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Assessing the Impact of Climate Physical Risk on Capital Markets: Evidence from Chinese Energy Stocks

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Abstract: Intensified climate change has brought about increasing climate physical risks, which have a substantial impact on the energy market. In this paper, based on the panel data of listed companies in China's energy industry from 2016-2023, we refer to the construction of the Climate Physical Risk Composite Index (CPRI) to systematically analyze its impact on energy stock return. The empirical results show that climate physical risk significantly dampens energy market return, and this negative effect is more significant among new energy firms, non-state-owned firms, large firms, and firms in regions with lower levels of economic development. Further mechanism tests find that investors' concern about climate change significantly amplifies the market shock of physical risk, and its impact has a lagged effect. This paper enriches the research on climate risk, explores the mechanism of climate physical risk in the energy stock market, and provides policy recommendations to effectively deal with climate risk shocks.

Keywords: climate change, physical risk, energy markets, stock return

1. Introduction

In recent years, with the globally frequent occurrence of natural disasters and climate events, climate change has been increasing, posing a major threat to the global ecological environment, economic development and human life safety [1][2]. The latest China Blue Book on Climate Change (2024) released by the China Meteorological Administration (CMA) points out that China is a sensitive area and a significant impact area of global climate change, and the climate risk is on the rise. At the same time, climate change also brings great risks and uncertainties to the global energy system [3]. As the world's largest energy producer and consumer, energy is the lifeblood of China's national economy. In response to the challenge of climate risk, China has proposed a ‘dual-carbon’ target by 2020, significantly accelerating the energy transition process and leapfrogging to become a global leader in the development of new energy sources.

Climate risks mainly include physical risk and transition risk. The former arises from direct asset losses caused by extreme weather events (e.g. droughts, heavy rains, etc.), which is sudden and unpredictable, and is an important exogenous shock to the financial system; while the latter arises from the revaluation of assets and changes in market expectations in the process of low-carbon transition, such as policy adjustments and technological changes, which is predictable and has a strong buffer window. For firms, droughts increase the risk of companies and their financing costs [4]. At the industry level, extreme temperatures have a significant impact on return in more than 40

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percent of industries [5], further exacerbating financial market turbulence. It is evident that physical risk will not only manifest itself in the form of natural disaster losses but also have an impact on all dimensions of financial markets. However, most of the existing studies still focus on the losses caused by specific climatic disasters such as typhoons and floods, and the portrayal of climate physical risk is not comprehensive enough.

Therefore, this paper focuses on the mechanism of the impact of climate physical risk on energy market return, and its impact path is divided into two main aspects. On the one hand, extreme climate events can have a direct impact on the energy industry. Taking the flood caused by extraordinarily heavy rainfall in Henan Province in 2021 as an example, Zhengzhou Coal and Electricity's share price fell by 13.25% within seven days after the flood; on the other hand, climate anomalies will affect market investors' perception of climate risk, causing market panic and thus affecting market return [6].

Based on this, this paper systematically assesses the impact of physical risk on energy stock return based on the Climate Physical Risk Composite Index (CPRI), and further identifies the impact pathways and the heterogeneous response mechanisms of firms. This paper helps to enrich the theory of climate risk pricing, and provides empirical support and policy reference for constructing a climate-adaptive energy financial system.

2. Literature review and research hypothesis

2.1. Literature review

Currently, climate risk pricing has received extensive attention in stock, real estate, bond and other [7] markets. Hong et al [8] found that food stock prices do not adequately reflect drought risk and that the capital market is under-responsive to climate risk. Murfin and Spiegel used sea level rise as an entry point and found that its price effect on the impact of residential real estate is limited [9]. Painter argued that sea level rise risk is significantly and positively related to long-term municipal bond issuance costs, with insignificant short-term effects [10]. However, most of the current research on physical risk is limited to the impact of single phenomena such as sea level rise, abnormal temperatures, droughts, and floods [11] on financial markets. Meanwhile, there is extensive literature on climate risk related to stock markets, but few studies have considered the impact of climate risk on energy stocks.

In recent years, investor climate perception has emerged as a useful way to measure climate risk, with studies often reflecting investor attention through the frequency of searches for climate-related terms [12]. However, although climate concern can reflect market dynamics, it is affected by subjective differences and media tendencies; in contrast, standardized meteorological parameters such as temperature and precipitation are more objective in reflecting actual risks. Therefore, this paper takes the climate physical risk composite index as the core and combines text analysis to construct climate attention to carry out research.

Now, energy stock market research can be divided into two main categories. On the one hand, it is the research on the influence factors of the energy stock market, which mainly explores the factors from the macroeconomy and major emergencies. The trade conflict between China and the United States has damaged the stock return of China's energy industry, which is further transmitted and amplified through the industrial chain [13]. The outbreak of the new crown epidemic had a more significant negative impact on traditional energy stock prices than new energy, during which new energy stock return improved due to investor attention [14]. On the other hand, there are studies on the relationship between the energy stock market and other financial markets.Sun et al. based on the VAR model found that the new energy stock price is positively correlated with the traditional energy price, while there is no significant relationship with the carbon futures price [15].

In conclusion, most existing domestic studies focus on a single climate type, and there are still fewer studies exploring climate risk and its pricing based on comprehensive indicators of extreme weather. Meanwhile, although there are extensive explorations on the influencing factors of the energy stock market, there is a lack of direct tests on whether physical risk affects the return of energy stocks. So this study introduces the Composite Climate Physical Risk Index (CPRI) as a proxy variable to expand the study of its relationship with energy stock return in China.

2.2. Research hypothesis

It is found that climate risk will increase the systemic risk of energy companies [16] and have a significant impact on asset prices. Specifically, on the one hand, extreme weather may directly damage production equipment and infrastructure, leading to higher operating costs, lower production and transport disruptions, which in turn undermines firms' profitability and depresses stock prices [17]. On the other hand, climate risk affects energy markets through mismatches between supply and demand: due to the high concentration of energy production, a shortage of supply in the core production areas and relatively stable demand will push up energy prices and raise costs for downstream firms, which in turn will be transmitted to stock price volatility.

In addition, differences in storage capacity exacerbate the vulnerability of new energy companies. Compared with traditional energy sources that are highly storable, new energy sources are highly dependent on climatic conditions, unstable energy supply and difficult to store [4]. Despite the continuous progress of energy storage technology, it is still difficult to fully hedge the risk of revenue decline and cost increase caused by its volatility. Based on the above mechanisms, this paper proposes the following two research hypotheses.

H1: Climate risk is negatively correlated with energy market stock return, and the impact on new energy firms is greater than that on traditional energy firms

H2: The higher the climate risk, the more volatile the stock price is

In addition, several studies have found that the energy market is not efficient and needs to take into account the psychological, emotional and behavioral factors of investors. As investors become aware of the impact of climate risk, they may demand additional risk premiums or engage in divestment behavior, leading to increased market uncertainty and volatility and further pressure on share prices. Therefore, the following assumptions are made.

H3: Market attention amplifies the impact of climate risk on share prices

Meanwhile, the impact of extreme climate events on financial markets has an obvious time lag effect [18]. On the one hand, disaster losses need to go through the process of insurance claims, auditing and assessment, and the impact is gradually visible. On the other hand, under information asymmetry, enterprises may cover up disaster impacts in the short term through surplus management, but with the gradual exposure of real losses, negative information will be released centrally. In addition, there is a delay in investors' perception of climate risk. Based on this, this paper proposes the following hypothesis.

H4: The impact of climate risk has a lagged effect, and the stock price reaction is most significant some time after the occurrence of climate disaster events

3. Research methodology and data description

In order to test the above empirical hypotheses, this paper constructs the following benchmark regression model:

$$\mathrm{RET}_{it} = \alpha_0 + \beta_1 \mathrm{CPRI}_{it} + \beta_2 \mathrm{Controls}_{it} + \mu_t + \varepsilon_{it} \quad (1)$$

In equation (1), the explanatory variable RET_{it} is the stock return of firm i in period t, which is measured using the logarithmic rate of return. The explanatory variable refers to Guo et al [19] and uses $CPRI_{it}$ as the climate physical risk of firm i in period t. The control variable $Controls_{it}$ is the return-related firm-level variable. μ_t is the firm-individual effect and ε_{it} is the residual term.

In this paper, the constituent stocks in the CNI Oil & Gas and CSI Coal indices are selected as representatives of traditional energy companies, while the constituent stocks of CSI New Energy are used for new energy companies. Stock return are derived by calculating the logarithmic rate of return through the formula Rt=ln(Pt/Pt-1), and Pt is calculated by choosing the average annual price of stocks in period t.

A company's climate risk is closely related to its geographical location [20], in addition, studies have shown that a company's main operational and economic activities are usually concentrated near its headquarters [21]. Therefore, in this paper, the location of a company's headquarters is used as a proxy for the geographic location of its main business operations, and the province-level composite index developed by Guo et al [19] is used as a proxy variable for company-level climate risk. The number of extreme low temperature (LTD), extreme high temperature (HTD), extreme rainfall (ERD), and extreme drought (EED) days per year in each province are used as the four sub-indices, which are then aggregated into a composite index (CPRI) to reflect the overall level of physical risk in a given province.

To effectively identify the impact of physical risk on energy market return, this paper controls for several variables that may have an impact on energy stock return: return on total assets (ROA), equity multiplier (EM), turnover of total assets (Turnover), book-to-market ratio (B/M), size of the firm (size), risk coefficient (β), and climate change concerns (CCA).

The research object of this paper is A-share listed companies in China's energy industry, covering 84 traditional energy companies and 80 new energy companies. Based on the availability of relevant data, the analysis sample includes unbalanced panel data of the above 164 companies for the years 2016-2023, the specific sources are shown in Table 1. In order to exclude the influence of outliers, this paper applies Winsorize shrinkage at the 1%-99% level to the continuous variables.

Table 1: Variable description

Category	Variable Name	Variable Meaning	Data Source
Explained variable	Stock return	Annual logarithmic rate of return on equities	Wind
Explanatory variable	Climate physical risk	Composite climate physical risk index for the province in which the enterprise is located	Guo, 2024
	Extreme low temperature	Number of days per year with extreme low temperatures in a given province or city	Guo, 2024
	Extreme high temperature	Number of days per year with extreme heat in a given province or city	Guo, 2024
	Extreme rainfall	Number of days per year with extreme rainfall in a given province or city	Guo, 2024
	Extreme drought	Number of days per year with extreme drought in a given province or city	Guo, 2024
Controlled variable	Profitability	The firm's annual return on total assets	CSMAR, Wind
	Financial leverage	Equity multiplier for the enterprise for each year	CSMAR, Wind

Table 1: (continued)

Managerial ability	Total asset turnover of the enterprise per year	CSMAR, Wind
B/M	Ratio of market price to book value per share	CSMAR, Wind
Enterprise size	Quantitative of size through core indicators such as total assets and market capitalization	Wind
Market beta	Correlation coefficient between stock return and market return	Wind
Climate change attention(CCA)	Level of investor perceptions of and concerns about climate change risk	Baidu index

4. Empirical results and analyses

4.1. Analysis of benchmark results

Table 2 reports the regression results of model equation (1). The results show that the regression coefficient of CPRI is significantly negative at the 1% level, indicating that physical risk significantly reduces energy market stock return. The reason for this is that the occurrence of extreme weather events is associated with corresponding changes in market supply and investment decisions, which affects firms' sales and cash flows, and consequently, their stock prices.

Further exploring the impact of the four types of extreme weather events on the stock return of traditional and new energy sources, a comparison of the results in Columns (2) and (3) reveals that extreme low temperature events have a significant negative impact on energy stock return, while extreme precipitation events do not have a significant impact. Meanwhile, the coefficient of HTD is significantly positive at 5% level and the regression coefficient of EED is significantly negative at 10% level in the results of the model with new energy companies as the study sample.

The above findings indicate that climate risk reduces energy market stock return and has a more significant impact on new energy companies than traditional energy companies, Hypothesis 1 is proved. In this paper, we believe that the above empirical results may be caused by two reasons: First, the extreme low temperature significantly pushed up the heating demand, the traditional energy short-term demand rose, and corporate profitability is expected to improve, easing the downward pressure on stock prices, part of the funds from the new energy thus shifted to coal, natural gas, etc., aggravating the new energy sector capital outflow; Second, the extreme high temperatures of the surge in electricity demand, new energy as the main power supply priority to be consumed, drive the Enterprise revenue rose.

Table 2: Benchmark regression results

	(1) Full sample	(2) Traditional energy	(3) New energy
CPRI	-0.0080***	-	-
	(-3.7754)		
LTD	-	-0.0045***	-0.0116***
		(-5.1664)	(-5.1697)
HTD	-	0.0016	0.0063**
		(1.5992)	(2.1678)
ERD	-	-0.0003	0.0017

Table 2: (continued)

		(-0.4524)	(1.0127)
EED	-	0.0005	-0.0065*
		(0.4412)	(-1.9089)
ROA	-0.0019	0.0076***	-0.0062
	(-0.7090)	(3.9634)	(-1.6156)
EM	0.0080	0.0022	0.0200
	(0.7272)	(0.6273)	(0.5059)
Turnover	0.3006***	0.1200***	0.4699***
	(3.9369)	(2.7358)	(3.2836)
B/M	-0.6850***	-0.4666***	-0.6641***
	(-10.0654)	(-9.2629)	(-4.8914)
size	0.2366***	0.0635	0.5080***
	(2.6951)	(0.8952)	(3.4927)
Beta	0.1610***	-0.1653***	0.1904***
	(6.6361)	(-5.9017)	(8.6886)
CCA	0.0021***	0.0014***	0.0027***
	(12.0739)	(10.3271)	(8.1600)
_cons	-0.9894***	-0.4669***	-2.1176***
	(-5.7403)	(-3.3964)	(-6.0160)
F	37.905	34.932	22.342
r2_a	0.095	0.302	0.206
N	1276	672	604

Note: t-values in parentheses, calculated based on robust standard errors, *, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

4.2. Mechanism tests

The pricing of physical risks in the energy stock market also depends on the climate change concern of investors. To test this mechanism, this paper re-examines the relationship between physical risk and energy market return by using the sum of Baidu search indices for ‘climate change’ and ‘global warming’ in China year by year as a proxy for climate change awareness (CCA). The regression results in columns (1) and (2) of Table 3 show that investors' climate change attention magnifies the impact of climate risk on energy stock return, and Hypothesis 3 is confirmed.

Table 3: Partial results of physical risk on energy market return model tests

	(1) No CCA	(2) With CCA	(3) State-owned	(4) Non-State-owned	(5) Large	(6) Small & medium
CPRI	-0.0074***	-0.0080***	-0.0015	-0.0067***	-0.0093***	0.0014
	(-3.2881)	(-3.7754)	(-0.9135)	(-2.7076)	(-4.5471)	(0.2566)

Note: t-values in parentheses, calculated based on robust standard errors, *, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

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4.3. Heterogeneity analysis

4.3.1. Heterogeneity of property rights nature

Considering that firms with different ownership natures are not uniformly affected by physical risk, regression analyses are conducted again based on two types of firms, state-owned and non-state-owned, and the results are shown in columns (3) and (4) of Table 3. The coefficients of CPRI on RET are negative for both state-owned and non-state-owned enterprises, but only the results for non-state-owned enterprises are significant. First, SOEs have a stronger risk tolerance and can reduce climate risk sensitivity through policy instruments such as tax cuts. Second, SOEs are mainly concentrated in the traditional energy sector, where their assets are inherently more climate resilient and their risk exposure is lower than asset-light in the private sector.

4.3.2. Firm size heterogeneity

The study further examines differential physical risk impacts by firm size, categorizing enterprises into large versus small/medium cohorts. Regression results (Table 3, columns 5-6)reveal significantly negative coefficients of large firms' physical risk on return, contrasting with statistically insignificant outcomes for small and medium-sized firms. This difference stems from the following reasons:first, the geographic asset concentration of large enterprises amplifies the magnitude of losses,and secondly the disruption of their complex supply chains will trigger a chain reaction.

4.3.3. Regional heterogeneity

Each geographic region has different environmental carrying levels and climate adaptation capacity, and extreme climate events will have differentiated impacts. Therefore, according to the National Bureau of Statistics of the division of standards, four major regions of the East, Central, West and Northeast are carry out a sub-sample regression, comparative analysis of the role of physical risk on the impact of different regions of China. Table 4 illustrates that there is significant regional heterogeneity in the impact of physical risk on the stock market. The possible explanation is concentrated energy firms in Eastern and Western zones with heightened climate hazard frequency and intensity, contrasting with lower physical risk in Central and Northeastern regions.

Table 4: Regional heterogeneity analysis of physical risk on energy stock return

	(1) Eastern	(2) Central	(3) Western	(4) Northeast
CPRI	-0.0074^{**}	0.0000	-0.0128^{***}	0.0005
	(-2.5602)	(0.0097)	(-3.3388)	(0.0711)

Note: t-values in parentheses, calculated based on robust standard errors, *, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

4.3.4. Heterogeneity in the level of economic development

In addition, several studies point out that economically developed regions have a higher level of marketization, which can provide a strong guarantee for companies to cope with climate risks. This paper identifies economically developed or underdeveloped regions based on GDP at the provincial level. The results suggests that the negative impact of physical risk on market return is more pronounced among firms located in less economically developed regions of China.

Table 5: Heterogeneity of physical risk on energy stock return by level of economic development

	(1) Developed	(2) Developed	(3) Underdeveloped	(4) Underdeveloped
CPRI	-0.0072	-0.0076*	-0.0117***	-0.0096***
	(-1.5585)	(-1.8845)	(-5.1370)	(-4.8282)
ROA		-0.0038		0.0060*
		(-0.9540)		(1.8680)
EM		-0.0608		0.0288*
		(-1.2527)		(1.8734)
Turnover		0.2020		0.1671**
		(1.5381)		(1.9791)
B/M		-0.5977***		-0.7152***
		(-4.5010)		(-10.4484)
size		1.5703***		-0.0993
		(7.5801)		(-1.2120)
Beta		0.2207***		0.0561*
		(6.0295)		(1.7755)
CCA		0.0022***		0.0018***
		(7.5833)		(8.9577)

Note: t-values in parentheses, calculated based on robust standard errors, *, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

4.4. Robustness tests

To avoid potential endogeneity and reverse causality problems, the one-period lagged term L.CPRI, and the two-period lagged term L2.CPRI, are introduced as explanatory variables into model (1). The results, as shown in Table 6, show that the regression coefficients of L.CPRI and L2.CPRI on RET are both significantly negative at the 1% level, which leads to a consistent conclusion with the baseline model and confirms its reliability. Meanwhile, the regression coefficients of L.CPRI and L2.CPRI on RET are between -0.0127 and -0.0158, which are lower compared to the results of the benchmark model. This shows that the transmission of physical risk pricing by the energy stock market does not occur instantaneously, but there is a delay and it is most significant within two years after an extreme weather event, Hypothesis 4 is proved.

Table 6: Impact analysis of physical risk lags

	(1) Lag 1	(2) Lag 2
L.CPRI	-0.0158***	
	(-7.2670)	
L2.CPRI		-0.0127***
		(-5.8286)

Note: t-values in parentheses, calculated based on robust standard errors, *, **, and *** represent significant at the 10%, 5%, and 1% levels, respectively.

5. Conclusions and recommendations

Currently, climate change and the risks it poses have received widespread attention. However, it remains to be further verified whether climate risks have been adequately priced by financial markets. In this paper, empirical tests find that physical risks significantly dampen the stock return of energy firms, and the negative impact is more significant for new energy firms. The relationship remains robust after introducing one- and two-period lagged climate risk indicators, further confirming the time lag of climate shocks. Meanwhile, non-state-owned firms, large firms, and firms with lower levels of regional economic development face higher climate risk exposure. The results of the mechanism test show that investors' concern about climate change significantly amplifies climate risk shocks and is a key mediating variable in the impact path.

Based on the above research, this paper puts forward the following suggestions: first, develop a scientific climate risk rating system to strengthen market pricing mechanisms. Second, establish a differentiated prevention and control system, focusing on highly sensitive industries and enterprises. Finally, enhance the climate adaptation capacity of the energy industry and strengthen the risk management of the energy system.

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