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Climate change and asset pricing: a focused review of literature

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Climate change and asset pricing: a focused review of literature

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Abstract

Climate change has a significant impact on the global economy and financial markets, making climate risk and uncertainty central to asset pricing decisions. These risks include potential economic losses due to extreme weather events or gradual changes and can impact business redundancy, infrastructure stability, and approval channels. We review the main theoretical models that incorporate climate risk in asset pricing and the empirical methods to assess the existence of a climate risk premium.

Keywords: Climate Risk, Uncertainty, Environmental Sustainability, Asset Pricing.

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1. Introduction

Climate risk and uncertainty have become central themes in asset pricing, as climate change is having a significant impact on the global economy and financial markets. On the one hand, climate risk refers to the potential economic losses caused by the effects of climate change. These can include extreme weather events, such as floods or droughts, but also gradual changes, such as rising sea levels or ocean acidification. These risks can affect the profitability of companies, the stability of infrastructure, and supply chains. On the other hand, the uncertainty associated with climate change stems from the complexity of natural systems and the unpredictability of human societies' responses. Scientific research continues to improve our predictions, but unknown variables remain, such as the speed of climate change or its intensity in specific regions. Climate risk and uncertainty affect the valuation of financial assets. For example, investors can ask for an additional risk premium associated with assets located in areas vulnerable to climate change. In addition, the growing focus on environmental sustainability is leading to a reallocation of capital towards activities considered "greener" or sustainable, affecting market prices.

Companies and governments are adopting environmental sustainability strategies to mitigate climate risk and reduce uncertainty. These strategies include reducing greenhouse gas emissions, energy efficiency, and investing in renewable energy. Environmental sustainability policies can also help reduce long-term financial risks and foster the resilience of economies. Climate risk assessment models are becoming important tools for investors and portfolio managers. These models consider various factors, including greenhouse gas emissions, environmental policies, and possible climate change scenarios, to determine the level of risk associated with an asset or portfolio. Therefore, climate risk and uncertainty are becoming essential elements in asset pricing. Environmental sustainability and strategies to mitigate climate risks are key to ensuring the long-term stability of financial markets and global economies. Svartzman, España and Tankov (2021) offer a comprehensive overview of the challenges and opportunities related to climate change and financial risks. They propose a reflection on the need for an integrated approach to manage these risks at the level of companies, investors, and regulators, in order to promote financial stability and long-term sustainable development.

A report published in 2019 by the Carbon Disclosure Project (CDP) titled "*Out of the Starting Blocks: Tracking Progress on Corporate Climate Action*" provides information on companies' progress toward their environmental sustainability goals and actions to address climate change. Specifically, the report analyzes companies' progress toward their environmental sustainability goals, assessing the initiatives and actions taken to reduce greenhouse gas emissions and to adapt to climate change. The CDP promotes transparency in companies' disclosure of environmental information, encouraging them to disclose details of their carbon emissions, reduction strategies and climate risks, and compares the performance of different companies and industries to highlight best practices and areas where improvements are needed. The report includes assessments of companies' performance based on data collected through CDP questionnaires, providing an overview of how companies are positioning themselves against their climate goals. It offers recommendations on how companies can improve their actions to tackle climate change, including adopting more ambitious strategies and integrating sustainable practices into business models. Therefore, CDP's report provides a detailed assessment of companies' actions to tackle climate change and offers recommendations to improve their environmental performance. It is an important resource for understanding trends and challenges in the field of corporate sustainability and climate risk management.

The Final Report Recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) published in 2017 provides a set of recommendations regarding the disclosure of financial information related to climate risks and opportunities. TCFD was established by the Financial Stability Board (FSB) to develop voluntary guidelines to help companies consistently and transparently disclose financial risks related to climate change. The TCFD report provides a number of recommendations to improve the disclosure of climate-related financial information by companies. Its goal is to help companies manage climate risks and opportunities more effectively, while at the same time providing investors with better information to make informed financial decisions.

In the report "*A Call for Action: Climate Change as a Source of Financial Risk*" published in 2019 by the Network for Greening the Financial System (NGFS), climate change as a source of financial risk is discussed and calls for immediate and coordinated action to address these challenges. The report identifies climate change-related risks as a significant source of financial risk. These risks include both physical risks (such as extreme weather events) and transition risks (such as economic challenges related to the transition to a low-carbon economy). The report makes an urgent call for immediate action to address the financial risks associated with climate change, stressing the importance of internationally coordinated efforts to reduce risks and promote financial stability. Specific recommendations are provided for financial regulators and central banks, encouraging them to include climate change in their risk assessments and supervisory policies. It also promotes greater awareness and integration of environmental, social and governance (ESG) criteria into the investment choices and policies of financial institutions, emphasizing the importance of international collaboration to address financial risks related to climate change. Sharing best practices and knowledge across different jurisdictions is seen as key to developing effective solutions.

The paper proceeds as follows. We present in Section 2 the main theoretical models that include a climate risk component in the determination of stock prices and the most recent studies related to the existence of a climate risk premium and the relative hedging strategies. Last section concludes, suggesting a future research agenda.

2. Climate Risk, Uncertainty and Asset Prices

In this section, we review in subsection 2.1 the main theoretical models that incorporate climate risk in asset pricing. In subsection 2.2 we review the empirical methods to assess the existence of a climate risk premium in equity markets and the relative hedging strategies.

2.1. Theoretical models

One of the main sources of uncertainty for policymakers and investors is the assessment of the socio-economic and financial impacts of climate change. However, traditional climate economic and financial risk models are unable to consider the characteristics of climate risks and the opportunities arising from climate alignment, since the latter models are based on equilibrium conditions and linearity of impacts, as well as the presence of representative agents and the use of intertemporal optimization. While several are the macroeconomic models (e.g. Nordhaus (1977), Nordhaus (2008), Nordhaus and Boyer (2000)) that include climate risk as a determining variable for the growth path of the economy (capital, consumption), few are the papers that incorporate climate risk in asset pricing.

One of the first contributions is Heinkel et al. (2001) that explore the effect of exclusionary ethical investing on corporate behaviour. They show that the practice of excluding unethical investments results in a reduced number of investors holding shares in companies with environmental issues, as environmentally conscious investors avoid stocks from such companies. The limited risk-sharing among investors who are not environmentally conscious, contributes to a decrease in the stock prices of environmentally problematic firms, consequently elevating their capital costs.

Karydas and Xepapadeas (2019) develop a dynamic asset pricing framework that incorporates macroeconomic events and climate change as sources of rare disasters. They link carbon emissions and portfolio composition with the likelihood of climate-related events. The results show a positive risk premium for climate change. Transition risk reduces the participation of carbon intensive assets in the market portfolio.

Another approach is intended to separate expected and unexpected components of climate risk. Using an Epstein-Zin utility function, Daniel et al. (2016) develop, an EZ-Climate model, a simple discrete-time optimization model in which uncertainty about the effect of CO_2 emissions on global temperature and on eventual damages is gradually resolved over time. They decompose the optimal carbon price into two components: expected discounted damages and the risk premium. In their model, the optimal carbon price is expected to decrease as time goes by. This reduction mirrors the pace at which information becomes available, the level of risk aversion, and the potential for technological advancements and backup solutions.

Hambel et al. (2020) analyze asset prices and climate policy in a global economy with green and carbon-intensive sectors. They reveal that asset diversification initially helps mitigating the damage of climate change, but there are long-term trade-offs. The optimal carbon price, risk-free rate, and risk premium are determined, with temperature negatively impacting the risk-free rate and risk premia.

The most recent contributions consider a change in agents' expectations and regulatory intervention (see e.g. Pástor et al. (2021)) or take into account the uncertainty of climate-related extreme events and their intensity through various possible scenarios (see e.g. Giglio et al. (2021)). There is nearly an unanimous evidence: climate risks have a negative effect on key macroeconomic variables, with both direct impacts (capital destruction) and indirect effects through changes in agents' preferences and regulation. This has repercussions in the financial system.

Regarding the existence of a climate risk premium, a pioneering paper is that of Pástor et al. (2021). They derive a financial model which includes firms differing in terms of sustainability in their business activity: “green” firms generate a positive externality for society, while “brown” firms a negative one. Agents also differ in their preferences for sustainability. First, agents get benefits from holdings of green firms and disutility from holdings of brown firms. Second, the investors are concerned about aggregate social impact of firms. It's demonstrated that agent’s preferences for green holdings affect asset prices because they are willing to pay more for greener firms, thereby lowering the firms’ cost of capital. Therefore, the authors state that “ESG preferences” (“green” preferences) move asset prices. Implementing a CAPM model, they show how the CAPM alphas for greener firms’ stock is lower, when risk aversion is low and the average ESG preference is strong, and negative. On the contrary, brown stocks have positive alphas. Moreover, they find that green assets have positive ESG betas and brown assets have negative ones.

Giglio et al. (2021) estimate the term structure of discount rates for a significant risky asset class, real estate, extending to the very long horizons relevant for climate change mitigation investments. Based on Lucas tree model (Lucas (1978)), they define a set of stochastic equations for aggregate consumption and real estate rents where are included a jump process as proxy of climate disaster. This variable can take value different to zero with a certain probability. The probability that climate disaster may occur is endogenous. Giglio et al. (2021) hypothesize that the probability of climate disasters increases following the occurrence of a disaster, thereby enabling climate shocks to trigger a self-reinforcing cycle in which each shock amplifies the likelihood of the next. Considering a constant relative risk aversion utility function, they derive a modified C-CAPM equation that include the magnitude of climate disaster shocks and its probability. They find that real estate faces both consumption and climate risks, with the discount rate structure declining, reaching 2.6% for returns extending beyond 100 years.

Zerbib (2022) develops an asset pricing model e.g. S-CAPM (Sustainable Capital Asset Pricing Model) incorporating partial segmentation and heterogenous preferences. Investors have mean-variance preferences and they are risk-averse. The sustainable investors, different to regular investors, have specific tastes for the assets in which they invest, preferring green asset and excluding sin stocks. The author identifies two exclusion premiums (exclusion-asset premium and exclusion-market premium) and a taste premium that show the connection between ESG factors and financial performance. Zerbib (2022) assess the theoretical model in US stocks. He finds that the average annual exclusion effect amounts to 2.79% for the period 1999–2019. While the annual preference effect fluctuates between -1.12% and +0.14% across industries for 2007–2019, the taste effect differential between the top and bottom terciles of companies within each industry may surpass 2% per year.

Karydas and Xepapadeas (2022) demonstrate how climate change threatens financial stability by increasing the frequency and intensity of extreme events and political risks, putting pressure on asset valuations. They study a dynamic CAPM model and show that climate change makes extreme events more frequent and less predictable, increasing the climate risk premium. The results also support a falling real interest rate.

Barnett (2023) offers a perspective on how climate change and the uncertainty associated with it may affect asset pricing, highlighting the importance of understanding and managing climate risks in financial markets and the implications for investors and regulators. A stochastic and dynamic general equilibrium model is studied to analyze the impact of climate change and climate model uncertainty on economic and financial market outcomes. It turns out that climate change leads to an increase in the production of clean inputs and a reduction in emissions, with a negative price of climate risk amplified due to the aversion to uncertainty of the climate model.

Rubtsov and Shen (2024) in their study examine the impact of the investment horizon on the optimal equity-bond-liquid portfolio in a dynamic model with climate change uncertainty. The equity risk premium is a function of global temperature and an unobserved factor. The optimal investment strategy has been found to be sensitive to climate uncertainty, with potentially high welfare losses.

Last, Ciano et al. (2021) analyse the evident connections between cooperative game models and various aspects of climate change issues. By examining the political dynamics surrounding the Kyoto Protocol and the Paris Agreement, they identify certain patterns and established scientific correlations, particularly with certain generalized exchange economy models.

2.2. Asset pricing: empirical methods

A growing literature analyse the pricing of climate risk in equity markets. We review the recent papers that assess the existence of a green premium in stocks markets and the relative hedging strategies.

Chen and Silva Gao (2012) explore how corporate climate risk is priced in capital markets. It is noted that climate risk is positively associated with the cost of capital measures, in particular equity and debt. Equity and debt investors evaluate climate risk differently, according to their different payoff function. Fixed income investors appreciate the efficiency gains from current capital investments.

Andersson et al. (2016) discuss some strategies for addressing climate risks in financial portfolios. They focus on how investors can protect their portfolios from climate change-related risks, which include both physical risks (such as extreme weather events) and transition risks (such as stricter carbon regulations). Therefore, the authors propose methods to hedge climate risks in financial portfolios, such as the use of sustainable investment strategies, which include the integration of environmental, social, and governance (ESG) criteria. In addition, they examine thematic investment opportunities in sectors related to the transition to a low-carbon economy, such as renewable energy and clean technologies. They propose the use of low-carbon portfolios as a tool to manage climate risks while potentially improving investment performance.

In Bolton and Kacperczyk (2021), the presence of a carbon premium on stock returns is analysed in the American market. As a measure of carbon risk, greenhouse gas (GHG) emissions are used according to The Greenhouse Gas Protocol classification. They investigate the relationship between stock returns and GHG emissions. The Scope 1, Scope 2 and Scope 3 emissions are included in the model, along with a vector of control variables. The level of emission intensity and the growth rate of emissions are investigated. A positive and statistically significant effect is observed for both the level of emissions and its growth rate, while no effect on stock returns is found for the intensity level of emissions. An issue highlighted by Bolton and Kacperczyk (2021) concerns the fact that small companies, besides being less profitable, tend not to provide data related to GHG emissions.

Alessi et al. (2021) provide evidence on the existence of a negative and highly statistically significant "*Greenium*"- i.e. the premium for transition risk- based on European individual stock. Investors buy stocks of greener and more transparent firms accepting a ceteris paribus lower return, as a hedging strategy to reduce their exposure to climate risk. They construct a "Synthetic greenness and transparency index" as a weighted average of the inverse of the ranking of firm *i* in terms of emission intensity (GHG/revenue) and the ranking of firm *i* in terms of E scores (Bloomberg Environmental disclosure score). They define the greenness and transparency factor as the difference between the return of the green portfolio and that of the brown portfolio. They use a linear factor model following the approach of Carhart (1997), Fama and French (1993) and Sharpe (1964) and Linter (1965).

Krueger et al. (2020) examine the increasing role that climate risks play in institutional investors' investment decisions. They examine how institutional investors assess and manage climate change-related risks and what impacts these risks have on their capital allocation decisions. They discuss the different strategies used by institutional investors to address climate risks, including the integration of environmental, social and governance (ESG) criteria into their decision-making processes and how climate risks can affect the financial performance of institutional investors' portfolios and their approach to risk diversification.

Climate change poses a significant financial risk, prompting central banks and financial supervisors to recommend that investors and institutions assess their exposure to climate-related financial risks. However, traditional approaches to macroeconomic and financial risk analysis face the deep uncertainty, non-linearity and endogeneity of climate risks.

Battiston et al. (2021) in their study aim to fill this gap by incorporating climate change into macroeconomic and financial analysis using innovative perspectives. Research insights can inform central banks' and supervisors' decisions on integrating climate change considerations into their policies and risk assessment.

Apostolou and Papaioannou (2021) propose a framework for understanding climate-related adaptation, mitigation, and transition risks, urging institutional investors to gather accurate information about these risks and assess them regularly. This approach could help manage climate-related risks and facilitate the transition from brown to sustainable green finance, even though individual investors cannot have a significant impact on climate developments.

In et al. (2022) present a framework for assessing climate resilience in energy infrastructure projects by assessing debt and equity investments. They identify asset-specific climate-related risks and turn them into financial risks using cash flow simulation and scenario analysis. The framework is applied to a utility-scale power generation plant powered by natural gas, demonstrating its application in risk management.

Venturini (2022) explores the potential role of climate change as a market risk, analyzing the data needed to understand the factors that shape stock market dynamics. It compares top-down and bottom-up approaches, focusing on investor beliefs and the implications of asset prices.

Dutta et al. (2023) examines the impact of climate risk on the return and volatility of green energy assets. They use the climate policy uncertainty index to assess the effects. The results show that increased climate risk encourages investment in alternative energy, increasing returns and decreasing volatility. The study also reveals that green energy-related assets are more effective than gold at hedging oil market risks.

Cepni et al. (2023) explore the impact of climate uncertainty on the spillover effects of conventional and ESG financial markets in Europe. It is noted that the transmission of shocks between conventional assets and ESG decreases during periods of high climate uncertainty. ESG investing offers diversification benefits against climate shocks, while ESG bonds help manage exposures to transition risk associated with political uncertainty. The results provide insights into the management of climate risk exposures.

Iqbal et al. (2024) examine the impact of China's climate policy uncertainty on Chinese asset prices, including carbon emission allowances, ESG securities, clean energy stocks, and oil and gas securities. The results show that increased uncertainty significantly reduces carbon emission allowance prices in the long run, while there is no asymmetric cointegration between uncertainty and the oil and gas equity index. The findings provide valuable information for investors, traders and policymakers in China.

3. Conclusions

Climate change has a significant impact on the global economy and financial markets, leading to climate risk and uncertainty becoming central themes in asset pricing. Climate risks include potential economic losses caused by extreme weather events or gradual changes such as sea level rise. These risks can affect the profitability of companies, the stability of infrastructure, and supply chains. The uncertainty associated with climate change stems from the complexity of natural systems and the unpredictability of human societies' responses. Despite improvements in scientific research, unknown variables, such as the speed or intensity of climate change, remain hard to be estimated. In general, climate risk and uncertainty are essential elements in asset pricing and investment decisions. Environmental sustainability and strategies to mitigate climate risks are key to ensuring the long-term stability of financial markets and global economies. Predictive analytics is a key tool in climate finance since it provides investors with important information about climate-related risks and opportunities. Despite challenges related to data quality, model uncertainty, regulatory complexities, and the integration of climate-related factors, predictive analytics has transformative potential to improve the resilience and sustainability of investment portfolios. A promising line of research is related to the integration of machine learning models to assess climate risk exposure in investment portfolios, highlighting how the use of real-time data and deep learning techniques can help developing advanced predictive models to manage climate risk exposure and improve investment strategies.

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Conflict of interest

The authors declare that they have no conflict of interest.

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