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Does management's climate risk attention affect corporate ESG performance? Empirical evidence from Chinese capital market

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ABSTRACT

Amid global climate challenges, this study examines how management's climate risk attention affects corporate ESG performance, focusing on Chinese A-share firms between 2009 and 2023. Findings suggest that increased climate risk attention from management significantly enhances ESG performance, with improving energy efficiency, green innovation, and internal controls as the main paths. Heterogeneity analysis reveals more prominent positive impacts among enterprises in non-traditional energy sectors and those in growth and maturity phases. Furthermore, economic consequences suggest that increased management's climate risk attention not only boosts ESG performance but also further contributes to lower carbon emissions, indicating that it can promote corporate ESG practices rather than ESG 'greenwashing'. These findings provide insights for enterprises to adapt to climate challenges, promote high-quality development, and help achieve the 'dual-carbon' goal.

KEYWORDS

Climate change; management's attention; ESG practice; carbon emission reduction; sustainable development

JEL CLASSIFICATION

G30; G41

1. Introduction

Environmental, social, and governance (ESG) have emerged as the primary measure of non-financial performance and play a vital role in evaluating enterprises' sustainable development capacity (He, Guo, and Yue 2024; Ren, Zeng, and Zhao 2023; Shu and Tan 2023). As sustainability agendas advance and China's economy shifts towards high-quality growth, ESG-oriented investment philosophies have become increasingly important. These philosophies guide enterprises to align their development goals with green production and operations, social responsibility fulfilment, and effective stakeholder management (He, Du, and Yu 2022; Pedersen, Fitzgibbons, and Pomorski 2021), supporting sustainable development. As a result, corporate ESG performance has attracted increasing attention.

Escalating environmental challenges related to climate change poses a serious threat to corporate ESG performance and sustainable growth. Addressing climate risk has become an urgent issue requiring in-depth research. Climate risk, divided into physical and transition risk, encompasses uncertainties caused by environmental changes and the societal shift towards sustainability,

affecting economic and financial activities (Faccini, Matin, and Skiadopoulos 2023). Physical risk damages the environment and triggers financial risk, such as loss of cash crops, property destruction, and asset impairment (Ginglinger and Moreau 2023; J. Hansen et al. 2019). Transition risk emerges from efforts to develop a low-carbon economy, with climate change causing swift accumulation of financial risk (Capasso, Gianfrate, and Spinelli 2020; L. P. Hansen 2022). Consequently, increased environmental regulation can significantly exacerbate short-term financial risk, and highly polluting firms' default rates tend to rise sharply with increased environmental policy exposure (B. Huang, Punzi, and Wu 2021). Furthermore, transition risk causes credit contraction (Painter 2020), weakening the balance sheets of residents and enterprises, affecting the potential growth rate of the economy and output gap, and subsequently affecting the financial system (Battiston, Dafermos, and Monasterolo 2021). In the short term, transition risk is a greater threat to firms with poor ESG scores, which neglects environmental protection, assumes less social responsibility, is relatively more carbon-intensive than environmentally friendly firms, and

faces significantly elevated financial risk (Yang, Li, and Chen 2024). Climate risk threatens environmental stability and corporate financial health. As central decision-makers in corporate climate risk responses, climate risk attention generally trends upwards for management (Figure 1). This reflects the response to global climate initiatives and is critical for formulating and implementing climate strategies, enhancing corporate ESG performance, and promoting sustainable development.

climate risk attention impacts ESG performance has not been thoroughly explored. Given the centrality of management in strategic decision-making, their attention to climate risk directly influences the direction and efficiency of resource allocation, ultimately shaping ESG performance. This research investigates how management's climate risk attention influences corporate ESG performance, offering implications for enterprises mitigating climate-related shocks and advancing

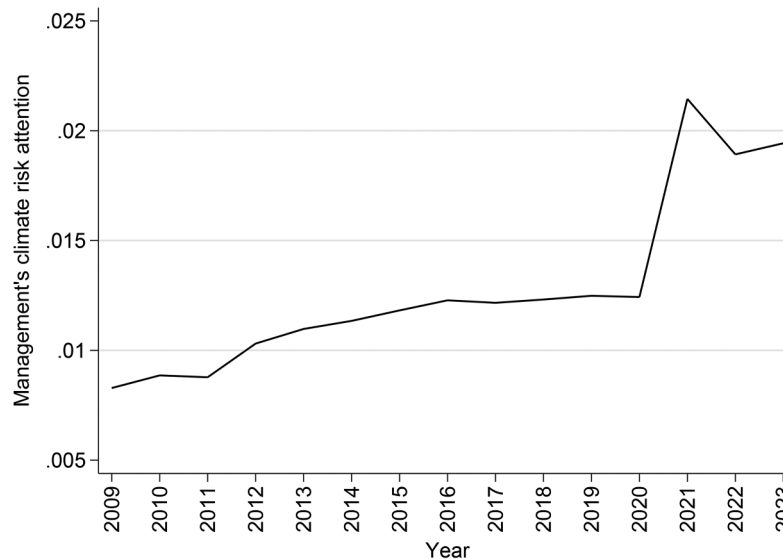


Figure 1. Annual trends in management's climate risk attention. Data source: Global Climate Risk Integration Database (GCRID).

Firms' internal development depends on management's decision-making efficiency, and management's attention largely determines how climate change imposes risk on corporations. Climate risk affects agricultural yields, asset pricing, and financial stability (Battiston, Dafermos, and Monasterolo 2021; Bernstein, Gustafson, and Lewis 2019; Faccini, Matin, and Skiadopoulos 2023; J. Hansen et al. 2019; Painter 2020), threatens business development (Boubaker et al. 2024; Kong et al. 2022), and negatively affects corporate ESG performance (Y. Chen et al. 2024). This leads management to consider and attach importance to climate risk issues, thereby promoting sustainable development through proactive risk management (Ikram et al. 2019). However, research linking management's climate risk attention to ESG performance remains limited. Although some studies have indicated that managerial climate attention lowers corporate carbon emissions (Y. Zhang, Zhao, and Zheng 2024), how management's

sustainable development.

Through empirical research, this article finds that greater management's climate risk attention contributes to improved ESG performance. Mechanism analysis indicates that such attention enhances energy efficiency, green innovation, and internal control, thereby improving ESG performance. Heterogeneity tests show that management's climate risk attention has a more pronounced positive effect on ESG performance in non-traditional energy sectors and among firms in the growth and maturity stages. Economic consequence analysis reveals that improved ESG performance driven by management's climate risk attention reduces corporate carbon emissions, suggesting that the enhancement stems from genuine ESG practices rather than symbolic 'greenwashing'.

This article makes the following contributions: First, the role of management's climate risk attention in shaping ESG performance is examined,

expanding previous research. Although early literature explored how climate change influences ESG performance, investigations into management's cognitive characteristics are lacking. By investigating management's climate risk attention, this research reveals the internal drivers of improved ESG performance and provides insights for Chinese firms enhancing their ESG practices, realizing high-quality development, and contributing to the national economic sustainability. Second, this study elucidates how management's attention to climate risk affects ESG performance. Pathways through which this attention influences ESG performance are identified by focusing on energy efficiency, green innovation, and internal controls, addressing research deficits concerning the impetus provided by management's climate risk attention to corporate sustainability. Third, heterogeneity tests of industry attributes and corporate life cycle and discussions of ESG 'greenwashing' reveal the main carriers through which management's climate risk attention influences ESG performance. Furthermore, this study helps market participants better understand the environmental governance effects of management's climate risk attention. These findings can inform corporate transformation strategies and ultimately help achieve the 'dual-carbon' goal.

The article proceeds as follows: [Section II](#) reviews relevant studies and presents research hypotheses. [Section III](#) outlines the methods. [Section IV](#) reports and discusses results. [Section V](#) provides further analysis. [Section VI](#) summarizes key findings and implications.

II. Literature review and research hypotheses

Literature review

Climate risk

Climate risk refers to the detrimental impact precipitated by climatic alterations (Dou et al. 2022), representing a global environmental risk with significant, widespread, and irreversible consequences (Chichilnisky 2000). There are two major classifications: physical and transition risk (Faccini, Matin, and Skiadopoulos 2023; Ginglinger and Moreau 2023). Physical risk is implicit and direct, stemming from the negative effects of climatic shifts and extreme

meteorological phenomena on sustainable economic development (Tankov and Tantet 2019). Transition risk refers to the implicit and indirect risks associated with policy adjustments, technological advancements, altered consumer preferences, and other factors in efforts to mitigate climate change and move towards a low-carbon economy (Faccini, Matin, and Skiadopoulos 2023; Semieniuk et al. 2021).

Climate change affects human industrial and agricultural production and the living environment as well as the financial system via real economic activities (Lamperti et al. 2021), reflecting a major concern among academics. The literature mostly explores how climate risk affects various components of the financial system. Regarding financial intermediation, research shows that climate risk profoundly affects banks, as capital connectors, in their internal operations and value chain cooperation (Battiston, Dafermos, and Monasterolo 2021; Capasso, Gianfrate, and Spinelli 2020). Climate risk also affects market prices of a range of financial instruments, such as stocks, bonds, and derivatives (Faccini, Matin, and Skiadopoulos 2023; Kruttli, Tran, and Watugala 2025; Painter 2020; Schlenker and Taylor 2021). Furthermore, climate risk promotes trade-offs and combinations of green finance policies (Lamperti et al. 2021). Thus, climate risk exerts an impact on various aspects of the financial system and has broad implications underscoring the significance of examining how such risk influences financial management. ESG performance is key to green financial management and inevitably closely linked to climate risk. Thus, investigating the link between management's climate risk attention and ESG performance is crucial.

Corporate ESG performance

ESG performance was introduced in the 2004 United Nations report 'Who Cares Wins', which highlighted the importance of integrating economic growth, social well-being, and environmental sustainability. In 2007, Goldman Sachs integrated ESG considerations into its investment strategies, focusing on corporate performance across these three dimensions and promoting the continuous ESG development and improvement. ESG is now a widely recognized framework for evaluating corporate sustainability across environmental, social, and governance dimensions (Fan, Chen, and Mo 2024; Leins 2020; Z. Zhang and Zhang 2024).

Green finance has gained significant momentum with the global trend towards carbon neutrality. Corporate ESG performance, a vital outcome of green finance initiatives, has drawn considerable attention. Research has primarily examined the ramifications and determinants of corporate ESG performance, indicating that strong ESG performance bridges information gaps (He, Du, and Yu 2022), expands financing channels (Luo, Wei, and He 2023), reduces capital costs (Guo et al. 2024; Lian et al. 2023), fosters innovation (Hao and He 2022), enhances business outcomes (Z. Chen and Xie 2022; Chen et al. 2023a), and increases overall value (Albuquerque, Koskinen, and Zhang 2019; Y. Li et al. 2018; Zheng et al. 2023a). However, it may also become a means for managers to seek personal gain, exacerbating management misconduct (He, Du, and Yu 2022), and inhibiting sustainable corporate growth (Pástor, Stambaugh, and Taylor 2021). Studies point to important factors influencing ESG performance, such as organizational culture (Bai, Shang, and Huang 2024), management myopia (Fan, Chen, and Mo 2024), internal control (Aureli et al. 2020), environmental regulatory distance (Xiong et al. 2024), sustainable lending (Gao and Liu 2023; Zheng et al. 2023b), carbon control policy risk (Shu and Tan 2023), green investors (Feng and Yuan 2024), customer concentration (Zheng et al. 2023c), media coverage (Akhtaruzzaman, Boubaker, and Umar 2022; He, Guo, and Yue 2024), digital finance (Mu et al. 2023; Ren, Zeng, and Zhao 2023), and climate change (Y. Chen et al. 2024). Although earlier studies have highlighted how climate change can negatively impact ESG performance, the degree that external environmental changes affect firms largely depends on management's attention or perceptions (Peng, Jia, and Zou 2023). Therefore, exploring the mechanisms driving ESG performance by examining management's climate risk attention is essential.

Theoretical analysis and hypotheses

Upper echelons theory suggests that management's cognitive characteristics shape firms' strategic decisions and investment choices (Ali et al. 2022). Combined with the attention-based view, management's climate risk

attention can better prioritize climate strategies in corporate resource allocation, driving enterprises' active engagement in climate action. In this context, corporate behaviour reflects a filtering and selection process through which firms assess issues and corresponding solutions. According to stakeholder theory, climate risk, as one critical external challenge, is directly linked to enterprises' long-term survival and development, attracting attention from various stakeholders. When management focuses closely on climate risk, they tend to recognize that improving ESG performance is essential for maintaining corporate image, meeting stakeholder expectations, and adapting to future environmental policy changes. Consequently, management's climate risk attention may prompt enterprises to proactively participate in ESG practices and improve ESG performance.

Management's climate risk attention improves energy utilization and directly enhances ESG performance. Policies such as the 'Double Reduction' initiative make traditional enterprises face the challenge of reducing carbon emissions and improving resource utilization. Management's climate risk attention drives proactive measures to improve energy utilization. Enterprises are more likely to proactively cut dependence on fossil energy, optimize energy consumption structure, and boost energy efficiency. They can eliminate the energy waste caused by redundant processes by standardizing and modularizing business processes. Value-stream analyses of production processes to remove energy waste in non-value-added activities can help enterprises reduce unnecessary energy consumption, enhance energy-use efficiency, and ultimately improve ESG performance. Furthermore, enterprises are more likely to break the 'path dependence' of traditional industries, promote industrial structure upgrading, and improve energy use efficiency. Climate risk significantly affects the energy sector in relation to energy production and supply and exacerbates energy price volatility (Sarker, Bouri, and Marco 2023) and reduces energy market efficiency, thus negatively affecting carbon emission efficiency.

(Y. Li et al. 2018). This drives energy-intensive industries to phase out high-energy-consumption and low-capacity segments, promoting industrial structure upgrading, improving energy-use efficiency, and enhancing ESG performance. Moreover, management's climate risk attention may prompt enterprises to proactively adopt key technologies, such as energy-saving and renewable energy technologies. Technological advancements can optimize industrial structures (Ge, Cai, and Song 2022), drive enterprises towards clean energy transformation (Yu, Chen, and Zhang 2022), improve energy-use efficiency (K. Li and Lin 2018), and ultimately enhance ESG performance. Thus, management's climate risk attention will protect the environment and fulfil social responsibilities by improving energy efficiency, maximizing the benefits of green production and operations, and enhancing corporate ESG performance.

Management's climate risk attention enhances green innovation, thus providing sustainable initiatives for improving corporate ESG performance. Management can concentrate on climate risk to actively pursue technological advancements and develop green products resistant to such risk, thereby reducing potential losses. This boosts energy efficiency, reduces emissions, and promotes the formation of differentiated green products, which are essential tasks for companies to realize economic and environmental benefits (Chang 2016). Regarding environment, green innovation promotes energy conservation, reduces emissions, and optimizes the value chain by disseminating green technologies, enhancing energy consumption structures, and leveraging the innovation compensation effect, thereby reducing environmental pollution (Amore and Bennedsen 2016; Wen et al. 2021) and enhancing corporate sustainability. Socially, green innovation builds a green image and enhances corporate reputation through environmental management (Chen et al. 2023b). Concurrently, the firm pursues green innovation, aligning with the 'dual-carbon' initiative and reflecting social responsibility fulfilment. Regarding governance, green innovation can address messaging challenges through greater disclosure (Zaman et al. 2021), improving internal

governance while fostering green development. Therefore, management's climate risk attention promotes green innovation, thus optimizing environmental stewardship, social responsibility, and internal governance and improving corporate ESG performance.

Management's climate risk attention strengthens internal control to provide a foundation for improving ESG performance. Internal control is an important corporate internal oversight mechanism with the ultimate goal of conducting effective corporate governance, an important factor for evaluating ESG performance. Drawing on agency theory, an enterprise can be viewed as an arrangement of contracts linking management with multiple stakeholders (Hamad et al. 2024). Thus, it is necessary for firms to move beyond shareholder-centric governance to cultivate strong relationships with multiple stakeholders. This drives corporate governance to consider various stakeholders' interests and demands, thereby improving internal control effectiveness. It can be achieved by creating dedicated environmental and social responsibility committees, assigning clear departmental responsibilities in response to climate risk, and enhancing mechanisms for monitoring internal environmental risks. These improvements facilitate a sound internal governance environment (Hoitash, Hoitash, and Bedard 2009), enabling firms to respond to climate-related challenges and opportunities more effectively, ultimately enhancing ESG performance. Thus, management's climate risk attention enhances internal control, establishing a foundation for improving ESG performance.

Hypothesis: Management's climate risk attention significantly improves corporate ESG performance.

III. Methods

Sample and data sources

This study examines Chinese A-share firms between 2009 and 2023, constrained by the availability of ESG performance data and

considering that data on management's climate risk attention are accessible up to 2023. Regarding selection criteria, firms are omitted if they (1) operate in the financial industry; (2) receive ST, *ST, or have similar risk warnings; or (3) have incomplete data. The final sample comprises 35,906 annual observations. Each continuous variable is winsorized at the 1st and 99th percentiles to mitigate extreme value bias.

GCRID provides access to data on management's climate risk attention. ESG performance is measured using Huazheng's ESG ratings. Green innovation metrics are obtained via CNRDS. Internal control indicators are obtained from the Shenzhen Dibao database. Energy utilization measures derive from Wind. Corporate carbon emission is manually calculated using information from social responsibility reports, official websites, and environmental department sources. Remaining variables are collated via CSMAR and processed by authors.

Variable selection

Management's climate risk attention

Management's climate risk attention reflects firms' recognition of the nature and impact of climate risk and their awareness of the need for risk mitigation to protect sustainability. Drawing on Lei et al. (2023), a management climate attention index is constructed to gauge management's climate risk attention by text-mining semi-annual and annual reports, particularly MD&A sections. This index is

established by comparing the relative occurrence of climate-specific words within the reports with the overall word count.

Corporate ESG performance

Referring to Ren, Zeng, and Zhao (2023) and Liu et al. (2024), ESG performance is evaluated using ratings provided by Huazheng. These ratings range from AAA (best) to C (worst). This study assigns corresponding values of 9, 8, 7, 6, 5, 4, 3, 2, and 1 from high to low to reflect corporate ESG performance.

Control variables

The control variables include $Size_{i,t}$, $Levi_{i,t}$, $ROE_{i,t}$, $Loss_{i,t}$, $Director_{i,t}$, $Indep_{i,t}$, $Dual_{i,t}$, $Top1_{i,t}$, $Big4_{i,t}$, $Mshare_{i,t}$, and $SOE_{i,t}$. Table 1 presents definitions of the variables.

Model construction

The article examines how management's climate risk attention affects ESG performance using a two-way fixed effects model:

$$\begin{aligned}
 ESG_{i,t} = & \alpha_0 + \alpha_1 CRP_{i,t} + \alpha_2 Size_{i,t} + \alpha_3 Lev_{i,t} \\
 & + \alpha_4 ROE_{i,t} + \alpha_5 Loss_{i,t} + \alpha_6 Director_{i,t} \\
 & + \alpha_7 Indep_{i,t} + \alpha_8 Dual_{i,t} + \alpha_9 Top1_{i,t} \\
 & + \alpha_{10} Big4_{i,t} + \alpha_{11} Mshare_{i,t} + \alpha_{12} SOE_{i,t} \\
 & + year_t + cp_i + \varepsilon_{i,t}
 \end{aligned} \quad (1)$$

where $ESG_{i,t}$ represents corporate ESG performance, $CRP_{i,t}$ denotes management's climate risk attention, and $year_t$ and cp_i denote time and individual fixed effects, respectively. The α_i coefficient holds special significance within

Table 1. Variable definitions.

Variable type	Abbreviation	Variable name	Description
Dependent variable	$ESG_{i,t}$	Corporate ESG performance	CSI ESG rating
Independent variable	$CRP_{i,t}$	Management's climate risk attention	Management climate attention index
Control variable	$Size_{i,t}$	Firm size	$\ln(\text{assets})$
	$Levi_{i,t}$	Gearing ratio	Liabilities/assets
	$ROE_{i,t}$	Return on equity	Net profit/owners' equity
	$Loss_{i,t}$	Whether or not it is a loss	Coded as 1 if net profit is negative, and 0 otherwise
	$Director_{i,t}$	Board size	$\ln(\text{board member count})$
	$Indep_{i,t}$	Board independence	The proportion of independent directors
	$Dual_{i,t}$	Dual positions	Takes on 1 if the CEO also chairs the board, and 0 in other cases
	$Top1_{i,t}$	Equity stake of the top shareholder	The fraction of shares held by the primary shareholder
	$Big4_{i,t}$	Big four audit	Assigned 1 for the four major audit firms and 0 otherwise
	$Mshare_{i,t}$	Management shareholding	Management shareholding as a percentage of total shares
	$SOE_{i,t}$	Equity properties	Assigned 1 or 0 depending on whether a firm is state-owned or not.

Table 2. Descriptive statistics.

Variable	N	Mean	Sd	Median	Min	Max
$ESG_{i,t}$	35906	4.1208	1.0126	4.0000	1.0000	8.0000
$CRP_{i,t}$	35906	0.0137	0.0111	0.0100	0.0013	0.0576
$Size_{i,t}$	35906	22.2267	1.2864	22.0426	19.3167	26.4523
$Levi_{i,t}$	35906	0.4288	0.2037	0.4226	0.0274	0.9198
$ROE_{i,t}$	35906	0.0616	0.1352	0.0706	-0.9385	0.4370
$Loss_{i,t}$	35906	0.1182	0.3228	0.0000	0.0000	1.0000
$Director_{i,t}$	35906	2.1223	0.1978	2.1972	1.6094	2.7081
$Indep_{i,t}$	35906	37.5965	5.3793	36.3600	25.0000	60.0000
$Dual_{i,t}$	35906	0.2765	0.4473	0.0000	0.0000	1.0000
$Top1_{i,t}$	35906	32.3472	16.0688	30.5998	0.0760	75.8434
$Big4_{i,t}$	35906	0.0580	0.2337	0.0000	0.0000	1.0000
$Mshare_{i,t}$	35906	12.8472	19.1548	0.4782	0.0000	70.5964
$SOE_{i,t}$	35906	0.3586	0.4796	0.0000	0.0000	1.0000

this model. If α_1 is significantly positive, the hypotheses can be verified, and vice versa, the hypotheses cannot be supported.

IV. Empirical analysis

Descriptive statistical analysis

As Table 2 shows, the mean of $ESG_{i,t}$ stands at 4.1208 (Sd = 1.0126), reflecting the variability in ESG performance across firms. Mean $CRP_{i,t}$ is 0.0137, ranging from 0.0013 to 0.0576, suggesting a broad range of management's climate risk attention among firms. The other variables also exhibit reasonable distributions.

Basic regression analysis

According to Table 3, columns (1) and (2) provide estimates excluding and including control variables, while Column (3) reports the standardized coefficients results. $CRP_{i,t}$ exhibits significance with a p-value under 0.01, indicating that from both statistical and economic perspectives,

management's climate risk attention boosts corporate efforts to improve energy utilization, foster green innovation, and strengthen internal control. These drivers promote better ESG performance, thus supporting the hypothesis.

Endogenous treatment

2SLS analysis

High ESG performance implies that companies are focused on long-term development and attentive to stakeholder interests. Thus, they are more capable and motivated to analyse the characteristics and negative effects of climate risk, resulting in greater management's climate risk attention. This implies that reverse causality could give rise to potential endogeneity concerns. To mitigate the issue, this study adopts an instrumental variable method. Specifically, the instrumental variable, $IV_{i,t}$, is expressed as the proportion of days with extreme rainfall. This is because the increase and intensification of extreme rainfall events can trigger floods, which cause significant economic losses and casualties. Considering their widespread and severe effects, such events are more likely to draw management's attention to climate risk (Y. Zhang, Zhao, and Zheng 2024). However, these macroclimatic phenomena generally do not directly affect corporate ESG performance. Following this, 2SLS analysis is conducted, with the findings reported in Table 4. $IV_{i,t}$ shows a coefficient of 0.0040, significant at 1%, supporting its relevance. $CRP_{i,t}$ exhibits a coefficient of 46.3879, significant at 10%, demonstrating that management's climate risk attention contributes to ESG performance after treating

Table 3. Basic regression analysis.

Variable	(1) $ESG_{i,t}$	(2) $ESG_{i,t}$	(3) $ESG_{i,t}$
$CRP_{i,t}$	8.4194*** (0.490)	4.0822*** (1.190)	0.0447*** (0.013)
Controls	No	Yes	Yes
FIRM&YEAR	No	Yes	Yes
R2	0.009	0.073	0.073
N	35906	35906	35906

* indicates $p < 0.10$; ** indicates $p < 0.05$; *** indicates $p < 0.01$. Parentheses contain cluster-robust standard errors. Owing to space limitations, only the regression results for the primary explanatory variables are reported. The same reporting convention is followed in subsequent sections.

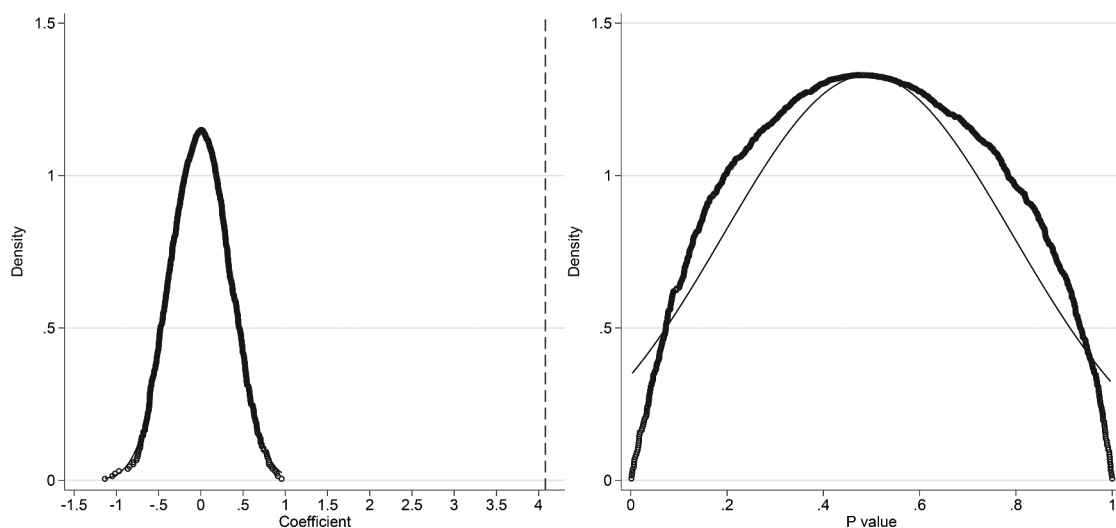
Table 4. 2SLS analysis.

Variable	(1) Phase I	(2) Phase II
$IV_{i,t}$	0.0040*** (0.001)	
$CRPI_{i,t}$		46.3879* (27.246)
Controls	Yes	Yes
FIRM&YEAR	Yes	Yes
N	34550	34550

endogeneity. The instrument validity test results, including the Kleibergen-Paap rk LM statistic ($p = 0.0000$) and the Cragg-Donald Wald F statistic (29.357), exceed the critical threshold of 8.96, thereby satisfying the identification and instrument strength requirements.

Falsification test: placebo test

Other random factors may influence how management's climate risk attention relates to ESG performance. To rule out this possibility, a placebo test is conducted by generating randomized measures of management's climate risk attention. As Figure 2 shows, the estimated coefficient distribution centres around zero, the probability of obtaining the actual estimated value (indicated by the vertical line on the right) is extremely low, and most p-values exceed 0.1. These findings confirm the promotional effect of management's climate risk attention on ESG performance.

**Figure 2.** Placebo test.

Dynamic panel GMM test

Considering the potential inertia in corporate ESG performance, this study employs a dynamic panel GMM. Table 5, Panel A, contains the findings. $CRPI_{i,t}$ is significantly positive, indicating that management's climate risk attention effectively promotes ESG performance. AR(1) and AR(2) tests suggest that first-order autocorrelation exists, while no autocorrelation is detected at the second order. A Hansen over-identification test confirms that the instrumental variables are valid.

Lagged test

Following Y. Zhang, Zhao, and Zheng (2024), the regression is re-estimated by lagging management's climate risk attention by one, two, and three periods, respectively, to address potential reverse causality concerns. Panel B of Table 5 indicates that, across all lag periods, management's climate risk attention promotes ESG performance.

Robustness tests

Changing methods

Considering the ordinal nature of ESG performance data, a basic regression is performed using an ordered logit model. Panel A of Table 6 shows that $CRPI_{i,t}$ remains significantly positive. Thus, the main conclusions hold.

Table 5. Dynamic panel GMM and lagged test.

Variable	Panel A: Dynamic panel GMM test	Panel B: Lagged test		
	(1) $ESG_{i,t}$	(2) $ESG_{i,t}$	(3) $ESG_{i,t}$	(4) $ESG_{i,t}$
$CRPi,t$	18.396* (10.256)			
$L1.CRPi,t$		5.6572*** (1.222)		
$L2.CRPi,t$			5.8795*** (1.467)	
$L3.CRPi,t$				3.5532** (1.720)
AR(1) test (p value)	0.018			
AR(1) test (p value)	0.192			
Hansen test (p value)	0.427			
Controls	Yes	Yes	Yes	Yes
FIRM&YEAR	Yes	Yes	Yes	Yes
R2		0.073	0.072	0.069
N	30034	35706	33045	30459

Table 6. Robustness tests.

Variable	Panel A: Changing methods	Panel B: Changing variable metrics	Panel C: Changing sample interval	Panel D: External shocks	
	(1) $ESG_{i,t}$	(2) $ESG_{i,t}$	(3) $ESG_{i,t}$	(4) Before 2015	(5) After 2015
$CRPi,t$	9.0714*** (0.953)	75.1549*** (17.648)	3.4876** (1.533)	1.6614 (2.379)	2.3111* (1.322)
Controls	Yes	Yes	Yes	Yes	Yes
FIRM&YEAR	Yes	Yes	Yes	Yes	Yes
Pseudo R^2/R^2	0.033	0.718	0.057	0.041	0.067
N	35906	10780	25499	10108	25798

Changing variable metrics

Drawing on Fazzini and Dal Maso (2016) and Ren, Zeng, and Zhao (2023), ESG performance is evaluated using ratings provided by Bloomberg. Panel B of Table 6 shows that $CRPi,t$ is significantly positive, thus supporting the positive hypothesis.

Changing sample interval

To rule out potential distortions from COVID-19, the sample period from 2020 to 2022 is excluded, and the relationship is re-examined. As Panel C of Table 6 shows, $CRPi,t$ remains significantly positive.

External shocks

As the problem of climate change intensified, the Paris Agreement was adopted by the United Nations in 2015, sparking widespread concern regarding effective responses to climate risk. As a result, management has become increasingly attentive to climate risk, potentially strengthening its role in bolstering ESG performance. To evaluate the impact of this external shock, the sample is divided into two groups: before and after 2015 (including 2015). Panel D of Table 6 shows that $CRPi,t$ is positive not significant before 2015,

whereas after 2015, it is positive and significant. This suggests that the 2015 Paris Agreement strengthened the impact of management's climate risk attention, further supporting the main findings.

V. Further analysis

Mechanism testing

Improving energy efficiency

Theoretical perspectives indicate that management's climate risk attention can potentially enhance ESG performance by improving energy efficiency. Accordingly, this study assesses how energy efficiency mediates this relationship. Drawing on J. Huang et al. (2023), the energy efficiency variable, $Enei,t$, is measured through total factor productivity. In Table 7 (Column 1), the $CRPi,t$ coefficient is 2.5576, with a p-value below 1%, suggesting that management's climate risk attention guides companies to use resources more efficiently. Table 7 (Column 2) indicates that the $Enei,t$ coefficient is 0.0500, with a p-value below 5%, demonstrating that improved energy efficiency

Table 7. Mechanism testing.

Variable	(1) <i>Enei,t</i>	(2) <i>ESGi,t</i>	(3) <i>Green Patenti,t</i>	(4) <i>ESGi,t</i>	(5) <i>ICi,t</i>	(6) <i>ESGi,t</i>
<i>CRPi,t</i>	2.5576*** (0.760)	2.0443** (1.017)	1.6139** (0.783)	4.0773*** (1.184)	0.4579*** (0.155)	3.7505*** (1.182)
<i>Enei,t</i>		0.0500** (0.019)				
<i>Green Patenti,t</i>				0.0681*** (0.012)		
<i>ICi,t</i>						0.5558*** (0.043)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FIRM&YEAR	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.768	0.048	0.037	0.075	0.201	0.077
N	38472	33238	41856	35906	40365	34472

enhances ESG performance. Together with the results of Model (1), these findings confirm the mediating effect of energy efficiency.

Enhancing green innovation

In addition to playing a catalytic role through the energy-efficiency pathway, management's climate risk attention can promote green innovation and foster ESG performance. Drawing on Liu et al. (2024), green innovation is denoted as $\ln(\text{green patents} + 1)$, denoted as *GreenPatenti,t*. Table 7 (Column 3) shows that the *CRPi,t* coefficient is 1.6139, with a p-value below 5%, suggesting that management's climate risk attention drives companies to adopt green innovation practices. In Table 7 (Column 4), the *GreenPatenti,t* coefficient is 0.0681, with a p-value below 1%, indicating that green innovation significantly enhances ESG performance. Together with the results of Model (1), these findings confirm the mediating effect of green innovation.

Improving internal control

Theoretical analyses suggest that management's climate risk attention promotes ESG performance by improving internal controls, in addition to enhancing energy efficiency and fostering green innovation. Therefore, this effect is tested using the internal control index, *ICi,t*, represented by its natural logarithm. In Table 7 (Column 5), the *CRPi,t* coefficient is 0.4579, with a p-value below 1%, indicating that management's climate risk attention improves firms' internal control. In Table 7 (Column 6), the *ICi,t* coefficient is 0.5558, with a p-value below 1%, suggesting that stronger internal control is conducive to ESG performance. Together with the results of Model (1), these

findings confirm the mediating effect of internal control.

Heterogeneity test

Heterogeneity of industry attributes

Industries have different development bases and capacities to cope with climate risk shocks. Traditional and non-traditional energy industries face different transformation and development costs owing to factors such as resource dependence and carbon reduction pressure. As climate change intensifies, climate risk has progressively emerged as a significant constraint on sustainable development, and management's climate risk attention has increased. This heightened attention enhances companies' motivation to adopt green low-carbon transformations. However, higher transition costs make it difficult for management's climate risk attention to promote ESG performance by improving energy efficiency, green innovation, and internal control in traditional energy industry enterprises. Therefore, management's climate risk attention is more likely to positively influence ESG performance in non-traditional energy industries. Accordingly, this study defines traditional energy industries as coal mining and washing, oil and gas extraction, gas production and supply, petroleum processing, coking, and nuclear fuel processing, and then conducts a heterogeneity test differentiating between samples from traditional and non-traditional energy industries. The results in Table 8 show that in traditional energy industries, the *CRPi,t* coefficient is positive but not significant, whereas in non-traditional energy industries, it is 4.4691, with a p-value

Table 8. Heterogeneity test: traditional vs. non-traditional energy sectors.

Variable	(1)	(2)
	Traditional energy industry	Non-conventional energy sector
$CRP_{i,t}$	4.2147 (5.096)	4.4691*** (1.264)
Controls	Yes	Yes
FIRM&YEAR	Yes	Yes
R^2	0.036	0.077
N	1546	34360

below 1%. This suggests higher transformation and development costs in traditional energy industries.

Impact of the corporate life cycle

Life cycle theory posits that enterprises face different resource and environmental constraints, and their ability to cope with climate risk shocks varies across distinct life cycle stages. Referring to Dickinson (2011), companies are categorized into growth, maturity, and recession stages according to the cash flow model. During the growth phase, companies have numerous investment opportunities but face strong resource and environmental constraints, limiting their sustainability when facing climate risk. At this stage, management's climate risk attention can drive improvements in energy efficiency, green innovation, internal controls, and ultimately, ESG performance. Transformation and development costs are lower for mature enterprises with stable operations and fewer resource and environmental constraints. Consequently, they are more resilient to climate risk shocks, increasing the likelihood that management's climate risk attention will drive their transformation and promote ESG performance. For firms in the recession stage, weak incentives and high thresholds for transition development result in low climate risk attention and difficult transition development. Collectively, these assertions suggest that management's climate risk attention exerts stronger influence on ESG performance in growing and mature firms. Therefore, a heterogeneity test is conducted using samples representing the growth, maturity, and recession stages. Table 9 shows that the $CRP_{i,t}$ coefficient is positive and significant for growing and mature enterprises, but positive and

Table 9. Heterogeneity test – corporate life cycle.

Variable	(1)	(2)	(3)
	Growth	Maturity	Recession
$CRP_{i,t}$	3.1066* (1.784)	3.7223* (2.007)	2.7341 (2.655)
Controls	Yes	Yes	Yes
FIRM&YEAR	Yes	Yes	Yes
R^2	0.064	0.069	0.094
N	14989	13141	7579

not significant for recessionary enterprises, verifying the above assertion.

Economic consequence analysis: ESG 'greenwashing' test

In September 2020, China set its 'dual-carbon' target, marking a new phase in its approach to addressing climate issues, emphasizing the need for green, high-quality development and highlighting the urgent need for carbon reduction. However, resource and environmental constraints limit enterprises' potential for carbon emission reduction, resulting in increased pressure to reduce emissions. This leads to a greater tendency to engage in 'greenwashing'. Consequently, whether the 'dual-carbon' target influences ESG performance, potentially leading to 'greenwashing', is examined. Accordingly, corporate carbon emissions, measured by Scopes 1 and 2 as outlined by Wang, Liu, and Zhang (2022), are used to construct Model (2) and test whether management's climate risk attention leads to genuine ESG practices or is merely 'greenwashing'. If the interaction between management's climate risk attention and ESG performance results in decreased corporate carbon emissions, it suggests that the beneficial impact of management's climate risk attention results from genuine ESG practices. Otherwise, it implies that ESG performance is a form of 'greenwashing'.

$$\begin{aligned}
 GHG_{i,t} = & \alpha_0 + \alpha_1 CE_{i,t} + \alpha_2 CRP_{i,t} + \alpha_3 ESG_{i,t} \\
 & + \alpha_4 Size_{i,t} + \alpha_5 Lev_{i,t} + \alpha_6 ROE_{i,t} + \alpha_7 Loss_{i,t} \\
 & + \alpha_8 Director_{i,t} + \alpha_9 Indep_{i,t} + \alpha_{10} Dual_{i,t} \\
 & + \alpha_{11} Top1_{i,t} + \alpha_{12} Big4_{i,t} + \alpha_{13} Mshare_{i,t} \\
 & + \alpha_{14} SOE_{i,t} + year_t + cp_i + \varepsilon_{i,t}
 \end{aligned} \quad (2)$$

where $GHG_{i,t}$ denotes corporate carbon emissions and $CE_{i,t}$ signifies the interaction between

Table 10. Analysis of economic consequences: corporate carbon emissions.

Variable	$GHG_{i,t}$
$CE_{i,t}$	-1.1661*** (0.371)
Controls	Yes
FIRM&YEAR	Yes
R^2	0.627
N	24051

management's climate risk attention $CRP_{i,t}$ and $ESG_{i,t}$. All other variables are defined consistently with Model (1). Thus the $CE_{i,t}$ coefficient is of particular interest in this model. If $CE_{i,t}$ is significantly negative, it implies that ESG performance does not stem from 'greenwashing', and the converse holds true.

Table 10 presents the economic consequence analysis. The $CE_{i,t}$ coefficient is -1.1661, with a p -value below 1%, suggesting that improvements in ESG performance driven by management's climate risk attention contribute to reducing carbon emissions, providing evidence that enhanced ESG performance is not 'greenwashing'.

Combining the main empirical findings and further analyses results, the 'cognition – behaviour – performance' logical framework for corporate sustainable development is verified. Unlike prior research that has primarily investigated how factors such as management myopia (Fan, Chen, and Mo 2024) and climate change (Jia & Li, 2020; Y. Chen et al. 2024; C. Li et al. 2024) shape ESG performance, the study investigates the relationship between management's cognitive characteristics and ESG performance by focusing on climate risk attention. Furthermore, it provides a mechanistic explanation for understanding how management's climate risk attention improves ESG performance, leveraging behavioural dimensions that enhance energy efficiency, strengthen green innovation, and optimize internal control. The findings on the economic consequences are logically consistent with those of Y. Zhang, Zhao, and Zheng (2024), highlighting the decisive role of management's cognitive traits in advancing corporate sustainability. However, unlike Y. Zhang, Zhao, and Zheng (2024), who directly examined how managerial climate attention affects corporate carbon emissions, this study explores how ESG performance driven by management's climate risk

attention influences corporate carbon emissions based on the dialectical relationship between ESG practices and 'greenwashing'. This exploration clarifies the driving logic behind sustainable corporate development.

VI. Conclusions and policy implications

As climate change intensifies, corporate climate risk increases, threatening sustainable development. Therefore, enterprises should respond effectively. This study adopts an ESG performance perspective and investigates the effect and mechanism of management's climate risk attention using data on Chinese companies listed on the A-share market from 2009 to 2023. Several key findings are provided. First, management's climate risk attention can promote corporate ESG performance. Second, management's climate risk attention can significantly improve energy efficiency, green innovation, and internal controls, positively affecting corporate ESG performance. Third, management's climate risk attention exerts stronger influence within non-traditional energy industries, indicating that enterprises in the traditional energy industry have higher transition and development costs. Fourth, this effect is more prominent among growing and mature enterprises. Fifth, the enhancement in ESG performance stems from ESG practices rather than 'greenwashing', which ultimately reduces corporate carbon emissions.

These findings reveal the need to proactively respond to climate risk shocks for corporate sustainability, offering recommendations for regulators, enterprises and other market participants to foster low-carbon green transformations, withstand climate risk shocks, enhance corporate ESG performance, and ultimately achieve the 'dual-carbon' goal. First, regulators should emphasize climate issues more by integrating climate risk into market risk monitoring systems. They should guide enterprises in recognizing the negative effects of climate risk and developing strategies in response. This will accelerate low-carbon green transformations and ESG practices, particularly for non-traditional energy industries and growing or mature enterprises. For traditional energy firms, regulatory support should focus on reducing

transition costs through policy guidance and financial incentives, facilitating a transition from fossil fuels towards renewable energy sources, and strengthening enterprises' resilience to climate risk. Second, enterprises should focus on determining and analysing the characteristics and hazards associated with climate change, increasing their attention to climate issues, and developing comprehensive risk-mitigation strategies that align with long-term business goals. They should actively implement low-carbon green transformations and ESG practices, optimize internal control while improving energy efficiency and green innovation, and enhance corporate sustainability. Enterprises in non-traditional energy industries or in growth or maturity stages should increase their climate risk attention and accelerate their transformation and ESG practices. Furthermore, traditional energy companies should focus on green technology research and development, reduce fossil energy dependence, gradually improve renewable energy systems, decrease transformation costs, and boost their ability to manage climate risk.

This study has several limitations. First, although intensifying climate change draws increasing management's attention, it may trigger heightened concern from other stakeholders, such as governments and the public. Clarifying these actors' distinct governance logics and coordination mechanisms could provide valuable insights for future research. Second, owing to variations in institutional environments, caution should be exercised when generalizing the findings to other capital markets. Subsequent studies may apply this research framework across alternative market environments to gain further insights.

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