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The Impact of Climate Risk on Firm Performance: An Empirical Analysis based on the ESG Perspective of Manufacturing Firms

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Abstract

This paper studies the ESG behavior and its influencing factors of manufacturing enterprises under the challenge of climate risk from the enterprise level. It is found that climate risk has a significant positive impact on ESG performance of enterprises, indicating that enterprises are more inclined to strengthen management and investment in environment, society and governance when responding to the challenge of climate change. Transformation risk is the main driving force, while physical risk has no significant impact. In addition, the analysis of regional differences shows that climate risk has a significant impact on the ESG performance of manufacturing enterprises in the central and eastern regions, but not on the western regions. Heavy polluting enterprises take more measures of technological transformation and upgrading in the face of climate risks, and their ESG performance is affected by climate risks 40% more than that of non-heavy polluting enterprises. The study also found that the higher the level of green innovation, the greater the impact of climate risk on the firm's ESG performance. Therefore, enterprises should attach importance to green innovation, improve environmental and social performance through technological innovation, strengthen climate risk management, and promote green innovation; Policy makers should take regional differences into account to formulate strategies, pay attention to the transformation of heavy polluters, promote cross-sectoral cooperation, and establish continuous monitoring and evaluation mechanisms to improve the performance of enterprises in ESG.

Keywords

Climate Risk; Corporate ESG Transformation; Green Innovation; Manufacturing Industry.

1. Introduction

In recent years, there have been many extreme weather events around the world that have caused huge human and economic losses. These events not only pose a major threat to human life and property, but may also further exacerbate climate change, with far-reaching impacts on society and the economy. As a result, a growing number of investors, financial institutions and regulators have begun to incorporate climate risk into their risk management frameworks, taking steps to mitigate its impact on financial stability. In China, the importance of ecological civilization building and green development was highlighted at the 20th Congress, and the task of tackling climate change, promoting green and low-carbon development, and achieving the goal of carbon peaking and carbon neutrality was put forward, and improving enterprises' awareness of climate risks and coping capacity to enhance sustainable development capacity was a key link in achieving the "two-carbon" goal.

The impact of climate risk on financial markets can be divided into two main categories: physical risk and transition risk. Physical risk covers natural disasters caused by climate change,

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such as asset damage, environmental degradation and casualties. Although the impact on asset values is relatively limited, it is highly uncertain (Financial Stability Board, 2020). Transition risks arise from the process of economic transition to green and low-carbon, including factors such as technological shocks, cost fluctuations of new energy and policy changes. These two types of risks are intertwined, threatening the stability of the financial system and affecting the normal functioning of financial markets, while also causing significant impacts on the real economy (Brunetti et al., 2021). Effective management and reduction of these risks is therefore essential to achieving sustainable development and addressing climate change.

There are multiple considerations when looking at the impact of climate risks on businesses, especially when assessing how companies respond to these risks. Existing studies mostly focus on the macro impact of climate risk on capital cost (Du Jian et al., 2023), default rate (Chen Guojin et al., 2023), bank risk (Xia Yiguo et al., 2023), and so on, while relatively few studies have focused on the coping strategies at the firm level. Although measures of climate risk such as temperature anomalies, direct economic losses and greenhouse gas emissions are usually taken from a macro perspective, different industries and enterprises may face very different climate risks due to specific industry characteristics and resource conditions. Jian Du et al. (2023) attempt to effectively measure climate risk at the firm level through methods such as text analysis. This method can more accurately reflect the actual situation and coping ability of enterprises under specific climate risks.

Therefore, this paper, starting from the enterprise level, studies the ESG behavior of manufacturing enterprises when facing the challenge of climate risk, and explores its influencing factors. The marginal contribution of this paper lies in: (1) enriching empirical research on the economic consequences of climate risks: This paper extends the existing research on the consequences of climate risks, especially focusing on how firms respond to these risks, and uses empirical analysis to add in-depth discussion on the strategies for coping with climate risks at the firm level. (2) Expanded research on ESG influencing factors: This paper explores the role of ESG (environmental, social, governance) capabilities of firms in the face of climate risks. The importance of ESG factors in corporate strategy is increasingly recognized, and climate risk is one of the key areas. (3) Provide theoretical support for enterprises to improve their ESG capabilities and promote green digital transformation: Through theoretical and empirical research, this paper provides guidance and support for enterprises to improve their ESG capabilities and promote green digital transformation when dealing with climate risks. These strategies not only help reduce the impact of risks, but also enhance the long-term competitiveness and sustainable development capacity of enterprises.

2. Literature Review and Research Hypothesis

2.1. Research on Economic Consequences of Climate Risks

Combing through the existing research, it is found that climate risk has a multi-faceted impact on the economic activities of enterprises. These impacts are grouped into three main categories: macro, public health and business. This paper focuses on the impact of climate risk on business. Chen Guojin et al. pointed out that the risk of climate transition increases the financing cost and asset impairment loss of enterprises, while reducing the growth rate of operating income, thus significantly increasing the default risk of enterprises. According to the research of Du Jian et al., climate risk will affect the risk-free interest rate and the beta coefficient of enterprises, thus aggravating market uncertainty and leading to a significant increase in the cost of equity capital of enterprises. In addition, Sun et al. 's analysis found that different types of climate risks have different impacts on the financial performance of mining enterprises, which may have both positive and negative effects. Therefore, enterprises need to take active measures to cope with climate change risks, so as to improve their financial performance.

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2.2. Impacts of Climate Risks on Enterprises and Their Behaviors

Literature research shows that climate risk has a broad and far-reaching impact on enterprises. It will not only directly impact the production facilities, supply chains and infrastructure of enterprises (Hallegatte et al., 2011; Kousky and Cooke, 2012) but also indirectly impacts firms through channels such as policies, markets and consumer behaviour (Aldy and Pizer, 2015; Brouhle and Harrington, 2009). In order to effectively address these challenges, relevant literature suggests that the following strategies can be adopted: First, enterprises should tailor climate change adaptation strategies according to their own characteristics and industry background, and establish an effective climate risk assessment system (Busch and Hoffmann, 2011; Busch et al., 2016); Second, companies should invest in clean energy, optimize production processes, improve energy efficiency, and work to reduce carbon emissions (Fujii et al., 2013; Linnenluecke et al., 2011); In order to reduce the risk of supply chain disruption caused by climate risk, enterprises can adjust the supply chain structure (Craighead et al., 2007; Weinhofer and Busch, 2013); Companies should pay close attention to trends in climate policies and regulations to ensure that corporate behavior is in line with relevant requirements, thereby reducing transition risks (Busch et al., 2016). In addition, business response to climate change is closely linked to its social responsibility and values.

When exploring the theoretical framework for the impact of climate risk on corporate environmental, social and governance (ESG) performance, it is critical to understand the dual impact of physical and transformational risks on corporate ESG metrics. Physical risks cover climate change-induced natural disasters and environmental degradation that directly affect a company's environmental performance, such as water resource management, carbon emission control and ecosystem protection. In the face of these challenges, companies need to strengthen their environmental adaptability, reduce their environmental impact through technological innovation and resource management, and safeguard their environmental reputation and sustainable development strategies. And transition risk mainly refers to the uncertainty of the economic transition to a low-carbon and green economy, which requires companies to reevaluate their ESG strategies and practices to meet new market requirements and policies and regulations. This may include adjusting supply chains, improving energy efficiency, adopting clean technologies and improving governance structures to adapt to future environmental and social pressures.

This leads to hypothesis 1: climate risk has a positive impact on ESG behaviour.

2.3. Climate Risk, Firm Innovation and Firm ESG Behavior

Climate risks affect businesses in many ways. First, it directly affects their operations and supply chains, for example through extreme weather events and natural disasters, among others. These events can lead to production disruptions, supply chain disruptions and logistics delays, which can affect a company's economic efficiency and market performance. The study by Li Guo and Hongru Wu (2023) points out that these direct impacts may force firms to re-evaluate their operating models and supply chain management strategies to enhance their resilience to climate risks.

In order to address the challenges posed by climate risks, companies can adopt green innovation as a strategic tool. Green innovation not only involves developing and applying environmentally friendly technologies, but also involves improving product design, production processes and business models to reduce dependence on limited resources. In this way, companies are able to reduce their exposure to climate risks and enhance their environmental resilience. The study by Xiu 'e Zhang and Mengying Li (2023) highlights that green innovation can also help companies enhance their reputation and win the support of stakeholders, especially in the context of increasing public concern about environmental issues.

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The climate change report released by the IPCC has further highlighted the impact of emissions from human activities on climate change, which has increased the pressure on companies in terms of environmental governance and social responsibility. Companies need to make greater efforts in ESG (Environmental, social and governance) to cope with the expectations of the public and regulators. This pressure has prompted companies to devote more resources and attention to ESG behaviour to demonstrate their concern and commitment to environmental and social issues.

Based on the above analysis, hypothesis 2 can be put forward: corporate green innovation ability plays a moderating role in the impact of climate risk on corporate ESG behavior. Specifically, the stronger the firm's green innovation ability, the better its response ability to climate risk, and thus the better its ESG performance.

3. Empirical Research

3.1. Data Description and Study Design

3.1.1. Data Description

This paper selects the data of Shanghai and Shenzhen A-share manufacturing listed companies from 2010 to 2022 as the initial research sample. Among them, the ESG performance of enterprises is from the ESG rating database of China Securities, and other financial data and corporate governance data are from the CSMAR database. In order to ensure the reliability of the data, the initial samples were processed as follows: (1) Exclusion of special treatment companies: First, the companies that were subjected to special treatment (ST, *ST or PT) during the sample period were excluded. These companies may be subjected to special treatment due to financial problems or other reasons, and their data may not accurately reflect the real business conditions of the companies. (2) Deletion of missing value samples: Secondly, deletion of samples containing missing values. The integrity of data is the basis of effective statistical analysis, and the existence of missing values may affect the accuracy of analysis results. (3) Tail indentation: A two-sided 1% tail indentation was applied to continuous variables to eliminate the effect of extreme values. Extreme values may cause great interference to the statistical analysis results, and such interference can be reduced by tail reduction treatment to make the analysis results more robust.

3.1.2. Definition of Variables

Explained variable: Enterprise ESG Performance (ESG). At present, the academic community usually uses the scores of third-party rating agencies to evaluate the ESG performance of enterprises. In view of the fact that the ESG evaluation system of Huaseng is more in line with the characteristics of the Chinese market, with high rating data update frequency, wide coverage and strong data continuity, this paper refers to the existing research and converts its nine grades into 1 to 9 points successively as explained variables in the study.

Explanatory variable: Climate risk (CR). Drawing on the practice of Du Jian, the ratio of the number of keywords of climate risk in the annual report and the total number of words in the annual report is multiplied by 100 to measure climate risk, so as to directly reflect the degree of concern and identification ability of enterprises on climate risk.

Moderating variable: Green innovation (GI). The number of corporate green patents is used as a proxy variable for the level of green innovation of manufacturing enterprises. The data of green patents were obtained through the China Research Data Service Platform (CNRDS), and the number of green invention and green utility model patents was first added up by referring to the practice of Wang Xin et al. (2021), and on this basis, the natural logarithm was taken to measure the level of green innovation.

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Control variables. This paper selects control variables by referring to existing literatures. At the macro level, the control variables are provincial economic development level (ProGDP), and at the micro manufacturing enterprise level, the control variables are enterprise Size (Size), enterprise Age (Age), ownership concentration (Sc), proportion of independent directors (Pid), Board size and Duality.

3.1.3. Model Design

In order to study the impact of climate risk on enterprise performance, this paper constructs a bi-directional fixed effect model with reference to Wen Lei (2024). The specific model is as follows:

$$\mathrm{ESG}_{it} = \alpha_0 + \alpha_1 CR_{it} + \alpha_2 Control_{it} + Year_i + Ind_t + \varepsilon_{it} \quad (1)$$

Among them, the explained variable, ESG_{it} , is enterprise ESG performance, the explanatory variable, CR_{it} , is climate risk, $Control_{it}$ representing other control variables that may affect enterprise ESG performance, $Year_i$ is time fixed effect, is individual fixed effect, representing random disturbance term.$CR_{it}\ Ind_t \varepsilon_{it}$

In order to test hypothesis 2, a moderating effect model is constructed, specifically as follows:

$$\mathrm{ESG}_{it} = \alpha_0 + \alpha_1 CR_{it} + \alpha_2 Control_{it} + Year_i + Ind_t + \varepsilon_{it}$$
$$\mathrm{ESG}_{it} = \beta_0 + \beta_1 CR_{it} + \beta_2 GInov_{it} + \beta_3 CR_{it} \times GInov_{it} + \beta_4 Control_{it} + Year_i + Ind_t + \varepsilon_{it} \quad (2)$$

$GInov_{it}$ is the regulatory variable, the proxy variable of the enterprise's green innovation level is used in the regression.

3.2. Empirical Analysis

3.2.1. Basic Regression Analysis

Table 1 reports the baseline regression results. In column (2), controlling for bidirectional fixed effects, the results show that the coefficient of climate risk is positive at the significant level of 1%, indicating that the increase of climate risk will make manufacturing enterprises pay more attention to their ESG performance and assume more corporate responsibility. This indicates that when facing the challenges brought by climate change, enterprises tend to strengthen the management and investment in environmental, social and governance aspects in order to adapt to the changing external environment, hypothesis 1 is verified.

Further, columns (3) to (5) report the impact of physical risks (including severe risks and chronic risks) and transformational risks on ESG performance of manufacturing firms, respectively. The results show that there is a significant positive correlation between transition risk and ESG performance of manufacturing firms, and its coefficient is very close to that of climate risk. This suggests that transition risk may be the main driving force of climate risk affecting ESG performance of manufacturing enterprises. Transition risks may include factors such as policy changes, technological advances, changes in market demand, etc. that drive firms to adopt more sustainable and responsible practices in their operations.

In contrast, the impact of physical risk on ESG performance of manufacturing firms is not significant. This may be because the impact of physical risks is more immediate and short-term, while firms may be more inclined to focus on long-term and systemic transformation risks. While physical risks such as extreme weather events, sea level rise, etc., have a direct impact on business operations, companies may be more focused on addressing these challenges through

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technological innovation and business model adjustments, rather than simply improving ESG performance.

Table 1. Basic regression results

	(1)	(2)	(3)	(4)	(5)
	ESG	ESG	ESG	ESG	ESG
CR	0.358***	0.291***			
	(0.050)	(0.050)			
Serious risk			0.433		
			(0.666)		
Chronic risk				1.389*	
				(0.733)	
Transition risk					0.277***
					(0.046)
ProGDP		0.304	0.277	0.265	0.309
		(0.403)	(0.407)	(0.407)	(0.403)
Size		0.892***	0.931***	0.926***	0.891***
		(0.110)	(0.110)	(0.110)	(0.110)
Board		0.596	0.589	0.585	0.593
		(0.443)	(0.444)	(0.445)	(0.443)
Pid		0.060***	0.060***	0.060***	0.060***
		(0.013)	(0.013)	(0.013)	(0.013)
Duality		-0.096	-0.091	-0.090	-0.098
		(0.127)	(0.127)	(0.127)	(0.127)
Sc		0.032***	0.033***	0.033***	0.031***
		(0.005)	(0.005)	(0.005)	(0.005)
Age		-3.398***	-3.507***	-3.501***	-3.431***
		(0.789)	(0.790)	(0.791)	(0.790)
_cons	72.580***	53.471***	53.361***	53.597***	53.574***
	(0.145)	(5.023)	(5.069)	(5.069)	(5.032)
N	22245	22243	22243	22243	22243
R2	0.013	0.031	0.028	0.028	0.031
Time effect	YES	YES	YES	YES	YES
Individual effect	YES	YES	YES	YES	YES

3.2.2. Robustness Test

In order to further verify the stability and reliability of the above analysis results, this paper adopts a variety of methods to test the benchmark model. First, the model is reestimated to test the robustness of the results by replacing the explained variables and the measures of the explanatory variables.

In column (2), the explanatory variables are replaced with management's discussion of climate risk (MCR). This indicator is obtained by calculating the ratio of keywords mentioning climate risk to the total number of words in the management discussion and analysis, and multiplying by 100. This indicator mainly reflects the level of management's awareness and recognition of climate risk. The degree to which management is concerned about climate risks may influence the strategic decisions and actions of the company, and thus indirectly affect the ESG performance of the company. In column (3), the explained variable is replaced by the corporate ESG index as calculated by Bloomberg (BloombergESG). After replacing the explained variables and the proxy variables of the explanatory variables, the empirical results show that climate

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risk still positively and significantly affects the ESG performance of manufacturing firms. This indicates that climate risk has a positive impact on firm behavior and performance, both in terms of management's identification of climate risk and overall firm ESG performance. This result further supports the previous conclusion that climate risk is an important factor driving the ESG performance of manufacturing firms.

In order to solve the possible endogenous problem, instrumental variables are also introduced in this paper. Climate risk may have a lag effect on ESG performance of firms, that is, the current ESG performance of firms may be affected by past climate risks. Therefore, in column (4), this paper uses the lagged term of climate risk as an instrumental variable to conduct regression analysis on corporate ESG performance. The results show that the coefficient of climate risk is positive at the significance level of 1%, indicating that even after controlling for potential endogenous problems, climate risk still positively and significantly affects the ESG performance of manufacturing enterprises.

Table 2. Robustness test

	(1)	(2)	(3)	(4)
	ESG	ESG	BloombergESG	ESG
CR	0.291***		0.575***	
	(0.050)		(0.117)	
MCR		0.394***		
		(0.129)		
L.CR				0.269***
				(0.050)
N	22243	22003	6970	19828
R2	0.031	0.029	0.731	0.030
Time effect	YES	YES	YES	YES
Individual effect	YES	YES	YES	YES

4. Further Analysis

4.1. Heterogeneity Analysis

Considering the large differences between manufacturing enterprises in regional and other factors, this paper refers to Shen Xiaobo et al. (2021) and divides the sample into three regions according to the registration place of enterprises for regression. The results are shown in Table 3. Climate risk will significantly positively affect the ESG performance of manufacturing enterprises in central and eastern regions, while it has no significant impact on the performance of manufacturing enterprises in western regions. It may be because the central and eastern regions have a more positive attitude and policy support in coping with climate change and implementing green development, while enterprises in the western region may face more resource constraints and development bottlenecks, and their response to climate risks is not obvious due to the limitations of geographical location and economic foundation.

Heavy polluting manufacturing enterprises may face more direct climate risks than other types of enterprises because they may rely on fossil fuels, face more stringent environmental regulations, and are subject to higher expectations from the public and consumers for environmental responsibility. As a result, such firms may be more proactive in taking steps to reduce greenhouse gas emissions, improve energy efficiency and focus on environmental protection through technological transformation and upgrading, thereby enhancing their ESG performance. Therefore, in this paper, according to Guo Ye et al. (2019), heavy polluting manufacturing enterprises are screened out, and heavy polluting enterprises are targeted for

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regression. The results show that climate risk will significantly positively affect manufacturing enterprises regardless of whether they are heavy polluters. However, the impact of climate risk on heavy polluting enterprises is more profound, which is 40% higher than that of non-heavy polluting enterprises. Therefore, climate risk may be a catalyst for these enterprises to promote environmental protection and ESG performance.

Table 3. Results of heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)
	East	West	Mid	Pollute	N-Pollute
CR	0.321***	0.008	0.318***	0.350***	0.250***
	(0.061)	(0.133)	(0.114)	(0.076)	(0.068)
N	15619	3769	2855	9331	12912
R2	0.030	0.044	0.053	0.040	0.029
Time effect	YES	YES	YES	YES	YES
Individual effect	YES	YES	YES	YES	YES

4.2. Adjustment Effect Analysis

When further analyzing the impact of climate risk on ESG performance of manufacturing enterprises, corporate green innovation may play a moderating effect: green innovation can not only improve the technical level and competitiveness of enterprises, but also help enterprises better cope with the challenges brought by climate change. This paper further analyzes the role of green innovation in the relationship between climate risk and ESG performance by introducing the metric index of green innovation.

The regression results are shown in Table 4. Climate risk, green innovation level and their interaction terms all have significant positive effects on ESG performance of enterprises, indicating that the higher the level of green innovation of enterprises, the greater the impact of climate risk on ESG performance of manufacturing enterprises. Hypothesis 2 has been proved. This may be because in manufacturing enterprises with high green innovation level, the management and employees have a deeper understanding of climate change, and can more effectively transform climate risk into innovation impetus and promote the performance of enterprises in ESG.

Table 4. Results of moderating effects

	(1)	(2)
	ESG	ESG
CR	0.286***	0.275***
	(0.050)	(0.050)
GInov	0.251***	0.209***
	(0.068)	(0.068)
CR*GInov		0.073**
		(0.035)
N	22243	22243
R2	0.032	0.032
Time effect	YES	YES
Individual effect	YES	YES

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5. Conclusion and Recommendations

This paper explores in depth the impact of climate risk on the environmental, social and governance (ESG) performance of manufacturing firms through benchmarking regression and robustness testing. It is found that climate risk has a significant positive impact on ESG performance of manufacturing enterprises, indicating that enterprises are more inclined to strengthen management and investment in environmental, social and governance aspects when facing the challenges brought by climate change. Further analysis shows that transition risk is the main driving force for climate risk to affect ESG performance of manufacturing enterprises, while physical risk has no significant impact.

In order to verify the stability of the results, this paper replaced the explained variables and the measures of the explanatory variables, and introduced instrumental variables to deal with endogenous problems, and the results remained robust. In addition, the analysis of regional differences shows that climate risk has a significant impact on the ESG performance of manufacturing enterprises in the central and eastern regions, but has no significant impact on the western regions. Heavy polluting manufacturing enterprises may take more proactive measures to carry out technological transformation and upgrading in the face of climate risk, and the impact of climate risk on them is 40% higher than that of non-heavy polluting enterprises.

Further analysis also found that the higher a firm's green innovation level, the greater the impact of climate risk on its ESG performance. Green innovation can improve the technological level and competitiveness of enterprises, and help enterprises better cope with the challenges brought by climate change. Therefore, enterprises should attach importance to green innovation and use technological innovation to improve their environmental and social performance.

Based on the above conclusions, this paper puts forward the following suggestions:

Strengthen climate risk management. Manufacturing companies should take climate risk management as a key strategy to improve their ESG performance, and better adapt to changes in the external environment by enhancing their understanding of and response to climate change.

Promote green innovation. Manufacturing companies should invest more in green innovation and use technological innovation to improve their environmental and social performance. Green innovation can not only bring economic benefits, but also enhance a company's social image and environmental responsibility.

Regional differentiation policy. Policymakers should consider regional differences and formulate climate risk response strategies suitable for different regions, especially in the central and eastern regions, and increase policy support to promote the performance of manufacturing companies in ESG.

Emphasis should be placed on the transformation of heavy polluters. For heavy polluting manufacturing enterprises, policymakers and business managers should pay special attention to their transformation needs in the face of climate risks, and help these enterprises carry out technological transformation, transformation and upgrading by providing technical and financial support.

Cooperation across sectors. Manufacturing companies should strengthen cooperation with government departments, scientific research institutions and non-governmental organizations to jointly promote the development of green technology and innovation. By working together across sectors, companies can more effectively deal with the challenges posed by climate change.

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Continuous monitoring and evaluation. Manufacturing companies should establish ongoing monitoring and evaluation mechanisms to regularly assess the impact of climate risks on ESG performance and adjust their strategies and action plans based on the findings. This helps companies respond to the challenges posed by climate change in a timely manner and improve their ESG performance.

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