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Climate risk and finance

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Abstract:

Climate risks, whether physical risks or transition risks, represent an increasingly important issue for companies, bankers and institutional investors. This article provides a review of the recent literature on the relationship between climate risks and finance. It examines institutional investors' perceptions of climate risks and reports findings on the impact of climate risks on the value of real estate, debt and equity.

JEL: G1, G2, G32, G41, Q54

Keywords: climate finance, climate risk, climate change, natural disasters, environmental policy, ESG, institutional investors.

Introduction

Climate risk represents an increasingly important issue for companies, bankers and institutional investors. Since preindustrial times, human activities have been estimated to have caused approximately 1.0°C of global warming. Global warming is likely to reach 1.5°C between 2030 and 2052 and 2 to 4°C by the end of the century if it continues to increase at the current rate (IPCC report, 2018), increasing the number of extreme hot days, heavy rainfalls, droughts and precipitation deficits as well as sea level rise.¹ While scientists have been drawing attention to climate change for many years, the financial community's commitment to climate change is more recent but is crucial for the future of our planet.

Climate change-related risks can be divided into two major categories: physical risks and transition risks. Physical risks may result from natural disasters linked to climate change (for example, hurricanes, storms, or floods) that can cause damage to assets and disrupt the supply chain. These risks, which are event driven, are called acute physical risks. Alternatively, physical risks may be chronic, referring to long-term shifts in climate patterns, such as increasing temperature or sea level rise. Transition risks are related to the process of transitioning to a lower-carbon economy and include legal risks (climate-related litigation claims), technology risks (new green technologies may disrupt part of a company's activity), market risks (consumers are turning to green products, shifting their buying habits), and reputation risks (the overall perception of the company may be affected by the transition process). Climate change may also trigger new opportunities for companies due to cost savings, access to new markets and the development of new products.

Finance academics have been very active in the topic of climate change since 2015: as Diaz-Rainey et al. (2017) point out, there were almost no publications on the topic in the major finance journals until 2015², although there have been some precursors³, as well as numerous papers on corporate social responsibility⁴ and in the field of economy, assessing the economic consequences of climate changes.⁵ A large number of studies in finance, mainly

¹ Swiss Re Institute reports that insured losses related to natural catastrophes amounted to \$219 billion in 2017 and 2018, the highest ever for a two-year period (Natural catastrophes and man-made disasters in 2018: "secondary" perils on the frontline, April 10, 2019).

² To address the lack of research in finance, in 2017, the Review of Financial Studies, one of the three major finance journals, launched a dedicated conference on climate and finance.

³ See, for example, Heinkel, Kraus and Zechner (2001). The authors build a model that indicates, with reasonable parameter estimates, that more than 20% of green investors are required to induce any polluting firm to clean up its activities.

⁴ For a recent review, see Christensen, Hail and Leuz (2018).

⁵ See Nordhaus and Moffat (2017) for a review. The macroeconomic literature provides a great deal of evidence of climate change affecting agricultural output, industrial output, energy demand, labor productivity,

empirical research, have been undertaken in recent years, and this article aims to provide a review of their results. Our first section provides an overview of recent steps in mobilizing institutional investors in the fight against climate change. In the second section, we discuss why climate risk is a challenge for finance and report a number of research findings on the impact of climate change on the value of real estate assets, debt and equity. Finally, the third section describes additional results, showing how much, in the climate field, the irrationality of investors can have an impact on asset values.

1. Institutional investors and climate change

1.1. Engagement and regulation

Even though various initiatives existed before, 2014 was a key year in the engagement of institutional investors in favor of combatting climate change, with two major pledges. First, the United Nations Principles for Responsible Investment's (UNPRI) Montreal Pledge focused on the measurement and disclosure of portfolios' carbon footprints.⁶ Second, the Portfolio Decarbonization Coalition (PDC), led by CDP (Carbon Disclosure Project) and the United Nations Environment Programme Finance Initiative (UNEP-FI), in 2014, emphasized the importance of decarbonizing portfolios.

The Paris Agreement, signed in December 2015, and its preparation were also critical steps in this process. The agreement aimed to make all financial flows consistent with a pathway towards low-emissions, climate-resilient development. It applied for the first time to developing countries with large emissions, such as India and China. The agreement sent a strong signal that all finance, both public and private, needs to be directed towards the climate challenge. It acknowledges that financing the decarbonization of the economy will require massive contributions from capital markets.⁷

Furthermore, also in 2015, the Financial Stability Board (FSB) established the Task Force on Climate-related Financial Disclosures (TCFD) to develop recommendations for more effective climate-related disclosures, leading in June 2017 to the release of its final recommendations. There is growing demand for decision-useful, climate-related financial

health, conflict, political stability and economic growth (Dell, Jones and Olken, 2014). See also Gollier, 2018, on ethical asset pricing, papers by Hourcade and co-authors at the Cired research center and the research carried out by the Climate Economics Chair at the Université Paris-Dauphine.

⁶ In June 2019, 2372 investors joined the United Nations' Principles for Responsible Investment (PRI) network, representing 86.3 trillion dollars in assets under management (compared to 203 signatories and 21 trillion in assets under management in 2010).

⁷ For a presentation of the investors' engagement process, see Andersson, Bolton and Samama, 2016a.

information by investors (for example Climate Action 100) and a growing interest in climate-related financial disclosures by financial regulators. In April 2019, the Network for Greening the Financial System (NGFS)—comprised of 36 central banks and supervisors and six observers, representing five continents—issued six recommendations aimed at facilitating the role of the financial sector in achieving the objectives of the Paris Agreement and encouraging financial actors to disclose in line with the TCFD recommendations.

Several laws requiring companies or investors to report climate risk data have also been voted on in Europe. In the U.K., the Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013, which was passed into law in July 2013, requires every UK quoted company to report comprehensive data on its greenhouse gas emissions in its annual reports. In France, article 173 of the 2015 Law on Energy Transition for Green Growth establishes new reporting requirements for financial and nonfinancial firms to improve the quality of information disclosure and foster the internalization of climate issues by firms and financial institutions.⁸

In 2018, the European Commission published its strategic long-term vision for a climate-neutral economy by 2050, and the publication of new guidelines on the disclosure of climate-related information by companies is part of this plan. This plan includes regulations on the establishment of a taxonomy to facilitate sustainable investment, on sustainability disclosures by institutional investors and asset managers, and on carbon-related benchmarks.

In summary, the last five years have seen major initiatives in the financial sector in favor of considering climate risk. Do these changes in the financial context also lead to changes in the perceptions and day-to-day practices of institutional investors?

1.2. Investors' climate risk perceptions

Krueger, Sautner and Starks (2019) conduct a survey of 439 institutional investors throughout the world regarding their climate-risk perceptions. The vast majority of respondents expect a rise in global temperatures by the end of the century, and 40% even predict an increase that exceeds the Paris 2° target. Twenty-one percent of the respondents started to incorporate climate risk into their investment process more than 10 years ago, whereas 65% of them started doing so in the last 5 years. Investors believe these risks have financial implications for their portfolio firms and that the risks have already begun to

⁸ There have been greenhouse gas emissions reporting obligations since 2010 for companies with more than 500 employees. See also for France: ACPR, 2019, « Les groupes bancaires français face au risque climatique », and « Les assureurs français face au risque de changement climatique ».

materialize, particularly regulatory risks. Thirty-eight percent of the respondents conduct analyses of portfolio firms' carbon footprints (35% for stranded asset risks). Twenty-six percent incorporate climate risks into their valuation models, and 25% use hedging against climate risks. Only 20% of the respondents divest problematic portfolio firms. Furthermore, investors with longer horizons and institutions with a higher fraction of holdings subject to ESG (environmental, social, and governance) analysis also engage in more climate-risk management. Finally, to engage with climate risks, the respondents discuss with management (43%), submit shareholder proposals on climate risk issues (30%) and vote against management on proposals because of climate-risk concerns (30%). The respondents believe that equity valuations do not fully reflect the risks from climate change, and the oil sector is considered the most overvalued sector overall, followed by traditional car manufacturers and electric utilities.

In a follow-up survey, Ilhan et al. (2019) highlight that the majority of respondents believe that climate risk reporting is as important as financial reporting, and 28% believe that climate risk reporting is even more important. Most investors (59%) plan to encourage portfolio firms to follow TCFD recommendations in reporting, and 60% of them plan to disclose the carbon footprints of their portfolios (which is mandatory in France since 2016). These answers are consistent with Krueger's (2015) findings that investors value increased climate-risk disclosure. Krueger uses a U.K. regulatory change from 2013 requiring every UK listed firm to report comprehensive data on its greenhouse gas emissions in their annual reports. He compares the firms that started disclosing after the law to similar firms that already reported voluntarily before the law was in place in the UK or to similar firms in other European countries. The author can therefore measure the effect of climate risk reporting on the value of firms. He finds a highly significant valuation increases after the regulation, regardless of the control group, suggesting that investors value transparency with respect to corporate climate risks.⁹

1.3. Shareholder activism and the voluntary disclosure of climate risks

Previous results highlight that investors value the increased disclosure of climate risks. Do investors engage in shareholder activism by submitting environment-related resolutions at general meetings to induce firms to voluntarily disclose their exposure to climate risks?

⁹ See also Matsumura et al. (2014), who find a positive valuation effect of voluntary greenhouse gas emissions disclosure.

Flammer (2019) examines this question for U.S. public companies over the period of 2008-2016. She uses data from the CDP on the disclosure of climate change-related risks and the Institutional Shareholder Services (ISS) database on shareholder activism for 10,084 firm-year observations. Even though 98% of the environment-related shareholder proposals were defeated, submitting them is a means of inducing management to address environmental issues. Flammer (2019) finds that environmental shareholder activism increases the voluntary disclosure of climate change risks and is particularly effective if it is initiated by long-term and green institutional shareholders. Companies that voluntarily disclose climate change risks following environmental shareholder activism achieve a higher valuation post disclosure. These findings highlight the ability of shareholders to elicit greater climate risk disclosure and confirm Krueger's (2015) results.

Do all types of investors behave homogeneously regarding environment-related resolutions? Briere, Pouget and Ureche-Rangau (2019) examine the voting behavior of investors on climate change resolutions. Using a sample of 213 U.S. fund families that voted on 13,108 different shareholder resolutions at 2,352 companies over the period of 2013 to 2016, the authors find that universal owners (well-diversified, long-term investors, such as BlackRock and Vanguard) tend to be less supportive of resolutions on climate change than other mutual fund families. The authors also find that the percentage of SRI funds in the fund family is positively related to support for climate change resolutions, which reflects the choice of the final clients of the funds. These results may reflect the preference of the largest investors for direct conversations with CEOs rather than engagement through votes on resolutions at general meetings. Furthermore, even in the absence of a positive vote, shareholders' proposals can have an effect on the disclosure of climate information, as Flammer's (2019) results, discussed above, highlight.

2. Climate risk, a challenge for finance

Climate risk may have an impact on the value of assets, the financing mix of firms, and the cost of debt and equity. One might think that climate risk is only one aspect of the overall risk of a company's business and that traditional risk management tools should already capture these risks. However, the complexity of climate change implications (biodiversity, migration, public health, water conflicts, etc.), investors' bounded rationality and the tragedy

of the horizon¹⁰ could explain why these risks are difficult to price and to hedge by market participants. One of the main questions in current research is whether climate risks are already taken into account by firms and priced by markets. Studies use different types of measures to assess the climatic risk to which a company or financial institution is exposed. A first set of measures involves physical data, such as temperature or sea level, or the occurrence of natural disasters, such as hurricanes or floods, in the vicinity of the entity's headquarters. In a second set of data, climate risk is assessed more precisely by specialized agencies such as Carbone 4 in France, and nonfinancial rating agencies are also refining their climate risk measures. Finally, measures of the potential for stranded assets due to climate-related developments are also used in some studies. As the number of articles increases continuously, it is difficult to be exhaustive. I present some results of articles that are examples of the type of research that is being conducted for real estate assets, debt and equity.

2.1. Real estate

Examining over 460 000 sales of residential properties between 2007 and 2016 in the US, Bernstein, Gustafson and Lewis (2019) find that coastal properties exposed to projected sea level rise (SLR) sell at an approximately 7% discount relative to similar properties (same zip code, distance-to-coast, property characteristics, and owner type). This SLR discount seems to be due to investors pricing long-horizon SLR costs, as it is primarily driven by properties unlikely to be inundated over the next 50 years. The discount is still 4% among properties not projected to be flooded for almost a century. Moreover, rental rates are not affected by SLR, reinforcing the idea that the discount is due to expectations of future damage, not current property quality. The evidence further suggests that this discount is driven by more sophisticated investors (non-occupiers). Within this market segment, the average SLR exposure discount is approximately 10% and has increased over time.

2.2. Climate risks, debt and the cost of debt

Most papers in this area of research find that entities incurring a high climate risk face a higher cost of debt. For example, examining municipal bonds in the U.S., Painter (2019) finds that counties more likely to be affected by climate change incur higher underwriting fees and initial yields. Delis, De Greif and Ongena (2019) use data on fossil fuel reserves from firms'

¹⁰ Carney (2015) states that “the catastrophic impacts of climate change will be felt beyond the traditional horizons of most actors – imposing a cost on future generations that the current generation has no direct incentive to fix.”

annual reports to examine whether banks price the risk of stranded assets. Fossil fuel reserves may lose their economic value in the near future due to incentives to move to clean technology. The authors find that before 2015, banks did not price climate risk. However, after 2015, an increase in the cost of credit by 16 basis points for a fossil fuel firm with mean proved reserves is highlighted. These results are robust to several additional tests, controlling for the crude oil price, the location of reserves and changing the mix of fixed effects used. Focusing on bond markets, Seltzer, Starks and Zhu (2019) find that polluting firms and firms with poor environmental performance tend to have lower credit ratings and higher yield spreads. The results are more pronounced for firms that are located in states with stricter environmental enforcement policies.

The previous papers mainly consider transition risks. Focusing on physical climate risks, Ginglinger and Moreau (2019) examine the impact of these risks on firms' leverage and the cost of debt. The authors measure the climate risks for each company of the MSCI World Index, relying on the CRIS (Climate Risk Impact Screening) methodology developed by a French company, Carbone 4. CRIS grades are quantified based on risk projections from the World Bank Climate Portal, the geographic division of activities, country-specific vulnerabilities and industry-specific vulnerabilities. The findings indicate that greater climate risk leads to lower firm leverage in the period after 2015.¹¹ They also highlight that after 2015, firms belonging to the high climate risk group faced an increase in bank-loan interest rates and an increase in bond yields at issue. The findings suggest that bankers charge four times more for climate risk than bondholders. The difference may result from an information advantage (banks may have branches close to headquarters and subsidiaries of firms) or from efficient banking supervision. The authors also document that the level of credit ratings does not yet reflect physical climate risks, which contributes to our understanding of the differences in the impact of climate risks on borrowing costs between bank loans and bonds. Recently, major credit rating agencies have acquired extrafinancial rating agencies, leading to the reinforcement of their expertise in climate risk rating and suggesting that the credit ratings they issue will soon better reflect climate risk. For example, in 2016, the S&P acquired Trucost, an agency specialized in corporate environmental performance ratings, and in 2019, Moody's acquired Vigeo-Eiris, a global leader in ESG ratings.

Overall, these results underline that we are only at the beginning of the process of integrating climate risk into the pricing of debt.

¹¹ These findings are in line with those of Sharfman and Fernando (2008), who find that enhanced environmental risk management leads to lower capital costs and allows for more leverage.

2.3. Climate risks and the stock market

Several papers try to assess the effect of climate risk on firm value. Other papers present methodologies to hedge climate risks.

Climate risk and equity value

Some articles show that climate risk is not taken into account by the markets, while others document real effects on stock prices. The differences in results are partly due to the use of different data sources and to the analysis of different time periods. These results are also due to the difficulties arising from being right too early regarding the markets.

Hong et al. (2019) use the Palmer Drought Severity Index to estimate countries' vulnerability to droughts as a result of climate change. The authors examine food industry stock returns across countries over the sample period of 1985 to 2014 and find that equity markets do not anticipate the effects of predictably worsening droughts on agricultural firms until after they materialize. Over the period of 2011-2016, Batten, Sowerbutts, and Tanaka (2016) find an insignificant market reaction to climate change news for oil and gas companies, which could mean that investors find it difficult to assess the impact of climate policies on the share price of these firms. Using Trucost data, Bolton and Kacperczyk (2019) even find an unexplained carbon premium.

Other papers document a real effect of climate factors on the value of stocks. Berkman, Jona and Soderstrom (2018) use a firm-specific climate risk measure based on textual analysis and find that firm value is negatively related to climate risk. Kruttli et al. (2018) examine weather uncertainty surrounding hurricanes and its impact on option and stock prices. The authors find that landfall uncertainty (where the hurricane will hit) and potential impact uncertainty (the level of economic consequences after landfall) are both priced before a hurricane makes landfall.

Most papers examining the effect of a rise in temperatures find that it is integrated into stock prices. Using a standard and commonly used set of 25 Fama and French book-to-market and size-sorted portfolios from the U.S. capital markets, Bansal, Kiku, and Ochoa (2016) find that long-run temperature shifts have a significant negative effect on equity valuations: on average, a one degree Celsius increase in the temperature trend leads to an approximately 8.6% decline in equity valuations. The temperature beta of equity returns is negative for

almost all equity portfolios, and the authors' results also hold in global markets (48 countries). The findings highlight that the premium for long-run temperature risks associated with global warming has been rising over time along with the rise in temperature. According to the authors, temperature provides information about the probability and extent of future natural disasters.

Hugon and Law (2018) find that firms' earnings, on average, are negatively impacted by an abnormally warm climate. In economic terms, a 1°C increase in temperature over the long-term average is associated with a 1.6% decrease in earnings in the following year, and much of the negative impact is concentrated in the warmest quintile. Furthermore, the summer effect seems larger than the winter effect. The authors find that an abnormally warmer climate induces decreased sales and increased expenses, and the latter is greater than the former. However, not all firms suffer from high temperatures. One-third of the companies are winners, i.e., they have positive sensitivity to a warmer climate. This is, for example, the case of 53% of healthcare firms. In related research, using quarterly firm-level temperature exposure over the period of 1990-2015, Adoum et al. (2019) find that extreme temperatures (5% warmest or coldest) significantly impact earnings in over 40% of industries.

These articles show that some aspects of climate risk are already taken into account in share prices, but in other situations, it is not the case. It remains to be shown that beyond temperature, climate risk in a more general sense is well integrated by investors. Recent regulations on climate risk disclosure by listed companies should help investors in their business valuation work.

Hedging climate risks

Due to the long-run and non-diversifiable nature of climate risk, standard futures or insurance contracts are hard to implement, leading investors to self-insure against climate risks. Andersson, Bolton and Samama (2016b) present a dynamic investment strategy that allows long-term passive investors to hedge carbon emissions. By holding a low-carbon index while minimizing tracking error with the benchmark index, investors hold a free option on carbon. As long as carbon emissions are not priced in the market, they obtain the same return as the benchmark index. Once carbon emissions are priced, the low carbon index should outperform the market.

Engle et al. (2019) propose a methodology for constructing climate risk hedge portfolios. The authors extract a climate news series from a textual analysis of news sources. They construct portfolios that overweight stocks performing well at the time of the arrival of

negative climate news so that an investor has a portfolio that benefits the next time such news about climate change is released. The ongoing updating of this portfolio based on new information about the relation between climate news and stock returns will eventually lead to a portfolio that is long on winners from climate change and short on losers. This approach proves to be more effective than the use of MSCI's or Sustainalytics' environmental scores.

The authors underline that future work could integrate better data to measure firm-level climate risk exposures and potentially differentiate between physical and transition climate risks.

3. How climate risk perceptions may change the financial impact of climate change

Individuals' beliefs about global warming and climate change may influence asset prices. Furthermore, their beliefs can be updated when they experience warmer than usual temperatures or a natural disaster in the surrounding area.¹² We will present examples of how the salience or the closeness of climate events (heat waves or natural disasters) can impact the value of assets. The effects seem to differ depending on whether the risks are acute or chronic.

3.1. Acute physical risks

Stock prices

Choi, Gao and Jiang (2019) find that attention to climate change, as proxied by Google search volume, increases in the presence of heat waves. Extreme local temperature can alert investors to climate change, especially as media attention appears high during heat waves. Over the period of 2001-2017, for 74 cities around the world with major stock exchanges, the authors find that carbon-intensive firms earn lower stock returns than other firms when the local exchange city is abnormally warmer in a given month. They find that retail investors sell high-emissions and buy low-emissions firms, whereas institutional investors do not respond systematically to local warming. While global warming is a long-term trend, retail investors react to salient short-term weather events, even if they are uninformative about the effective climate trend. However, investors' actions have a real impact on prices and trading activity.

¹² As Tversky and Kahneman (1974) underline, "the impact of seeing a house burning on the subjective probability of such accidents is probably greater than the impact of reading about a fire in the local paper", which, applied to climate events, would lead to an increase in the subjective probability of climate risks for individuals having themselves experienced a tangible consequence of climate change.

Fund managers and natural disasters

Alok, Kumar and Wermers (2019) find that, on average, there is a postdisaster decrease in the portfolio weights of disaster-zone stocks for all funds, but using a difference in difference strategy, they show that the decrease is significantly greater for close funds than for distant funds. This result could be due to an informational advantage of close fund managers, who themselves live in the disaster zone, or to a salience bias since proximity leads fund managers to overestimate the impact of the disaster. However, postdisaster change in the performance of firms in the disaster zone relative to those in the near-disaster zone is statistically indistinguishable from zero. Conducting several additional tests, the authors confirm the salience bias of funds managers. Fund managers are not the only ones who overestimate the effects of natural disasters. Dessaint and Matray (2017) find that after a hurricane, the managers of companies close to affected areas but not affected themselves also hoard excess cash.

These results suggest that investors overstate the consequences of acute physical risks, due to the salience effects of these events.

3.2. Chronic physical risks

Real estate

Baldauf, Garlappi and Yannelis (2018) confirm the 7% discount for real estate exposed to sea level rise risk found by Bernstein, Gustafson and Lewis (2019), which was presented above, but they highlight that these results hold only in “believer” counties (counties in which respondents have an above median belief in climate change happening). Their results suggest that heterogeneity in beliefs about climate change risks affects the value of real estate assets. The authors highlight that a category of investors underestimates the effects of the chronic risk that sea level rise materializes.

Stock prices

Hugon and Law (2018), discussed above, also find that, on average, the probability that managers issue an overly optimistic forecast increases by 5% for each 1°C increase in temperature and by more than 10% when firms are headquartered in states with high climate change skepticism. These results suggest that managers, on average, underestimate the chronic risk represented by the increase in temperature.

Overall, the results in these studies suggest that at least some investors, mainly retail investors but, in some cases, also fund managers, overestimate the effects of acute climate risks that occur in their surroundings and underestimate the effects of chronic risks.

Conclusion

Recent research findings show that institutional investors are increasingly aware of climate risks and are willing to commit to having the companies in their portfolios publish more information on their climate risk. In addition, although disclosure of the carbon footprint of their portfolios is not mandatory for most of them, 60% of institutional investors worldwide plan to do so. Until recently, both equity markets and bond markets only partially priced climate risk. The 2015 Paris Agreement seems to have been a major step in addressing climate risk. Several papers document a significant increase in the cost of debt and a decrease in the leverage of high climate risk firms after 2015. Results on equity markets are more heterogeneous, but the most recent papers show that equity valuations reflect temperature increases as well as the probability of natural disasters. However, the findings also suggest that investors overstate the consequences of acute physical risks, especially when they occur in their neighborhood, and underestimate the effects of chronic risks. All these results indicate a growing awareness of climate risks among investors. The efforts made in terms of risk assessment by nonfinancial rating agencies, banks, and investors should lead to an increasing integration of climate risk into asset prices.

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