Impact of Climate Risk on Stock Market

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Abstract. This study provides an in-depth look at the intricate interplay between climate risk and its repercussions on the stock market, analyzing in detail the differences across markets and time intervals. The study reveals a notable correlation between climate risk and the stock market and that there are some variations in this relationship. Specifically, the U.S. market is more sensitive to climate risk, while the European market is relatively less so. In addition, the COVID-19 has a short-term impact. This study summarizes and generalizes the literature of the last three years and employs a variety of descriptive methods in order to reveal the intrinsic link between the two. The findings provide a crucial reference for investors and policy makers to gain a more nuanced comprehension of the ramifications of climate risk on equity markets. Subsequent investigations could go deeper into the relationship between climate risk on other financial markets (e.g., bond markets) and the differences in response to climate risk across different climate sectors.

Keywords: Climate risk, stock market, market comparison, time interval comparison, COVID-19.

1. Introduction

The China Climate Change Report 2021 shows that the rate of increase in extreme temperatures in China has accelerated markedly compared with the global average, indicating that China is more sensitive to and has a bigger effect on climate change worldwide. To reach the targets of reaching carbon neutrality by 2060 and peak carbon emissions by 2030, China will take a series of low-carbon measures, which will put pressure on high-carbon industries and large energy consumers. At the same time, a significant amount of China's energy system is made up of coal, and adjusting the energy structure to reduce international pressure is an important issue faced. Compared with industrialized western countries, China's task of achieving carbon neutrality is more difficult, challenging and time-critical. Therefore, China's economy will face far-reaching and severe climate financial risks in the process of realizing the "dual-carbon" goal and low-carbon transition. In recent years, financial risks have attracted much attention. Predicting, controlling and disposing of financial risks have become the focus of academic research and industry interest. Investment portfolio is an effective strategy to deal with risks and plays an important role in safeguarding financial stability. However, traditional macroeconomic and financial risk analysis methods are difficult to cope with complex risks such as climate risk [1]. Therefore, it is crucial to incorporate climate financial risks into the financial risk management system. Adjusting the proportion of asset allocation in the portfolio and reducing the risk impact when climate disasters and policies are introduced are not only of practical value to investors, but also of great significance to enterprises and regulators in protecting the interests of all parties and maintaining economic and social stability.

Research pertaining to the influence of climate risk on the stock market has predominantly centered on the meticulous evaluation and prospective forecasting of its precise effects on market dynamics. To deal with this issue, an in-depth analysis of the intrinsic link between climate risk and financial markets is needed, and appropriate analytical models are put to use. Various statistical methodologies, including regression analysis, time series analysis, and event study methodology, are viable avenues for delving into the influence of climate risk factors on stock markets. Historical data can also be collected to compare the responses of different markets and time zones in the face of climate risk, revealing the market's sensitivity and adaptability to climate risk.

When understanding the implications of climate risk on the stock market, the first task is to clarify the research question. This impact is a multifactorial, multivariate and complex problem, so it is necessary to choose appropriate methods and models when constructing the research framework.

Methods such as regression analysis, time series analysis or event studies can be applied to investigate in depth the relationship between climate risk and indicators, or instance, stock prices, trading volume and volatility. In addition, a comparative analysis of climate risk in different markets and time zones, combined with actual cases, can help to draw more comprehensive and accurate research conclusions.

2. Climate risk

2.1. Concept

Climate risk pertains to the potential adversities stemming from the effects of climate change and extreme weather events that could pose a significant threat to human social, economic and environmental systems. Climate risks include, but are not limited to, temperature changes, changes in rainfall patterns, a series of extreme weather events such as heavy rainfall, droughts, heat waves, etc., and sea level rise.

In recent years, various types of potential risks due to weather changes have been assembled into the concept of climate risk. Bian Yuchen and Gu Haifeng point out that these risks include natural disasters, increased environmental pollution, and the onset of extreme laborious weather. These risks are very destructive and may have far-reaching impacts on social life and economic systems [2]. According to Cui, Cai and Yuan, the annual economic losses due to natural disasters have far exceeded $100 billion and the number of victims is in the hundreds of millions [3]. In the 2017 California fires, nearly 10,000 houses were destroyed and dozens of people's lives were lost; for example, the natural disasters triggered by Hurricane Katrina, which shocked the whole United States in 2005, brought about economic depletion of up to about 100 billion U.S. dollars, which is a huge amount of money, making it the second largest disaster in U.S. history can not be wiped out [4]. These horrific events not only present a formidable peril to the safety of individuals and the security of their assets, but also have a far-reaching impact on the country's economic construction and social stability.

2.2. Measurement

The measurement of climate risk is a multifaceted and pivotal undertaking, entailing the meticulous quantitative evaluation of the potential ramifications stemming from climate change. These impacts have direct or indirect effects on human societies and economic systems. For the proficient quantification of climate risks, a range of scientific methods and tools are required, including climate models, risk assessment frameworks and data analysis techniques.

2.2.1 Carbon Emission Intensity Indicator

Zhang explicitly mentioned that carbon emission intensity, as an important environmental indicator, measures the amount of carbon emissions generated by China's Gross Domestic Product (GDP) during the production process. This indicator reveals the intrinsic connection between economic development and carbon emissions, providing an important basis for understanding the impact of economic growth on the environment [5]. In the context of China's active promotion of green development, the study of carbon emission intensity is of great significance for crafting tailored policies aimed at reducing emissions. Miao points out that it is important to understand the carbon emission intensity of different industries in order to better identify high-carbon industries. High-carbon industries are usually those with higher energy consumption and more serious carbon emissions, such as electric power, iron and steel, cement and so on [6]. Analyzing these industries can identify the causes of higher carbon emission intensity and provide a basis for policy makers.

Carbon emission intensity is an indicator that measures the amount of carbon dioxide emissions produced by a unit of economic activity in a country or region after a specific amount of time. It reflects the relationship between economic activity and carbon emissions and is a key parameter for assessing climate risk and managing carbon footprints. Measuring carbon intensity helps to understand the carbon emission status of a country or region, and provides a foundation of science for the creation of emission reduction policies and the implementation of low-carbon transition.

Measurement of carbon emission intensity is usually based on national or regional energy consumption data, industrial production data, transportation data, etc. Through analysis and calculation, data can yield the emission intensity of various sectors and industries. These findings, along with the compiled time-series database, aid in monitoring trends and predicting future emissions.

When measuring carbon emission intensity, scientific methods and tools need to be adopted to uphold the precision and dependability of the data. At the same time, economic, social and environmental differences between different countries and regions need to be taken into account to ensure the fairness and comparability of the measurement results.

Measuring carbon emission intensity can provide an important reference for countries or regions to formulate emission reduction targets and policies. For example, if a country or region has a high carbon emission intensity, it needs to take more aggressive emission reduction measures for the purpose of lessening carbon emissions and alleviating the repercussions of climate change. Furthermore, carbon intensity measurements can provide a decision-making basis for businesses and investors, promoting the advancement towards an economy characterized by low carbon emissions and the growth of green investments. Carbon intensity indicator measurement is an important tool for assessing climate risk and managing carbon footprint. Measurement through scientific metha pivotal instrument inods and tools can offer a solid scientific foundation for the development of emission reduction policies and the implementation of low-carbon transition, while also fostering sustainable development and bolstering global endeavors in the battle against climate change.

2.2.2 Carbon Market Price Indicators

The carbon market price discussed by Zhang and Chen refers to the actual value of each unit of carbon emission right above the specially set carbon emission right trading platform [7]. It is not difficult to find that the fluctuation of carbon market price will directly affect the cost of enterprises in the process of dealing with carbon emissions, and then have a profound and important impact on their overall profitability. An in-depth study of carbon market price fluctuations can provide a more accurate understanding of the market's understanding of the potential risks confronted with climate change and the corresponding coping strategies.

The measurement of carbon market price is mainly based on the transaction data of the carbon market, including the transaction volume and price of carbon emission rights. By analyzing these data statistically, we can understand the price trend, volatility and trading volume of the carbon market. In addition, the carbon market price can be predicted and analyzed by combining domestic and international policies, economy, environment and other factors to provide decision-making reference for investors, enterprises and policy makers.

2.2.3 Climate Policy Index

Zhu 's research points out that the climate policy index is designed to measure the strength of governments' response to climate change. This index includes policy measures, target setting, international cooperation and other aspects [8]. The level of climate policy index exerts a direct influence on the consideration of climate risk in the investment decision of enterprises and investors.

The measurement of climate policy index is mainly based on public information such as policy documents, international agreements, and financial commitments released by governments. By combing and analyzing this information, it is possible to assess the strength of policies, implementation and actual effects of countries in addressing climate change. At the same time, the climate policy index can also be interpreted and analyzed in depth by combining the economic development, energy structure, environmental conditions and other factors of each country.

2.2.4 Extreme Climate Event Indicators

Extreme climate events, including high temperatures, heavy rains and droughts, directly affect the decisions of businesses and investors. Song and Zhang conduct an analysis focusing on the frequency and intensity of extreme weather events, utilizing these parameters as tools for evaluating the potential

effects of climate risks on financial markets [9]. The measurement of extreme weather event indicators is a key step in assessing climate risk and involves quantitative analysis and assessment of parameters such as frequency, intensity and duration of extreme weather and climate events. These events include heavy rains, floods, droughts, typhoons, hurricanes, extreme heat and extreme cold, etc., which have a major impact on and damage to human societies and economic systems.

To effectively measure indicators of extreme weather events, a large amount of meteorological, hydrological, environmental and socio-economic data needs to be collected and analyzed. These data can be obtained by meteorological observation stations, satellite remote sensing, numerical simulation, etc. At the same time, it is also necessary to use statistics, meteorology, hydrology and other multidisciplinary knowledge and methods to process and analyze these data, and extract key indicators related to extreme weather events

2.2.5 Green Finance Development Indicators

Green finance refers to financial support provided for environmental protection, energy conservation, low-carbon projects, and other initiatives to achieve sustainable development. Research by Zhu and Wang indicates that green finance development indicators can reflect the level of financial support a country provides amidst the shift towards a low-carbon economy [10]. The evolution of green finance plays a pivotal role in mitigating climate risks and bolstering the resilience of financial markets.

Green credit indicators measure the scale and proportion of green loans provided by financial institutions, as well as the environmental, low-carbon, and sustainable nature of the loans. By analyzing the scale, interest rates, and allocation of green credit, the level and effectiveness of financial institutions' support for promoting green economic development can be evaluated.

Green bond indicators assess the scale and activity of financial institutions in issuing green bonds, as well as the environmental, low-carbon, and sustainable nature of the bonds. Through analysis of the issuance scale, interest rates, and investment areas of green bonds, the ability and effectiveness of financial institutions in raising funds to support green projects can be understood.

3. Impact of climate risk on financial markets

3.1. Climate Risk and Stock Prices

The consequential influence of climate risk on the stock market demands attention. Over recent years, an escalating volume of research has unveiled a closely intertwined relationship between climate change and the performance of stock markets. Particularly against the backdrop of frequent extreme weather events, shadow of climate risk could loom over stock markets, while its influence becomes more pronounced. The impact of climate risk on stock prices primarily manifests in its effects on the performance of listed companies. Taking agriculture as an example by Ma Ge, climate change may lead to reduced crop yields or decreased quality, thereby affecting the profitability of related agricultural companies. Additionally, extreme weather events may also trigger natural disasters, resulting in direct economic losses for listed companies. These factors are reflected in stock prices, causing fluctuations [11].

Climate risk may also induce market panic and investor sentiment fluctuations, thereby impacting the stock market. During extreme hot or cold weather, people may reduce outdoor activities and consumption, leading to a decline in the performance of related industries such as tourism and retail. This psychological impact may prompt investors to sell related stocks, leading to a decline in stock prices. For a more comprehensive evaluation and effective mitigation of the ramifications of climate risk on the stock market, Xu Wei suggests the need to establish a comprehensive climate risk assessment model. This model should consider the prospective effects of climate change on different industries, regions, and listed companies, as well as market and investor reactions [12]. Based on this, investors can adopt a more rational approach to assessing climate risk, avoiding blind panic or risk neglect.

3.2. Climate Risk and Trading Volume

The influence of climate risk on trading volume within the stock market is substantial. According to research by Du Jian, extreme weather events may lead to a decrease in stock market trading volume because investors concentrate on how climate change is affecting the economy rather than on company fundamentals. After Hurricane Katrina struck the southern United States in 2005, stock market trading volume significantly decreased as investors were concerned about the hurricane's economic damage [13]. Furthermore, climate change may increase market volatility, further affecting trading volume. During extreme weather events, investors may sell stocks to cope with potential economic losses, leading to increased market volatility and decreased trading volume.

Climate risk not only affects stock prices but also impacts trading volume in financial markets. During extreme weather events, investors' risk preferences typically change, leading to fluctuations in trading volume. For example, after disasters such as heavy rainfall and floods, investors may worry about the future prospects of affected industries, leading to decreased trading volume in related stocks [14]. Moreover, to cope with potential losses, investors may adjust their investment portfolios, further affecting market trading volume.

Additionally, climate risk may also affect market liquidity. During extreme weather events, financial institutions may face operational interruptions, asset losses, etc., leading to decreased market liquidity. In such situations, investors may find it difficult to buy and sell stocks quickly, further exacerbating market instability.

In order to contend with the repercussions of climate risk on trading volume, financial institutions need to strengthen risk management and increase sensitivity to market changes. Additionally, it behooves policymakers to keenly observe the effects of climate risk on financial markets and devise judicious policies and measures to uphold market stability.

3.3. Climate Risk and Strategy Returns

The assessment of the impact of climate risk on strategy returns is a multifaceted matter necessitating the consideration of an amalgamation of factors. Anupam named that climate change may lead to natural disasters and extreme weather events, which will have an adverse effect on the production and operation of enterprises, thereby influencing the performance of the stock market. Climate change may also be an important driver of strategic transformation and innovation, bringing new opportunities and benefits to companies [15].

To investigate the relationship between climate risk and strategic returns in depth, a comprehensive analytical framework needs to be constructed in Xu residence [16]. This framework should include the following aspects: identifying and assessing the vulnerabilities and adaptations of different industries and firms with respect to climate risks; analyzing the ramifications of climate change on corporate strategies and business models and how to respond to these challenges through innovation and transformation; and needing to study how investors assess the impacts of climate risks on corporate value and stock prices and how to formulate effective investment strategies to cope with these risks.

In practice, a variety of data sources and analytical tools can be utilized for the evaluation of the correlation between climate risk and strategy returns. Corporate financial statements and stock price data can be collected to einvestigate the influence of climate risk on corporate profitability and stock prices, employing methodologies such as regression analysis and time series analysis. In addition, qualitative research approaches like case studies and in-depth interviews can be employed to glean insights into the accomplishments and hurdles faced by companies in dealing with climate risk.

3.4. Climate risk and stock markets

The intersection of climate risk with stock markets is a complex and multidimensional topic. As global climate change intensifies, an expanding array of scholarly work indicates that climate factors have become an important variable affecting stock market performance. Catastrophic occurrences

like hurricanes, floods, and droughts, may not only lead to direct economic losses, but also trigger chain reactions that affect supply chains, productivity, and financial market stability.

In the United States, for example, the National Oceanic and Atmospheric Administration claims that in 2022, the United States experienced 18 extreme weather events, which caused more than $100 billion in economic losses [17]. Among these events, Hurricanes Ian and Fiona wreaked havoc in Florida and Puerto Rico. These disasters not only led to damage to infrastructure and disruption of production, but also raised concerns about future economic stability.

In financial markets, climate risk is also seen as an important investment consideration. Many investors are beginning to look at the environmental, social and governance (ESG) performance of companies for the evaluation of their ability to cope with climate risk. Insurance companies need to undertake evaluations of how climate change affects their insurance business, while investors need to assess the robustness of their portfolios against the impacts of climate change.

For a more comprehensive grasp and evaluation of the implications of climate risk on equity markets, many financial institutions have begun to adopt climate risk assessment models. These models can help investors identify companies that could be impacted by climate change and assess their potential financial risks [18]. A company may be exposed to higher climate risk if most of its operations are concentrated in regions that are vulnerable to climate change.

3.5. Climate risk and bond markets

The impact of climate risk on bond markets constitutes a multifaceted and multidimensional issue. As an important part of the global financial system, the bond market's stability and liquidity are important for maintaining national economic security. However, with the increasing severity of global climate change, its repercussions for bond markets have come to the fore.

Climate risk may lead to increased volatility in the bond market. Zhang and Liu pointed out that due to the uncertainty of climate change, investors may be concerned about the risk of the bond market, which triggers market volatility. Extreme weather events could increase the risk of defaults on infrastructure projects, which in turn could affect the volatility of related bond prices. Climate risk may have an impact on credit ratings in the bond market [19]. For those companies or countries that perform poorly in environmental protection and sustainable development, the bonds they issue may be at risk of credit rating decline. On the contrary, for those enterprises or countries that actively combat climate change and promote green development, the bonds they issue may receive higher credit ratings. Climate risk may also affect investment strategies and asset allocation in the bond market. With the growing concern about climate change, more and more investors are paying attention to corporate environmental and social responsibility performance, which has prompted the bond market to continuously innovate and improve new products such as green bonds. These products provide investors with new investment opportunities and asset allocation options, while also providing companies with new financing channels and opportunities to reduce financing costs.

To effectively mitigate and navigate through the ramifications that climate risk poses upon the bond market, a series of measures need to be taken. First, strengthening information disclosure and data collection is key. By improving the degree to which enterprises and financial institutions divulge their adherence to and practices within the realms of environmental, social, and governance (ESG) criteria, the transparency and comparability of the market can be increased, providing investors with more comprehensive and accurate information. Second, improving relevant laws, regulations and regulatory policies is also necessary. Governments and regulators should strengthen monitoring and early warning of climate risks, formulate stricter environmental protection standards, and enhance supervision and penalties for financial institutions.

4. Discussion

4.1. Comparison between different markets

The extent to which climate risk affects stock markets exhibits a considerable degree of variability, differing markedly from one market to another. The U.S. market is more sensitive to climate risk, while the European market is relatively less sensitive. This difference may be related to factors such as regulatory policies, corporate governance structures, and investor behavior in different markets. A comparative analysis of different markets is needed to understand this difference more deeply. Differences in carbon intensity, climate resilience, and investor perceptions and attitudes towards climate risk can be compared across markets. In addition, econometric models can be used to analyze the performance and effectiveness of different markets in addressing climate risk. Comparisons can be made the correlation between carbon intensity and stock returns across various markets, and how this relationship varies across markets. These comparisons and analyses can lead to a deeper comprehension of the impact of climate risk on the stock market and offer investors more targeted advice to investors.

4.2. Comparison between different time intervals (COVID-19)

The influence exerted by climate risk upon both stock and bond markets also varies somewhat across time intervals. Taking the COVID-19 pandemic period as an example, it can be observed that the fluctuations in climate risk manifest divergently in their effects on these two distinct markets in the short run.

The onset of the COVID-19 pandemic resulted in a profound and substantial impact on the stock market which impact on the production and operations of many firms, resulting in a relatively low climate risk in the short term. This is because, during the outbreak, the focus of many firms shifted from environmental protection to survival and recovery. In addition, some firms received government subsidies and policy support during the epidemic, which reduced the impact of climate risk on their business and share price. However, over an extended duration, the ramifications of the epidemic on climate risk is complex. The epidemic has led some companies to focus more on green and sustainable development, thereby reducing climate risk; it may also have exacerbated carbon emissions and environmental pollution in some industries, thereby increasing climate risk.

In terms of bond markets, the impact of the COVID-19 epidemic on credit ratings and bond prices has also been reflected in different time frames. The credit ratings of many corporations and governments suffered during the epidemic. Some firms faced operational difficulties during the epidemic, which could have led to an increased risk of bond defaults, while some governments increased their fiscal spending and debt levels in response to the epidemic, thus making the bond market more credit risky. However, in the short term, some green bonds and sustainable development bonds were favoured by investors because of their better resilience in the context of the epidemic.

5. Conclusion

The examination of climate risk's influence on the stock market constitutes a complex research issue that primarily focuses on assessing and predicting the effects of climate risk on the stock market. Research needs to delve into the intrinsic connections between climate risk and financial markets and utilize appropriate analytical models. Statistical methods like time series analysis, or event study methods can be employed to the repercussions of climate-related risk variables, including severe meteorological occurrences and catastrophic natural events, on various facets of the stock market, encompassing fluctuations in stock prices, the volume of trades, and the degree of market instability. Additionally, collecting historical data to compare the reactions of different markets and time periods to climate risk can reveal the sensitivity and adaptability of markets to climate risk.

During the research process, it is important to clarify the research issues and select appropriate analytical models and methods. Research findings indicate a close association between climate risk

and financial markets, significantly impacting the stock market. Extreme weather events may lead to increased stock market volatility, decreased trading volume, or even systemic risk. Furthermore, climate risk may affect investor sentiment and decision-making, further impacting stock market performance. Therefore, investors and policymakers must be mindful of climate risk and take measures to mitigate its negative impact on the stock market.

Future research can explore multiple aspects, such as conducting additional in-depth analyses to explore how climate risk affects the stock market across diverse markets and temporal intervals, exploring more complex climate risk indicators such as climate change policies and regulations, considering the introduction of more advanced analytical methods such as machine learning and artificial intelligence technologies, and examining the ramifications of climate risk upon investor behavior and decision-making.

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