon footprint, government fiscal assistance can significantly alleviate the burden of these initial investments. Secondly, given that innovation often comes with high risk, government subsidies can act as a risk-sharing mechanism, encouraging firms to venture into the development of green technologies that have yet to be commercialized (Mateut, 2018). Additionally, government subsidies send a clear signal to the market in support of the green economic transition, which may motivate companies to participate more actively in green

TABLE 11 Heterogeneity analysis of corporate ESG on green innovation: profitability and operational risks.

Items	(1) Low-profit group F.Green_GET	(2) High-profit group F.Green_GET	(3) Low-operational risk group F.Green_GET	(4) High-operational risk group F.Green_GET
ESG	−3.4524***	−1.1619	−0.4227	−2.6662**
	(1.2561)	(1.0032)	(0.9845)	(1.1534)
ESGPF	0.0714***	0.0299**	0.0178	0.0563***
	(0.0187)	(0.0141)	(0.0145)	(0.0160)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−843.5876***	−596.6224***	−491.5497***	−789.0920***
	(137.4215)	(97.3665)	(92.0256)	(121.9394)
Observations	5,174	5,174	5,174	5,174
R-squared	0.2376	0.2625	0.1662	0.3107

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

innovation. Lastly, considering that green investments often require a long-term cycle, high costs, and may not yield significant returns in the short term, subsidies can help firms alleviate the cost pressures of green innovation and maintain a competitive edge in both current and future markets.

Moreover, the paper also suggests that improving corporate management levels is another key strategy for companies with low ESG ratings to tackle these challenges. Green innovation often takes time to yield economic benefits and requires substantial initial investment. For companies already facing financial difficulties, such investments may exacerbate existing financial pressures. Therefore, strong management capabilities are crucial for ensuring the effective execution of projects and their alignment with the company's overall strategy. For companies with low ESG ratings, enhancing management levels could be key to mitigating the adverse effects of low ESG ratings. Effective management can improve the efficiency of resource allocation, ensuring optimal use of limited resources, especially during times of resource scarcity. Furthermore, better management helps companies more adeptly identify and seize opportunities for green innovation, even under conditions of limited resources.

In summary, through government subsidies and improved management efficiency, companies with low ESG ratings can reduce the negative impact on green innovation output while enhancing their ESG ratings, and potentially even reverse this trend, thereby achieving sustainable development goals. These strategies not only aid in the transformation of the businesses themselves but also support the achievement of broader environmental and social objectives.

To this end, we use the ratio of government grants received to total assets as a measure of government subsidies and the logarithmic value of the average executive compensation income (the total remuneration of directors, supervisors, and senior executives divided by their number) to analyze the moderating effects. The formula is as follows:

$$\begin{aligned} Green_{GET\,i,t+1} = {} & \alpha_0 + \alpha_1 ESG_{i,t} + GS_{i,t} + \alpha_2 ESG_{i,t} \times GS_{i,t} \\ & + \alpha_3 ESGPF_{i,t} + \alpha_2 ESGPF_{i,t} \times GS_{i,t} \\ & + \gamma Controls_{i,t} + \sum\nolimits_t Year_t + \sum\nolimits_i Individual_i + \varepsilon_{i,t} \end{aligned} \tag{3}$$

$$\begin{aligned} Green_{GET\,i,t+1} = {} & \alpha_0 + \alpha_1 ESG_{i,t} + ECL_{i,t} + \alpha_2 ESG_{i,t} \times ECL_{i,t} \\ & + \alpha_3 ESGPF_{i,t} + \alpha_2 ESGPF_{i,t} \times ECL_{i,t} \\ & + \gamma Controls_{i,t} + \sum\nolimits_t Year_t + \sum\nolimits_i Individual_i + \varepsilon_{i,t} \end{aligned} \tag{4}$$

In Equations (3)–(4), $GS_{i,t}$ represents government subsidies, while $ESG_{i,t} \times GS_{i,t}$ denotes the interaction term between ESG ratings and government subsidies. $ESGPF_{i,t} \times GS_{i,t}$ signifies the quadratic term of ESG ratings interacting with government subsidies. Other variables remain consistent with Equation (1). $ECL_{i,t}$ symbolizes executive compensation levels, $ESG_{i,t} \times ECL_{i,t}$ is the interaction term between ESG ratings and executive compensation levels, and $ESGPF_{i,t} \times ECl_{i,t}$ represents the quadratic interaction of ESG ratings and executive compensation levels.

The regression results are presented in Table 12. Observing Column 1, the positive coefficient of the interaction between ESG and GS (government subsidies) suggests that for companies with lower ESG ratings, government subsidies can effectively mitigate the adverse impact on green innovation associated with improving ESG ratings. Conversely, the negative coefficient for the interaction between ESGPF (ESG performance) and GS implies that for companies with higher ESG ratings, government subsidies might diminish the positive impact on green innovation when improving ESG ratings. This phenomenon may be attributable to the fact that companies with lower ESG ratings face substantial financial pressures and cannot allocate significant funds for prolonged green innovation research and development. Through government subsidies, these enterprises can access additional funds, aiding them in allocating resources for green innovation research and development, thereby ensuring a competitive edge in the future. Companies with higher ESG ratings, which are

TABLE 12 Moderating mechanisms of government subsidies and executive compensation levels.

Items	(1) F.Green_GET	(2) F.Green_GET
ESG	−2.7102***	−21.9659**
	(0.9033)	(9.6100)
ESGPF	0.0626***	0.3708**
	(0.0137)	(0.1467)
GS	−1,925.7833*	
	(1,050.0993)	
ESG*GS	193.1071**	
	(79.1181)	
ESGPF*GS	−3.9072***	
	(1.4153)	
ECL		−22.4681*
		(11.9602)
ESG*ECL		1.4569**
		(0.7118)
ESGPF*ECL		−0.0234**
		(0.0106)
Control variables	YES	YES
Year fixed	YES	YES
Individual fixed	YES	YES
Constant	−645.6486***	−342.2991*
	(75.7734)	(175.0466)
Observations	10,322	10,271
R-squared	0.2575	0.2556

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

generally in good operational health with ample cash flow, possess sufficient motivation and funds for green innovation research and development. Government subsidies in these cases may lead to a more "comfortable" position, potentially causing them to blindly expand their scale of operations, reducing investment in green innovation, and thus impeding the promotive role of ESG ratings on green innovation.

Therefore, how much government subsidy is necessary to assist companies with lower ESG ratings in enhancing their ESG ratings while simultaneously reducing the unfavorable impact on their green innovation output? Is it possible for government subsidies to reverse this adverse effect? This study, referencing Haans et al. (2016), calculates the inflection point of government subsidies as 0.0160 (0.0626/3.9072), indicating that when government subsidies reach 0.0160, the relationship between green innovation and ESG performance shifts from a positive U-shape to an inverted U-shape. This is crucial, as it means when government subsidies reach 0.016, companies with lower ESG ratings can improve their ESG ratings without adversely affecting green innovation. The likely reasons for this include, firstly, significant government financial support alleviating the cost pressures these companies face in enhancing ESG ratings. These firms, often with limited funds, may be under considerable financial strain under hefty investments in green innovation. The increase in government subsidies, especially when reaching or surpassing the critical threshold of 0.016, provides essential financial backing for these companies to undertake the necessary initial investments in green innovation. Secondly, the escalation in government subsidies considerably reduces the risks these companies encounter in the process of green innovation. Given that green innovation projects typically involve high risks and extended periods for investment returns, the injection of government funds helps enterprises undertake these risks with more confidence and enhances their ability to make long-term investments. Furthermore, government subsidies also ignite internal enthusiasm and motivation for green innovation within the company. Realizing that government support can ease financial pressures, the company's management and staff might engage more actively in exploring and implementing green innovation projects, thus propelling the company towards sustainable development.

In addition, we also elucidate the relationship between the inflection point of ESG ratings and government subsidies as shown in Table 13. It is evident that as government subsidies increase from 0.001 to 0.00016, the inflection value continually decreases. This suggests that in the positive U-shaped relationship between ESG and green innovation, as government subsidies rise, more and more companies on the right side of the inflection point demonstrate a positive relationship between ESG ratings and green innovation. When government subsidies reach 0.013, no company has an ESG rating below the inflection value (the range of corporate ESG ratings is between 0.9085 and 68.9166). When government subsidies exceed the tipping point, the relationship between corporate ESG ratings and green innovation turns into a U-shape, with the ESG rating inflection point gradually decreasing from 74.132 to 36.95992. This indicates that with the increase in government subsidies, the number of companies on the left side of the inflection point is continuously decreasing, and fewer and fewer companies show a positive relationship between ESG ratings and green innovation. Therefore, we posit that for companies with lower ESG ratings, the government should intensify subsidy efforts.[3] For companies with higher ESG ratings, the government needs to appropriately reduce subsidy intensity.

Looking at Column 2, the positive coefficient for the interaction between ESG and ECl (executive compensation level) indicates that for companies with lower ESG ratings, executive compensation levels can effectively alleviate the adverse impact on green innovation associated with increasing ESG ratings. We argue that for companies with lower ESG ratings, raising executive compensation levels can effectively improve management standards, optimizing management strategies and enhancing management efficiency. This helps better mobilize resources and ignite the potential for green innovation, thereby supporting green innovation activities while enhancing ESG ratings.

[3]Upon examining the data sample, it was found that among the samples with ESG ratings below the inflection point (21.59173), there are 2,348 samples. Of these, 75% receive government subsidies less than 0.0056778. This indicates that the majority of companies with lower ESG ratings receive minimal government assistance.

TABLE 13 Inflection points of government subsidies and executive compensation levels.

Government subsidy gradient	Government subsidy inflection point	Management level gradient	Executive compensation level inflection point
0.001	21.45748	9.5	27.37315
0.002	21.22522	10	27.0527
0.003	20.95726	10.5	26.67224
0.004	20.64469	11	26.21318
0.005	20.27534	11.5	25.64834
0.006	19.83221	12	24.93643
0.007	19.29073	12.5	24.01138
0.008	18.61407	13	22.76064
0.009	17.7444	13.5	20.97545
0.01	16.5854	14	18.22017
0.011	14.96386	14.5	13.40908
0.012	12.53387	14.6	11.98136
0.013	8.490085	14.7	10.30323
0.014	0.4256412	14.8	8.302435
0.015	−23.58417	14.9	5.876072
0.016	−4220.961	15	2.87214
0.017	74.13209	15.5	−38.6340
0.018	49.27896	16	179.6618
0.019	41.05836	16.5	67.08643
0.02	36.95992	17	51.57882

The negative coefficient for the interaction between ESGPF (ESG performance) and ECL suggests that for companies with higher ESG ratings, executive compensation levels might reduce the positive impact on green innovation when improving ESG ratings. we contend that in companies with higher ESG ratings, which are inherently "good companies" with solid operational health, there is no urgent pressure on the management to improve company conditions. This may lead to highly compensated executives becoming more shortsighted, lacking strong motivation for green innovation, and even pursuing short-term gains, thereby reducing the promotive role of ESG ratings on green innovation.

Through calculation, it is determined that the tipping point for executive compensation levels is 15.84 (at this level, the relationship between green innovation and ESG performance shifts from a positive U-shape to an inverted U-shape). However, examining the sample data reveals that 99% of the companies have executive compensation levels below 15.84. Thus, adjusting executive compensation levels can achieve the model's tipping point. Moreover, it is observed that as executive compensation levels increase from 9.5 to 15.5, the inflection value continually decreases. This implies that with the enhancement of management standards, more and more companies on the right side of the inflection point demonstrate a positive relationship between ESG ratings and green innovation. Therefore, the paper suggests that companies with lower ESG ratings should recruit more outstanding managers to improve corporate management capabilities. For companies with higher ESG ratings, it is necessary to appropriately reduce the compensation of management personnel or establish measures to reduce their shortsighted behaviors.

6 | CONCLUSION AND POLICY RECOMMENDATIONS

In this study, we think that for "good" companies, which typically boast commendable operational performance and relatively stable financial conditions, green innovation represents a potential growth area. Developing ESG (Environmental, Social, and Governance) scores emerge as an efficacious means to foster green innovation, yielding positive economic and sustainable development returns. Conversely, for "bad" companies, the pivotal task lies in stabilizing their operational conditions, potentially necessitating investments in fixed assets and conventional innovations to achieve a positive Net Present Value (NPV). Hence, these entities may prefer to allocate resources to these domains, thereby constraining their investments and efforts in green innovation. Building on this premise, we explore how a company's ESG rating influences its green innovation. Additionally, we delve into the measures that enterprises and governments should adopt to minimize the adverse impact on green innovation while enhancing the ESG ratings of companies with lower ratings. Through this process, our paper comprehensively examines the impact of corporate ESG ratings on green innovation and their corresponding response strategies. Our research is empirically supported by data from 1,330

Chinese A-share companies listed on the Shanghai and Shenzhen stock exchanges from 2011 to 2022. The empirical findings of this study offer valuable insights into public policy, corporate ESG strategies, and their financial practices.

Firstly, we demonstrate a positive U-shaped relationship between a company's ESG rating and its green innovation. This is primarily attributed to the positive U-shaped relationship between corporate governance scores and green innovation. Our empirical evidence suggests that "bad" companies are more inclined to improve their corporate governance scores to enhance their overall ESG ratings. Faced with environmental regulatory pressures, these companies tend to purchase end-of-pipe treatment equipment rather than invest in green innovation research and development. However, once surpassing the inflection point, "good" companies, in the process of elevating their ESG ratings, regard green innovation as a crucial growth vector, heavily investing in green innovation research and development, thereby positively influencing green innovation. By visualizing the distribution of our sample provinces around this U-shaped curve, we observe that most sample companies are situated to the right of this turning point. These companies, in the process of elevating their ESG ratings, allocate more funds for green innovation research and development, consequently fostering green innovation. For the majority of these sample companies, the benefits of green innovation surpass its costs.

Secondly, we also examine the impact of corporate ESG ratings on various types of green patents. A positive "U" shaped relationship exists between corporate ESG ratings and both independent and collaborative inventive green innovations. For inventive green innovations, "bad" companies can mitigate the negative impacts of ESG development on green inventive innovations through collaboration; for non-inventive green innovations, these companies can realize the positive effects of ESG ratings on green innovation through independent research and development. Our findings indicate that companies, in the process of enhancing their ESG ratings, make appropriate strategic choices for green innovation based on their specific conditions and needs.

Lastly, by differentiating between profitability and operational risks, we discover that the positive "U" shaped relationship between a company's ESG rating and green innovation only exists in groups with low profitability and high operational risks. This indicates that companies with lower ESG ratings are characterized by lower profitability and higher operational risks. It is these risks that necessitate "bad" companies to focus their resources on strengthening corporate governance, thereby hindering the continuous allocation of resources to green innovation, which typically involves long investment and return cycles and high failure risks.

Additionally, we delve deeply into the impact of government subsidies and corporate executive compensation levels on the relationship between a company's ESG (Environmental, Social, and Governance) score and green innovation. A pivotal discovery is that when government subsidies reach 0.016, the positive U-shaped relationship between a company's ESG rating and green innovation undergoes a reversal, transforming into an inverted U-shaped relationship. This suggests that subsidies exceeding 0.016 enable "bad" companies to increase their investment in green innovation during the process of enhancing their scores, thereby elevating the level of green innovation. For such companies, government subsidies can significantly alleviate financial pressures, providing the necessary funding for green patent research and development, and consequently mitigating the adverse impact of ESG ratings on green innovation capabilities. Simultaneously, elevating corporate management standards helps companies improve operational conditions, enabling them to allocate a portion of their funds to green innovation investment. This development strategy is crucial for fostering green innovation. However, for "good" companies, already possessing sound operational status and ample cash flow, additional government subsidies may lead to excessive operational comfort. This could result in companies blindly expanding their scale of operations, reducing investment in green innovation, thereby hindering the positive influence of ESG ratings on green innovation. Additionally, for the management of these companies, the lack of pressure to improve company conditions may lead to shortsightedness, a lack of motivation for green innovation, or even a pursuit of short-term benefits, thus diminishing the promotive effect of ESG ratings on green innovation.

Chinese enterprises face immense pressure to enhance their environmental protection, social responsibility, and internal governance performance. Our study finds that "bad" companies are more inclined to improve corporate governance to enhance operational conditions, which may adversely affect green innovation, while "good" companies can foster green innovation by elevating their ESG ratings. Therefore, the paper posits that for "bad" companies, priority should be given to improving corporate governance structures to elevate their ESG ratings. This not only helps in enhancing overall operational efficiency but is also a key step in transitioning into "good" companies and thereby enhancing green innovation capabilities. Furthermore, when considering compliance with environmental regulations, "bad" companies should balance short-term adaptations with long-term sustainable development strategies, finding an appropriate equilibrium between internal research and development and external technological acquisitions. This ensures compliance with environmental regulations while laying a solid foundation for the company's future development.

Regarding investment strategies for green innovation, "bad" enterprises might lean towards developing independent, non-inventive green innovation patents. Such a strategy allows for controlling costs while meeting current green requirements. Non-inventive green innovations usually involve lower research and development costs and risks, enabling even resource-limited companies to make progress in the green technology sector. By focusing on such innovations, "bad" companies can effectively balance their financial constraints with environmental responsibilities, while actively responding to the growing demand in the green market. Lastly, companies should enhance the management level of their personnel. Introducing managers with a strong ESG consciousness and a background in green innovation, along with training the existing management in ESG and green innovation, can improve their professional skills and awareness. This not only helps the company boost profitability and reduce operational risks, ensuring sufficient funds for green innovation but also ensures that specific funds support green innovation projects while elevating ESG ratings, thereby effectively enhancing ESG practices while minimizing the adverse impact on green innovation.

Additionally, the government needs to formulate more nuanced subsidy policies. Firstly, the government should implement differentiated subsidy strategies, adjusting according to the company's ESG ratings and green innovation needs. For "bad" enterprises, government subsidies should focus more on providing financial support for green innovation, especially when the subsidy amount reaches or exceeds "0.016", to enhance their green innovation capabilities while improving ESG ratings. Secondly, the government needs to avoid excessive subsidies; for "good" companies, subsidies should be granted cautiously to prevent them from neglecting the necessity of green innovation due to excessive comfort. The government could ensure the effective use of subsidies by setting subsidy caps or linking them to specific green innovation projects. Lastly, the government should establish effective monitoring and evaluation mechanisms to ensure that subsidy funds are correctly used for green innovation projects and to regularly assess the outcomes of these projects. This helps to maximize the efficacy of policies while reducing resource wastage.

ACKNOWLEDGMENTS

The authors acknowledge support from the National Natural Science Foundation of China (71721001 and 72371256) and the Excellent Young Team Project Natural Science Foundation of Guangdong Province of China (2023B1515040001).

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How to cite this article: Yang, C., Zhu, C., & Albitar, K. (2024). ESG ratings and green innovation: A U-shaped journey towards sustainable development. *Business Strategy and the Environment*, 1–22. https://doi.org/10.1002/bse.3692

APPENDIX A

TABLE A1 Robustness test: replacing the dependent variable.

Items	(1) F.Green_APP	(2) F.Green_APP^{I,NU}	(3) F.Green_APP^{I,NU}	(4) F.Green_APP^{NI,U}
ESG	−1.5975***	−1.7137***	−2.2842***	−2.0803***
	(0.5651)	(0.5138)	(0.3681)	(0.3264)
ESGPF	0.0391***	0.0390***	0.0440***	0.0366***
	(0.0076)	(0.0069)	(0.0050)	(0.0044)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−670.0991***	−502.7734***	−217.0831***	−111.8795***
	(46.8364)	(42.5866)	(30.5120)	(27.0532)
Observations	10,348	10,348	10,348	10,348
R-squared	0.2298	0.1672	0.0946	0.0593

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE A2 Robustness test: replacing the core explanatory variable.

Items	(1) F.Green_GET	(2) F.Green_GET^{I,NU}	(3) F.Green_GET^{I,NU}	(4) F.Green_GET^{NI,U}
HZesg	−5.7717***	−5.3533***	−2.9425***	−4.3734***
	(1.5793)	(1.1025)	(0.7603)	(0.9777)
HZesg^2	1.4132***	1.0399***	0.5547***	0.8083***
	(0.2611)	(0.1874)	(0.1319)	(0.1705)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−620.4776***	−295.7620***	−105.7735***	−124.9496***
	(38.8567)	(27.4609)	(16.2323)	(18.4023)
Observations	33,107	33,107	33,107	33,107
R-squared	0.2209	0.0969	0.0416	0.0487

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.

TABLE A3 Robustness test: U-shape test.

Items	(1) F.Green_GET	(2) F.Green_GET^{I,NU}	(3) F.Green_GET^{I,NU}	(4) F.Green_GET^{NI,U}
ESG	−2.1152***	−2.3143***	−2.2190***	−2.7070***
	(0.8043)	(0.6361)	(0.4868)	(0.7468)
ESGPF	0.0490***	0.0458***	0.0374***	0.0464***
	(0.0116)	(0.0097)	(0.0077)	(0.0113)
Control variables	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES
Constant	−634.3863***	−345.3180***	−173.4432***	−133.4492***
	(75.2353)	(59.6682)	(40.5678)	(47.4085)
Observations	10,348	10,348	10,348	10,348
R-squared	0.2554	0.1351	0.0715	0.0802
Inflection point	21.5917	25.28898	29.70524	29.1549
Proportion of samples on the left of the inflection point	22.8%	36.2%	63.6%	61.3%
Utest (P-value)	0.0259	0.00106	0.0000	0.0004

Note: ***, **, and * respectively represent statistical significance at the 1%, 5%, and 10% levels.