Received: 8 October 2024 | Revised: 23 December 2024 | Accepted: 26 December 2024 | Published online: 10 January 2025

RESEARCH ARTICLE

Green and Low-Carbon Economy
2025, Vol. 00(00) 1–12
DOI: 10.47852/bonviewGLCE52024501

The Impact of Extreme Temperature on Enterprise ESG: An Empirical Analysis of China

Yanni Yu[1,3,4,*,†], Xin Meng[2,3,†] and Chengqing Ren[2,3]

[1]*Institute for Interdisciplinary Research of Shandong University, China*

[2]*Institute of Blue and Green Development, Shandong University, China*

[3]*Center for Human Sustainability, Shandong University, China*

[4]*Department of Land Economy, University of Cambridge, UK*

Abstract: Global climate warming leads to frequent extreme temperature events. Extreme temperatures bring uncontrollable uncertainty factors to the operation and management of enterprises. The Environmental, Social, and Governance (ESG) performance of enterprises is closely related to their business management. However, empirical evidence on to what extent extreme temperatures affect the ESG performance of enterprises is still lacking. The paper analyzes the influence of extreme temperatures on the ESG performance of enterprises to bridge this gap by constructing temperature intervals. There are several important results: (1) For each additional day within the temperature range of 30°C and above, the ESG score decreased by 0.09 points; (2) Extreme temperatures adversely affect ESG through operating costs, shareholders' equity, and information disclosure levels of enterprises; (3) Extreme temperatures are more likely to negatively impact the ESG performance of enterprises in the realty, manufacturing, electricity, and transportation industries. Therefore, at the macrolevel, the government should formulate relevant policies to address global warming. At the microlevel, enterprises should gradually incorporate climate change risks into their daily management systems to reduce the negative impact of extreme temperatures on their ESG performance.

Keywords: extreme temperature, ESG performance, operating costs, shareholders' equity, information disclosure

1. Introduction

Global warming is driving an increase in the frequency of extreme temperature events [1]. This rising frequency is making climate change an escalating risk for enterprises, presenting new challenges to their operations, financial stability, and social responsibility. Environmental, Social, and Governance (ESG) criteria are crucial for assessing enterprise sustainability and play a pivotal role in helping enterprises identify and address these risks [2]. Therefore, managing the risks associated with extreme temperatures has become a key component of an enterprise's sustainability strategy. This is both theoretically and practically significant for encouraging enterprises to actively address the challenges of climate change and pursue sustainable development. It also provides a valuable framework for investors, regulators, and the public to assess the long-term value and social responsibility of enterprises.

Currently, both domestic and international scholars have extensively studied the impact of climate change at the enterprise level, focusing on its effects on corporate operations, finances, social responsibility, and governance. For instance, Somarin et al. [3] show that climate change and global warming are increasing the frequency and intensity of extreme weather events, which disrupt supply chains and critical infrastructure, including transportation, water, sanitation, and energy systems. Wang et al. [4] emphasize that extreme temperatures pose a significant risk to listed companies, threatening corporate assets and highlighting the need for stronger risk mitigation strategies. Xiong et al. [5] quantify the financial impact of extreme weather by analyzing abnormal stock returns, emphasizing the substantial economic consequences of such events. Liang et al. [6] reveal a significant negative relationship between extreme weather and corporate labor productivity. In response, an increasing number of companies are incorporating extreme weather into their strategic planning and adopting measures, such as carbon emission management, to reduce the impact of these events [7].

While both domestic and international scholars have made significant strides in examining the impact of climate change on various aspects of corporate operations, the growing frequency of extreme temperature events and the uncertainty surrounding climate change continue to present major challenges. The question of how companies can effectively manage these risks and adjust their ESG performance remains a critical area for further investigation. Research on this topic can provide valuable insights to support the sustainable development of businesses and offer decision-making guidance for local governments in crafting effective climate change adaptation policies.

[†]Co-first authors.
***Corresponding author:** Yanni Yu, Institute for Interdisciplinary Research of Shandong University, Center for Human Sustainability, Shandong University, China and Department of Land Economy, University of Cambridge, UK. Email: yanniyu@sdu.edu.cn

This paper makes three key contributions to the literature: firstly, while existing studies have primarily focused on the relationship between ESG practices and corporate financial investment [8, 9], there has been limited exploration of corporate ESG performance in the context of temperature change. Secondly, this study introduces a novel research method that moves beyond the traditional analysis of annual mean temperatures [10, 11]. By utilizing a temperature chamber to simulate temperature variations and subdividing the temperature range, the study provides a more precise evaluation of how different temperature levels impact corporate ESG performance. Finally, existing literature has not fully explored the mechanisms by which temperature changes influence ESG performance, often lacking a clear causal framework. This paper addresses this gap by analyzing the effects of extreme temperatures on ESG performance across three dimensions: operating costs, shareholders' equity, and information disclosure. In doing so, it provides a theoretical foundation to guide policymakers in developing more effective climate adaptation strategies and corporate governance measures.

The remainder of the paper is as follows. Section 2 introduces the theoretical framework of the influence of extreme temperature on enterprise ESG. Section 3 presents the data and methodology. Section 4 highlights empirical results and discussion. Section 5 shows the conclusion and policy suggestions.

2. Theoretical Analysis

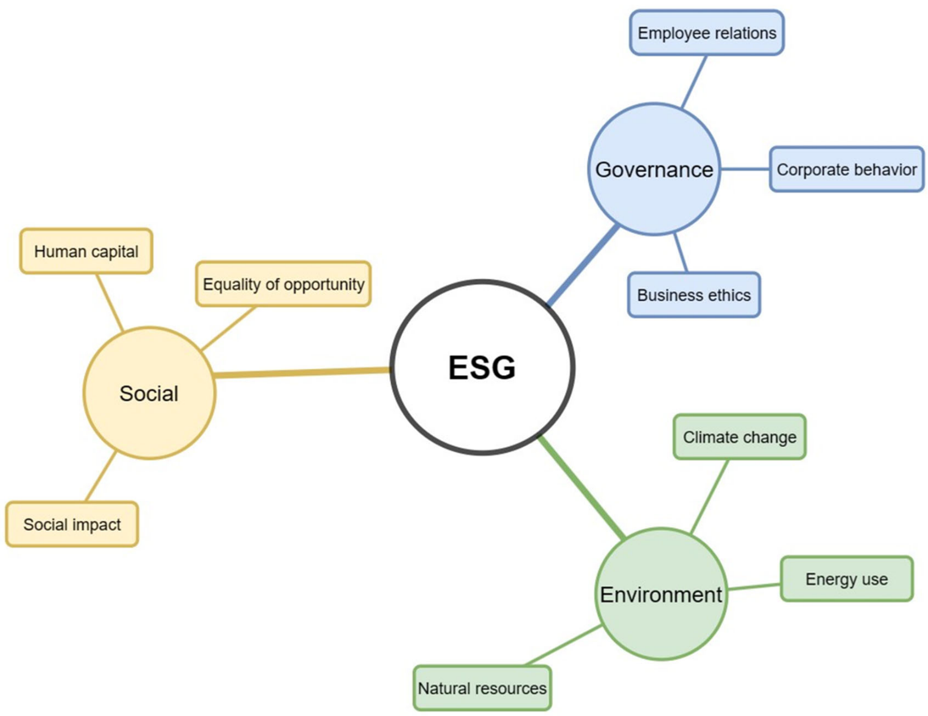
2.1. Direct effect

Global climate change is frequent as the greenhouse effect increases. It not only affects physical attributes such as temperature, precipitation, and biodiversity around the world but also significantly influences human health, the economy, and social stability. According to the Global Risk Report 2021 by the World Economic Forum, climate change has emerged as a major risk affecting the ESG performance of enterprises over the next decade. Therefore, the sensitivity of enterprises to climate risks is closely related to their level of development.

Climate change is the main reason for the increase in extreme temperature phenomena [12, 13]. Temperature change is associated with all three dimensions of ESG performance. The three dimensions of ESG include energy use, pollutant emissions, employee rights, social responsibility, corporate behavior, and business ethics. Figure 1 [2] shows the specific content included in ESG. At the environmental level, the occurrence of extreme temperatures can affect the accuracy and service life of production equipment. To ensure efficient production, enterprises often deploy large-scale cooling systems in their production areas, which can increase electricity consumption. At the societal level, the emergence of extreme temperatures places higher demands on operational techniques during production. This increases the workload of enterprise employees. Meanwhile, the frequent occurrence of high temperatures easily influences the health of employees. Extreme temperatures can increase the risk of cardiovascular, respiratory, and other related diseases [14]. Additionally, exposure to high temperatures can lead to heat stress and fatigue, which may trigger emotions such as depression and anger among employees [15, 16]. At the governance level, it shows that the frequency of extreme temperatures causes enterprises to adjust their business behaviors [17]. For example, in terms of recruitment strategies, enterprises are more likely to recruit highly skilled employees. Therefore, this paper proposes Hypothesis 1.

H1: Extreme temperature negatively affects the ESG performance of enterprises.

Figure 1
ESG content



2.2. Influence mechanism

1) Operating costs

Operating costs refer to the expenses incurred by enterprises during production and operations. These costs are crucial for an enterprise, as they directly impact profitability and growth [18]. Operating costs can be classified into direct and indirect costs. Direct costs are those directly associated with the production of goods or services, such as raw materials, labor, and manufacturing expenses. Indirect costs are not directly linked to production and include overhead, selling expenses, and finance costs.

Global warming leads to frequent extreme temperatures. Extreme temperatures affect not only human daily life but also the business activities of enterprises. Extreme temperatures can increase the strain on production equipment, resulting in higher energy consumption for enterprises [19]. Additionally, they may disrupt supply chains, significantly affecting transportation and causing delays in the delivery of raw materials. Furthermore, extreme temperatures can impact individuals' psychological well-being and cognitive abilities, leading to decreased workforce motivation [20, 21]. In this case, enterprises often encourage employees to work actively by increasing labor compensation. In other words, extreme temperatures cause higher operating costs for enterprises. The increase in operating costs affects not only the profits of enterprises but also indicators such as employee welfare, leading to the deterioration of enterprise ESG performance. Therefore, this paper proposes Hypothesis 2.

H2: Extreme temperatures increase the operating costs of enterprises, leading to a decline in their ESG performance.

2) Shareholders' equity

Shareholders' equity evaluates the governance level and decision-making process of enterprises and has an important effect on the governance dimension of ESG. Shareholders' equity is the total equity of the owners in the enterprise. It is an important indicator to measure the profitability of enterprises, which not only reflects the economic interests enjoyed by shareholders in the assets of enterprises but also reflects the capital of enterprises.

From the perspective of enterprises themselves, extreme temperatures affect their investment and financing decisions and generate economic loss time. This leads to higher leverage of the enterprise, affects its operations and governance, and thus reduces the undistributed profits and surplus reserves in shareholders' equity [22]. From the perspective of investors, the emergence of extreme temperatures reduces their confidence in investing in enterprises, leading to a decrease in capital investment and a decrease in corporate equity [23]. In addition, Peillex et al. show that extreme temperatures can also negatively affect the energy, mood, and concentration of investors [24]. This affects trading behavior and has an adverse impact on shareholders' equity. The governance (G) dimension of ESG evaluates an enterprise's governance structure and decision-making processes. Shareholders' equity is an important indicator of G dimension, which directly affects ESG performance [25, 26]. Therefore, this paper proposes Hypothesis 3.

H3: Extreme temperatures reduce the shareholders' equity of enterprises, leading to a decline in their ESG performance.

3) Information disclosure level

The level of information disclosure by enterprises reflects to some extent their market transparency. There are significant differences in environmental transparency between different industries. Institutional or cultural factors can affect the quantity and quality of enterprise information disclosure [27].

Extreme temperatures are a form of negative meteorological event. It can pose some unexpected risks to the public. This makes the public averse to extreme temperatures. In this background, enterprises tend to disclose more information to achieve a good equilibrium in the market. For example, they examine how enterprises make information disclosure decisions when audience preferences are uncertain [28]. The results show that as the public becomes more risk averse, enterprises become more difficult to keep silent. This is because silence creates more unknown risks for the market audience, which negatively affects the enterprise. Different quality of information disclosure leads to differences in ESG performance. When enterprises increase the level of information disclosure, this can expose more true information about the enterprise, and thus show the true and lower market value of the enterprise [29]. The market value of the enterprise is positively related to ESG performance, so the true ESG performance also decreases. Therefore, this paper proposes Hypothesis 4.

H4: Extreme temperatures increase the information disclosure quality of enterprises, leading to a decline in their ESG performance.

3. Data and Methodology

3.1. Variables

1) Dependent variables

At present, domestic and foreign research mainly measure the ESG performance of Chinese-listed enterprises based on databases such as Hexun ESG and Huazheng ESG [30, 31]. This paper uses the Hexun ESG data as the baseline to construct the dependent variable. There are two main reasons for this:

First, at the level of data consistency, Hexun ESG data have rated and scored most of the listed enterprises in Shanghai and Shenzhen A-shares for many years. Compared with other ESG rating agencies, Hexun ESG data cover more listed enterprises and a wide range [32, 33]. Second, at the level of data completeness, the evaluation system of ESG by Hexun includes specific scores for each sub-indicator. This facilitates further analysis. Therefore, we apply Hexun ESG data to measure the ESG performance of Chinese-listed enterprises in benchmark regression. Huazheng ESG data is used for robustness tests.

2) Independent variables

The temperature changes vary greatly throughout the year. If the annual average temperature is directly used, a large amount of information of temperature will be lost. This affects the validity of the estimation results. Therefore, in order to clarify the impact of different temperature variations on the ESG performance of enterprises, this paper refers to them [34, 35], and adopts the temperature box approach to characterize the overall distribution of temperature. We construct temperature intervals based on average daily temperatures and use 3°C as the interval length to calculate the number of days in a year when different temperatures fall into each interval.

3) Control variables

The control variables include sunshine hours, wind speed, precipitation, relative humidity, and atmospheric pressure. This paper identifies the region of listed enterprises based on the location of their main business and thus matches the weather-level control variables.

3.2. Econometric model

$$ESG_{it} = \alpha_0 + \sum_n \alpha_n Temp_{it}^n + \beta X_{it} + \delta_i + \mu_t + \epsilon_{ct} \qquad (1)$$

Equation (1) is the benchmark regression model for this paper—where *i, t,* and *c* denote the enterprise, the year, and the county of the enterprise, respectively. ESG_{it} denotes the ESG performance of enterprise *i* in year *t*. $Temp_{it}^n$ denotes the number of days in year *t* when the average daily temperature of enterprise *i* falls into the nth temperature interval. This paper divides the average daily temperature into 13 intervals. The length of each temperature interval is 3°C. $Temp_{it}^1$ denotes the number of days in year *t* when the average daily temperature of enterprise *i* falls into the interval (−∞°C, −3°C). $Temp_{it}^2$ denotes the number of days in year *t* when the average daily temperature of enterprise *i* falls into the interval [−3°C, 0°C]. $Temp_{it}^{13}$ denotes the number of days in year *t* when the average daily temperature of enterprise *i* falls into the interval [30°C, +∞]. The rest of the daily average temperature intervals follow this pattern. X_{it} is control variables. δ_i and μ_t denote enterprise fixed effects and year fixed effects, respectively. ϵ_{ct} clusters to the county level.

In the baseline regression, this paper chooses [12°C, 15°C] as the control group in order to avoid multicollinearity. This is because [12°C, 15°C] is in the middle of the 13 temperature intervals and is the most suitable temperature perceived by people. Therefore, the regression coefficient represents the impact of each additional day in which the daily average temperature falls into the interval *n* on the ESG performance of enterprises compared with the temperature interval [12°C, 15°C].

3.3. Data sources

The study uses the annual data of Chinese A-share listed enterprises in Shanghai and Shenzhen from 2011 to 2020 as the research sample. In the benchmark regressions, this paper mainly uses data on both ESG scores and weather variables. Table 1 shows the descriptive statistics of the variables in the baseline regression.

The ESG score data come from the Wind[1] database. The sample selection process of listed enterprises includes three main steps. First, due to the high investment risks and uncertainties associated with ST and ST* enterprises, which affect the accuracy of the research results, these enterprises are excluded from this study. Second, this paper excludes enterprises listed in the current year to avoid information disclosure differences caused by the short time of listing. Third, this paper excludes enterprises with significant data gaps to ensure data completeness.

Climate-level variables come from the China National Meteorological Science Data Centre (CNMDC). The CNMDC dataset includes climate variables such as average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours, atmospheric pressure, and relative humidity. This paper matches the raw data to specific districts and counties based on the latitude and longitude information of the sites provided in the raw data. For districts and counties with multiple sites, this paper uses the arithmetic mean of the daily data from multiple sites as the daily data for this district and county. Finally, we match the data of listed enterprises in the Wind database with the weather data in the CNMDC to screen out 721 listed enterprises and obtain 7,210 sample observations for benchmark regression analyses.

[1]https://www.wind.com.cn/newsite/edb.html

Table 1
Descriptive statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
ESG_hexun	7,210	30.45	19.53	−12.98	90.87
ESG_huazheng	7,210	7.08	1.20	1	9
Wind speed	7,210	2.235	0.490	0.92	5.30
Atmospheric pressure	7,210	994.00	42.78	620.70	1,017
Sunshine hours	7,210	1,883	423.10	662.70	3,416
Humidity	7,210	70.84	9.418	33.92	87.05
Precipitation	7,210	1,258	552.20	119	3,009

4. Empirical Results and Discussion

4.1. Baseline regression

Figure 2 shows the regression coefficients of each temperature interval. Table 2 shows the regression results obtained based on formula (1). Columns (1)–(6) indicate that when controlling variables at the weather level are gradually added, the regression coefficients and significant changes in each temperature interval are relatively small and generally stable. Column (6) shows that $Temp_{it}^n$ is significantly negative at the 1% level and $Temp_{it}^{13}$ is significantly negative at the 5% level. This indicates that for each additional day the average daily temperature falls within the ranges of [27°C, 30°C] and [30°C, +∞], the score decreases by 0.13 points and 0.09 points, respectively. This verifies hypothesis 1 of this paper.$Temp_{it}^{12}$

ESG is a method and tool for measuring enterprise performance in the ESG areas. It represents the overall situation of enterprises in the market. Climate change not only threatens natural ecosystems but also has a profound impact on the economic sustainability of enterprises [36]. For example, climate change leads to extreme weather events. In recent years, the intensity and frequency of extreme temperatures have continued to increase. From the perspective of production processes, extreme temperatures increase the operating load of machine and equipment. From the perspective of the supply chain, extreme temperatures increase the demand for energy in enterprises. Therefore, extreme temperatures can directly affect the production and supply chain of enterprises,

Figure 2
Regression coefficient of temperature interval

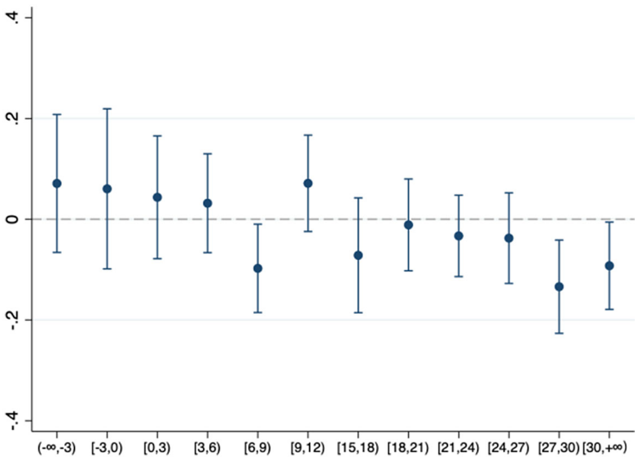


Table 2
Baseline regression result

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$Temp_{it}^{1}$	0.067	0.071	0.070	0.070	0.067	0.071
	(0.071)	(0.070)	(0.071)	(0.071)	(0.071)	(0.070)
$Temp_{it}^{2}$	0.054	0.055	0.051	0.051	0.061	0.060
	(0.082)	(0.082)	(0.082)	(0.083)	(0.082)	(0.081)
$Temp_{it}^{3}$	0.029	0.031	0.031	0.031	0.032	0.044
	(0.063)	(0.063)	(0.063)	(0.063)	(0.063)	(0.062)
$Temp_{it}^{4}$	0.011	0.014	0.016	0.016	0.020	0.032
	(0.051)	(0.050)	(0.051)	(0.051)	(0.051)	(0.050)
$Temp_{it}^{5}$	−0.107**	−0.104**	−0.101**	−0.101**	−0.102**	−0.098**
	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.045)
$Temp_{it}^{6}$	0.059	0.059	0.062	0.062	0.062	0.071
	(0.049)	(0.048)	(0.049)	(0.049)	(0.049)	(0.049)
$Temp_{it}^{8}$	−0.080	−0.077	−0.073	−0.074	−0.075	−0.072
	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.058)
$Temp_{it}^{9}$	−0.030	−0.025	−0.022	−0.022	−0.023	−0.011
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.046)
$Temp_{it}^{10}$	−0.054	−0.049	−0.045	−0.045	−0.047	−0.033
	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.041)
$Temp_{it}^{11}$	−0.056	−0.051	−0.046	−0.046	−0.049	−0.038
	(0.046)	(0.046)	(0.046)	(0.046)	(0.047)	(0.046)
$Temp_{it}^{12}$	−0.150***	−0.147***	−0.140***	−0.140***	−0.145***	−0.134***
	(0.048)	(0.048)	(0.048)	(0.048)	(0.048)	(0.047)
$Temp_{it}^{13}$	−0.128***	−0.118***	−0.112***	−0.112***	−0.122***	−0.092**
	(0.042)	(0.042)	(0.042)	(0.042)	(0.044)	(0.044)
Sunshine		−0.002	−0.002	−0.002	−0.003	−0.002
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Wind speed			1.658	1.678	1.701	2.485
			(1.683)	(1.904)	(1.905)	(1.906)
Atmospheric pressure				0.003	−0.009	−0.009
				(0.110)	(0.110)	(0.110)
Humidity					−0.134	−0.203
					(0.141)	(0.144)
Precipitation						0.003***
						(0.001)
Constant	57.212***	58.839***	54.082***	51.259	75.491	67.690
	(12.810)	(12.851)	(13.244)	(110.390)	(113.553)	(113.782)
Enterprise FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	7,210	7,210	7,210	7,210	7,210	7,210
R-squared	0.534	0.534	0.534	0.534	0.535	0.535

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

and thus affect the economic performance of enterprises. The economic performance of enterprises is related to their ESG performance [37]. Therefore, with the frequency of extreme temperatures, the ESG performance of enterprises becomes worse.

4.2. Mechanism analysis

The influence mechanism of extreme temperature on enterprise ESG has three main aspects. First, extreme temperature affects the daily operation activities of enterprises. This increases the operating costs of enterprises. Second, extreme temperatures can affect the investment and financing activities of enterprises, leading to a decrease in their shareholder equity. Third, extreme temperatures affect the market equilibrium and lead to an increase in the information disclosure level of the enterprise. The paper reports the analysis results of these impact mechanisms in Tables 3, 4, and 5.

(1) Operating costs

High temperatures can trigger a series of chain reactions. On the one hand, high temperatures increase the electricity load. The increase in electricity load increases the operating cost of enterprises. On the other hand, as an important environmental factor, high temperature affects the labor cost of enterprises. From the perspective of employees, high temperatures not only affect their physical health but also have a significant impact on their own psychological state. Heutel et al. [38] use health insurance data to show that high temperatures weather increases employee healthcare expenditures [38]. Baylis et al. [39] use social media data to show that high temperatures and weather lead to emotional decline among employees [39]. In the context of physical health and mental state damage, employees often demand that enterprises pay high-temperature subsidies. This adds to the operating expenses of enterprises.

Table 3
The impact of extreme temperatures on operating costs

VARIABLES[2]	(1)	(2)	(3)	(4)	(5)	(6)
$Temp_{it}^{12}$	1.214**	1.181**	1.046**	1.128**	1.156**	1.145**
	(0.504)	(0.514)	(0.510)	(0.507)	(0.478)	(0.476)
$Temp_{it}^{13}$	1.113**	1.012**	0.897*	1.017*	1.066**	1.043**
	(0.500)	(0.511)	(0.520)	(0.519)	(0.475)	(0.474)
Sunshine		0.018	0.023	0.024	0.028	0.027
		(0.022)	(0.021)	(0.021)	(0.025)	(0.025)
Wind speed			−34.594*	−49.507**	−49.613**	−50.230**
			(19.311)	(20.801)	(20.831)	(19.606)
Atmospheric pressure				−2.034**	−1.987**	−1.989**
				(0.923)	(0.885)	(0.888)
Humidity					0.618	0.672
					(1.646)	(1.651)
Precipitation						−0.003
						(0.014)
Constant	−103.931	−118.929	−21.071	2,009.844**	1,905.971**	1,914.275**
	(150.557)	(151.418)	(173.277)	(949.652)	(885.375)	(891.661)
Enterprise FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	6,450	6,450	6,450	6,450	6,450	6,450
R-squared	0.940	0.940	0.940	0.940	0.940	0.940

Table 4
The impact of extreme temperature on shareholders' equity

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$Temp_{it}^{12}$	−0.671***	−0.688***	−0.729***	−0.713***	−0.712***	−0.675***
	(0.199)	(0.200)	(0.204)	(0.206)	(0.208)	(0.212)
$Temp_{it}^{13}$	−0.442**	−0.499***	−0.530***	−0.505**	−0.504**	−0.419**
	(0.176)	(0.190)	(0.193)	(0.197)	(0.198)	(0.198)
Sunshine		0.010	0.011	0.012	0.012	0.013
		(0.008)	(0.008)	(0.009)	(0.010)	(0.010)
Wind speed			−10.104	−13.829	−13.834	−11.669
			(8.438)	(9.466)	(9.533)	(9.517)
Atmospheric pressure				−0.507	−0.506	−0.509
				(0.525)	(0.522)	(0.517)
Humidity					0.013	−0.192
					(0.723)	(0.686)
Precipitation						0.009***
						(0.003)
Constant	236.468***	229.117***	257.528***	765.288	763.143	745.539
	(49.244)	(48.491)	(54.490)	(527.543)	(525.804)	(521.244)
Enterprise FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	5,980	5,980	5,980	5,980	5,980	5,980
R-squared	0.841	0.841	0.841	0.842	0.842	0.842

In addition, the increase of high-temperature days also adds to the risk of employees voluntarily leaving their jobs. The situation of employees leaves increases the cost of re-recruiting labor for the enterprise. Enterprise ESG performance requires capital investment and support. However, increased costs may reduce ESG-related investments, thereby weakening overall ESG performance.

This paper replaces the dependent variable in Equation (1) with the operating cost of enterprises to test the existence of the operating cost mechanism. The control variables remain unchanged. Table 3 reports the regression results. Columns (1)–Column (6) show that the regression coefficients and significance of [27°C, 30°C] and [30°C, +∞] are less variable and generally stable. Column (6) shows that $Temp_{it}^{12}$ and $Temp_{it}^{13}$ are significantly positive at the 5% level. This shows that as the number of days with the daily average temperature falling into [27°C, 30°C] and [30°C, +∞] increases, the operating costs of enterprises increase. This verifies hypothesis 2 of this paper.

[2]Due to space constraints, this paper only shows the results of temperature intervals $Temp_{it}^{12}$ and $Temp_{it}^{13}$.

Table 5
The impact of extreme temperatures on information disclosure

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$Temp_{it}^{12}$	−0.010***	−0.010***	−0.009***	−0.009***	−0.009***	−0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$Temp_{it}^{13}$	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***	−0.007***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Sunshine		0.000	0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wind speed			0.219**	0.257**	0.256**	0.248**
			(0.093)	(0.109)	(0.109)	(0.109)
Atmospheric pressure				0.005	0.005	0.005
				(0.007)	(0.007)	(0.007)
Humidity					0.004	0.004
					(0.009)	(0.009)
Precipitation						−0.000
						(0.000)
Constant	3.047***	2.946***	2.321***	−2.458	−3.109	−3.028
	(0.848)	(0.838)	(0.784)	(6.615)	(6.631)	(6.655)
Enterprise FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	6,290	6,290	6,290	6,290	6,290	6,290
R-squared	0.460	0.460	0.461	0.461	0.461	0.461

(2) Shareholders' equity

The frequent occurrence of high-temperature weather brings many uncertainties to the economic activities of enterprises. On the one hand, high-temperature weather affects investment and financing decisions of enterprises [40]. Since high-temperature weather may lead to an increase in climate instability and natural disasters, the operation and governance of enterprises are affected. This may cause enterprises to become cautious about new investment opportunities or even postpone some important investment plans. Meanwhile, high-temperature weather also raises the cost of financing for enterprises [41]. Due to the presence of climate risks, financial institutions tend to take a more cautious approach to loans involving high-risk industries. This can increase the difficulty and cost of financing for enterprises. The outcome of investment and financing by enterprises is related to the distribution of shareholders' equity.

On the other hand, high-temperature weather can affect investor confidence in the enterprise. For example, Battiston et al. [42] show that as the extent of climate change increases, the asset value of the industry decreases [42]. This causes investors to reduce their willingness to invest in enterprises operating in high-risk industries. Investors' panic may lead to the decline in share price and decrease in market capitalization for enterprises, and thus affect the shareholders' equity of enterprises. Shareholders' equity is one of the key indicators of enterprise governance and business performance. The impact of high-temperature weather on shareholders' equity directly reflects on the G dimension of ESG performance. Therefore, high-temperature weather makes ESG performance worse by affecting shareholders' equity of enterprises.

This paper replaces the dependent variable in Equation (1) with the shareholders' equity of enterprises to test the existence of the shareholders' equity mechanism. The control variables remain unchanged. Table 4 reports the regression results. Columns (1)–Column (6) show that the regression coefficients and significance of [27°C, 30°C] and [30°C, +∞] are less variable and generally stable. Column (6) shows that $Temp_{it}^{12}$ is significantly negative at the 1% level and $Temp_{it}^{13}$ is significantly negative at the 5% level. This shows that as the number of days with the daily average temperature falling into [27°C, 30°C] and [30°C, +∞] increases, the shareholders' equity of enterprises decreases. This verifies hypothesis 3 of this paper.

(3) Information disclosure level

With the increasingly severe situation of climate change, the impact of extremely high temperature on the production and operation of enterprises is increasingly significant. In this context, enterprises often choose to increase their information disclosure levels [3]. The increase in information disclosure has great significance for enterprises, investors, and the relevant authorities. First, information disclosure can help enterprises better assess the risks associated with extremely high temperatures. Second, information disclosure can help investors accurately assess the value of enterprises and avoid investment risks. Third, information disclosure can help relevant authorities to obtain more climate-related data, and thus help them to stabilize the market.

Different quality of information disclosure can bring about differences in ESG performance. Yuan et al. [43] show that effective disclosure reduces the opacity of the enterprise and limits the surplus management of the enterprise, thus reducing the propensity for financial irregularities [43]. This may reveal a true lower financial profile of enterprises and lead to lower ESG performance related to finance. Therefore, the frequent occurrence of extremely high temperatures promotes higher levels of information disclosure by enterprises and thus affects their ESG performance.

This paper replaces the dependent variable in Equation (1) with the quality of information disclosure of enterprises to test the existence of the information disclosure mechanism. The control variables remain unchanged. We refer to Kim and Verrecchia [44] for measuring disclosure quality with the KV index [44]. Table 5 reports the regression results. Columns (1)–Column (6) show that the regression coefficients and significance of [27°C, 30°C] and [30°C, +∞] are less variable and generally stable. Column (6) shows that $Temp_{it}^{12}$ and $Temp_{it}^{13}$ are significantly negative at the 1% level. KV index is a reverse indicator of the quality of information disclosure. This shows that as the number of days with the daily average temperature falling into [27°C, 30°C] and [30°C, +∞] increases, the information disclosure of enterprises increases. This verifies hypothesis 4 of this paper.

4.3. Heterogeneity analysis

The paper separately regresses the ESG performance of enterprises in different industries according to the three-digit code of the industry. Figures 3 and 4 show the estimation results by industry. We can see that among the 12 industries in the sample of this paper, extremely high temperatures have significantly negative impacts on the ESG performance of four industries. This shows that as the number of days with the daily average temperature falling into [27°C, 30°C] and [30°C, +∞] increases, the ESG performance of these industries becomes worse. These industries include the realty, manufacturing, electricity, and transportation industries.

4.4. Robustness tests

1) Replace ESG measurement methods

The study applies the Huazheng ESG score to replace the ESG performance indicators in the benchmark regression for robustness

Figure 3
[27°C, 30°C] interval heterogeneity analysis results

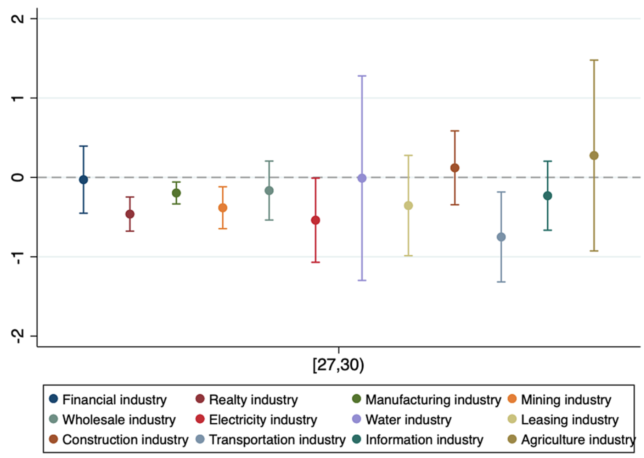
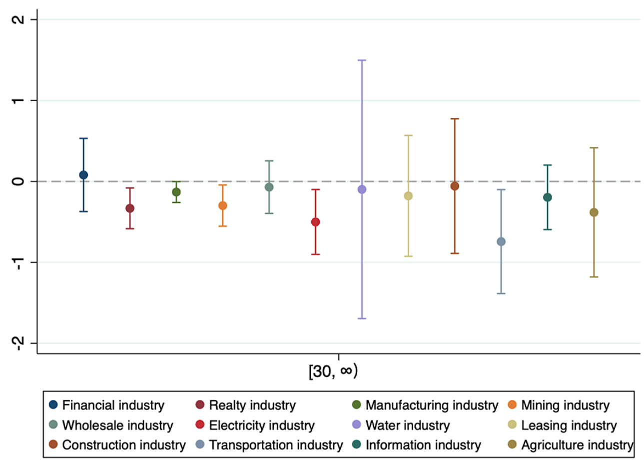


Figure 4
[30°C, +∞] interval heterogeneity analysis results



tests. Column (1) of Table A1 in the appendix is the regression result. The result shows that $Temp_{it}^{12}$ and $Temp_{it}^{13}$ are significantly negative at the 5% level. This indicates that the conclusions of the paper are not sensitive to the selection of the dependent variable, and proves the robustness of the results.

2) Adjust control variables

This paper further controls for enterprise-level and city-level variables. The control variables at the enterprise level include enterprise size, operating income, asset-liability ratio, and the proportion of independent directors. City-level control variables include total regional GDP and the GDP share of the third industry. Among them, total assets at the end of the period represent the enterprise size. Liabilities at the end of the period divided by total assets at the end of the period represent the asset-liability ratio. The number of independent directors divided by the number of directors represents the ratio of independent directors. Column (2) in Table A1 shows the regression results after adjusting control variables. The result shows that $Temp_{it}^{12}$ is significantly negative at the 1% level and $Temp_{it}^{13}$ is significantly negative at the 5% level. This shows that adjusting the control variables does not affect the results of the benchmark regression, and again proves the robustness of the results.

3) Control different fixed effects

This paper controls for the joint fixed effect of three-digit industry codes and years to control for the influence of unobservable factors in the industry over time on the estimation results. Table A1 column (3) shows the regression results after adding the joint fixed effects of industry and year. The result shows that $Temp_{it}^{12}$ and $Temp_{it}^{13}$ are significantly negative at the 1% level. This indicates that after further controlling for the joint fixed effects of industry and year, the results of this study remain robust.

5. Conclusions and Policy Implications

5.1. Conclusions

The paper empirically analyzes the influence of extreme temperature on enterprise ESG performance. Meanwhile, the paper also analyzes the influence mechanism of extreme temperature on enterprise ESG performance. The main research conclusions are as follows:

1) Extreme temperatures negatively impact the ESG performance of enterprises. As the external environment of economic activity, extreme temperatures have an irresistible and significant impact on macro- and microeconomic performance. At the macrolevel, extreme temperatures create certain shocks to industrial and agricultural production, energy supply, and capital markets. This causes the price of the corresponding product to increase. The increase in prices drives up the level of inflation and affects the total supply and demand for products. Under the influence of the macrolevel, the production and operation of microlevel enterprises are facing risks such as rising financial pressure due to shortages of raw materials and unstable supply chains. Therefore, with the frequent occurrence of high-temperature weather, the ESG performance of enterprises becomes worse.
2) Extreme temperatures adversely affect ESG through operating costs, shareholders' equity, and information disclosure levels of enterprises. First, extreme temperatures not only affect the operation of infrastructure but also the physical and mental health of employees. These increase the expenses of

enterprises. Enterprises need to invest capital, time, and labor costs to carry out ESG-related activities. The increase in operating costs leads to the poor ESG performance of enterprises. Second, extreme temperatures introduce uncertainty into the economic activities of enterprises. This is difficult to control. When enterprises are unsure of the future economic environment, they tend to approach investment decisions cautiously. The investment and financing results of enterprises are related to the distribution of shareholders' equity. This directly reflects in the G dimension of ESG performance. Third, extreme temperatures pose some unexpected risks to the public. Enterprises tend to disclose more information to achieve a good equilibrium in the market. This can expose more true information about the enterprise, and thus show the true and lower market value of the enterprise. The market value of the enterprise is positively related to ESG performance, so the true ESG performance also decreases.

3) Extreme temperatures are more likely to negatively impact the ESG performance of enterprises in the realty, manufacturing, electricity, and transportation industries. For the realty industry, high temperatures tend to affect public mood. People may cut back on plans to buy homes. For the manufacturing industry, high temperatures negatively affect the working environment and the physical condition of employees, which in turn reduces the productivity of the enterprise. For the electricity industry, high temperatures can lead to a lack of hydroelectric power generation. For the transport industry, high temperatures create many uncertainties in the transport process. Therefore, extremely high temperatures are more likely to negatively impact the ESG performance of enterprises in the realty, manufacturing, electricity, and transportation industries than in the rest of the industries.

5.2. Policy implications

Based on the findings of this paper, we offer policy implications for how enterprises can achieve sustainable development and how governments can design effective climate change policies. This is reflected in two main aspects:

1) Enterprises should gradually incorporate climate change risks into their daily management systems and strengthen climate change risk monitoring and assessment. Global warming leads to the growth of instability in the climate system. This adds to the frequency and intensity of extremely high temperatures. Extreme temperature is a difficult problem for enterprises to ignore, affecting their operating costs, shareholders' equity, and information disclosure levels and leading to poorer ESG performance. Therefore, on the one hand, enterprises should improve their risk management capabilities and clearly define the responsibilities of different management roles to deal with climate change [45]. This enables enterprises to better prevent and respond to potential risks. On the other hand, enterprises should actively transform themselves to reduce the unavoidable costs of climate adaptation, minimize the adverse impacts of high temperatures, and thus improve their ESG performance.
2) The government should formulate relevant policies to address global climate change. Global warming is the trigger for the frequent occurrence of extreme temperatures. The frequent occurrence of extreme temperatures can affect the sustainable development of enterprises. Energy conservation and emission reduction are effective measures to slow down global warming. Therefore, on the one hand, the government should encourage the development of renewable energy. Through increasing the proportion of renewable energy and reducing reliance on fossil fuels, greenhouse gas emissions can be reduced [46, 47]. On the other hand, the government should promote the transformation and upgrading of highly polluting and energy-consuming industries to clean and low-carbon industries. By eliminating outdated production capacity and accelerating green technological innovation, we can reduce greenhouse gas emissions.

Although this study provides a preliminary empirical analysis of the impact of extreme temperatures on corporate ESG performance, several areas warrant further investigation—firstly, the study relies primarily on existing quantitative data, which may not fully capture the complexity and diversity of climate change's effects on corporate social responsibility. Future research could benefit from integrating qualitative methods, such as case studies or in-depth interviews, to better understand the specific challenges and effectiveness of ESG practices across different companies. Secondly, this paper focuses on overall ESG performance across the three dimensions—environment, society, and governance—without examining how extreme weather impacts each dimension individually. Future studies could investigate the distinct effects of extreme weather on each of these ESG components.

Funding Support

This work is sponsored by National Natural Science Foundation of China (NSFC) [72022009].

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Yanni Yu: Conceptualization, Methodology, Validation, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Xin Meng:** Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Chengqing Ren:** Data curation, Visualization.

References

[1] Souloukngа, M. H., Coban, H. H., Falama, R. Z., Mbakop, F. K., & Djongyang, N. (2022). Comparison of different models to estimate global solar irradiation in the Sudanese zone of Chad. *Jurnal Elektronika Dan Telekomunikasi*, *22*(2), 63–71. https://doi.org/10.55981/jet.508

[2] Serafeim, G., & Yoon, A. (2023). Stock price reactions to ESG news: The role of ESG ratings and disagreement. *Review of*

Accounting Studies, *28*(3), 1500–1530. https://doi.org/10.1007/s11142-022-09675-3

[3] Somarin, A. R., Sharma, P., Tiwari, S., & Chen, S. (2023). Stock reallocation policy for repairable service parts in case of supply disruptions due to extreme weather events. *International Journal of Production Economics*, *256*, 108743. https://doi.org/10.1016/j.ijpe.2022.108743

[4] Wang, H., Qi, S., & Li, K. (2023). Impact of risk-taking on enterprise value under extreme temperature: From the perspectives of external and internal governance. *Journal of Asian Economics*, *84*, 101556. https://doi.org/10.1016/j.asieco.2022.101556

[5] Xiong, Y., Han, R., Ma, X., Lam, H. K. S., & Lyons, A. (2024). Mitigating the negative financial effects of extreme weather events through supply chain analytics. *International Journal of Production Economics*, *279*, 109441. https://doi.org/10.1016/j.ijpe.2024.109441

[6] Liang, C., Zhu, M., Lee, P. K. C., Cheng, T. C. E., & Yeung, A. C. L. (2024). Combating extreme weather through operations management: Evidence from a natural experiment in China. *International Journal of Production Economics*, *267*, 109073. https://doi.org/10.1016/j.ijpe.2023.109073

[7] Qian, X., Qiu, S., & Yang, X. (2024). Extreme weather exposure and corporate carbon emissions management: Evidence from forty countries. *Journal of Multinational Financial Management*, *75*, 100872. https://doi.org/10.1016/j.mulfin.2024.100872

[8] Gao, C., & Zhang, S. (2024). ESG performance and corporate financialization: A dual perspective of risk management and value creation. *Finance Research Letters*, *71*, 106442. https://doi.org/10.1016/j.frl.2024.106442

[9] Tang, N., Xu, X., Hsu, Y.-T., & Lin, C.-Y. (2024). The impact of ESG distance on mergers and acquisitions. *International Review of Financial Analysis*, *96*, 103677. https://doi.org/10.1016/j.irfa.2024.103677

[10] Dua, P., & Garg, N. K. (2024). Impact of climate change on productivity growth in India. *Indian Economic Review*, *59*(Suppl 1), 259–286. https://doi.org/10.1007/s41775-024-00229-9

[11] Kotz, M., Wenz, L., Stechemesser, A., Kalkuhl, M., & Levermann, A. (2021). Day-to-day temperature variability reduces economic growth. *Nature Climate Change*, *11*(4), 319–325. https://doi.org/10.1038/s41558-020-00985-5

[12] Ibrahim, N. A., Wan Alwi, S. R., Abd Manan, Z., Mustaffa, A. A., & Kidam, K. (2024). Climate change impact on solar system in Malaysia: Techno-economic analysis. *Renewable and Sustainable Energy Reviews*, *189*, 113901. https://doi.org/10.1016/j.rser.2023.113901

[13] Risely, A., Müller-Klein, N., Schmid, D. W., Wilhelm, K., Clutton-Brock, T. H., Manser, M. B., & Sommer, S. (2023). Climate change drives loss of bacterial gut mutualists at the expense of host survival in wild meerkats. *Global Change Biology*, *29*(20), 5816–5828. https://doi.org/10.1111/gcb.16877

[14] Yang, Z., Yang, B., Liu, P., Zhang, Y., Hou, L., & Yuan, X. C. (2022). Exposure to extreme climate decreases self-rated health score: Large-scale survey evidence from China. *Global Environmental Change*, *74*, 102514. https://doi.org/10.1016/j.gloenvcha.2022.102514

[15] Noelke, C., McGovern, M., Corsi, D. J., Jimenez, M. P., Stern, A., Wing, I. S., & Berkman, L. (2016). Increasing ambient temperature reduces emotional well-being. *Environmental Research*, *151*, 124–129. https://doi.org/10.1016/j.envres.2016.06.045

[16] Lee, S., Lee, H., Myung, W., Kim, E. J., & Kim, H. (2018). Mental disease-related emergency admissions attributable to hot temperatures. *Science of the Total Environment*, *616–617*, 688–694. https://doi.org/10.1016/j.scitotenv.2017.10.260

[17] Li, F. W., Lin, Y., Jin, Z., & Zhang, Z. (2020). Do firms adapt to climate change? Evidence from establishment-level data. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3573260

[18] Vennemo, H., Rosnes, O., & Skulstad, A. (2022). The cost to households of a large electricity outage. *Energy Economics*, *116*, 106394. https://doi.org/10.1016/j.eneco.2022.106394

[19] Morakinyo, T. E., Ren, C., Shi, Y., Lau, K. K.-L., Tong, H.-W., Choy, C.-W., & Ng, E. (2019). Estimates of the impact of extreme heat events on cooling energy demand in Hong Kong. *Renewable Energy*, *142*, 73–84. https://doi.org/10.1016/j.renene.2019.04.077

[20] Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. *Journal of Political Economy*, *124*(1), 105–159. https://doi.org/10.1086/684582

[21] Banerjee, R., & Maharaj, R. (2020). Heat, infant mortality, and adaptation: Evidence from India. *Journal of Development Economics*, *143*, 102378. https://doi.org/10.1016/j.jdeveco.2019.102378

[22] Benincasa, E., Betz, F., & Gattini, L. (2024). How do firms cope with losses from extreme weather events? *Journal of Corporate Finance*, *84*, 102508. https://doi.org/10.1016/j.jcorpfin.2023.102508

[23] Zhao, Y., Liu, Y., Dong, L., Sun, Y., & Zhang, N. (2024). The effect of climate change on firms' debt financing costs: Evidence from China. *Journal of Cleaner Production*, *434*, 140018. https://doi.org/10.1016/j.jclepro.2023.140018

[24] Peillex, J., El Ouadghiri, I., Gomes, M., & Jaballah, J. (2021). Extreme heat and stock market activity. *Ecological Economics*, *179*, 106810. https://doi.org/10.1016/j.ecolecon.2020.106810

[25] Billio, M., Costola, M., Hristova, I., Latino, C., & Pelizzon, L. (2021). Inside the ESG ratings: (Dis)agreement and performance. *Corporate Social Responsibility and Environmental Management*, *28*(5), 1426–1445. https://doi.org/10.1002/csr.2177

[26] Wang, Z., Chu, E., & Hao, Y. (2024). Towards sustainable development: How does ESG performance promotes corporate green transformation. *International Review of Financial Analysis*, *91*, 102982. https://doi.org/10.1016/j.irfa.2023.102982

[27] Chouaibi, S., & Affes, H. (2021). The effect of social and ethical practices on environmental disclosure: Evidence from an international ESG data. *Corporate Governance: The International Journal of Business in Society*, *21*(7), 1293–1317. https://doi.org/10.1108/CG-03-2020-0087

[28] Bond, P., & Zeng, Y. (2022). Silence is safest: Information disclosure when the audience's preferences are uncertain. *Journal of Financial Economics*, *145*(1), 178–193. https://doi.org/10.1016/j.jfineco.2021.08.012

[29] Eng, L. L., Fikru, M., & Vichitsarawong, T. (2021). Comparing the informativeness of sustainability disclosures versus ESG disclosure ratings. *Sustainability Accounting, Management and Policy Journal*, *13*(2), 494–518. https://doi.org/10.1108/SAMPJ-03-2021-0095

[30] Jin, C., Monfort, A., Chen, F., Xia, N., & Wu, B. (2024). Institutional investor ESG activism and corporate green innovation against climate change: Exploring differences between digital and non-digital firms. *Technological Forecasting and Social Change*, *200*, 123129. https://doi.org/10.1016/j.techfore.2023.123129

[31] Liu, A., Dai, S., & Wang, Z. (2023). Environmental protection tax on enterprise environmental, social and governance performance: A multi-perspective analysis based on

financing constraints. *Journal of Asian Economics*, *89*, 101671. https://doi.org/10.1016/j.asieco.2023.101671
[32] Chen, Y., Ren, S., Narayan, S., & Huynh, A. (2024). Does climate risk impact firms' ESG performance? Evidence from China. *Economic Analysis and Policy*, *81*, 683–695. https://doi.org/10.1016/j.eap.2023.12.028
[33] He, F., Guo, X., & Yue, P. (2024). Media coverage and corporate ESG performance: Evidence from China. *International Review of Financial Analysis*, *91*, 103003. https://doi.org/10.1016/j.irfa.2023.103003
[34] Yu, X., Lei, X., & Wang, M. (2019). Temperature effects on mortality and household adaptation: Evidence from China. *Journal of Environmental Economics and Management*, *96*, 195–212. https://doi.org/10.1016/j.jeem.2019.05.004
[35] Agarwal, S., Qin, Y., Shi, L., Wei, G., & Zhu, H. (2021). Impact of temperature on morbidity: New evidence from China. *Journal of Environmental Economics and Management*, *109*, 102495. https://doi.org/10.1016/j.jeem.2021.102495
[36] Graff Zivin, J., Song, Y., Tang, Q., & Zhang, P. (2020). Temperature and high-stakes cognitive performance: Evidence from the national college entrance examination in China. *Journal of Environmental Economics and Management*, *104*, 102365. https://doi.org/10.1016/j.jeem.2020.102365
[37] DasGupta, R., & Roy, A. (2023). Firm environmental, social, governance and financial performance relationship contradictions: Insights from institutional environment mediation. *Technological Forecasting and Social Change*, *189*, 122341. https://doi.org/10.1016/j.techfore.2023.122341
[38] Heutel, G., Miller, N. H., & Molitor, D. (2021). Adaptation and the mortality effects of temperature across U.S. climate regions. *The Review of Economics and Statistics*, *103*(4), 740–753. https://doi.org/10.1162/rest_a_00936
[39] Baylis, P., Obradovich, N., Kryvasheyeu, Y., Chen, H., Coviello, L., Moro, E., . . . , & Fowler, J. H. (2018). Weather impacts expressed sentiment. *PLOS ONE*, *13*(4), e0195750. https://doi.org/10.1371/journal.pone.0195750
[40] Huang, H. H., Kerstein, J., & Wang, C. (2018). The impact of climate risk on firm performance and financing choices: An international comparison. *Journal of International Business Studies*, *49*(5), 633–656. https://doi.org/10.1057/s41267-017-0125-5
[41] Aguilar-Gomez, S., Gutierrez, E., Heres, D., Jaume, D., & Tobal, M. (2024). Thermal stress and financial distress: Extreme temperatures and firms' loan defaults in Mexico. *Journal of Development Economics*, *168*, 103246. https://doi.org/10.1016/j.jdeveco.2023.103246
[42] Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. *Nature Climate Change*, *7*(4), 283–288. https://doi.org/10.1038/nclimate3255
[43] Yuan, X., Li, Z., Xu, J., & Shang, L. (2022). ESG disclosure and corporate financial irregularities: Evidence from Chinese listed firms. *Journal of Cleaner Production*, *332*, 129992. https://doi.org/10.1016/j.jclepro.2021.129992
[44] Kim, O., & Verrecchia, R. E. (2001). The relation among disclosure, returns, and trading volume information. *The Accounting Review*, *76*(4), 633–654. https://www.jstor.org/stable/3068930
[45] Vestrelli, R., Fronzetti, A., & Pisello, L. (2024). When attention to climate change matters: The impact of climate risk disclosure on firm market value. *Energy Policy*, *185*, 113938. https://doi.org/10.1016/j.enpol.2023.113938
[46] Vaidyanathan, G. (2021). Scientists cheer India's ambitious carbon-zero climate pledge. *Nature*, *600*, 19–20. https://doi.org/10.1038/d41586-021-03044-x
[47] Alam, S. Md. T. (2020). Sustainable energy security for economic development: Trends and challenges for Bangladesh. *The Journal of Energy and Development*, *46*(1/2), 219–238. https://www.jstor.org/stable/27107174

How to Cite: Yu, Y., Meng, X., & Ren, C. (2025). The Impact of Extreme Temperature on Enterprise ESG: An Empirical Analysis of China. *Green and Low-Carbon Economy*. https://doi.org/10.47852/bonviewGLCE52024501

Appendix

Table A1
Robustness test results

VARIABLES	(1)	(2)	(3)
$Temp_{it}^{1}$	0.005	0.079	0.025
	(0.003)	(0.066)	(0.072)
$Temp_{it}^{2}$	−0.000	0.054	−0.034
	(0.004)	(0.077)	(0.078)
$Temp_{it}^{3}$	0.002	0.046	0.015
	(0.003)	(0.060)	(0.068)
$Temp_{it}^{4}$	0.002	0.030	0.041
	(0.003)	(0.048)	(0.052)
$Temp_{it}^{5}$	−0.001	−0.090**	−0.100**
	(0.003)	(0.042)	(0.045)
$Temp_{it}^{6}$	0.001	0.070	0.046
	(0.003)	(0.048)	(0.052)
$Temp_{it}^{8}$	−0.007**	−0.070	−0.118**
	(0.003)	(0.055)	(0.058)
$Temp_{it}^{9}$	0.001	−0.007	−0.021
	(0.002)	(0.045)	(0.046)
$Temp_{it}^{10}$	−0.002	−0.037	−0.066
	(0.002)	(0.040)	(0.041)
$Temp_{it}^{11}$	−0.006**	−0.034	−0.061
	(0.002)	(0.044)	(0.047)
$Temp_{it}^{12}$	−0.007**	−0.134***	−0.176***
	(0.003)	(0.045)	(0.047)
$Temp_{it}^{13}$	−0.005**	−0.086**	−0.123***
	(0.002)	(0.043)	(0.044)
Sunshine	0.000*	−0.002	−0.003*
	(0.000)	(0.002)	(0.002)
Wind speed	−0.276**	2.239	2.679
	(0.123)	(1.913)	(1.860)
Atmospheric pressure	−0.009	−0.011	0.067
	(0.009)	(0.108)	(0.124)
Humidity	0.004	−0.210	−0.220
	(0.008)	(0.143)	(0.146)
Precipitation	0.000	0.003***	0.003***
	(0.000)	(0.001)	(0.001)
Constant	17.282*	67.650	4.624
	(8.802)	(111.678)	(128.024)
Enterprise FE	Y	Y	Y
Year FE	Y	Y	Y
Enterprise control variable	N	Y	N
Urban control variable	N	Y	N
Industry-Year FE	N	N	Y
Observations	7,210	7,210	7,210
R-squared	0.648	0.542	0.599