

Article

Green Innovation and ESG Rating Divergence: The Mediating Role of Product Market Competition in Chinese Manufacturing

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Abstract

This study examines the impact of green innovation investment on ESG rating divergence and the mediating role of product market competition, based on 11,768 firm-year observations of Chinese A-share listed manufacturing enterprises from 2011 to 2023. We measure green innovation by lagged green patent applications (distinguishing invention and utility model patents), ESG rating divergence by the standard deviation and range of scores from six mainstream international and domestic agencies, and product market competition using the Herfindahl–Hirschman Index. Using mediating effect models with multi-dimensional fixed effects and heterogeneity analysis, we find that green innovation significantly widens ESG rating divergence, with green invention innovation exerting a stronger impact. Product market competition plays a partial mediating role, as green innovation intensifies industry competition and further amplifies rating divergence. Heterogeneity analysis shows no significant effect for heavily polluting firms, while green invention innovation of high-attention firms is more likely to cause rating disputes. This study reveals the reverse spillover effect of green innovation on ESG evaluation, providing new perspectives for understanding rating divergence and references for corporate green strategies and rating system optimization.

Keywords: green innovation investment; ESG rating divergence; product market competition; China's manufacturing enterprises

1. Introduction

Against the backdrop of the global transition towards sustainable development, ESG (Environmental, Social, and Governance) rating has become a core tool for the capital market to evaluate enterprises' long-term value. However, with the widespread application of ESG ratings, the ESG rating system exhibits significant discrete characteristics. The correlation coefficient of ESG composite scores assigned to the same enterprise by different rating agencies is significantly lower than that of traditional credit ratings [1,2]. This systemic divergence not only reflects the heterogeneity of evaluation standards among different rating agencies. It may also lead to cognitive biases among stakeholders, and its economic consequences have attracted widespread attention.

ESG rating divergence interferes with investors' valuation judgments of enterprises and exacerbates information asymmetry between enterprises and investors [3]. Some retail investors thus choose to avoid enterprises with large ESG divergence, which reduces the activity of stock trading and further impairs the operational efficiency of the capital market and future

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stock returns [4]. Meanwhile, ESG rating divergence increases enterprises' operational risks and reputation risks [5], affecting their financing capacity [3]. The uncertainty caused by rating divergence [6] requires higher expected risk compensation to cover additional risk exposure, exerting a greater impact on sensitive investors [7]. Investors struggle to assess enterprises' true ESG performance, which reduces the information value conveyed by ESG performance [5]. To protect their own interests, investors will reduce investment in such enterprises, thereby lowering the enterprises' external financing capacity.

As an important path to improve ESG performance, enterprises' green innovation investment possesses significant dual attributes. On one hand, its environmental improvement function aligns with the external expectations of governments and the public. On the other hand, its characteristics of high investment and long cycle create potential conflicts with enterprises' goal of maximizing short-term profits. Hall [8] pointed out that even without considering differences in depreciation rates, the rate of return on R&D investment is still significantly lower than that of traditional investment. In addition to the high risks similar to traditional innovation activities, green innovation cannot bring short-term economic returns like traditional innovation due to its characteristics in upfront investment, return cycle, opportunity cost, and regulatory constraints [9]. Its long-term rate of return may also not have obvious advantages. In summary, rational managers will conduct green innovation investment more cautiously, and green innovation investment is highly correlated with enterprises' market competitiveness.

Market competition can be regarded as an external governance mechanism. It exerts supervisory, incentive, and guiding effects on enterprises' internal behaviors, thereby prompting enterprises to improve internal governance efficiency. Focusing on manufacturing enterprises, due to the abundance of homogeneous products in the market, external competitive pressure forces enterprises to improve the quality of ESG disclosure to respond to investors and various other social concerns. A large number of existing studies have discussed the impact of market competition on innovation, but the conclusions remain inconsistent. The main explanations include the competition-hinders-innovation theory based on Schumpeter's hypothesis, the competition-encourages-innovation theory based on Arrow's "ex-ante market power", and the inverted U-shaped relationship theory that attempts to reconcile the two. However, existing literature mostly focuses on the one-way impact of market competition on innovation. Research on how innovation investment reacts to market competition is obviously insufficient. Specifically in the field of green innovation, Chen et al. [10] pointed out that green products and green technologies significantly enhance enterprises' competitive advantages. Ambec et al. [11] further explained the dual paths through which green innovation strengthens enterprises' market position by improving environmental performance and competitiveness. Nevertheless, these discussions only focus on the competitiveness of individual enterprises and do not involve the impact of green innovation on the industry competition pattern.

In summary, the causes and consequences of ESG rating divergence have received extensive attention. The one-way mechanism of ESG rating divergence on enterprises' green innovation investment has also been confirmed. However, the possible result that enterprises' green innovation investment reacts to ESG rating divergence has been ignored. In manufacturing enterprises, the intensity of product market competition may be an important path through which green innovation affects ESG rating divergence, but this mechanism has not yet been tested. From the perspective of product market competition, this paper takes manufacturing industry as the research object to explore the impact mechanism of enterprises' green innovation investment on ESG rating divergence. It aims to reveal the complex relationship between green strategies and rating consistency under market competitive pressure, providing a theoretical basis for improving the ESG rating system and enterprises' sustainable development decisions.

2. Impact Mechanism

2.1. ESG Rating Divergence Expansion Effect of Green Innovation Investment

The emergence of ESG divergence stems from both rating agencies and rated enterprises. From the perspective of rating agencies, differences among various agencies in data sources, ESG information interpretation, rating methods, and weights lead to the inevitability of ESG divergence. These differences mainly include: (1) Disparities in the acquisition of secondary data sources other than enterprises' public reports among various rating agencies [12]. (2) The lack of unified and universal ESG rating standards, and the procedures of rating agencies are not subject to unified supervision [13]. After obtaining information, different rating agencies use different methods and weights to measure ESG input or output, leading to further differences in ESG ratings [1]. From the perspective of rated enterprises, ESG rating divergence actually reflects their internal governance level or motivation for cosmetic disclosure. A specific manifestation is that some enterprises adopt behaviors such as selective disclosure or "greenwashing" to cater to the rules of certain rating agencies, beautifying their own image. At the same time, this affects the judgments of other rating agencies, thereby resulting in ESG rating divergence [5,14].

Elame & Boulhaga [15] reveal the decisive role of corporate governance in the information value of ESG from the capital supply side, providing a new theoretical perspective for understanding rating heterogeneity. Based on an analysis of non-financial firms in the UK FTSE All-Share Index, finding that pure ESG disclosure itself significantly increases a firm's weighted average cost of capital (WACC), but strong corporate governance completely reverses this relationship. This result indicates that the divergence in rating agencies' assessments of firms' ESG performance essentially reflects differences in the credibility of ESG disclosure across firms: firms with weak governance are more likely to have their ESG information regarded as "greenwashing", leading to higher risk premiums and greater rating divergence. This perspective deepens the discussion of rating heterogeneity from the mere methodological level to the fundamental level of corporate governance structure and information quality, explaining why identical ESG disclosure content can produce significant differences across rating agencies. In addition, industry differences and regional policy differences also exacerbate ESG rating divergence. For example, (1) a large number of manufacturing enterprises have the characteristic of high resource consumption, so the rating divergence in the environmental dimension is particularly prominent. In contrast, financial enterprises have higher rating consistency due to improved information disclosure. (2) Due to the impact of differences in regional development levels and ESG policies, the degree of rating divergence of enterprises in emerging markets is also higher than that in developed markets.

This study builds its theoretical framework on the capital depreciation model developed by Lin [16], whose original research aimed to analyze how the endogenous technological progress affects cross-sectional stock returns. When the uniform accounting depreciation rate mandated by GAAP deviates from the true economic depreciation rate determined by technological progress, it creates systematic measurement bias in corporate asset values. This core logic is directly transferable and highly applicable to the study of ESG rating divergence. Following the approach of Lin [16], this paper divides enterprises' means of production into green R&D capital and green production capital based on the AK model. We make three targeted adaptations to Lin's [16] original model to fit the ESG rating context: (1) we extend the single representative investor perspective to include multiple heterogeneous rating agencies with different information sets; (2) we replace the stock return variable with ESG rating scores as the outcome variable of interest; (3) we explicitly incorporate the intangible nature of green assets which amplifies measurement uncertainty. On this basis, it explains the impact of green innovation investment on ESG

divergence from a mathematical model perspective. The production function of green innovation investment is shown in Equation (1):

$$Y_t = e^{x_t} A_t K_t \quad (1)$$

The green output Y_t of the enterprise in period t is mainly determined by the green production capital investment K_t , the endogenous green technological progress A_t , and the external shock e^{x_t} . The external shock x_t mainly comes from systematic risk factors and enterprise-specific heterogeneity risk factors.

Based on the new economic growth theory, green innovation investment is one of the important indicators for evaluating an enterprise's green innovation capability. Without considering the influence of green technology spillovers and foreign direct green investment, green innovation investment determines the enterprise's green technology level, as shown in Equation (2):

$$A_t = (\theta n_t)^\alpha \quad (2)$$

n_t is the green R&D capital, which is the sole input factor for the enterprise's internal green R&D activities. The θ portion of the green R&D capital is used for green technology improvement, and the $(1 - \theta)$ portion of the green R&D capital forms new green production capital. α is the output elasticity of the green R&D capital. At this time, Equation (1) can be expressed as follows, as shown in Equation (3):

$$Y_t = e^{x_t} (\theta n_t)^\alpha K_t \quad (3)$$

The accumulation process of green capital is as shown in Equation (4):

$$n_{t+1} = (1 - \delta_n) n_t + o_t \quad (4)$$

δ_n is the accounting depreciation rate of green R&D capital, which usually does not change over time; o_t is the directly quantifiable green R&D investment.

Referencing Lin [16], an asymmetric capital accumulation equation is constructed, and then the accumulation process of green production capital follows Equation (5):

$$K_{t+1} = (1 - \delta_k) K_t + \phi[i_t, (1 - \theta) n_{t+1}] \quad (5)$$

δ_k is the accounting depreciation rate of green production capital, which also usually does not change over time; i_t is the directly quantifiable green production investment; $\phi[i_t, (1 - \theta) n_{t+1}]$ can be regarded as a constant elasticity of substitution function, as shown in Equation (6):

$$\phi[i_t, (1 - \theta) n_{t+1}] \stackrel{\text{def}}{=} B \{b(i_t)^\rho + (1 - b)[(1 - \theta) n_{t+1}]^\rho\}^{1/\rho} \quad (6)$$

In Equation (6), B , b , ρ are all constants, where $B > 0$, $1 > b > 0$, $\rho < 1$ and $\rho \neq 0$. At the same time, its partial derivatives satisfy: $\phi_{11} < 0$, $\phi_{22} < 0$, $\phi_{12} > 0$.

According to the Euler transformation, Equation (5) is transformed into Equation (7):

$$K_{t+1} = (1 - \delta_k) K_t + i_t \phi_1[i_t, (1 - \theta) n_{t+1}] + (1 - \theta) n_{t+1} \phi_2[i_t, (1 - \theta) n_{t+1}] \quad (7)$$

After adjustment, we get:

$$\frac{K_{t+1}}{\phi_1[i_t, (1 - \theta) n_{t+1}]} = \frac{(1 - \delta_k) K_t}{\phi_1[i_t, (1 - \theta) n_{t+1}]} + i_t + \frac{(1 - \theta) n_{t+1} \phi_2[i_t, (1 - \theta) n_{t+1}]}{\phi_1[i_t, (1 - \theta) n_{t+1}]} \quad (8)$$

$\phi_1[i_t, (1 - \theta) n_{t+1}]$ is the marginal capital accumulation of the green productive investment i_t . Then, $\widetilde{K}_{t+1}$ is the replacement cost of the green production capital K_{t+1} , that is:

$$\widetilde{K}_{t+1} \stackrel{\text{def}}{=} \frac{K_{t+1}}{\phi_1[i_t, (1 - \theta) n_{t+1}]} \quad (9)$$

The investment in green R&D capital promotes the improvement of the enterprise's green technology, causing the replacement cost of green production capital to decline as the

green R&D investment increases, thereby reducing the enterprise's green production costs. Green R&D innovation brings about green technological progress, accelerating the economic depreciation of green investment (denoted as $\widetilde{\delta}_k$). The green economic depreciation rate is higher than the accounting depreciation rate, which is specifically shown in Equation (10):

$$\frac{(1 - \delta_k)K_t}{\phi_1[i_t, (1 - \theta)n_{t+1}]} = \frac{(1 - \delta_k)}{\phi_1[i_t, (1 - \theta)n_{t+1}]/\phi_1[i_{t-1}, (1 - \theta)n_t]} \frac{K_t}{\phi_1[i_{t-1}, (1 - \theta)n_t]} \stackrel{\text{def}}{=} (1 - \widetilde{\delta}_k)\widetilde{K}_t \quad (10)$$

It is a common practice to measure the stock of innovation capital using the perpetual inventory method with a depreciation rate of 15% [8,17], as shown in Equations (11) and (12):

$$n_t = o_{t-1} + (1 - \delta_n)n_{t-1} \quad (11)$$

$$n_0 = \frac{o_0}{g + \delta_n} \quad (12)$$

Among them, n_t is the stock of green innovation capital in the base period, n_0 is the green innovation capital in the base period, g is the average annual growth rate of the industry's green innovation capital, and δ_n is the general accounting depreciation rate (15%). At this time, the stock of green innovation capital is overestimated, which may have negative impacts such as an exacerbation of information asymmetry, overly optimistic external evaluations, and overly high future expectations of the enterprise. This overestimation translates into ESG rating divergence through a three-step logical chain derived directly from our adapted Lin [16] model. First, measurement bias generation. Green innovation accelerates technological obsolescence, making the true economic depreciation rate δ^e of green R&D capital significantly higher than the fixed accounting depreciation rate (15%). This may create a persistent measurement gap $M_{it} = |\delta^a - \delta^e|$ in reported green asset values. Second, heterogeneous correction by rating agencies. Unlike financial accounting which follows uniform GAAP standards, ESG rating agencies have no mandatory guidelines for correcting this measurement bias. Each agency j applies its own correction factor $\lambda_j \in [0, 1]$ to the reported accounting value, resulting in an adjusted green asset value $V_{ijt} = K_{it}(1 - \delta^a + \lambda_j M_{it})$. Third, rating divergence formation. Since ESG environmental scores are positively correlated with adjusted green asset values ($E_{ijt} = \alpha V_{ijt} + \epsilon_{ijt}$), the divergence between any two agencies j and k is given by $D_{it} = |E_{ijt} - E_{ikt}| = \alpha K_{it} |\lambda_j - \lambda_k| M_{it}$. This equation formally proves that ESG rating divergence is an increasing function of both the accounting depreciation mismatch M_{it} and the heterogeneity in agency correction factors $|\lambda_j - \lambda_k|$. These impacts, in turn, will lead to divergence in ESG ratings.

Notably, this overestimation does not lead to uniform upward bias in ESG ratings as intuitively expected, but rather drives divergent evaluations across agencies through a integrated transmission mechanism that takes accounting measurement bias as the core micro-foundation. Unlike financial accounting which follows uniform GAAP/IFRS standards, ESG rating agencies have no unified guidelines for adjusting green innovation capital measurement, and their inherent heterogeneities are amplified by this accounting bias. First, the accounting measurement channel: the divergent correction rules for green R&D capital (the core starting point). Agencies adopt drastically different approaches to R&D capitalization and depreciation [12]. Some directly use unadjusted accounting data accepting the 15% depreciation rate, others apply industry-specific green technology depreciation rates ranging from 20% to 30%, and a small number even expense all green R&D investment entirely. We do not assume that all rating agencies have equal access to firms' internal technology obsolescence rates. On the contrary, differences in agencies' information acquisition capabilities are a fundamental source of this divergence in correction rules. Agencies with stronger industry connections and research capabilities can obtain more accurate estimates of actual economic depreciation rates, while smaller agencies rely

solely on uniform accounting standards. This divergence in correction rules translates the same overestimated accounting capital into vastly different adjusted values across agencies, creating the initial foundation for rating disagreement.

Second, the information asymmetry channel: ambiguous value signals of intangible green assets. The overestimation of green innovation capital contains inherently conflicting value signals. It may reflect unbooked future emission reduction potential and long-term competitive advantages, but also implies impending asset impairment risks and inflated short-term profits. Unlike tangible assets with clear market values, green innovation is an intangible asset whose future benefits are highly uncertain. Recent research also points out that the technical complexity and long payback cycle of green technology innovation further exacerbate this information asymmetry between firms and external stakeholders [18], and significant regional differences in green innovation efficiency across China add another layer of complexity to information interpretation [19]. Importantly, this information asymmetry is significantly amplified by the lack of standardized third-party technical verification for green invention patents in the Chinese market. While utility model patents undergo strict formal examination with standardized authorization criteria, green invention patents only receive substantive examination focusing on novelty and inventiveness, with no independent verification of their actual environmental benefits, technical maturity, or commercialization potential. Firms can self-declare the environmental attributes of their invention patents without mandatory third-party validation, creating substantial information asymmetry between firms and rating agencies. This inherent ambiguity leaves greater room for subjective interpretation by different rating agencies.

Third, the strategic disclosure channel: selective information release by firms. Faced with the ambiguous value signals of green innovation, enterprises adopt differentiated strategic disclosure behaviors. Some firms emphasize the environmental benefits and long-term value of green innovation to attract ESG investors, while others downplay the associated financial risks to avoid negative market reactions. Institutional investor preference for green innovation also exerts heterogeneous pressure on firms' disclosure strategies [20], further increasing the diversity of information available to rating agencies. This selective disclosure further increases the complexity of ESG information, making it more difficult for rating agencies to form consistent evaluations. Fourth, the rater heterogeneity channel: divergent evaluation paradigms for intangible assets. Rating agencies systematically differ in their fundamental evaluation frameworks for intangible assets [1]. Environment-focused agencies prioritize the upside potential of green innovation and assign higher scores, while finance-focused agencies emphasize downside financial risks and assign lower scores. International agencies focus on global comparability of green technologies, while domestic agencies pay more attention to compliance with Chinese local regulations. This fundamental heterogeneity in evaluation paradigms transforms the same set of green innovation information into vastly different ESG ratings across agencies.

In summary, the economic depreciation rate of green innovation investment in manufacturing is higher than the accounting depreciation rate of traditional innovation investment judged based on past experience. The difference in the accounting treatment of R&D itself is an important factor affecting enterprise valuation [21]. The main reasons include inflated profits caused by distorted financial statements, increased tax burden due to overestimated taxable profits, investment decision biases caused by underestimated costs, and increased subsequent innovation pressure due to misjudgment of the speed of technological and market progress. Combined with the explanations of the sources of ESG rating divergence in previous studies, the above factors based on accounting will directly or indirectly lead to ESG score divergence. This accounting depreciation mismatch mechanism provides a micro-founded explanation for ESG rating divergence that complements existing explanations focused on rating agency methodology differences. Unlike cosmetic

disclosure which is a strategic behavior, the measurement bias identified here is a structural feature of current accounting standards that affects all firms engaging in green innovation. Based on this, Hypothesis 1 of this paper is proposed:

Hypothesis 1. *Green innovation investment expands ESG rating divergence of manufacturing enterprises.*

2.2. Green Innovation Investment, Product Market Competition, and ESG Divergence

Considering the objective phenomenon of industry competition among manufacturing enterprises, this paper focuses on the product market to study the impact of competition on green innovation investment and ESG rating divergence of manufacturing enterprises. In a monopolistically competitive market, each manufacturer has partial influence on product prices. The inverse demand function of manufacturers is shown in Equation (13). The price elasticity of product demand is closely related to the degree of competition [22]. The more intense the product market competition, the easier it is for consumers to purchase related substitutes, and the greater the price elasticity of demand.

$$P_t = Y_t^{-\frac{1}{\varepsilon_t}} \quad (13)$$

When the price elasticity of product demand is greater than 1, R&D capital input reduces production costs by improving enterprises' total factor productivity [23]. Green innovation input has the same economic effect. Although the increase in supply in the market will lead to a decrease in equilibrium prices, advantages such as cost reduction and output expansion can buffer the price impact [24], which may still promote enterprises' green performance. This promotion effect is mainly affected by the marginal operating performance of green R&D capital and the green capital retention rate [21,25,26]. The promotion effect of green R&D capital on green performance is affected by the degree of product market competition in which it operates. The greater the price elasticity of product market demand, the better the promotion effect. In a highly competitive product market, the price elasticity of demand is large, and products are more substitutable. The marginal performance brought by green R&D capital is also greater. Early studies on developed countries have also confirmed that the marginal performance of R&D capital will increase with the increase in industry competition [27].

Although it is generally believed that products with price elasticity of demand less than 1 account for a larger proportion in developing economies, the input of green R&D capital may cause excessive short-term supply growth and overly rapid decline in market equilibrium prices, leading to a decline in overall operating performance. However, this adverse impact is relatively limited. First, based on the perspective of neoclassical economics, market price fluctuations are short-term manifestations of supply and demand imbalances. Enterprises will adapt to price changes by adjusting output, costs, or technological innovation, eventually forming a new equilibrium. Meanwhile, innovation theory and endogenous growth models suggest that short-term price shocks will accelerate enterprises' technological upgrading. In the long run, the performance of such enterprises is better than the industry average. Second, green R&D input has obvious external economies, including government policy support [28], tax incentives, and direct economic subsidies [29]. External policy support itself is an important factor driving enterprises' green innovation input [30]. Such support and government endorsement strengthen the marginal output capacity of green innovation input. Consumers are generally unwilling to pay a premium for pure environmental attributes, and the pricing power of green products mainly comes from quality improvement rather than environmental characteristics. This finding greatly enriches the discussion on "why green innovation intensifies product market competition": it is precisely due to the failure of the cost transmission mechanism that green investments in manufacturing firms cannot be converted

into excess profits, but instead force firms to engage in more intense games between cost control and market share, which is highly consistent with the widespread “green non-premium” dilemma faced by Chinese manufacturing firms. Third, the spillover effect of green innovation knowledge will intensify industry competition, forcing enterprises to continuously invest to maintain their competitive advantages, forming a spiral development trend of “innovation-competition” [31], and even leading to excessive competition [32]. Under such competition, the intensification of competition within the industry makes the demand curve flatter. Although green innovation input may promote product differentiation, it will still lead to competitive outcomes such as “price wars” [33]. Especially in manufacturing enterprises with abundant substitutes, consumers are more sensitive to price changes [34].

Regardless of the price elasticity of demand, green innovation input has a positive impact on long-term green marginal performance. In this case, some enterprises may over-invest in green innovation, thereby affecting the market competition pattern and intensifying ESG rating divergence in the short term. Considering that green innovation requires continuous investment, this impact on ESG divergence may also persist. Product market competition is influenced by the green innovation policies of various enterprises. On the other hand, through its information amplification effect, it expands ESG rating divergence. In summary, Hypothesis 2 is proposed:

Hypothesis 2. *Green innovation input intensifies product market competition of manufacturing enterprises, thereby expanding ESG rating divergence.*

Based on the above theoretical analysis, we construct a conceptual framework that integrates the direct effect of green innovation on ESG rating divergence and the mediating effect of product market competition, as shown in Figure 1. This framework clearly illustrates the heterogeneous impacts of different types of green patents, the core transmission channels, and the complete logical chain from green innovation investment to ESG rating divergence.

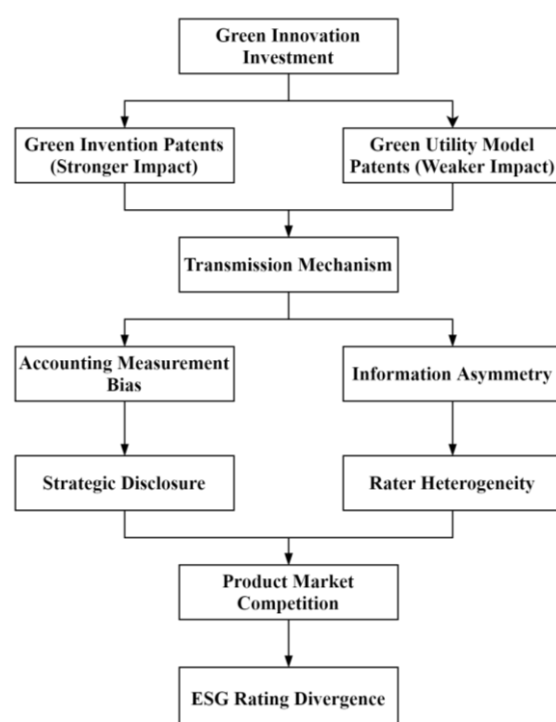


Figure 1. Conceptual Framework of Green Innovation Affecting ESG Rating Divergence.

3. Study Design

3.1. Sample Selection and Data Sources

After the 2009 Copenhagen Climate Conference, governments at all levels in China began to promote the concept of a low-carbon economy and advocate green emission reduction goals. This paper takes 2010, the “first year of low-carbon entrepreneurship in China”, as the starting point. It selects manufacturing enterprises listed on China’s Shanghai and Shenzhen A-shares from 2010 to 2023, which have fierce market competition and improved information disclosure. Meanwhile, to more reasonably study the impact of green R&D input in a monopolistically competitive market, samples with fewer than 15 companies in sub-industries are excluded. This threshold is a standard practice in industrial organization research to ensure that the market structure approximates monopolistic competition, as markets with fewer than 15 firms typically exhibit oligopolistic or monopolistic characteristics that violate the theoretical assumptions of our model. Our sample retains approximately 95% of all manufacturing sub-industries, including all major high-tech manufacturing sectors such as electrical machinery, electronic equipment, and pharmaceutical manufacturing. The excluded sub-industries are mostly highly specialized niche sectors with incomplete green patent and ESG rating data, which would introduce significant measurement error if included. The main data sources are from the CSMAR database, and samples with missing key variables are deleted. To avoid the impact of outliers on regression analysis, all data are winsorized at the 1% level.

3.2. Design of Variables

(1) Dependent Variable: ESG Rating Divergence. This study selects six ESG score sources covering both international mainstream rating agencies and Chinese local rating agencies, namely FTSE Russell, MSCI, CHIndices, Wind, Menglang, and SynTao. Since the six agencies adopt completely different original scoring systems, including both numerical scales and letter-grade scales, direct comparison of raw scores is impossible. To unify these heterogeneous scales while preserving the relative interval information of original ratings, we first convert all non-numerical letter grades to continuous integer values in ascending order of ESG performance. Next, we linearly scale the numerical scores of all six agencies to a uniform 1–8 point interval, which ensures that the relative differences between scores within each agency are retained. For each manufacturing firm-year observation, we collect the six standardized 1–8 point scores from the six agencies, and construct two complementary measures of ESG rating divergence based on these unified scores. (1) *ESGdif6*, the sample standard deviation of the six standardized scores that measures the overall dispersion of ratings, and (2) *ESGrange6*, the range (maximum value minus minimum value) of the six standardized scores that captures the extreme disagreement between the most optimistic and most pessimistic agencies. The selection of these six agencies is based on three core criteria that collectively ensure our measure captures the full spectrum of systemic ESG rating divergence in the Chinese market. First, they represent the most widely used ESG rating agencies by domestic and international investors in China. Second, the six agencies represent three distinct evaluation paradigms, which are critical for measuring systemic rating divergence. Third, these are the only six agencies that provide continuous, complete ESG rating data for A-share manufacturing firms covering our full sample period from 2011 to 2023.

(2) Independent Variable: Green Innovation Investment. Green patents are important manifestations of enterprises’ green innovation input and carriers of green innovation results. This study measures the level of enterprises’ green innovation input by the number of green patent applications (*Greenapply_total*). It further distinguishes between the number of green invention patent applications (*Greenapply_invent*) and the number of green

utility model patent applications (*Greenapply_utility*). Considering that the formation of green patents takes a long time, when various rating agencies announce their ESG scores, they mostly refer to enterprises' past data for judgment. Therefore, the lagged one-period number of green patent applications is used to measure enterprises' green innovation input. Before 2010, Chinese enterprises did not pay sufficient attention to green innovation. The lagged one-period green innovation input data do not have sufficient practical significance for the impact of ESG divergence in 2010. The actual regression analysis period of this study is 2011–2023. This approach also avoids endogeneity issues such as reverse causality to a certain extent.

While green R&D expenditure is conceptually a direct flow measure of innovation investment, we believe lagged green patent applications are the most valid and reliable proxy for green innovation investment in the context of our study for several important reasons. First, there is a severe lack of disaggregated green R&D data in the Chinese market. Chinese listed firms were not required to separately disclose total R&D expenditure until 2018, and even today, less than 15% of firms explicitly distinguish between green R&D and traditional R&D in their annual reports. No public database provides continuous green R&D expenditure data for A-share firms before 2018, which would reduce our sample size by over 70% and eliminate the early critical period of China's green transition. Second, green R&D data suffers from significant accounting noise and greenwashing risks. There is no uniform accounting standard for green R&D in China, and firms vary widely in their treatment of green R&D as capitalized or expensed. Many firms also inflate their reported green R&D by including non-green expenditures to obtain government subsidies or improve their ESG images. In contrast, green patent applications require substantive technical review by the China National Intellectual Property Administration (CNIPA), with strict classification criteria for green technologies based on the WIPO Green Inventory, making them far less susceptible to manipulation. Third, lagged patent applications have perfect temporal alignment with ESG rating practices. ESG rating agencies primarily rely on publicly verifiable outcome data rather than internal expenditure data when evaluating green innovation.

(3) Mediating Variable: Market Competition. The Herfindahl–Hirschman Index (*HHI*) is a traditional indicator to measure the degree of product market competition. The calculation of the Herfindahl–Hirschman Index is shown in Equation (14):

$$HHI = \sum_{i=1}^k \left(\frac{x_i}{x} \right)^2 = \sum_{i=1}^k s_i^2 \quad (14)$$

Considering the characteristics of manufacturing enterprises, in Equation (14), x_i represents the main business income of the i -th enterprise in the industry, and k represents the number of enterprises in the industry. The *HHI* index assigns greater weight to large-scale enterprises than small-scale enterprises, so it is more sensitive to the market share of leading enterprises. A lower *HHI* value indicates a more competitive product market.

(4) Control variables. Based on the studies of Paltrinieri et al. [35], Khemakhem et al. [36], and Song et al. [37], considering data availability, the following variables are specifically controlled in the empirical analysis: enterprise size (*Size*), financial leverage (*Lev*), return on total assets (*ROA*), total asset turnover (*TAT*), ownership nature (*SOE*), duality of chairman and general manager (*Dual*), shareholding ratio of the largest shareholder (*Top1*), proportion of independent directors (*Indep*), and international Big Four accounting firms (*Big4*). This paper also controls for year (*Year*), province (*Province*), and sub-industry (*Industry*) fixed effects. The variable definitions are shown in Table 1.

Table 1. Definition of main variables.

Variable Type	Variable Symbol	Variable Name	Variable Definition
Dependent Variable	<i>ESGdif6</i>	ESG Divergence Standard Deviation	Sample standard deviation of year-by-year percentile standardized ESG ratings from 6 sources
	<i>ESGrange6</i>	ESG Divergence Range	Range of year-by-year percentile standardized ESG ratings from 6 sources
Independent Variable	<i>Greenapply_total</i>	Green Innovation Investment	Natural logarithm of the lagged one-period number of enterprises' green patent applications
	<i>Greenapply_invent</i>	Green Invention Innovation Investment	Natural logarithm of the lagged one-period number of green invention patent applications
	<i>Greenapply_utility</i>	Green Utility Innovation Investment	Natural logarithm of the lagged one-period number of green utility model patent applications
Mediating Variable	<i>HHI</i>	Product Market Competition	Herfindahl–Hirschman Index of sub-industries
Control Variable	<i>Size</i>	Enterprise Size	Natural logarithm of total assets
	<i>Lev</i>	Financial Leverage	Total liabilities/Total assets
	<i>ROA</i>	Profitability	Return on total assets
	<i>TAT</i>	Asset Efficiency	Total asset turnover
	<i>SOE</i>	Ownership Nature	Dummy variable: 1 if state-owned enterprise, 0 otherwise
	<i>Dual</i>	Duality	Dummy variable: 1 if the chairman and general manager are the same person, 0 otherwise
	<i>Top1</i>	Ownership Concentration	Shareholding ratio of the largest shareholder
	<i>Indep</i>	Board Independence	Proportion of independent directors
	<i>Big4</i>	Big 4 Audit	Dummy variable: 1 if the audit opinion is issued by one of the international Big Four accounting firms, 0 otherwise
	<i>Year</i>	Year	Year fixed effect
	<i>Province</i>	Province	Province fixed effect
	<i>Industry</i>	Sub-Industry	Sub-industry fixed effect

3.3. Models Specification

To study the impact of green innovation investment on ESG rating divergence of manufacturing enterprises, that is, to verify Hypothesis 1, Model (1) is constructed:

$$\begin{aligned}
 &ESGdif6_{i,t} \setminus ESGrange6_{i,t} \\
 &= \beta_0 + \beta_1 Greenapply_{i,t} + \beta_\tau Controls_{i,t} + \sum Year \quad \text{Model (1)} \\
 &+ \sum Province + \sum Industry + \varepsilon_{i,t}
 \end{aligned}$$

To study the mediating role of product market competition between green innovation investment and ESG rating divergence of manufacturing enterprises, that is, to verify Hypothesis 2, Models (2) and (3) are constructed:

$$HHI_{i,t} = \gamma_0 + \gamma_1 Greenapply_{i,t} + \gamma_\tau Controls_{i,t} + \sum Year + \sum Province + \sum Industry + \varepsilon_{i,t} \quad \text{Model (2)}$$

$$\begin{aligned}
 &ESGdif6_{i,t} \setminus ESGrange6_{i,t} \\
 &= \theta_0 + \theta_1 HHI_{i,t} + \theta_2 Greenapply_{i,t} + \theta_\tau Controls_{i,t} \quad \text{Model (3)} \\
 &+ \sum Year + \sum Province + \sum Industry + \varepsilon_{i,t}
 \end{aligned}$$

If γ_1 in Model (2) is significantly negative, it indicates that green innovation investment significantly enhances market competition. The Herfindahl–Hirschman Index (*HHI*) is computed at the sub-industry-year level rather than the firm level, which creates a level mismatch between the firm-level independent variable and the industry-level mediator. This specification is theoretically justified and widely adopted in industrial organization

research for three key reasons. First, product market competition is inherently an industry-level structural characteristic that cannot be meaningfully defined at the individual firm level. A single firm's green innovation does not change its own level of competition but rather reshapes the competitive dynamics of the entire industry in which it operates. Second, we have mitigated potential aggregation bias by controlling for sub-industry fixed effects in all regressions, which absorb all time-invariant industry characteristics that could affect both *HHI* and *ESG* rating divergence. In our robustness tests, we further control for industry $\times$ year high-dimensional fixed effects, which absorb all time-varying industry-level shocks and significantly reduce the risk of spurious correlation. At this time, if θ_1 in Model (3) is significantly negative and θ_2 is significantly positive, it indicates that market competition plays a partial mediating role in the path of green innovation investment affecting *ESG* rating divergence of manufacturing enterprises. If θ_1 in Model (3) is significantly negative and θ_2 does not pass the significance test, market competition plays a full mediating role.

4. Empirical Analysis

4.1. Descriptive Statistics and Correlation Analysis of Variables

The results of descriptive statistics of variables are shown in Table 2. There is a certain degree of divergence in *ESG* ratings among manufacturing enterprises. The range of *ESG* scores is larger than the overall standard deviation of *ESG* scores. There are obvious differences in green innovation investment among various enterprises. After distinguishing between green invention innovation investment and green utility innovation investment, the difference in invention innovation investment is greater. The Herfindahl–Hirschman Index of market competition among manufacturing enterprises is small, indicating fierce market competition.

Table 2. Descriptive Statistics of Variables.

	N	Mean	p50	SD	Var	Min	Max
<i>ESGdif6</i>	11,769	0.403	0	0.609	0.371	0	2.121
<i>ESGrange6</i>	11,769	0.732	0	1.146	1.313	0	4.000
<i>Greenapply_total</i>	11,769	0.978	0.693	1.229	1.512	0.000	4.934
<i>Greenapply_invent</i>	11,769	0.657	0	1.026	1.053	0.000	4.443
<i>Greenapply_utility</i>	11,769	0.675	0.000	0.970	0.940	0.000	3.951
<i>HHI</i>	11,769	2.061	2.055	0.555	0.308	1.000	3.320
<i>Size</i>	11,769	22.372	22.206	1.179	1.391	20.248	25.894
<i>Lev</i>	11,769	0.389	0.387	0.170	0.029	0.062	0.751
<i>ROA</i>	11,769	0.057	0.047	0.043	0.002	0.001	0.211
<i>TAT</i>	11,769	0.736	0.653	0.394	0.155	0.181	2.556
<i>SOE</i>	11,769	0.321	0	0.467	0.218	0	1
<i>Dual</i>	11,769	0.287	0	0.452	0.205	0	1
<i>Top1</i>	11,769	34.952	33.260	14.395	207.229	9.190	74.660
<i>Indep</i>	11,769	3.151	3.000	0.516	0.266	2	5
<i>Big4</i>	11,769	0.066	0	0.248	0.061	0	1

From the results of correlation analysis between variables, the correlation coefficients between most variables in the model are less than 0.2. Through VIF variance inflation factor test, the maximum VIF value is only 1.78, and the average VIF value is 1.21. Moreover, this paper does not discuss the contribution of individual variables from their specific regression coefficients. It can be considered that there is no obvious multicollinearity between the variables of the overall model. Due to space limitations, the detailed results are not presented.

4.2. Empirical Analysis of the Impact of Green Innovation Investment on ESG Rating Divergence

The regression results of Model (1) are shown in Table 3. The overall green innovation input, green invention innovation input, and green utility innovation input of manufacturing enterprises have significant positive impacts on ESG rating divergence calculated by different methods. With the increase in green innovation input, ESG divergence gradually increases, and Hypothesis 1 is verified. In addition, compared with green utility innovation input, green invention innovation input has a greater impact. The reason is that invention innovation has a higher threshold, larger upfront investment, and attracts more external attention than utility innovation. More importantly, as discussed in our theoretical framework, the lack of standardized third-party technical verification for green invention patents in China further amplifies this effect. Utility model patents, with their simpler technical content and standardized formal examination process, have relatively clear and consistent value signals across all rating agencies. In contrast, the unvalidated environmental claims and uncertain technical value of green invention patents force rating agencies to rely on their own evaluation criteria and subjective judgments, leading to significantly larger rating divergence.

Table 3. Impact of Green Innovation Investment on ESG Rating Divergence.

	(1) <i>ESGdif6</i>	(2) <i>ESGrange6</i>	(3) <i>ESGdif6</i>	(4) <i>ESGrange6</i>	(5) <i>ESGdif6</i>	(6) <i>ESGrange6</i>
<i>Greenapply_total</i>	0.021 *** (4.07)	0.055 *** (5.73)				
<i>Greenapply_invent</i>			0.028 *** (4.56)	0.077 *** (6.69)		
<i>Greenapply_utility</i>					0.015 ** (2.41)	0.042 *** (3.49)
<i>Size</i>	0.157 *** (26.69)	0.377 *** (34.94)	0.156 *** (27.09)	0.374 *** (35.21)	0.162 *** (27.73)	0.390 *** (36.09)
<i>Lev</i>	−0.002 (−0.39)	−0.014 (−1.36)	−0.002 (−0.32)	−0.013 (−1.22)	−0.003 (−0.52)	−0.016 (−1.54)
<i>ROA</i>	0.494 *** (3.86)	1.823 *** (7.55)	0.495 *** (3.87)	1.831 *** (7.58)	0.487 *** (3.80)	1.807 *** (7.47)
<i>TAT</i>	−0.022 (−1.61)	−0.085 *** (−3.56)	−0.021 (−1.55)	−0.083 *** (−3.47)	−0.022 (−1.64)	−0.087 *** (−3.60)
<i>SOE</i>	−0.065 *** (−5.33)	−0.107 *** (−4.80)	−0.067 *** (−5.46)	−0.112 *** (−5.03)	−0.063 *** (−5.17)	−0.101 *** (−4.56)
<i>Dual</i>	−0.038 *** (−3.54)	−0.063 *** (−3.31)	−0.039 *** (−3.61)	−0.065 *** (−3.42)	−0.039 *** (−3.55)	−0.063 *** (−3.32)
<i>Top1</i>	−0.002 *** (−4.57)	−0.002 *** (−2.64)	−0.002 *** (−4.55)	−0.002 *** (−2.61)	−0.002 *** (−4.58)	−0.002 *** (−2.65)
<i>Indep</i>	−0.013 (−1.28)	−0.021 (−1.12)	−0.013 (−1.27)	−0.021 (−1.11)	−0.013 (−1.27)	−0.021 (−1.10)
<i>Big4</i>	0.183 *** (7.65)	0.349 *** (7.73)	0.179 *** (7.46)	0.338 *** (7.44)	0.184 *** (7.73)	0.353 *** (7.84)
<i>Cons.</i>	−3.021 *** (−23.90)	−7.627 *** (−33.06)	−3.008 *** (−24.16)	−7.551 *** (−33.16)	−3.127 *** (−24.80)	−7.888 *** (−34.09)
<i>Year</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	11,768	11,768	11,768	11,768	11,768	11,768
<i>Adj.R²</i>	0.329	0.395	0.328	0.396	0.328	0.394

Note: *t*-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$.

4.3. Mediating Effect of Product Market Competition

Table 4 reports the estimation results of Model (2), which examines the impact of firm-level green innovation on industry-level product market competition. As shown in Table 4, the overall green innovation input, green invention innovation input, and green utility model innovation input of manufacturing enterprises have significant negative impacts on the Herfindahl–Hirschman Index. That is, they all significantly increase the degree of product market competition. This result confirms that individual firms' green innovation activities have industry-wide spillover effects that intensify overall market competition, which is consistent with the theoretical prediction of the escape competition effect [38]. When a firm introduces new green technologies or products, it gains a temporary competitive advantage, forcing other firms in the industry to invest more in green innovation to catch up, thereby increasing the overall intensity of competition in the industry. On this basis, as shown in Table 5, the Herfindahl–Hirschman Index plays a significant partial mediating role in green innovation input expanding ESG rating divergence, and Hypothesis 2 is verified.

Table 4. Impact of Green Innovation Investment on Product Market Competition.

	(1) <i>HHI</i>	(2) <i>HHI</i>	(3) <i>HHI</i>
<i>Greenapply_total</i>	−0.011 ** (−2.22)		
<i>Greenapply_invent</i>		−0.012 ** (−2.14)	
<i>Greenapply_utility</i>			−0.014 ** (−2.56)
<i>Cons.</i>	1.399 *** (12.61)	1.413 *** (13.03)	1.448 *** (13.21)
<i>Controls</i>	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes
<i>N</i>	11,768	11,768	11,768
<i>Adj.R²</i>	0.292	0.292	0.292

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$.

Table 5. Mediating Role of Product Market Competition.

	(1) <i>ESGdif6</i>	(2) <i>ESGrange6</i>	(3) <i>ESGdif6</i>	(4) <i>ESGrange6</i>	(5) <i>ESGdif6</i>	(6) <i>ESGrange6</i>
<i>Greenapply_total</i>	0.021 *** (4.09)	0.056 *** (5.76)				
<i>Greenapply_invent</i>			0.028 *** (4.58)	0.078 *** (6.72)		
<i>Greenapply_utility</i>					0.016 ** (2.42)	0.042 *** (3.50)
<i>HHI</i>	−0.023 ** (−2.33)	−0.058 *** (−3.24)	−0.023 ** (−2.35)	−0.058 *** (−3.27)	−0.022 ** (−2.25)	−0.056 *** (−3.12)
<i>Cons.</i>	−3.034 *** (−23.81)	−7.664 *** (−32.99)	−3.022 *** (−24.08)	−7.589 *** (−33.11)	−3.140 *** (−24.70)	−7.924 *** (−34.01)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes	Yes	Yes

	(1) <i>ESGdif6</i>	(2) <i>ESGrange6</i>	(3) <i>ESGdif6</i>	(4) <i>ESGrange6</i>	(5) <i>ESGdif6</i>	(6) <i>ESGrange6</i>
N	11,768	11,768	11,768	11,768	11,768	11,768
Adj.R ²	0.329	0.395	0.330	0.396	0.329	0.394

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$.

We conduct a bias-corrected accelerated Bootstrap test with 5000 repeated samplings. This method does not require the indirect effect to follow a normal distribution, which is the most rigorous standard for mediation analysis in contemporary empirical research. We set the random seed to 20,000 to ensure complete reproducibility of the results.

The results in Tables 6 and 7 confirm that all core coefficients remain statistically significant at conventional levels and are nearly identical in magnitude to the baseline regression results in Tables 4 and 5. The Bootstrap test verifies that product market competition plays a significant partial mediating role in the relationship between green innovation and ESG rating divergence. This result provides rigorous statistical evidence supporting Hypothesis 2.

Table 6. Bootstrap Robustness Test: Impact of Green Innovation on Product Market Competition.

	(1) <i>HHI</i>	(2) <i>HHI</i>	(3) <i>HHI</i>
<i>Greenapply_total</i>	−0.010 ** (−2.21)		
<i>Greenapply_invent</i>		−0.012 ** (−2.18)	
<i>Greenapply_utility</i>			−0.014 *** (−2.59)
<i>Cons.</i>	1.301 *** (11.10)	1.310 *** (11.52)	1.294 *** (11.36)
<i>Controls</i>	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes
N	11,768	11,768	11,768
Adj.R ²	0.293	0.293	0.293

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$.

Table 7. Bootstrap Robustness Test: Mediating Role of Product Market Competition.

	(1) <i>ESGdif6</i>	(2) <i>ESGrange6</i>	(3) <i>ESGdif6</i>	(4) <i>ESGrange6</i>	(5) <i>ESGdif6</i>	(6) <i>ESGrange6</i>
<i>Greenapply_total</i>	0.022 *** (4.17)			0.057 *** (5.97)		
<i>Greenapply_invent</i>		0.027 *** (4.50)			0.077 *** (6.66)	
<i>Greenapply_utility</i>			0.017 *** (2.60)			0.046 *** (3.86)
<i>HHI</i>	−0.023 ** (−2.29)	−0.023 ** (−2.31)	−0.022 ** (−2.22)	−0.058 *** (−3.23)	−0.058 *** (−3.25)	−0.056 *** (−3.12)
<i>Cons.</i>	−3.361 *** (−24.65)	−3.353 *** (−24.92)	−3.463 *** (−25.52)	−8.560 *** (−34.28)	−8.498 *** (−34.36)	−8.811 *** (−35.38)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes	Yes	Yes	Yes

	(1) <i>ESGdif6</i>	(2) <i>ESGrange6</i>	(3) <i>ESGdif6</i>	(4) <i>ESGrange6</i>	(5) <i>ESGdif6</i>	(6) <i>ESGrange6</i>
<i>Industry</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	11,768	11,768	11,768	11,768	11,768	11,768
<i>Adj.R²</i>	0.332	0.333	0.332	0.401	0.402	0.400

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$.

4.4. Handling of Endogeneity Issues

To address potential omitted variable bias and reverse causality, this study has already implemented two core identification strategies in all baseline regressions: we control for three-dimensional fixed effects of year, industry, and province, and use lagged one-period green patent applications as the core independent variable. These two measures have largely mitigated the main endogeneity concerns in our research design. Regarding the potential reverse causality between green innovation and product market competition, our temporal design provides a strong defense: we use lagged one-period green innovation to predict current market competition, making it theoretically impossible for current competition levels to influence past innovation decisions. Rating agencies primarily rely on publicly disclosed patent application information when evaluating corporate green innovation performance. This means that our lagged one-period design accurately captures the temporal sequence: green innovation activities in year $t-1$ are publicly disclosed through patent applications, which then affect ESG ratings and market competition in year t . It is theoretically impossible for ESG rating divergence or market competition in year t to influence green innovation decisions made and publicly disclosed in year $t-1$. To further enhance the robustness of our causal inference, we additionally conduct two more stringent tests below: adopting high-dimensional interaction fixed effects and refining regional fixed effects from provincial to city level.

4.4.1. Adoption of High-Dimensional Fixed Effects

On the basis of lagging the independent variable by one period as mentioned above, the interaction fixed effects of industry and year ($Ind \times Year$) and the interaction fixed effects of province and year ($Prov \times Year$) are controlled. This method effectively controls all time-varying factors at the industry and regional levels and can further mitigate endogeneity issues. After using high-dimensional fixed effects, the intensifying effect of lagged one-period green utility innovation input on market competition is no longer significant. This result is related to the hierarchical protection logic of the patent law for technological innovation. Compared with invention patents, utility model patents focus on “partial improvements” with lower overall requirements and corresponding lower green innovation input. Other regression results have no significant changes compared with the above. Due to space limitations, the detailed results are not presented.

4.4.2. Control of More Detailed Regional Fixed Effects

On the basis of controlling province fixed effects as mentioned above, the impact of more detailed regions is further examined, and city fixed effects (*City*) are used for regression analysis. The results are consistent with the above. After controlling the interaction fixed effects of industry and year ($Ind \times Year$) and the interaction fixed effects of city and year ($City \times Year$), the intensifying effect of lagged one-period green utility innovation input on market competition is no longer significant. Other regression results also have no significant changes compared with the above. Due to space limitations, the detailed results are not presented.

4.5. Robustness Tests

4.5.1. Bootstrap Resampling

The Bootstrap resampling method is used for robustness testing. This method achieves an unbiased asymptotic population distribution by repeatedly sampling the original sample multiple times, improving the validity and consistency of the estimation results. In this part, the seed value is set to 20,000, and 5000 random times are drawn. The regression results of the robustness test using the Bootstrap resampling method are basically consistent with the above. Due to space limitations, the detailed results are not presented.

4.5.2. Changing Variable Scales

Differences in the dimensions of various variables in the model may lead to estimation biases, and variables may have original errors. The method of changing variable scales is adopted to perform Min-Max normalization on each variable for robustness testing. After changing the variable scales, the regression results are basically consistent with the above. Due to space limitations, detailed results are not presented.

4.6. Heterogeneity Analysis

4.6.1. Enterprise Pollution Heterogeneity

The degree of information ambiguity of green innovation determines the magnitude of ESG rating divergence. Heavily polluting enterprises face the most stringent environmental regulatory constraints globally, and their green innovation activities exhibit fundamentally different characteristics from non-heavily polluting enterprises. We classify heavily polluting enterprises according to the List of Heavily Polluting Industries for Environmental Verification issued by the Ministry of Ecology and Environment of China, which includes 16 sub-industries such as thermal power, steel, cement, and chemical manufacturing. The regression results of the impact of green innovation on ESG rating divergence for heavily polluting and non-heavily polluting enterprises are reported in Table 8. The results show that for non-heavily polluting enterprises, total green innovation, green invention innovation and green utility model innovation all significantly widen ESG rating divergence at the 1% level; however, for heavily polluting enterprises, the coefficients of all types of green innovation are close to zero and statistically insignificant, with only the coefficient of total green innovation on ESGrange6 being marginally significant at the 10% level. This result is consistent with our theoretical analysis.

Table 8. Heterogeneous Impact of Enterprise Pollution Level.

	<i>ESGdif6</i>			<i>ESGrange6</i>		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Heavily Polluting Enterprises						
<i>Greenapply_total</i>	0.008 (0.80)			0.032 * (1.65)		
<i>Greenapply_invent</i>		0.004 (0.33)			0.029 (1.23)	
<i>Greenapply_utility</i>			0.005 (0.40)			0.027 (1.06)
<i>Cons.</i>	−2.776 *** (−12.45)	−2.813 *** (−12.81)	−2.806 *** (−12.54)	−7.556 *** (−18.86)	−7.637 *** (−19.32)	−7.636 *** (−18.92)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes	Yes	Yes	Yes

<i>Industry</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	4403	4403	4403	4403	4403	4403
<i>Adj.R²</i>	0.336	0.336	0.336	0.396	0.395	0.395
Panel B. Non-Heavily Polluting Enterprises						
<i>Greenapply_total</i>	0.024 *** (3.89)			0.062 *** (5.56)		
<i>Greenapply_invent</i>		0.031 *** (4.33)			0.087 *** (6.51)	
<i>Greenapply_utility</i>			0.017 ** (2.28)			0.047 *** (3.39)
<i>Cons.</i>	−3.768 *** (−21.70)	−3.730 *** (−21.57)	−3.913 *** (−22.81)	−9.249 *** (−28.94)	−9.080 *** (−28.51)	−9.608 *** (−30.17)
<i>Controls</i>	Yes	Yes	Yes	Yes		
<i>Year</i>	Yes	Yes	Yes	Yes		
<i>Province</i>	Yes	Yes	Yes	Yes		
<i>Industry</i>	Yes	Yes	Yes	Yes		
<i>N</i>	7365	7365	7365	7365	7365	7365
<i>Adj.R²</i>	0.345	0.344	0.343	0.416	0.417	0.414

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$; ** indicates $p < 0.05$; * indicates $p < 0.1$.

The insignificant effect for heavily polluting enterprises can be explained by three interrelated reasons, all of which are rooted in the elimination of information ambiguity that drives rating disagreement. First, green innovation in heavily polluting enterprises is predominantly compliance-driven rather than strategy-driven. Unlike non-heavily polluting enterprises that invest in green innovation to gain competitive advantages, green innovation in heavily polluting enterprises is mainly a mandatory response to environmental regulations such as emission standards and pollution taxes. These compliance-oriented green innovations have clear technical standards and predictable environmental benefits, leaving little room for subjective interpretation by rating agencies. Second, strong regulatory pressure enforces standardized ESG disclosure, eliminating the space for strategic disclosure. Heavily polluting enterprises are required to disclose detailed environmental information including pollutant emissions, energy consumption, and environmental protection investments in accordance with uniform regulatory templates. This standardized disclosure significantly reduces information asymmetry and prevents enterprises from adopting selective disclosure strategies, which is a key channel through which green innovation leads to rating divergence. Third, rating agencies converge on evaluation logic for heavily polluting enterprises. For heavily polluting enterprises, all rating agencies prioritize compliance with environmental regulations as the core evaluation criterion, with minimal differences in indicator weights. There is a broad consensus across agencies that any green innovation that reduces pollutant emissions should be rewarded, and any violation of environmental regulations should be penalized. This convergence in evaluation paradigms eliminates the rater heterogeneity that is the ultimate source of ESG rating divergence. In contrast, non-heavily polluting enterprises face much weaker regulatory constraints. Their green innovation investment is more driven by strategic considerations such as brand building and market differentiation, with greater flexibility in both technology selection and information disclosure. This creates significant information ambiguity and amplifies the existing heterogeneity in rating agencies' evaluation frameworks, leading to larger rating divergence. This contrasting result strongly supports our theoretical argument that information ambiguity and rater heterogeneity are the fundamental drivers of ESG rating disagreement.

4.6.2. Heterogeneity in Attention Level

We define “high-attention enterprises” based on the number of financial analysts tracking the firm, which is the most widely used and validated measure of external information environment intensity in corporate finance research. Specifically, we sort all sample firms by the number of analyst coverages in each year, and classify firms in the top 25% of the annual distribution as the high-attention group and those in the bottom 25% as the low-attention group. The regression results of the impact of green innovation on ESG rating divergence for high-attention and low-attention enterprises are reported in Table 9. The results show that for high-attention enterprises, total green innovation and green invention innovation significantly widen ESG rating divergence at the 1% level, while green utility model innovation has no significant effect; for low-attention enterprises, none of the green innovation measures have a significant impact on rating divergence. This result confirms that external attention amplifies the rating divergence caused by green invention innovation with high information ambiguity.

Table 9. Heterogeneous Impact of External Attention Level.

	<i>ESGdif6</i>			<i>ESGrange6</i>		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. High-Attention Enterprises						
<i>Greenapply_total</i>	0.032 *** (3.55)			0.066 *** (3.63)		
<i>Greenapply_invent</i>		0.031 *** (3.00)			0.070 *** (3.42)	
<i>Greenapply_utility</i>			0.013 (1.23)			0.033 (1.48)
<i>Cons.</i>	−4.892 *** (−17.39)	−4.964 *** (−17.76)	−5.147 *** (−18.41)	−11.889 *** (−22.17)	−11.973 *** (−22.61)	−12.362 *** (−23.06)
<i>Controls</i>	Yes	Yes	Yes	Yes		
<i>Year</i>	Yes	Yes	Yes	Yes		
<i>Province</i>	Yes	Yes	Yes	Yes		
<i>Industry</i>	Yes	Yes	Yes	Yes		
<i>N</i>	3088	3088	3088	3088	3088	3088
<i>Adj.R²</i>	0.481	0.480	0.479	0.548	0.548	0.546
Panel B. Low-Attention Enterprises						
<i>Greenapply_total</i>	0.007 (0.67)			0.019 (1.12)		
<i>Greenapply_invent</i>		0.005 (0.36)			0.021 (0.99)	
<i>Greenapply_utility</i>			0.009 (0.71)			0.016 (0.76)
<i>Cons.</i>	−1.030 *** (−3.74)	−1.062 *** (−3.90)	−1.032 *** (−3.77)	−3.084 *** (−6.69)	−3.109 *** (−6.79)	−3.146 *** (−6.80)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Province</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	4034	4034	4034	4034	4034	4034
<i>Adj.R²</i>	0.240	0.239	0.240	0.246	0.246	0.246

Note: t-values calculated using robust standard errors are in parentheses; *** indicates $p < 0.01$.

The stronger effect for high-attention enterprises can be explained by three theoretical mechanisms. First, richer information sources increase rather than reduce rating divergence due to differential information acquisition and interpretation. As Berg et al. [1] point out, rating agencies differ significantly in their data sources and information processing methods. High-attention enterprises generate a large amount of heterogeneous information from multiple channels including analyst reports, media coverage, and investor meetings. Different rating agencies may access different subsets of this information and interpret the same information differently, leading to larger evaluation gaps. In contrast, low-attention enterprises have very limited public information, and all rating agencies rely almost exclusively on mandatory annual reports, resulting in highly convergent evaluations. Second, green invention innovation is regarded as a core competitive advantage for high-attention enterprises, creating large room for value judgment divergence. For high-attention enterprises, especially technology-intensive manufacturing firms, green invention innovation is a key determinant of long-term growth potential. Rating agencies have fundamentally different views on how to value intangible green assets: environment-focused agencies assign high weights to technological breakthroughs and future emission reduction potential, while finance-focused agencies emphasize the high costs and uncertain returns of green innovation. This divergence in evaluation paradigms is amplified for high-attention enterprises where green innovation has a material impact on firm value. Third, external attention amplifies the impact of strategic disclosure. High-attention enterprises have stronger incentives to strategically disclose information about their green innovation activities to influence market perceptions. They may emphasize the environmental benefits of their innovations in ESG reports while downplaying the associated financial risks in financial reports. Different rating agencies assign different weights to information from different sources, further increasing rating divergence.

5. Discussion

This study empirically examines the impact of green innovation investment on ESG rating divergence of manufacturing enterprises and the mediating role of product market competition, with Chinese A-share manufacturing enterprises as samples. The key findings are discussed as follows:

First, our finding that green innovation investment significantly widens ESG rating divergence, with green invention innovation exerting a stronger effect, makes two key contributions to the literature on the antecedents of ESG rating divergence. Most importantly, we complement and extend the classic study by Berg et al. [1] by shifting the research perspective from rating agency heterogeneity to corporate strategic behavior. They argue that ESG rating divergence primarily stems from differences in rating methodologies, indicator weights, and data sources across agencies. While we fully acknowledge the importance of these agency-side factors, our study demonstrates that substantive corporate actions such as green innovation are equally important drivers of rating disagreement. Green innovation creates inherent information ambiguity that amplifies existing agency heterogeneities, revealing that ESG rating divergence is not just a “rating agency problem” but also a reflection of fundamental uncertainty about the value of corporate sustainable development behaviors. Second, our study challenges the dominant one-way causal logic in existing research. Prior studies have predominantly focused on how ESG performance drives corporate green innovation [3], largely ignoring the reverse spillover effect of innovation on ESG evaluation. We show that green innovation does not automatically lead to better and more consistent ESG evaluations as commonly assumed; instead, it can widen rating divergence due to its intangible nature and uncertain value. This finding is consistent with Du et al. [18]’s observation that green innovation has unique information characteristics that differ from traditional corporate behaviors,

and we further extend their research by revealing how these characteristics translate into systematic disagreement across ESG rating agencies. Our finding also complements Christensen et al.'s [5] research on cosmetic disclosure by showing that even substantive green actions can increase rating disagreement due to inherent information complexity.

Second, the partial mediating effect of product market competition resolves a longstanding debate in the innovation literature and provides a new explanation for ESG rating divergence. The classic Schumpeterian view argues that market power promotes innovation, while Arrow's perspective emphasizes that competition incentivizes innovation. Our study extends this debate by demonstrating that green innovation itself reshapes industry competition patterns. Consistent with Ambec et al.'s [11] extension of the Porter hypothesis, we find that green innovation enhances firms' competitive advantages and intensifies overall industry competition. More importantly, we reveal that this intensified competition further amplifies ESG rating divergence. In highly competitive markets, firms adopt differentiated information disclosure strategies to signal their strengths, which increases the complexity of ESG information for rating agencies. This finding fills a critical gap in the ESG literature, which has previously treated market competition as a control variable rather than a key transmission mechanism between corporate strategic behavior and external evaluation.

Third, the heterogeneous effects across firm characteristics highlight the contextual nature of ESG rating formation. For heavily polluting firms, the insignificant relationship between green innovation and rating divergence supports Kimbrough et al.'s [14] finding that standardized disclosure reduces rating disagreement. Strict environmental regulations force heavily polluting firms to adopt uniform ESG disclosure frameworks, leaving little room for subjective interpretation by rating agencies. In contrast, the significant effect for high-attention firms aligns with Serafeim & Yoon's [3] research on investor attention and ESG disagreement. High-attention firms receive more scrutiny from multiple information sources, but different agencies prioritize different aspects of green innovation. For example, some agencies emphasize technical breakthroughs, while others focus on financial costs, leading to more divergent evaluations. This heterogeneity suggests that a one-size-fits-all ESG rating system is inappropriate, and contextualized evaluation standards are needed.

Overall, this study integrates innovation theory, industrial organization theory, and ESG rating research to construct a comprehensive framework explaining the formation of ESG rating divergence. It moves beyond the traditional focus on rating agency differences to show that corporate strategic behavior and market dynamics are equally important drivers of rating disagreement.

6. Implications

6.1. Theoretical Implications

This study makes four specific, testable contributions to the intersection of ESG rating research, innovation economics, and industrial organization theory.

(1) Establishes a quantitative micro-foundation for ESG rating divergence by integrating AK endogenous growth model and R&D capital depreciation theory. Existing literature [1,5] attributes ESG rating divergence almost exclusively to rating agency heterogeneity (methodology, weights, data sources) and corporate cosmetic disclosure. This study breaks this monopoly by demonstrating that systematic accounting measurement bias in green innovation is an overlooked fundamental driver. Specifically, we show that the gap between the economic depreciation rate of green R&D capital (accelerated by technological progress) and the uniform 15% accounting depreciation rate used in practice distorts corporate valuation and creates inherent information ambiguity. This finding fills the gap of insufficient quantitative analysis of enterprise-side drivers of ESG divergence

and provides a new accounting-based explanation for why substantive green actions can still trigger rating disagreements.

(2) Reverses the dominant one-way causal logic and reveals the spillover mechanism of “green innovation → information complexity → ESG rating divergence”. Existing studies [3,37] focus on how ESG performance affects corporate green innovation, treating ESG ratings as an exogenous input to corporate strategy. This study empirically verifies the reverse causal relationship and further distinguishes the heterogeneous impacts of different green innovation types. We find that green invention innovation, with its high technical threshold, long payback cycle, and uncertain long-term returns, not only creates greater information asymmetry than utility model innovation but also intensifies industry competition through cost pressure, thereby amplifying rating divergence. This result expands the research boundary of the interaction between green innovation and ESG and corrects the implicit assumption that better green performance leads to more consistent ESG evaluations.

(3) Integrates industrial organization theory into ESG research and identifies the transmission path of “green innovation → market competition → differentiated disclosure → ESG rating divergence”. Prior ESG literature has treated product market competition as a marginal control variable rather than a core transmission mechanism. This study resolves the longstanding Schumpeter-Arrow debate on innovation and competition in the green context by showing that green innovation not only responds to competition but also reshapes industry competition patterns. More importantly, combined with Elame & Boulhaga’s [15] capital transmission mechanism, we construct a complete analytical chain of “green investment–cost absorption–market competition–capital cost–rating divergence”. This finding connects micro corporate strategic behavior to macro market structure and provides a new theoretical perspective for understanding the formation of ESG rating divergence.

(4) Identifies two boundary conditions of the green innovation-ESG divergence relationship. Existing studies generally assume a uniform relationship between green innovation and ESG outcomes across firms. This study reveals two critical moderating effects. First, the regulatory standardization effect: Strict environmental regulations force heavily polluting firms to adopt uniform ESG disclosure frameworks, eliminating the room for subjective interpretation and thus weakening the impact of green innovation on rating divergence. Second, the attention amplification effect: High external attention increases the diversity of information sources and the heterogeneity of agency priorities, amplifying the rating divergence caused by complex green invention innovation. These findings challenge the ESG rating paradigm and provide a theoretical basis for constructing contextualized evaluation systems.

6.2. Managerial Implications

Based on the empirical findings, we provide targeted, actionable recommendations for three key stakeholders.

6.2.1. For Manufacturing Enterprises

(1) Implement differentiated green innovation and ESG disclosure strategies based on firm characteristics. For heavily polluting firms: Maintain standardized and compliance-oriented ESG disclosure. Since regulatory requirements have already aligned rating agencies’ expectations, focus on disclosing verifiable emission reduction data and compliance records rather than over-disclosing subjective information about green innovation benefits. For non-heavily polluting firms: Improve the transparency of green innovation information. Disclose not only the number of patents but also R&D investment breakdowns, expected environmental benefits, technology roadmaps, and commercialization

timelines to reduce information ambiguity. For small and medium-sized manufacturing enterprises, prioritize building internal knowledge sharing mechanisms and cultivating transformational leadership, as these organizational factors have been proven to be more critical drivers of green innovation effectiveness than external capital injections [39].

(2) Proactively manage ESG rating risks for high-value green invention innovation. For high-attention firms, green invention innovation is the main driver of rating divergence. Establish a dedicated ESG communication team to engage with all major rating agencies proactively. Provide supplementary technical reports and third-party verification of green innovation outcomes to align agencies' understanding of long-term value. Avoid sudden large-scale green invention investment announcements without supporting information, which can trigger excessive rating volatility.

(3) Balance short-term rating divergence risks and long-term competitive advantages. Do not reduce high-quality green invention innovation investment due to short-term ESG rating divergence. The results show that green invention innovation enhances long-term market competitiveness even if it temporarily increases rating disagreement. Construct a long-term ESG performance evaluation system that decouples executive compensation from short-term ESG rating fluctuations.

To help manufacturing firms systematically mitigate ESG rating volatility caused by high-value green invention patent announcements, we propose a three-stage information transparency roadmap covering the entire lifecycle of green innovation disclosure, as shown in Figure 2. This roadmap addresses the reviewer's concern about overly broad implications by providing actionable, step-by-step guidance for firms to standardize their disclosure practices and proactively align rating agencies' perceptions.

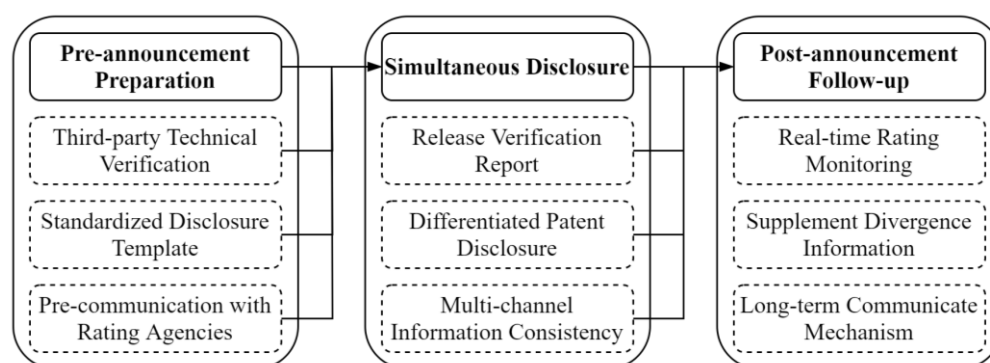


Figure 2. Three-stage Information Transparency Roadmap for Green Innovation Announcement.

6.2.2. For ESG Rating Agencies

(1) Develop a layered, contextualized green innovation evaluation framework

Assign different weights to green innovation indicators based on firm characteristics: for heavily polluting firms, prioritize compliance and emission reduction outcomes; for high-attention technology firms, increase the weight of long-term technical potential and environmental spillover effects. Distinguish between green invention and utility model innovation explicitly. For invention patents, establish a multi-dimensional evaluation system that includes technical complexity, industry impact, and commercialization potential, rather than just counting the number of patents.

(2) Unify accounting standards for green innovation and increase rating transparency. Formulate industry-specific guidelines for green R&D capital measurement, including recommended depreciation rates for different types of green technologies and clear rules for capitalization vs. expensing. Publicly disclose the detailed calculation methods, data sources, and weight allocations of green innovation indicators. Provide a divergence

explanation report for firms with large rating differences, specifying which indicators drive the disagreement.

(3) Establish a cross-agency data sharing mechanism for green innovation. Collaborate with patent offices, environmental protection departments, and industry associations to build a unified green innovation database. Reduce data acquisition differences among agencies, which is a major source of rating divergence identified in this study.

6.2.3. For Policymakers and Regulators

(1) Improve accounting standards for green innovation and standardize disclosure requirements. Issue special accounting standards for green R&D activities to address the mismatch between economic depreciation and accounting depreciation. Mandate non-financial disclosure of green innovation inputs, outputs, and expected benefits for listed manufacturing firms, with clear requirements for third-party verification.

(2) Establish a regulatory framework for ESG rating agencies and promote standardization. Set minimum entry standards and code of conduct for ESG rating agencies. Establish a cross-agency coordination mechanism to reduce systemic rating divergence. Encourage the development of industry-specific ESG rating standards, especially for the manufacturing sector.

(3) Design targeted green innovation policies that account for ESG rating impacts. For non-heavily polluting firms, provide subsidies for green innovation information disclosure and third-party verification to reduce their ESG communication costs. Specifically, the government should establish a standardized third-party technical verification system for green invention patents, requiring mandatory independent assessment of their environmental benefits, technical maturity, and commercialization potential before they can be recognized as valid green innovation indicators in ESG evaluations. For high-attention firms, establish a green innovation valuation guidance system to help investors and rating agencies better assess the long-term value of complex green technologies.

7. Conclusions and Limitations

7.1. Conclusions

Against the backdrop of global sustainable development transition, this study takes Chinese A-share manufacturing enterprises from 2011 to 2023 as samples, systematically explores the impact of green innovation investment on ESG rating divergence and the mediating mechanism of product market competition, and conducts heterogeneous analysis based on enterprise characteristics. The main conclusions are as follows:

First, green innovation investment of Chinese manufacturing enterprises significantly expands ESG rating divergence, and the impact of green invention innovation investment is stronger than that of green utility innovation. Second, product market competition plays a partial mediating role—green innovation investment intensifies product market competition, which in turn amplifies ESG rating divergence. Third, there are heterogeneous effects: green innovation investment has no significant impact on ESG rating divergence of heavily polluting enterprises, while green invention innovation investment of highly concerned enterprises is more likely to trigger rating disputes.

This study reveals the internal logic of green innovation affecting ESG rating divergence, provides a new perspective for understanding the causes of ESG rating divergence, and offers practical references for enterprises' green strategic decision-making, the improvement of ESG rating systems, and policy formulation.

7.2. Limitations

First, this study proxies green innovation investment by the number of green patent applications, which mainly captures the quantity of innovation output but ignores two critical dimensions: innovation quality and non-patented green practices that are not reflected in patent data. In the future, multi-dimensional indicators combining patent quality indicators and green process transformation expenditure can be used to more comprehensively evaluate the heterogeneous impact of different types of green innovation on ESG rating differences.

Second, this study measures overall ESG rating divergence using the standard deviation and range of six agencies' scores, but does not decompose the sources of divergence or compare the evaluation logics of different agencies. It remains unclear whether international and domestic agencies assign different weights to green innovation indicators, or which ESG sub-dimension drives most of the disagreement. In the future, the rating preferences of international and domestic ESG institutions can be compared, and the overall divergence can be broken down into environmental, social, and governance sub-dimensions to identify the core drivers of rating divergence related to green innovation.

Third, this study only verifies the partial mediating role of product market competition, but does not explore other potential transmission paths or boundary conditions. For example, media sentiment and analyst attention may also amplify the information ambiguity of green innovation and affect rating consistency. In the future, the moderating effect of media coverage intensity and analyst attention can be tested, and the chain mediation mechanism of "green innovation → information asymmetry → scoring divergence" can be further explored.

Fourth, while we have employed multiple strategies to address endogeneity issues, observational studies cannot completely eliminate all potential endogeneity concerns. In the future, if the information disclosure system of Chinese listed companies is further improved and accounting standards are further aligned with international standards to clearly distinguish between green investment and traditional investment, researchers can conduct more precise studies from the perspective of actual green innovation investment to further alleviate endogeneity problems. Regarding the identification method of exogenous policy shocks, China has not yet introduced a unified national mandatory green innovation policy. There are significant differences in the implementation intensity, coverage and support intensity of policies in different regions, which will instead amplify the uncertainty of regression results. If a unified national exogenous green innovation policy is introduced in the future, methods such as difference-in-differences can be further used to strengthen causal identification.

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