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Climate Risk and Its Hedging-Literature Review

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Abstract: Entering the 21st century, climate risks such as typhoons, droughts, floods and global warming are becoming more and more significant. This passage will first discuss the types and impacts of climate risks. Since physical and transition part coexist, the second part of this passage will discuss some of the transition effects, from energy, stock markets, to municipal bonds, by analyzing data and examples from other literature. Compared with the same type of research, we find that investors often underestimate for enterprises to the potential impact of climate change, they pay more attention to enterprise's climate risk management practices and the ESG factors related proportion in the investment decision-making. At the same time, this article links green bonds to climate risk, pointing out that investors tend to invest in projects with strong resilience to climate change, which provides a new perspective on the green bond market. In addition, hedging climate uncertainty is receiving increasing attention, with an introduction to the basic concepts of the two risks, hedging strategies and the integration of the management of climate risk into corporate strategies under different mechanisms.

Keywords: climate risk, physical and transition impacts, energy price, financial market, hedging

1. Introduction

With the progress of human society, a large number of greenhouse gas emissions and various climate risks led by global warming are causing harm to human beings, so it is urgent to find solutions to solve climate risks. This paper will first introduce the background of climate risks, namely physical risks and transition risks, including their impacts. After introducing physical effects, represented by energy and financial market transition effect will be the key to focus on. The innovation of this paper is to provide an in-depth analysis of the direct and indirect impacts of climate change on financial assets, and to highlight the attention of investors to corporate climate risk management and the significant role of ESG factors in investment decisions. This provides important theoretical value and practical significance for the future development direction of the financial sector. In response to

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climate risk, hedging strategies have become an important tool for companies and investors to cope with the uncertainty and potential impacts of climate change on their respective businesses and portfolios.

2. Physical Impacts

2.1. Ecosystems

The climate risks can be largely reflected in the destruction of ecosystems, this essay provides the groundwater as an example, which is known as one of the greatest providers of living services. According to the data from EC (2008), around three quarters of the population of the European Union use the ground water as their main supply of daily use. Hence the issue of ground water has been urgent than ever [1]. A very important factor is that the water level of ground water is in the condition of continuous lowering, which threatens the living and working condition of people. Another fact is the dispersal of nutrients and the contamination of water sources with pesticides and heavy metals, which can be extremely harmful to human beings. However, the attention paid to ground water is much more less than surface water, which is due to the invisibility of the pollution problems [1]. For example, the dead fish or the algal blooms are usually invisible and hard to be discovered [1]. Although groundwater and groundwater dependent ecosystems (GDEs) are protected by a number of Europe Union directives, national legislation and environmental action programmed to preserve biodiversity, many GDEs in Europe are still under threat and degrading [1].

2.2. Health of People

Climate risk could lead to a decrease in population and even affect the entire human race in a hostile environment. While this may seem like a distant future scenario, studies have shown that some of the extreme weather events that occur in long-lived places are changing the environment in ways that make people less likely to survive[2]. According to studies, extreme weather and sever environment, such as extreme heat and cold when people are unable to warm up at night or cool down in the daytime, poses a major threat to some vulnerable populations. In research held by a team from the Harvard School of Public Health, the researchers defined the poor and elderly as vulnerable population and took about 7.8 million deaths from 1989 to 2000 as sample [2]. In the research, the researchers used the genetic research technique that identifying time-invariant factors to modify the effect of weather and temperature. They had not only proved that the dying rate in the extreme weather is increasing, but also reached a further conclusion that the variety of individual characteristics may lead to different vulnerability to weather extremes, for example, the atrial fibrillation.

2.3. infrastructure

Climate risks also directly cause some economic property losses. Some of the most destructive extreme weather, such as hurricanes, tsunamis and heavy rains, can cause huge economic losses. With the deterioration of the environment and the loss of vegetation, such extreme phenomena will significantly increase financial risks. For the economic loss, this article takes infrastructure as an example. The infrastructure is equipped with the function of offering services to society, such as heating in the winter, lighting at night and sanitation that are vital for human society [3]. In every country, the budget for infrastructure is always huge. For example, in 2020/21 the British government planned to invest 300 billion pound in the construction of infrastructure, and it was about an astonishing 2.5 trillion dollars spent on infrastructure globally [3]. Currently, those risks of climate change have greatly impacted the performance of infrastructure and disrupted the people's daily life and economy. For example, Hurricane Sandy damaged New York's infrastructure networks in 2012;

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in 2013, storms swept through UK, leading to a great loss of power for over 150000 homes in a long period. This trend of those risks disrupting infrastructure will continuously exist and probably be worse. For instance, the higher average temperatures affect the normal operation of these facilities, and even reduce efficiency and even cause damage and destruction [3].

3. Transition Impacts

3.1. Energy Transition and relevant consequences

The energy industry is impacted by climate change in many different ways, with oil being the main area of concern. In terms of the environment, burning oil produces a considerable amount of greenhouse gas emissions, which fuels global warming and its side consequences, such as extreme weather patterns and rising sea levels. Air quality and ocean health are subsequently impacted by this. Due to disruptions caused by climate change, the oil markets are more volatile economically, which affects consumer prices and energy bills. The stability of the oil sector may be impacted by a shift to cleaner energy sources to address climate change, which may diminish demand for oil and perhaps result in stranded assets. Strategically, infrastructure disruption caused by climate change makes energy security susceptible, and competition over diminishing oil supplies may lead to geopolitical instability. Therefore, when oil prices are affected by climate risks, the following knock-on effects occur.

3.1.1. Energy-intensive businesses

As mentioned before, some industries (such as the fossil fuel or oil industry) may be negatively affected by progressive climate policies, ultimately resulting in depreciating assets and uncertain future earnings prospects. Therefore, energy-intensive companies may be impacted by changes in energy prices, which could impair their profitability. Shipping and aviation look to be the industries directly affected by the first round's effects the most, according to [4], because they are strongly reliant on oil. An increase in oil prices can significantly affect the profitability of these companies because fuel costs often make up the bulk of their operating expenses. The evidence for this is provided by examples from [5], which demonstrate the airlines' remarkable sensitivity to changes in the price of oil. Oil costs account for more than 30% of the total costs for many airlines, including labor and other expenses. For instance, the total expenditures of Korean Airlines and Air China were impacted by oil expenses by 32% and 36%, respectively, from 2012 to 2016.

3.1.2. markets and transformation of advantageous products.

Changes in oil prices because of climate risk have an impact on the market, which in turn affects consumer purchasing and further influences the development of beneficial products. Consumers are starting to cut back on their discretionary spending as a result of the fact that the cost of living and basic household expenses are rising more quickly than salaries. As a result, spending on footwear and sporting goods is declining [6]. This scenario also applies to fluctuations in oil costs, which means spending on various services and leisure would likely decrease. Changes in oil prices can have an impact on the Chinese vehicle market, according to [7]. The traditional vehicle industry may suffer from the increase in oil prices. However, unlike manufacturers of conventional fuel vehicles like Volkswagen, new energy vehicle manufacturers like Tesla have responded favorably to oil prices, which facilitates the transition from conventional fuel vehicles to electric vehicles [7]. For instance, from 647,809 vehicles in 2017 to 1,072,085 in 2020, China's sales of electronic vehicles climbed annually by 16.37% (ibid.). As a result of drivers delaying the purchase of new vehicles and increased

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oil prices, plug-in hybrid vehicle market penetration and market share increase, moving new energy vehicles toward beneficial products [7].

3.2. Financial Markets

The overarching impacts of climate risk on financial markets are multifaceted and profound. Climate change, with its associated environmental and societal ramifications, introduces a heightened level of uncertainty into financial decision-making processes. This heightened uncertainty reverberates throughout the global financial system, impacting asset pricing, risk assessment, and investment strategies[8]. The increasing frequency and severity of climate-related events, such as hurricanes, wildfires, and flooding, pose direct threats to the value of physical assets, leading to increased insurance liabilities and potentially substantial losses for investors. Additionally, regulatory changes and evolving disclosure requirements related to climate risk compel companies to adapt their business practices and financial reporting, thus affecting market dynamics. [9] contend that investors swiftly alter stock prices in response to market occurrences that provide fresh knowledge regarding transition climate hazards. As a result, the financial markets are witnessing a transformation in which climate risk is not merely an environmental concern but a critical determinant of financial performance and market stability. This paradigm shift necessitates a reevaluation of traditional financial models and risk assessment methodologies to incorporate the evolving landscape of climate-related challenges and opportunities.

3.2.1. corporate bonds and stock market

Climate change impacts financial assets through direct and indirect channels. Directly, it can harm or hasten the depreciation of physical capital assets like infrastructure, factories, and coastal properties [10]. These effects often result from extreme weather events such as hurricanes, floods, and wildfires, disrupting income-generating capacities and affecting bonds and stocks tied to these assets. This can be proved by companies are exposed to damage from climate-related events as mentioned earlier, which can lead to reduced profitability and solvency, thereby increasing the risk of debt default. In addition, climate-related disruptions can interrupt supply chains, further impacting affected entities and their financial assets, while the insurance sector can incur substantial losses. Indirectly, climate change reshapes economic activities by altering weather patterns and consumer preferences. For example, disruptions in agriculture can affect companies dependent on it, and the growing emphasis on sustainability can influence stock prices. Regulatory changes aimed at mitigating climate risks can impact industries' profitability and, consequently, their financial assets. This combined influence introduces new risks and uncertainties into financial markets, influencing asset prices, portfolio strategies, and investment decisions. Understanding this intricate relationship is of paramount importance for stakeholders navigating climate-related financial risks in an increasingly complex landscape. These multifaceted direct impacts on physical capital assets generate economic uncertainty and can influence investor confidence, ultimately bearing repercussions for asset prices and financial markets as a whole.

3.2.2. Credit Quality and Municipal Bond

The degree of susceptibility exhibited by municipal bonds to climate risk is contingent upon temporal maturity, credit rating, and the geographic predisposition to climatic vulnerabilities. The distinctive impact of climate change risk on long-term municipal bonds, which are significantly influenced by their level of exposure to climate risk is one fact. These bonds experience noticeably increased issuance costs as climate risk intensifies in their respective counties since they will experience longer exposure, which means they will be influenced more in a negative way. In contrast, short-term

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municipal bonds appear to be largely unaffected by climate risk because of their shorter climate risk horizon, demonstrating a stark contrast in how different types of municipal bonds respond to environmental uncertainties. According to [11], it's important to note the robustness of these conclusions, which confirm that the risk of climate change has a significant impact on long-term bonds because they hold true over a range of term structure parameters. Additionally, since municipal bonds with different time horizons will be affected in diverse ways, their credit quality will be transformed due to climate risk. Alterations in climate patterns exert a direct impact on the credit rating assessments conducted by pertinent institutions, subsequently influencing decisions regarding credit rating upgrades and downgrades for bonds (ibid.). Bonds characterized by lower credit ratings experience heightened issuance costs as a consequence of their susceptibility to climate risk. Conversely, bonds with higher credit ratings demonstrate greater resilience in the face of climate-related challenges. The extent to which climate risk is manifested also varies across distinct geographical regions. The municipal bond market may be at greater risk in areas that are more affected by climate, especially those that are coastal cities or vulnerable to floods and storms. For example, the inexorable rise in sea levels in these regions portends significant threats to both infrastructure and residential zones, thereby imperiling the inhabitants' quality of life. Consequently, this jeopardizes the credibility of governmental entities and concomitantly diminishes the valuation of municipal bonds.

3.2.3. Investors' Reaction

3.2.3.1. Investors' Reaction in Stock Markets

The inadequate pricing will occur when people consider the climate change risk but uncertainty of the climate risk still exists in the real world. Therefore, investors will underestimate the potential impact to the companies from the climate changes. Thus, the potential inadequate pricing will occur. Finding pricing models that more accurately reflect the risks of climate change is key, then. Second, investors are focusing on the trend of corporate climate risk management. At the same time, they also are focusing on methods that utilizing by companies to manage climate change risks. They will assess whether companies are already taking steps to mitigate potential climate-related damage, such as reducing carbon emissions, improving sustainability, and improving supply chain resilience.

On the other hand, investors Some investors may direct their money to businesses that actively address climate risks, including companies' aggressive actions in reducing their carbon footprint, green technology innovation, renewable energy investments, and more. This trend of where money is going is also seen as a way to encourage companies to adopt climate-friendly initiatives. All in all, investors are concerned about how companies respond to climate change risks and may do so by investing and requesting more information to ensure that their investments are sustainable and not adversely affected by future climate-related risks. This reinforces the point made above that ESG is becoming an important consideration in investment decisions.

The findings from investor speech data on the StockTwits social media from [12] platform explain the relationship between emotions and climate change to final investment decisions, where emotions can act as a mediating factor in how investors view climate change risks and thus their final decisions [13].

3.2.3.2. investor sentiment

Climate change may have an impact on investor sentiment, which in turn indirectly affects investors' final investment decisions. Frequent extreme weather events, natural disasters, or climate-related issues may elicit concerns and emotional responses from investors [14] . These events may cause investors to feel anxious, worried or angry, reflected in their social media statements. At the same

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time, information related to climate change, such as scientific studies, climate reports or changes in government policies, can also affect investor sentiment. For example, a report might highlight the negative effects of climate change, such a report will lead to a negative shift in investor sentiment. When investor sentiment changes, it will cause that investor sentiment affects their investment decisions. Optimism will make them more willing to invest in companies who devote themselves to make environmental protection and sustainable development [15]. The reason why they believe that these cooperates will have good performance in the future. Conversely, pessimism leads investors to avoid sectors associated with climate change risk, such as fossil fuels or high-carbon industries, since they are afraid that these firms may perform poorly as the time going. Second, climate risks affect investment decisions. The reason why some of the industries or companies will influenced by long-term climate change trends and extreme meteorological events directly. Investors might consider these factors to adjust their portfolios. Moreover, government climate policies, regulatory changes or the signing of international agreements (such as the Paris Agreement) may have an impact on the company's operating environment, which will affect investors' decisions. (IPCC Energy sector)

[16] states that for investors, according to a survey of investors' expectations about climate change is generally believed that by the end of the century the global temperature will rise significantly. These means are expected to have at least a significant number of respondents to the influence of climate change on the portfolio held deep concern. At the same time, the results of the survey also showed that investors motivation in incorporating climate risk into the investment decision making can be a financial incentive. Investors consider climate risk because they want to protect reputation, comply with legal or custodian obligations, and improve investment returns and reduce risk [17]. In terms of reputation, investors think the climate risk into the investment process can protect its reputation. Because focusing on climate risk indicates that investors are concerned about social responsibility and sustainable development and want to maintain their good reputation by managing climate risk. Second, in terms of compliance with the law, investors believe that incorporating climate risk into the investment process is part of their legal and custodian responsibilities, so investors believe that managing climate risk is an act that complies with laws, regulations and custodian requirements. Finally, in terms of improving investment returns and reducing risk, investors believe that incorporating climate risk into the investment process can improve investment returns and reduce the risk of the portfolio. Because investors think climate risk will be the value of the portfolio and return a negative impact, so they hope to manage these risks to improve investment returns and lower risks [18].

3.2.4. Green bonds and ESG

Today, climate change is a focus issue, and it is important to consider climate risk in the investment process, which has led more and more investors to think more broadly about ESG and start realigning their portfolio allocations. Investing in ESG [19,20]. Blackrock's Larry Fink, for example, wrote in his 2020 letter to ceos that "our investment belief is that a sustainability and climate integrated portfolio can provide investors with better risk-adjusted returns" and concluded that there will soon be a significant reallocation of capital. This also corroborates the findings of the systematic analysis presented with [21]. Furthermore, the growing emphasis on environmental, social, and governance (ESG) considerations in investment strategies has led to a significant shift in capital allocation, favoring companies with robust climate risk management practices.

With the wide attention of society, green bonds have emerged. The purpose of the green bond is supporting sustainable and environmentally friendly projects, so it relatively less exposure to climate risk. However, climate risk still affects these markets since investors may pay more attention to the long-term sustainability of these projects and their resilience to climate change. If climate risks

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increase, investors are more inclined to invest in projects that are more resilient to these risks, that is green bonds with long-term sustainability and resilience to climate change.

4. Hedging

4.1. The effect of climate risk and hedging concept

The Earth's climate is undergoing alterations, but there is significant uncertainty about how these changes will unfold and the economic impacts they will have. For an investor, this climate risk uncertainty should be understood as an increasingly important risk factor [22]. Climate change poses a formidable challenge to our planet, with increasingly evident and far-reaching consequences. As the global community grapples with the complexities of this issue, it becomes increasingly crucial for individuals, businesses, and governments to address the economic risks associated with climate change. Hedging climate risk has emerged as a key strategy for navigating this uncertain terrain. In this part, we will delve into the concept of climate risk hedging, discuss and explore the various tools and approaches that allow stakeholders to safeguard their interests and investments in the face of an ever-evolving climate landscape.

4.2. Theoretical Foundations of Climate Risk

In terms of theoretical distinctions, some see climate change as a systemic risk to the global economy, similar to a financial market crash. They argue that traditional risk management tools need to be adapted to account for climate-related risks, while some divide climate risks into two types- transition and physical climate risks. Climate risks can have different impacts on equity returns, depending on the type of physical or transitory risk to which they are exposed. [23] contend that the effects of physical risk like climate hazards and extreme weather events become evident through actual financial losses incurred by companies. Transition risk mainly affects enterprises in energy-intensive industries heavily dependent on fossil fuels [24]. However, people focus on is depending on their position and perspective, either type of climate risk is an uncertainty for an investor.

4.3. Real-World Applications of Climate Risk Hedging

As evidence of rising global temperatures and CO2 emissions accumulates, there is growing concern and awareness of the impact of climate risk. Increased CO2 emissions accelerate climate change and thus climate-related economic losses [25]. Two types of climate risks have been described above, the core elements are differential exposure of assets to these climate risk factors [26]. Rising temperatures could lead to more frequent and severe extreme weather events, such as hurricanes, floods and forest fires. These events could cause physical damage to property, infrastructure and supply chains. This physical risk can directly impact industries such as insurance, real estate and agriculture. The transition to a low-carbon economy involves technological advances, such as the widespread adoption of renewable energy. Such a transition can create opportunities for companies investing in green technologies, while posing risks to those investing heavily in fossil fuels. Regenerative agriculture is an approach to farming and land management that focuses on improving and restoring the health of ecosystems, soil, and biodiversity while also addressing climate change [27] .

4.4. Strategies and Approaches in Climate Risk Management

Meanwhile, there are also some strategies can be used for hedging the climate risk. This can include risk mitigation strategies like diversification of investments, adaptation measures like building resilient infrastructure, and sustainable practices like transitioning to renewable energy sources. Financial markets are a primary vehicle for mitigating and hedging climate risk [28]. Many literature

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discuss some strategies against the negative effect of climate risk to the company and investor. Engle suggest the dynamic hedging strategy can be a method that using the climate news and time series to form a long-term hedge. However, they still have challenge in observe a limited number of months of climate news realisation but have a large number of assets that they can use to form portfolios.

5. Conclusion

In conclusion, climate change has become a central source of risk in the global system, prompting increased attention in recent years due to its diverse nature encompassing both physical and transition impacts. Physical risks will bring about direct and huge damage, while transition risks will bring about more long-term financial and economic impacts. Sectors display varying sensitivities to climate risk, with industries like fossil fuels vulnerable to adverse climate policies, while renewable energy stands to benefit. In the corporate bond market, climate risk can significantly affect credit quality and debt-servicing capacity. This has led to the development of hedging methods as financial markets adapt. Financial markets experience multifaceted impacts, affecting asset pricing, risk assessment, and investment strategies. The study provides an in-depth look at the direct and indirect impacts of climate change on financial markets, with particular emphasis on the importance of climate risk management and ESG factors for investors, providing a more comprehensive perspective on financial decision-making. The innovation of this study is that it reveals the direct and indirect impact of climate risk on financial assets, and highlights the key role of ESG factors in future financial trends, which has far-reaching theoretical value and practical application significance. Integrated hedging strategies to reduce climate risk not only enhance our ability to cope with environmental uncertainty, but also enable us to thrive in a rapidly changing global environment.

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