



Impact of environmental information uncertainty and market competition on corporate ESG performance

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ARTICLE INFO

Keywords:

Environmental information

Market competition

ESG performance

ABSTRACT

Using sample data from China's A-share non-financial listed companies covering the period from 2011 to 2022, this study empirically finds that environmental information uncertainty hinders corporate environmental, social, and governance (ESG) performance. The impact of environmental information uncertainty on ESG performance differs between state-owned enterprises (SOEs) and non-SOEs, with a more pronounced effect on non-SOEs. Moreover, the influence of environmental information on ESG performance varies across firms in different life cycles. Specifically, environmental information uncertainty has a significantly negative (*positive*) impact on the ESG performance of growth-stage (*mature*) firms, suggesting that mature firms adopt positive measures to address environmental information uncertainty and thus leading to better ESG performance. Uncertainty regarding environmental information significantly and negatively affects the ESG performance of firms in the decline period, and this effect is more pronounced than that experienced by growth-stage firms. Furthermore, market competition positively affects the firms' ESG performance, with varying effects across firms in different life cycles. Market competition enhances the ESG performance of growth- and mature-stage enterprises. However, it significantly and negatively influences the ESG performance of enterprises in the decline period.

1. Introduction

Uncertain environmental information has a wide-ranging impact, influencing various aspects of individual choices, corporate operations, societal advancement, and global administration (Vural-Yavas, 2021). At the personal level, the ambiguity of environmental specifics creates increased risks and complications. Highly accurate and precise information complicates forecasting and assessing future scenarios, potentially leading to individuals making ill-informed decisions about investments, career paths, or consumption habits, resulting in financial losses and lifestyle disruptions. In organizational contexts, unclear environmental data significantly influences strategic planning, market positioning, and risk management (Kong & Liu, 2024; Zhao & Luo, 2024). Moreover, it may prevent businesses from accurately understanding market dynamics and consumer demands, undermining their ability to develop effective strategies and operational plans.

Market rivalry denotes the process by which various corporations or individual economic entities compete for scarce market resources and advantages to gain a larger share of the market and profits through pricing, merchandise, services, branding, etc. Furthermore, it is an essential component of a market-driven economy and a key catalyst for its operational dynamics. Characterized by unfettered competition, every economic participant competes within the legal and regulatory boundaries without imposed constraints (Tian et al., 2024).

Numerous factors can affect market competition, including the market environment, which significantly impacts market competition (Zhang & Zhou, 2024). Policies and regulations, economic fundamentals, and cultural customs all impact business activities, directly or indirectly (Han et al., 2024). For example, policies and regulations such as tax policies, price controls, and commercial protectionism can increase or decrease the operating costs of enterprises, thus affecting market competitiveness (Zhang & Zhang, 2024). Meanwhile, economic

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<https://doi.org/10.1016/j.irfa.2025.103935>

Received 23 August 2024; Received in revised form 27 December 2024; Accepted 16 January 2025

Available online 18 January 2025

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development can cause changes in market size and demand, affecting businesses' competitiveness (Roger, 2024). Simultaneously, cultural customs affect consumers' preference for product quality and style, which will impact enterprise market positioning and product strategy. The market size directly determines the number of customers and spending power in the market (Wang, Ma, et al., 2023). The larger the market size, the greater the potential number of consumers and purchasing power, giving enterprises more room for development. Enterprises can realize growth by increasing sales and market share (Shaikh, 2022); consumer demand is the driving force behind market competition. The enterprise's market positioning and product strategy will be directly affected by changes in consumer demand. Enterprises must pay close attention to changes in consumer demand and adjust their products and services in real time to meet market demand (Qureshi & Ahsan, 2022). The enterprise's competitiveness is a critical factor in determining the outcome of market competition. The enterprise's production capacity, financial situation, marketing ability, technological innovation, and other factors will directly affect its market competitiveness. Enterprises must constantly improve their competitiveness to be unbeatable in the fierce market competition. Apart from the aforementioned factors, market competition is also affected by the number of vendors in the market, the degree of differentiation in the products produced by the vendors, the level of control that individual vendors have over market prices, and the ease with which vendors can enter or exit an industry (David et al., 2024).

Environmental, social, and governance (ESG) organizational performance encompasses three primary dimensions, namely, ecological, societal, and governance (Wong & Zhang, 2024). These dimensions comprehensively assess a company's stewardship in these domains, demonstrating its commitment to societal obligations (Yousaf et al., 2024). The ecological aspect focuses on the firm's environmental footprint and conservation efforts, such as carbon emissions, energy consumption, and waste generation. A corporation's environmental performance influences its long-term viability and contributes to society's overall sustainable growth (Kamarudin et al., 2022; Kong & Zhu, 2022; Zhang et al., 2019). Concurrently, societal indicators encompass employee well-being, community engagement, and consumer protection. They assess whether a company prioritizes employee well-being, actively contributes to public welfare, and supports neighborhood initiatives, indicating a commitment to social responsibility (Zhang & Liu, 2022). Meanwhile, governance indicators focus on a company's governing framework, transparency, anti-bribery practices, and robust corporate governance safeguards against corruption and malpractices, ensuring equitable and transparent decision-making processes (Sun, 2024). Moreover, ESG assessment criteria evaluate these outcomes, reflecting investors' and society's expectations of corporate sustainability and social accountability. Consequently, firms must prioritize ESG management and improve their ESG performance to meet market demands and societal expectations (Alandejani & Al-Shaer, 2023). Indeed, China's ESG is still in its early stages. The data show that although the number of companies disclosing ESG independently increases, the percentage is still relatively small.

In conjunction with the literature search results, Chinese scholars investigated the factors influencing corporate ESG performance. Analyst attention positively affects corporate ESG performance. The direct impact of analysts' external monitoring role and the indirect effect of specific investors' participation in corporate governance attracted by their information intermediary role work together to promote better corporate ESG performance (Zhao et al., 2023). Analysts pay special attention to improving corporate ESG subscores. Furthermore, analyst research and green concerns raised during the research process significantly influence corporate ESG performance. Aside from analyst attention, digital transformation is a factor that influences corporate ESG performance (Afik et al., 2024). Moreover, digital transformation encourages green innovation, public concern, and increased transparency of internal information, affecting ESG and improves corporate ESG

performance. Scholars are yet to examine the relationship between environmental information uncertainty, market competition, and corporate ESG performance as two factors affecting corporate ESG performance. Therefore, this study's findings can contribute to the body of knowledge regarding the factors influencing corporate ESG performance.

2. Theoretical analysis and research hypotheses

Environmental information uncertainty has the following major negative impacts on corporate ESG performance: The first is increased decision-making difficulty. When confronted with uncertain environmental information, companies struggle to accurately assess their ESG risks and opportunities. This may lead to confusion and even wrong decisions when companies develop ESG strategies and action plans (Kim & Park, 2023). Second, the quality of ESG disclosure deteriorates: uncertainty about environmental information may cause firms to be more conservative or vague in their ESG disclosures. Firms may be concerned that too much disclosure will expose potential risks or weaknesses, so they disclose selectively or avoid the most important ones (Qureshi et al., 2023). This may affect how investors and stakeholders understand and evaluate a firm's ESG performance. Third, uncertainty in environmental information can lead to increased questions and criticism for companies (Tseng et al., 2020). If a company fails to respond to the challenges posed by uncertainty in an effect, its ESG performance may suffer, damaging its reputation and image (Zhan, 2023). Finally, it affects the achievement of the SDGs: uncertainty in environmental information may make it difficult for firms to accurately predict and respond to environmental issues, preventing them from achieving the SDGs. For example, when faced with uncertainties such as climate change and resource scarcity, firms may struggle to develop effective countermeasures, affecting their ESG performance (Wan et al., 2024).

Hence, the study presents the following assumptions:

H1. Environmental information uncertainty inhibits corporate ESG performance.

Uncertainty in environmental data can impact the ESG performance of both state-owned enterprises (SOEs) and non-SOEs. Still, this impact varies depending on their nature, operation, and social responsibilities (Lian et al., 2023).

SOEs face higher social expectations and stricter regulatory requirements because of their close ties with the government and special status (Chouaibi & Affes, 2021). Therefore, when environmental information is uncertain, SOEs may be more likely to implement robust and transparent ESG strategies to protect their social image and avoid potential policy risks. Furthermore, SOEs typically have richer resources and a higher risk tolerance, allowing them to deal with and solve problems in the face of uncertain environmental information (Wang, Wang, et al., 2023).

The situation may differ for non-SOE's operations are more focused on economic efficiency and market competition. Thus, they may focus on short-term benefits while ignoring the impact of ESG factors on the firm's long-term value when environmental information is uncertain (He et al., 2024). Furthermore, non-SOEs may need to exercise greater caution in terms of resources, capital, and risk tolerance, limiting their ESG investment and performance.

To summarize, the study makes the following hypothesis.

H2. The impact of environmental information uncertainty on ESG performance varies between SOEs and non-SOEs.

Environmental information uncertainty does have a differential impact on the ESG performance of firms with different life cycles. Firms typically go through four stages of development, namely, start-up, growth, maturity, and decline. Moreover, the firms' resources, capabilities, strategic focus, and market position of each stage vary. Thus, their reactions to environmental information uncertainty and ESG

performance may differ (Kim & Kim, 2022).

During the start-up phase, firms are small, have limited resources, and focus primarily on product development and market expansion. Furthermore, uncertain environmental information may lead start-ups to underinvest in ESG because they must prioritize survival and growth (Bilyay-Erdogan, 2022). Firms that enter the growth phase develop a distinctive product line and steadily increase their market share (Chang & Yoo, 2023). At this point, companies may face highly significant social and environmental pressures to meet ESG targets (Lemma et al., 2022). However, the firm's investment in ESG may need to be increased because it needs to invest heavily in expanding production and market share. To maintain a positive corporate image and reputation, some rapidly expanding firms may focus on ESG management (He, Ding, et al., 2023). During the maturity period, enterprises are well-funded, technologically advanced, have a large human resource base, and are highly viable and competitive. Currently, firms are usually more capable and willing to invest in ESG to maintain their market position and comply with increasing regulatory requirements (Reber et al., 2022). Simultaneously, firms can use ESG management to reduce environmental risks and improve their social reputation, boosting their long-term competitiveness (Ng & Rezaee, 2020). During the recession, firms face challenges such as declining market share and failed new product trials. Moreover, a lack of capital and resources may limit a firm's investment in ESG, resulting in poor ESG performance (Mooneapeen et al., 2022).

Accordingly, the study presents the following hypothesis.

H3. The impact of environmental information on ESG performance of firms varies depending on their life cycle.

The impact of market competition on corporate ESG performance manifests itself in several beneficial ways: First, increased competition forces businesses to prioritize ESG initiatives. In a competitive market landscape, companies strive to improve their brand identity and reputation in order to gain a larger market share and consumer trust, with ESG performance serving as an important indicator of their commitment to sustainability, environmental stewardship, and responsible governance, all of which contribute to a positive corporate image and brand equity. Consequently, firms are encouraged to invest more in ESG management to remain competitive, to improve their performance in these areas (Cheng & Feng, 2023). Second, the pressure from market competition encourages corporations to proactively meet their ESG responsibilities. As ESG investing principles gain traction and stakeholders become more aware of ESG factors, investors and consumers increasingly base their decisions on a company's ESG performance. To gain a competitive edge, businesses are motivated to actively address their ESG obligations, such as implementing more robust environmental safeguards, improving employee welfare, tightening supply chain oversight, and refining corporate governance structures to foster a robust ESG profile (Wang et al., 2020). Moreover, market competition drives continuous improvement of ESG management capabilities within organizations. To navigate the ESG challenges posed by competition, companies must stay current on evolving ESG concepts and best practices while increasing transparency through improved ESG disclosures and communication. This enables better identification and management of ESG risks, ultimately fostering their capacity for sustainable growth (He, Feng, & Hao, 2023).

H4. Market competition positively affects firms' ESG performance.

Resources, capabilities, strategic focus, and market position of firms vary depending on their life cycle stage. Consequently, the impact of market competition on the ESG performance of firms at various stages of their life cycles will differ (Huang et al., 2023). Furthermore, due to limited resources, low brand awareness, and insufficient market influence, start-up enterprises may prioritize product development and market expansion to improve market competitiveness. They may invest less in ESG, thus affecting enterprises' ESG performance (Zheng &

Aishan, 2023). Entering the growth stage, enterprises may face more social and environmental pressures as they expand their market share and gradually build their brand. To improve their corporate image and compete in the market, these firms may start investing more in ESG and their ESG performance will improve (Su & Xue, 2024). Companies typically have a stable market share and a high level of brand awareness when they mature. At this point, they may prioritize sustainable development and long-term value creation, resulting in highly systematic and in-depth ESG investment and management. To increase their market competitiveness and influence, these companies may improve their ESG performance by developing comprehensive ESG strategies, strengthening supply chain management, and encouraging product innovation (Huang et al., 2024). Companies in recession may limit ESG investment due to declining market share and profitability. Under market competition pressure, firms' ESG performance may be affected (Kao, 2023).

Thus, this study presents the following hypothesis.

H5. The impact of market competition on ESG performance varies across firms with different life cycles.

3. Research design

3.1. Data sources

The study focuses on non-financial Chinese A-share listed firms between 2011 and 2022 as its subjects. ESG ratings data for these firms are sourced from the WIND database, whereas all complementary data are derived from the China Stock Market and Accounting Research database. During data preprocessing, the study initially excludes firms labeled as ST and *ST and those in the financial sector. Next, it removes data from the year of a firm's listing and instances with substantial missing information, resulting in a sample size of 12,376 observations. To mitigate the influence of extreme values on the empirical findings, this study trims continuous variables at 1 % upper and lower thresholds.

3.2. Definition of variables

3.2.1. Dependent variable

Corporate ESG performance (ESG): The extant body of research primarily uses CSI ESG ratings to evaluate corporate ESG performance. This rating system includes a broader range of A-share firms, covers a longer historical period, and uses a three-tiered framework to holistically assess enterprises' ESG performance. It also includes indicators relevant to rural rejuvenation, closely aligned with the Chinese market context. Consequently, this study uses the CSI ESG rating (ESG) as a proxy for the ESG performance of the corporations in the analysis. The Bloomberg ESG score includes three pillars: environment, society, and governance, with transparent assessment standards based on publicly available data. This scoring system is widely used and recognized globally, serving as an important reference for investors looking to evaluate corporate sustainability. Therefore, this paper chooses to use companies' Bloomberg ESG score (PESG) as a measure of ESG performance in robustness testing.

3.2.2. Independent variables

Environmental information uncertainty (EI): The study chose to quantify environmental data uncertainty using fluctuations in regional environmental regulators. A metric is developed in which a shift in local environmental protection officers at a company's location corresponds to a coefficient of 1, indicating a change. However, if there is no alteration in the environmental regulators at the company's location, the indicator is assigned 0. This study uses the change in local environmental protection officials as an indicator to measure environmental information uncertainty because changes in officials are frequently accompanied by shifts in policy orientation and enforcement intensity,

directly affecting companies' expectations and compliance with environmental regulations, reflecting the uncertainty of environmental information. This indicator is simple and effective at capturing the impact of policy changes on corporate ESG performance.

Market competition (*Lerner*): The Lerner Index is a popular tool used to measure the degree of market competition at the industry level. It is calculated by comparing the product price to the marginal cost, representing the market's monopolistic power. Specifically, the difference between the product price and the marginal cost is computed and divided by the product price. A higher ratio indicates stronger monopolistic power and weaker market competition; therefore, this paper uses the difference between 1 and the firm's Lerner Index value to measure the level of competition the firm faces. This results in a positive indicator.

3.2.3. Control variables

The control variables include firm size (*Size*), dual (*Dual*), gearing (*Lev*), ownership type (*State*), equity concentration (*First*), cash flow (*Cf*), and board size (*Board*). The variables are defined as shown in Table 1.

3.3. Model construction

Due to the characteristic of corporate ESG performance as an ordered discrete variable, where ESG ratings or scores are arranged in a specific order but remain discrete, model selection requires special consideration. The ordered probit regression model is an excellent choice for handling such data because it captures the inherent sequential relationship between ordered categorical variables. Using this model, we can more accurately assess the significance and direction of these factors' impact on corporate ESG performance, providing empirical support for understanding the market dynamics and environmental information mechanisms that drive corporate ESG behavior.

Table 1
Variable definition.

Variable type	Variable name	Variable symbol	Variable definition
Dependent variable	Corporate ESG Score	<i>ESG</i>	CSI ESG ratings, assigned from lowest (1) to highest (9)
Independent variable	Uncertainty of environmental information	<i>EI</i>	Changes in environmental protection officials in the province where the enterprise is registered, assigned a value of 1, otherwise 0
	market competition	<i>Lerner</i>	Market share/marginal cost of the largest firm in the industry
	Enterprise size	<i>Size</i>	$\ln(1 + \text{Total enterprise asset size})$
	Nature of property rights	<i>State</i>	State-controlled listed companies take the value of 1, others 0
Control variable	two jobs in one	<i>Dual</i>	If the chairman of the board of directors and general manager is not the same person, assigned a value of 1, otherwise take 0
	shareholding concentration	<i>First</i>	Percentage of shareholding of the first largest shareholder
	asset-liability ratio	<i>Lev</i>	Total liabilities/total assets
	cash flow	<i>Cf</i>	Cash holdings at year-end/total assets at year-end
	Board size	<i>Board</i>	$\ln(\text{Number of Board of Directors})$

$$ESG_{i,t} = \mu_0 + \mu_1 EI_{i,t} + \sum_{k=1}^n \mu_k control_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$ESG_{i,t} = \eta_0 + \eta_1 Lerner_{i,t} + \sum_{k=1}^n \eta_k control_{i,t} + \varepsilon_{i,t} \quad (2)$$

4. Empirical analysis

4.1. Descriptive statistical analysis

According to the descriptive statistics in Table 2, the mean ESG score for the sampled corporations is 6.028, with a minimum of 1 and a standard deviation of 2.149, indicating significant variation in ESG performance across firms. The maximum (0.957) and minimum (0.473) values for Lerner's market competition index suggest that companies face significant differences in competitive market pressures. Table 2 summarizes the descriptive statistics for the remaining indicators.

4.2. Baseline regression analysis

Table 3 displays regression results for ESG as the dependent variable, with market information uncertainty (*EI*) and market competition (*Lerner*) in columns 1 and 2, respectively, both accompanied by control variables. The coefficient for market information uncertainty (*EI*) in column 1 is -0.148 , statistically significant at 1 %, suggesting a negative effect of EI on firm ESG performance and thus supporting H1. In column 2, the coefficient for market competition (*Lerner*) is 0.189, which is also significant at 1 %, indicating that increased market competition significantly improves ESG performance, consistent with H4. Enterprises are motivated by market competition to develop sustainable practices, improve ESG performance, boost competitiveness, attract investors and consumers, and maximize long-term profits.

4.3. Heterogeneity test

The impact of ambiguous environmental information on different enterprises' ESG performance was examined using heterogeneity analysis. Table 4 shows that in the sample of SOEs, the coefficient of environmental information uncertainty (*EI*) is -0.072 , which is statistically insignificant. In contrast, in the sample of non-SOEs, the coefficient of environmental information uncertainty (*EI*) is -0.193 , which is statistically significant. These findings suggest that environmental information uncertainty has a greater impact on the ESG performance of non-SOEs than SOEs, thus confirming H2. This result may stem from the fact that non-SOEs, compared to SOEs, are more sensitive to changes in environmental policies and have relatively limited resources and adaptability, leading to a greater impact on their ESG performance.

Since this study focuses on Chinese publicly traded companies, these entities are typically found in the growth, maturity, or decline phases. The cash flow portfolio approach divides the sampled corporations' life cycles into three distinct stages—growth, maturity, and decline. Table 5 presents the disparities in the impact of environmental information uncertainty (*EI*) on the ESG performance of companies at different life cycle stages.

Table 2
Descriptive statistical analysis.

	N	Mean	Std	Min	Max
<i>ESG</i>	12,376	6.028	2.149	1.000	9.000
<i>Lerner</i>	12,376	0.642	0.118	0.473	0.957
<i>EI</i>	12,376	0.179	0.192	0.000	1.000
<i>Size</i>	12,376	20.742	1.825	18.462	28.013
<i>Cf</i>	12,376	0.158	0.115	0.02	0.602
<i>Lev</i>	12,376	0.431	0.245	0.038	0.924
<i>State</i>	12,376	0.381	0.492	0.000	1.000
<i>First</i>	12,376	0.362	0.152	0.093	0.781
<i>Board</i>	12,376	2.061	0.884	0.825	3.891

Table 3
Basic regression results.

	(1)	(2)
	ESG	ESG
<i>EI</i>	−0.148*** (−4.29)	
<i>Lerner</i>		0.189*** (9.32)
<i>Size</i>	0.127*** (2.84)	0.131*** (2.97)
<i>ROE</i>	0.142*** (5.31)	0.147*** (5.59)
<i>Lev</i>	−0.042 (−0.93)	−0.047 (−1.04)
<i>First</i>	−0.018 (−0.171)	−0.016 (−0.152)
<i>Cf</i>	0.128*** (4.61)	0.134*** (4.95)
<i>State</i>	0.131*** (4.54)	0.128*** (4.27)
<i>Board</i>	0.071 (0.94)	0.073 (0.97)
Constant	1.237*** (3.27)	1.218*** (3.19)
N	12,376	12,376
Pseudo R ²	0.427	0.431

Table 4
Heterogeneity test results (firm type).

	(1) Nationalized business	(2) Non-state enterprise
<i>EI</i>	−0.072 (−0.81)	−0.193*** (−8.74)
<i>Size</i>	0.136*** (3.24)	0.132*** (3.18)
<i>ROE</i>	0.139*** (5.24)	0.143*** (5.71)
<i>Lev</i>	−0.032 (−0.85)	−0.046 (−1.03)
<i>First</i>	−0.015 (−0.164)	−0.019 (−0.215)
<i>Cf</i>	0.125*** (4.37)	0.137*** (5.02)
<i>Board</i>	0.074 (0.96)	0.072 (0.91)
Constant	1.204*** (3.04)	1.183*** (2.99)
Pseudo R ²	0.433	0.442

Table 5
Heterogeneity test results (life cycle).

	(1) Full sample	(2) Formative years	(3) Maturity	(4) Recession
<i>EI</i>	−0.148*** (−5.29)	−0.124*** (−2.97)	0.131*** (4.59)	−0.247*** (−15.38)
<i>Size</i>	0.127*** (2.84)	0.129*** (3.01)	0.151*** (4.93)	0.097 (1.14)
<i>ROE</i>	0.142*** (5.31)	0.145*** (5.43)	0.018 (0.68)	0.125*** (2.81)
<i>Lev</i>	−0.042 (−0.93)	−0.045 (−0.97)	−0.016 (0.49)	−0.403*** (−8.81)
<i>First</i>	−0.018 (−0.171)	−0.014 (−0.148)	−0.021 (−0.258)	−0.028 (−0.331)
<i>Cf</i>	0.128*** (4.61)	0.132*** (4.78)	0.139*** (4.93)	0.122*** (3.49)
<i>State</i>	0.131*** (4.54)	0.126*** (4.15)	0.135*** (4.61)	0.118*** (3.04)
<i>Board</i>	0.071 (0.94)	0.074 (0.98)	0.084 (1.02)	0.052 (0.61)
Constant	1.242*** (3.25)	1.216*** (3.05)	1.238*** (3.19)	1.257*** (3.31)
Pseudo R ²	0.424	0.427	0.431	0.433

For firms in the growth phase, the coefficient associated with environmental information uncertainty (*EI*) is −0.124 %, a figure that withstands statistical significance, suggesting a substantial negative effect of *EI* on the ESG performance of these firms. However, the *EI* coefficient for mature companies is 0.131 %, which is also statistically significant, indicating that environmental information uncertainty significantly influences mature firms' ESG performance. These firms respond proactively to *EI*, resulting in improved ESG outcomes. The declining firms' cohort has a coefficient of −0.247 % for *EI*, passing the significance test and indicating a greater negative effect on ESG performance than growth-stage firms. Consequently, the impact of environmental information uncertainty (*EI*) on ESG performance varies significantly across firms and lifecycle stages, supporting H3.

Table 6 examines market competition's (*Lerner*) heterogeneous influence on ESG performance across firms at various life cycle stages. For firms in the growth phase, the coefficient with market competition is 0.191 %, which is statistically significant and suggests that increased competition encourages improved ESG performance among these companies. In the mature firms' sample, the coefficient for market competition is 0.197 %, which is also statistically significant, implying that it improves mature firms' ESG performance more significantly than growth-stage companies. Conversely, within the group of declining firms, the coefficient of market competition (−0.125) passes the significance test, indicating a substantial negative effect of market competition on the ESG performance of firms in decline. Consequently, the impact of market competition (*Lerner*) varies significantly across firms in different life cycle stages, thus supporting H5. Market competition positively affects mature enterprises' ESG performance, possibly because they have stronger information processing and response capabilities, allowing them to turn environmental uncertainties into motivators for improvement. Meanwhile, market competition negatively affects the ESG performance of declining enterprises, most likely due to resource constraints and difficulties in strategic adjustment, limiting their ability to effectively deal with market pressures. Therefore, although environmental information uncertainty affects the ESG performance of all enterprises, the direction and extent of this impact vary among enterprises at different lifecycle stages due to their inherent capabilities.

4.4. Robustness test

The initial step is substituting the dependent variables into the array of robustness checks. Bloomberg's ESG scoring mechanism assesses a company's ESG performance using an index based on the firm's

Table 6
Heterogeneity test results (life cycle).

	(1) Full sample	(2) Formative years	(3) Maturity	(4) Recession
<i>Lerner</i>	0.189*** (9.32)	0.191*** (9.71)	0.197*** (10.03)	−0.125*** (−2.92)
<i>Size</i>	0.131*** (2.97)	0.135*** (3.04)	0.151*** (5.34)	0.012 (0.41)
<i>ROE</i>	0.147*** (5.59)	0.151*** (5.73)	0.159*** (6.07)	0.137*** (4.42)
<i>Lev</i>	−0.047 (−1.04)	−0.042 (−0.93)	−0.018 (0.64)	−0.226*** (−8.91)
<i>First</i>	−0.016 (−0.152)	−0.012 (−0.108)	−0.004 (−0.08)	−0.153*** (−5.02)
<i>Cf</i>	0.134*** (4.95)	0.138*** (5.11)	0.142*** (5.24)	0.091 (0.47)
<i>State</i>	0.128*** (4.27)	0.133*** (4.42)	0.137*** (4.73)	0.018 (0.74)
<i>Board</i>	0.073 (0.97)	0.078 (1.05)	0.081 (1.12)	0.045 (0.31)
Constant	1.241*** (3.23)	1.223*** (3.14)	1.235*** (3.17)	1.246*** (3.35)
Pseudo R ²	0.428	0.436	0.439	0.433

disclosed information, with higher scores indicating better performance. This scoring standard has gained substantial acceptance within domestic and international scholarly communities. Consequently, this study employs the firm's Bloomberg ESG score (*PESG*) as a robustness test to evaluate ESG performance. This substitution results in a negative coefficient for environmental information uncertainty (*EI*). In contrast, the coefficient for market competition (*Lerner*) shows a positive, statistically significant value, confirming the paper's theoretical hypothesis. Table 7 presents the results of the robustness test.

To examine the resilience of the findings, this study also employs substitution empirical approaches. The initial regression used an ordered Probit model, and for the robustness check, this study uses the standard ordinary least square method. Table 8 shows that the environmental information uncertainty (*EI*) coefficients are negative, whereas those for market competition (*Lerner*) are positive. Both coefficients can withstand significance tests.

4.5. Endogeneity test

Table 9 presents the results of substituting the central variables of Models 1 and 2 with a one-period lag of EI_{-1} and $Lerner_{-1}$. This strategy effectively addresses endogeneity issues. Table 9 shows that the coefficients for EI_{-1} and $Lerner_{-1}$ remain positive and statistically significant, confirming the robustness of this paper's conclusions to endogeneity challenges.

5. Conclusion

The interrelationship between environmental information uncertainty, market competition, and corporate ESG performance has not been explored. Therefore, this study verifies this interrelationship based on data from Chinese listed companies. This study reaches the following conclusions. Environmental information uncertainty inhibits corporate ESG performance. There are differences in the impact of environmental information uncertainty on the ESG performance of SOEs and non-SOEs. Environmental information uncertainty has a more significant impact on the ESG performance of non-SOEs than SOEs. Differences exist in the impact of environmental information on the ESG performance of enterprises. Environmental information uncertainty significantly and negatively affects the ESG performance of growth-stage firms. Environmental information uncertainty significantly and positively affect mature firms' ESG performance, implying that mature firms will take

Table 7
Results of stability tests (replacement of explained variables).

	(1) PESG	(2) PESG
<i>EI</i>	−0.142*** (−4.17)	
<i>Lerner</i>		0.178*** (8.31)
<i>Size</i>	0.125*** (2.82)	0.133*** (3.02)
<i>ROE</i>	0.141*** (5.19)	0.145*** (5.42)
<i>Lev</i>	−0.041 (−0.91)	−0.045 (−1.02)
<i>First</i>	−0.016 (−0.162)	−0.017 (−0.167)
<i>Cf</i>	0.129*** (4.71)	0.132*** (4.84)
<i>State</i>	0.133*** (4.61)	0.126*** (4.25)
<i>Board</i>	0.074 (0.97)	0.071 (0.95)
Constant	1.262*** (3.74)	1.271*** (3.85)
N	12,376	12,376
Pseudo R ²	0.435	0.438

Table 8
Stability test results (OLS method).

	(1) ESG	(2) ESG
<i>EI</i>	−0.139*** (−4.05)	
<i>Lerner</i>		0.181*** (8.24)
<i>Size</i>	0.125*** (2.72)	0.134*** (3.05)
<i>ROE</i>	0.138*** (5.02)	0.145*** (5.41)
<i>Lev</i>	−0.047 (−0.95)	−0.049 (−1.06)
<i>First</i>	−0.017 (−0.268)	−0.018 (−0.271)
<i>Cf</i>	0.131*** (4.67)	0.136*** (5.01)
<i>State</i>	0.129*** (4.52)	0.131*** (4.62)
<i>Board</i>	0.073 (0.95)	0.075 (0.98)
Constant	1.38*** (4.13)	1.45*** (4.36)
Industry	Yes	Yes
Year	Yes	Yes
N	12,376	12,376
Adj.R ²	0.432	0.435

Table 9
Endogeneity test results.

	(1) ESG	(2) ESG
EI_{-1}	−0.141*** (−4.02)	
$Lerner_{-1}$		0.179*** (8.12)
Controls	Yes	Yes
Pseudo R ²	0.418	0.422

proactive measures to deal with environmental information uncertainty and resulting in improved ESG performance. Environmental information uncertainty significantly and negatively influence the ESG performance of declining-period firms, which is greater than the negative impact on growth-period firms. Moreover, market competition positively affects the ESG performance of firms; however, the impact of market competition on the ESG performance of firms with different life cycles varies. Market competition can improve growth- and mature-stage enterprises' ESG performance. However, it significantly and negatively influences enterprises' ESG performance during the decline period.

Although this study demonstrates the impact of environmental information uncertainty and market competition on corporate ESG performance, some limitations remain. First, the data samples are mainly sourced from Chinese listed companies, which may not accurately reflect the global market situation. Second, there may be biases in the research methodology, such as measurement indicators for environmental information uncertainty and the assessment methods for market competition, which still have room for improvement. Future research can be extended to include different markets to confirm the universal applicability of these relationships. Furthermore, using more long-term data can allow us to explore how these relationships change across different economic cycles.

CRediT authorship contribution statement

Dinghao Shi: Writing – original draft. **Haoyu Tan:** Writing – original draft. **Yixin Ling:** Data curation, Formal analysis. **Yunuo Liu:** Writing – review & editing. **Bo Liu:** Writing – review & editing.

Yongqian Tu: Supervision.

Data availability

No

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