How Does Climate Change Interact with the Financial System?

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We survey the literature on the interaction between climate change, which is associated with the growing intensity and frequency of natural disasters, and the financial system. This paper focuses on three topics. First, we review whether prices of assets, such as real estate, stocks, and green bonds, incorporate climate risks. While many studies show that asset prices reflect climate risks to some extent, many others show that real estate properties, in particular, do not adequately reflect climate risks. Such mispricing may deter efforts to address climate change. Furthermore, investor behavior and asset prices can overreact when risks become more clearly recognized. However, disclosure may help alleviate mispricing and overreaction. Second, we discuss how natural disasters affect bank behavior. Credit demand increases in affected areas. However, credit supply, particularly from non-local banks to young and small firms, is suppressed even in unaffected areas, especially when banks have low capital ratios. Third, we consider the role of insurance and related challenges. Insurance facilitates risk sharing and often complements bank finance. There are, however, at least three challenges: increasing insurance coverage, particularly among low-income households and young and small firms, maintaining insurer solvency, and avoiding moral hazard.

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I. Introduction

Recent years have seen a growing interest in global warming and the associated changes in the climate. Climate science suggests that rising temperatures are likely to be associated with changes in climate patterns, including an increasing intensity and frequency of extreme weather events such as floods and wildfires. With a potential impact of climate change on the financial system, financial institutions and authorities worldwide have taken an interest in climate change. However, research on the relationship between climate change and the financial system has only surged in recent years.[1]

This paper aims to provide an extensive survey of the literature on the interaction between climate change and the financial system. With this aim in mind, this survey paper focuses mainly on asset prices, bank behavior, and insurance. Further, our survey covers not only the literature on climate-related natural disasters (such as floods) and environmental performance (such as reductions in greenhouse gas emissions) but also natural disasters and environmental outcomes not directly linked to climate change (such as earthquakes and toxic emissions). This is because they share many similarities and the literature often arrives at similar conclusions. Our survey suggests that climate change and the financial system interact in a fundamental way: climate change threatens financial stability, and at the same time, the financial system has the potential to reduce the cost of climate change and even to slow its progression.[2]

The structure of this paper is as follows: Section II summarizes channels through which climate change and the financial system affect each other. There have been many discussions on how the real economy and the financial system are affected when climate risks materialize. At the same time, the causal links from the financial system to climate change through the real economy are also important. For instance, financial constraints can increase greenhouse gas emissions by preventing firms from taking action such as investment in green technologies.

Section III reviews whether asset prices factor in climate-related risks. This question is important because, for instance, the misevaluation of climate risks can lead to a misallocation of resources. While many studies show that prices of assets, such as stocks, corporate and municipal bonds, syndicated loans, and weather derivatives, factor in climate-related risks to some extent, many other studies show that asset prices do

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1. This development is illustrated by the publication of the special issue on "Climate Finance" of *the Review of Financial Studies* in 2020. Hong, Karolyi, and Scheinkman (2020), who provide an overview of the special issue, observe: "Even though we financial economists are late to the game, we hope that this climate finance issue illustrates that there are many important questions where financial economists are naturally suited given their toolkit and interests." How rapidly the literature has changed can also be seen from the study by Diaz-Rainey, Robertson, and Wilson (2017), who find that three highly regarded finance journals, including *the Review of Financial Studies*, had not published a single article related to climate finance between January 1998 and June 2015.
2. Since the release of the working paper version of this survey, several survey papers focusing on specific aspects of this literature have been published. For instance, Giglio, Kelly, and Stroebel (2021), Pástor, Stambaugh, and Taylor (2024), de Bandt et al. (2024), and Vyshnevskyi and Sohn (2025) focus on asset pricing of climate risks, the financial effects of sustainable investing, the effects of climate change-related risks on banks, and the role of central banks in supporting climate actions, respectively. This paper complements these surveys by providing an overview of the transmission channels of the interactions between climate change and the financial system and surveying the literature on various aspects of this interaction.

not adequately reflect climate risks. For instance, several studies show that properties exposed to sea level rise risk tend to sell at more discounted prices in areas with a lower percentage of residents who believe in global warming, all else being equal. A number of studies provide evidence that investors can overreact when risks become more clearly recognized due to, for instance, natural disasters occurring in nearby regions. These results suggest that asset prices could fall substantially as climate-related risks materialize. Several studies show that real estate properties tend to be overvalued in areas with insufficient disclosure. Meanwhile, the results for the premium on the yields of green bonds—i.e., bonds issued to support specific climate-related or environmental projects—are mixed.

Section IV discusses bank behavior when natural disasters occur. It has been observed that the banks' solvency deteriorates when the areas in which they operate are affected by a natural disaster. Several studies show that while the demand for credit increases in the affected areas, the supply of loans is suppressed due in part to a lack of bank capital. Some studies suggest that young and small firms are susceptible to borrowing constraints. A number of studies, however, find that local banks in affected areas are more likely than non-local banks to continue lending to households and firms. Many studies find that credit supply also tends to be restricted in unaffected areas. This effect is stronger when banks have a low capital ratio, the unaffected areas are unimportant to banks (for instance, because the areas account for a small share of the banks' business), and the unaffected areas are exposed to a high risk of disasters. Meanwhile, public support for banks has the side effect of distorting resource allocation.

Section V investigates the role of insurance and related challenges. Insurance is important in alleviating damage from disasters and often complements bank finance. There are, however, at least three challenges related to insurance: increasing insurance coverage to provide more protection and improve risk sharing, maintaining the solvency of insurance firms when climate-related risks materialize, and avoiding the problem of moral hazard. The problem of inadequate insurance coverage is particularly prevalent among low-income households and young and small businesses. Some studies suggest that this is partly due to a lack of awareness on the demand side and could be improved with better risk communication. Among other things, the difficulty of diversifying natural disaster risk hinders the supply of insurance. Some studies suggest that natural disasters have deteriorated insurance firms' health, leading to fire sales of assets, higher insurance fees, and reduced underwriting of insurance. Meanwhile, there are concerns that insurance creates moral hazard and slows down efforts to reduce the impact of climate change.

Finally, Section VI concludes this paper. While the studies surveyed in this paper are diverse and wide-ranging, we here focus on three major policy implications.

II. Channels through which Climate Change and the Financial System Affect Each Other

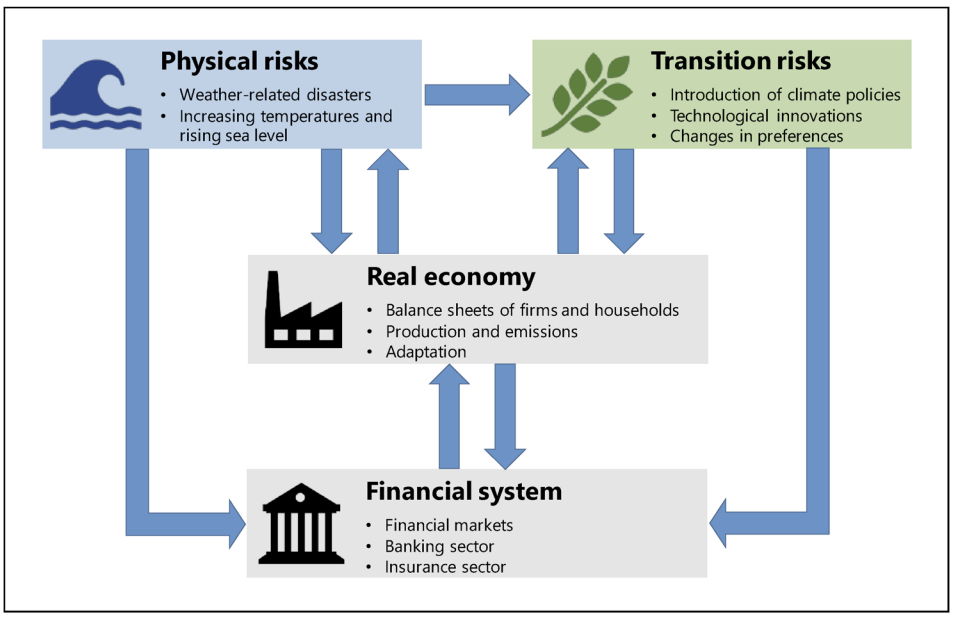
Considerable attention has been paid to the effects of climate change on financial stability, in particular channels through which climate change affects the financial system

(Batten et al. 2016, 2020), as central banks and supervisors have expressed their strong interest in this issue (see, e.g., Carney 2015; Lagarde 2020). At the same time, it is also important to deepen our understanding of how the financial system can affect climate change. Against this background, Figure 1 provides an overview of how climate change and the financial system affect each other.

Climate-related risks can be classified into physical and transition risks. When these risks materialize, the financial system is affected through, broadly speaking, two types of channels: direct channels and indirect channels via the real economy. Furthermore, once the financial system is affected, feedback loops between the real economy and the financial system may start to operate.

Physical risks arise from the physical impacts of climate change and can be further divided into acute physical risks, i.e., risks driven by extreme weather events such as floods and droughts, and chronic physical risks, i.e., risks driven by longer-term shifts in the environment, such as rising sea levels. When physical risks materialize, physical capital, such as factories and houses, is damaged. This leads to a deterioration in firms' and households' creditworthiness and the value of collateral, which in turn affects banks' balance sheets and limits the ability of firms and households to borrow. For these reasons, credit supply from banks is restricted exactly when firms' and households' demand for recovery and liquidity purposes increases. It is also possible that if the losses caused by the materialization of physical risks are covered by insurance, insurers may conduct a fire sale of assets to finance payouts. If payouts are sufficiently large, this can lead to a deterioration in the health of insurance firms. Moreover, if expected losses are revised upward, some physical risks may no longer be insurable, reducing the availability of insurance for firms and households. Financial institutions may also be directly affected by physical destruction in the form of damage to their of-

Figure 1 Interaction between Climate Change and the Financial System



fices, systems infrastructure, and human resources, which can reduce their operational capacity. When physical risks materialize, their impact on the economy is likely to be uncertain for a while, leading to a drop in the prices of risky assets as well as more cautious behavior on the part of firms, households, and financial institutions.

Meanwhile, *transition risks* arise from a transition to a lower-carbon economy. Specific factors that drive such risks include policy changes, technological breakthroughs, and shifts in preferences and social norms. For instance, if a carbon tax is introduced in an attempt to reduce greenhouse gas emissions, firms that emit large amounts of CO_2 could face difficulties in their business. In addition, the market value of fossil fuels such as oil and coal may drop substantially, leaving firms with "stranded assets" that are no longer able to earn an economic return, such as fossil fuels in the ground, production and processing facilities, and distribution infrastructure. As a result, the balance sheets of firms that own those assets may be greatly damaged.[3] On the other hand, energy prices overall may rise as cheap fossil fuels are no longer available, which may reduce firms' profitability. It is also possible that technological changes that spur the transition to a low-carbon economy affect the profitability of certain firms and industries. For instance, technological advances in electric vehicles may make conventional automobile manufacturers obsolete. Further, financial institutions with large exposure to such industries may incur losses as a result of technological changes, even though technological progress benefits the economy in the long run. Lastly, there have already been large shifts in preferences and social norms associated with climate change that are affecting financial markets. The growing awareness of environmental responsibilities can potentially influence asset prices and firm behavior. Note that transition risks may materialize even before an actual transition occurs through the expectations of financial markets or firms.

Physical risks and transition risks are likely to interact with each other. For instance, if physical risks become apparent to all through natural disasters, voters may become more aware of climate change and urge politicians to make policy changes. On the other hand, transition risks may also alter physical risks. For instance, if the introduction of a carbon tax is much slower than warranted, mitigation efforts of firms and households would be insufficient to reduce greenhouse gas emissions, leading to high physical risks.[4] Financial institutions' efforts would also be affected. For instance, banks may enable inefficiently large investment in carbon-intensive capital if they do not consider the cost of associated climate change.

There are also transmission channels in the opposite direction through which the financial system influences climate change risks and their impacts on the real economy through people's mitigation and adaptation efforts. Mitigation focuses on containing

3. The impact of a carbon tax on financial institutions depends on the policies of other countries. For instance, Laeven and Popov (2023) find that the introduction of a carbon tax is associated with a decline in bank lending to coal, oil, and gas companies in domestic markets, but an increase in foreign markets. This form of tax arbitrage is particularly pronounced for banks with large exposures to fossil fuel lending. They also find that banks reallocate a relatively larger share of their fossil loan portfolios to countries with less stringent environmental regulation and bank supervision.
4. There is evidence that lobbying has delayed the transition to a low-carbon economy. Meng and Rode (2019) examine the case of the Waxman-Markey bill, which failed to be enacted, using comprehensive U.S. lobbying records. They find that lobbying by firms expecting losses from the bill was more effective than lobbying by firms expecting gains.

climate change itself, for instance, through the reduction of greenhouse gas emissions, while adaptation reduces the impact of climate change, for instance, through the construction of better flood defenses.

The financial system may impede mitigation and adaptation actions for a variety of reasons. One possible source of this impediment is the mispricing of assets. For instance, if stock markets, in their valuation of firms, do not adequately distinguish between firms with high and low carbon emissions, this can deter efforts to reduce emissions. As discussed by Anderson et al. (2019), if property markets fail to incorporate climate-related risks such as floods and tropical cyclones, they may induce excessive investment in areas that are exposed to high risks, and, at the same time, discourage development of areas that are relatively shielded from these risks. Furthermore, public policy, such as the provision of public disaster insurance at subsidized rates, can induce moral hazard and distort resource allocation. The literature also suggests that there is generally not sufficient public information to accurately assess the value of assets or to optimize decisions with regard to, for instance, stock investment. Mandatory disclosure could be used to address insufficient information.

Another potential source of impediment is financial constraints. Although one might expect that tight financial conditions reduce production and therefore emissions, the literature suggests the opposite: they prevent firms from taking action. For example, using data on 10,776 firms across 22 emerging markets, De Haas et al. (2025) show that credit constraints reduce investment in green technologies, such as more energy-efficient machinery, and increase CO_2 emissions. They also estimate that bank deleveraging due to the global financial crisis increased carbon emissions by 5.6 percent a decade later. Bartram, Hou, and Kim (2022) find that after California introduced its cap-and-trade regulation, financially constrained firms shifted emissions and output to other states, particularly those nearby or with less stringent regulations, and increased their total emissions. This behavior was especially common among firms that had invested less in abatement technologies prior to the regulation. In contrast, this pattern is not observed among unconstrained firms.

The characteristics and behavior of investors can also drive the environmental performance of firms. This is illustrated, for example, by Dyck et al. (2019), who find that institutional ownership improves environmental and social performance when institutional investors come from countries with a strong community belief in the importance of environmental and social issues.[5] Meanwhile, Shive and Forster (2020) find that, within public firms, greenhouse gas emissions are negatively associated with mutual fund ownership and board size, suggesting that increased oversight may result in firms improving their environmental performance.

Recent studies also examine the roles of equity finance in environmental performance and provide mixed evidence. For instance, using data from 48 countries and 16 industries over the period 1990–2015, De Haas and Popov (2023) find that carbon-intensive industries reduce emissions more rapidly in countries with deeper stock mar-

5. Although many empirical studies, including Dyck et al. (2019), rely on ESG ratings, ratings from different providers are found to disagree substantially. The divergence in ratings poses a challenge for empirical research, as the choice of data source can alter a study's findings. See Chatterji et al. (2016), Liang and Renneboog (2017), and Berg, Kölbel, and Rigobon (2022) for further discussions.

kets, primarily because stock markets facilitate green innovation in these industries. In contrast, Shive and Forster (2020) find that private firms that are not sponsored by private equity funds are less likely to emit greenhouse gases and incur administrative penalties than comparable public firms, while there are no differences between private sponsor-backed firms and public firms. These findings suggest that short-termist pressure from outside investors for financial performance force public firms to emit more greenhouse gases than private firms.

III. Do Asset Prices Reflect Climate-Related Risks?

Whether prices of assets, such as real estate, stocks, bonds, and loans, reflect climate change risks has significant implications for the stability of the financial system. If they do not, or do so only partially, there is a risk that asset markets will experience significant disturbance when climate change risks materialize, or when people become more aware of the risks. This disturbance, in turn, will have implications for the real economy as households', firms', and financial institutions' balance sheets may be damaged as a result of the abrupt repricing of their assets. Moreover, if these assets are used as collateral, a decline in asset prices may severely impair agents' ability to borrow.

The misevaluation of climate change risks can also lead to misallocation of resources. For instance, if stock markets do not adequately price firms with low carbon emissions relative to those with high emissions, this can deter efforts to reduce emissions. Similarly, if real estate property prices do not reflect the risk of floods or sea level rise, this may encourage excessive development in risky areas, which poses an immense threat to housing, infrastructure, and people's lives.

Against this background, in the present section, we review the literature investigating whether—and to what extent—prices of a wide range of assets incorporate climate change risks. We start with the market for real estate, on which there is a rich literature on the association with climate change risks and which provides a good illustration of what factors encourage (or hinder) the incorporation of climate change risks into prices (Section III.A). We then review the literature on stocks (Section III.B), green bonds (Section III.C) and other types of financial assets such as corporate and municipal bonds, syndicated loans, and weather derivatives (Section III.D). Finally, we briefly summarize this section (Section III.E).

A. Real Estate Property

Many studies—most using data from the United States—find that property prices do not adequately reflect the physical risks of climate change, such as sea level rise and floods. For instance, Bernstein, Gustafson, and Lewis (2019) find that, on average, homes exposed to sea level rise sell at a discount relative to unexposed properties, but the price discount is concentrated in the non-owner-occupied segment of the market, in which buyers tend to be more sophisticated.[6] They also find that although the prices

6. The authors find that descriptive statistics are consistent with the idea that non-owner occupiers are more sophisticated, as they tend to originate from zip codes with higher education and income levels. Further, owner-occupier to non-owner occupier sales earn higher returns than non-owner occupier to owner-occupier sales.

of owner-occupied properties are not significantly related to sea level rise exposure on average, such exposure does affect prices when residents are sufficiently worried about sea level rise, which suggests that "unsophisticated" buyers are susceptible to local beliefs.[7]

Another study examining whether house prices reflect different beliefs about climate change is that by Baldauf, Garlappi, and Yannelis (2020), who use comprehensive transaction data to relate prices to flood projections of individual homes and measures of beliefs about global warming in each county in the United States. They find that houses projected to be underwater due to sea level rise in believer neighborhoods (i.e., counties with a relatively large share of people believing in global warming) sell at a discount compared to houses in denier neighborhoods. As a placebo test, they also examine commercial properties, for which differences in local beliefs are likely less important because the participants in those transactions tend to be more sophisticated than those in residential real estate transactions. Additionally, firm headquarters may be located somewhere else and decisions by corporations may therefore be made in a different geography from where the real estate is located, which is not the case in residential housing transactions. Consistent with this intuition, the authors find that differences in beliefs about climate change do not appear to affect the price of commercial real estate.

Meanwhile, using two decades of sales data covering the universe of homes in the United States, Hino and Burke (2021) find little evidence that the discounts on properties located in floodplains reflect the expected damage. Their findings indicate that floodplain homes are currently overvalued by US$44 billion in total. They also find that the home price discount is larger for commercial buyers, who are regarded as a group likely to have more experience purchasing real estate and greater resources to seek out flood-related information than individuals and households. Furthermore, a large discount tends to be observed in states where sellers must disclose information about flood risk to potential buyers. This result suggests that policies to enhance disclosure could improve the functioning of the market. That a lack of information disclosure leads to the overpricing of houses is also shown by Giglio et al. (2021). They perform a systematic textual analysis of for-sale listings to measure the frequency with which climate-related text (e.g., mentions of flood zones) appears in the written description of the listed properties. They show that when the fraction of property listings with climate-related text doubles, there is a 2–3 percent relative decrease in the prices of properties in a flood zone compared to comparable properties.

While the studies mentioned so far suggest that house prices partially reflect sea level rise risk, Murfin and Spiegel (2020) consistently find no evidence for effects of sea level rise exposure on real estate prices in a variety of specifications and test settings. They highlight the identification problem that arises from the presence of correlation between amenity and risk exposure. In particular, while the literature often uses

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7. Bernstein, Gustafson, and Lewis (2019), as well as many others, such as Baldauf, Garlappi, and Yannelis (2020) and Murfin and Spiegel (2020), use data from the Yale Climate Opinion Survey (Howe et al. 2015). This survey provides answers of respondents in the United States at the county level to questions such as (i) whether they think that global warming is happening, (ii) whether they will be personally harmed by global warming, and (iii) how worried they are about global warming.

data on housing elevation (i.e., the elevation above sea level) and assumes that this is negatively associated with sea level rise exposure, housing elevation is also correlated with housing amenity, such as scenic views. Thus, even if house prices are found to be higher for higher elevations, we cannot identify whether this is due to less sea level rise exposure or greater amenity. To address this identification challenge, Murfin and Spiegel (2020) exploit cross-sectional differences in trends in vertical land motion due to land subsidence and land rebound, which provide variation in the expected time to flood due to sea level rise for properties of similar elevation.[8]

The importance of heterogeneity in risk perceptions as a source of overpricing in housing markets is highlighted by Bakkensen and Barrage (2022). Constructing a theoretical model with heterogeneity, they argue that the impact of risks on property prices may be suppressed since optimistic people move to high-risk regions in place of non-optimistic people when the risks increase. Conducting their survey, they indeed find significant heterogeneity in flood risk perceptions and amenity values. Using this survey result, they calibrate their theoretical model and find that house prices exceed fundamentals by around 10 percent.

In sum, the literature finds that property prices do not adequately reflect climate change risks. In particular, properties tend to be overpriced when buyers are unsophisticated, they do not believe in global warming, or information disclosure is insufficient. These results suggest that property prices may drop significantly once people become aware of the risks. In fact, several studies find that when natural disasters happen, property prices decline even in areas that are not directly affected or damaged. For instance, Hallstrom and Smith (2005) find that although Hurricane Andrew did not hit Lee County, Florida, in 1992 and the storm was a "near-miss," home values in high-risk flood areas of the county declined by at least 19 percent relative to those in low-risk areas of the county. This suggests that the large hurricane conveyed risk information to homeowners in the county. Further evidence in this regard is provided by Ortega and Taşpınar (2018), who use Hurricane Sandy in 2012 as a natural experiment. They show that Sandy persistently reduced house prices in New York City's flood zone relative to similar properties in the rest of the city, even if the hurricane did not damage the properties: a price penalty among non-damaged properties in the flood zone has gradually emerged, reaching 8 percent in 2017 and showing no signs of disappearing. Examining several hypotheses to explain their findings, such as out-migration or damaged neighbors (residential properties, businesses, and infrastructure), they conclude that updated perceptions of flood risk likely drove the persistent price decline.

While this subsection focused on the market prices of real estate properties, financial institutions' valuations of property as collateral also matter. Overvaluation of collateral can lead to distortions in the allocation of resources, and a downward adjustment in the prices of collateral can threaten financial stability. For instance, Garbarino and Guin (2021) find that after a severe flood event in England in 2013–14, market prices of properties declined but lenders did not adjust interest rates or loan amounts

8. Relatedly, while being close to the waterfront increases the exposure to sea level rise and flood risks, it also improves amenity by providing scenic views and access to water activities. To disentangle the effects of flood hazard and ocean view on coastal house prices, Bin et al. (2008) construct a three-dimensional measure of ocean view.

because their valuations of properties (used for mortgage refinancing) did not mark-to-market against the market price declines in neighborhoods. Their result implies that the lenders may have effectively provided subsidies for borrowers to invest in high-risk areas. Nguyen et al. (2022) show that lenders charge higher interest rates on mortgages for properties exposed to greater sea level rise risk. However, this risk premium is smaller in areas with a higher share of climate change deniers, which is consistent with the housing price literature showing that beliefs influence market outcomes.

B. Stocks

While the literature on real estate focuses on physical risks such as floods and sea level rise, many studies on stocks focus on transition risks faced by firms. Typical examples of firms with high transition risks are those that emit large amounts of CO_2. If policy measures are taken to penalize CO_2 emissions, such firms could face difficulties in their business. If a firm is more exposed to climate change risks than others, investors should demand higher returns, or carbon premia, from its stock in compensation, all else being equal. Some studies show that firms more exposed to climate change risk indeed provide higher returns, which suggests that stock prices, to some extent, incorporate some types of climate change risk. However, other studies find opposite results. In what follows, we first survey studies on the relationship between risk exposures and stock prices and then discuss the potential problems arising from mispricing and the usefulness of disclosures.

Using firm-level carbon emissions estimated by a data vendor, Bolton and Kacperczyk (2021) find evidence of a positive carbon premium in the United States; that is, stock returns are higher for companies with higher carbon emissions. Further, in a separate study, Bolton and Kacperczyk (2023) estimate the carbon premium for over 14,400 firms in 77 countries and find a widespread carbon premium in all sectors.

However, Aswani, Raghunandan, and Rajgopal (2024) find that the positive associations between carbon emissions and stock returns reported in previous studies, including Bolton and Kacperczyk (2021), disappear when using firms' self-disclosed emissions rather than vendor-estimated emissions. Bauer et al. (2022) show that green stocks across G7 countries generally outperformed brown stocks over the almost entire period from 2010 to 2021. While they intensively check the robustness of results, they find positive carbon premia only when using vendor-estimated emissions. Zhang (2025) points out that emissions are closely tied to sales and are known to investors only with substantial delay. After accounting for the data release lag, she finds that carbon returns turn negative in the United States and insignificant globally. She concludes that the positive carbon premia documented in previous studies reflect forward-looking information about firm performance contained in emissions data, rather than a true risk premium in ex ante expected returns.

Pástor, Stambaugh, and Taylor (2022) attribute high returns of green assets to unexpectedly strong increases in climate-related concerns. Supporting this view, Ardia et al.'s (2023) index of climate change concerns, which is constructed from news published by major U.S. newspapers and newswires, exhibits an upward trend. Ardia et al. (2023) show that, on days with unexpected increases in climate concerns, the green stock prices tend to rise whereas brown stock prices fall. This pattern holds for both

transition and physical risks. These results suggest that high returns of green assets may be driven by shifts in investors' risk perception, rather than negative carbon premia, and highlight the challenges of estimating premia from ex-post returns when unexpected changes in risk factors play an important role.

Recent studies quantify firm-level climate-related exposures using textual analysis of quarterly earning call transcripts. Sautner et al. (2023) define exposures to opportunity, physical, and regulatory shocks associated with climate change as the percentage of conversation in a transcript devoted to each topic. Using data on over 10,000 firms from 34 countries between 2002 and 2020, they find that the exposures are reflected in stock and option prices. In options, the relationship is particularly strong in the tails and for opportunity exposures. Li et al. (2024) measure exposures to physical and transition risks and identify firms that proactively respond to climate risks. They show that firms facing high transition risk have been valued at a discount, particularly after 2010, only when they do not actively manage their transition risk.

A widely used approach in the literature to examine the causal impact of climate risks on asset pricing is the event study. Some studies, for instance, use announcements of the issuance of green bonds as the event. For example, Flammer (2020) documents that stock market investors respond positively to the announcement of the issuance of green bonds, and that the responses are stronger for first-time issuers and bonds certified by third parties. The stronger response for first-time issuers than seasoned issuers suggests that initial issues convey substantial new information about the firm's commitment to green projects, while subsequent issues provide relatively less information. She also finds that, after the announcement, issuers' environmental rating improves, their CO_2 emissions fall, and they experience an increase in ownership by long-term and green investors. Along similar lines, Tang and Zhang (2020) examine the announcement returns in 28 countries and document that stock prices positively respond to green bond issuance. They also show that institutional ownership increases and stock liquidity improves after a firm issues green bonds.

Another strand of the literature focuses on political events. Since the likelihood of introducing climate change policies depends heavily on the political environment, transition risks may evolve discontinuously in the wake of political events, as exemplified by the adoption of the Paris Agreement in 2015 and the election of U.S. President Trump in 2016.[9] If the Paris Agreement helped strengthen markets' expectations of transition to a lower-carbon economy, asset prices may have started to reflect transition risks to a greater extent. On the other hand, the election of President Trump, a climate skeptic, potentially lowered expectations of climate change policies. In fact, there are quite a number of studies focusing on the election of President Trump. Ramelli et al. (2021), for example, find that firms with high current carbon emissions enjoyed relatively high abnormal returns after Donald Trump was elected president in 2016. Hsu, Li, and Tsou (2023) suggest that 3-day window returns around this event for firms with higher toxic emission intensity are higher. Ilhan, Sautner, and Vilkov (2020) show that

9. The Paris Agreement set the goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change." The agreement requires all parties to report regularly on their emissions and on their implementation efforts.

the cost of option protection against downside tail risks of carbon-intensive firms decreased after the election of President Trump. They also find that the cost rises when public attention to climate change spikes, as measured by increases in Google search volume data for the topic "climate change" and Engle et al.'s (2020) negative climate change news index, which captures the share of news articles that are about "climate change" and have been assigned to a "negative sentiment" category.

Many papers, except for those estimating carbon premia from ex-post returns, suggest that stocks, to some extent, price in some climate change risks. However, the literature also finds evidence for mispricing. For instance, examining the stock prices of food companies, which rely on water and hence are sensitive to drought risk, in 31 countries, and data on droughts since 1900, Hong, Li, and Xu (2019) find that a stronger long-term trend toward droughts in a particular country predicts lower profit growth and stock returns of food companies in that country. This predictability of returns indicates that the stocks of food companies are mispriced.

One concern that arises from the mispricing of climate-related risks is potential sudden changes in risk perceptions, which could lead to a shift away from risky assets, a plunge in stock prices, and severe financial instability. In fact, the literature indicates that events that raise the awareness of risks, such as abnormal weather events, lead to a larger decline in stock prices of firms with greater climate-related risks. For instance, using temperature data from 74 cities around the world where stock exchanges are located, Choi, Gao, and Jiang (2020) find that the number of Google searches on global warming-related topics in those cities increases significantly when they experience abnormally warm temperatures, implying that beliefs about climate change of individual investors are revised upward. They also find that stocks of carbon-intensive firms underperform those of firms with low carbon emissions in abnormally warm weather. In addition, retail investors (not institutional investors) sell off carbon-intensive firms in such weather, which is consistent with the conjecture that retail investors tend to be influenced by notable events. Moreover, stock returns are affected by extreme temperatures regardless of whether the firms are domestic or international or whether firms belong to specific industries, such as utilities and leisure, whose earnings are likely to be directly affected by rising temperatures. These results suggest that changes in returns are due to changes in investor perceptions rather than changes in firms' fundamentals or future cash flows. The authors, therefore, argue that, as investors become more aware of climate risk, they seem to avoid holding stocks of high-emission firms similarly to "sin" stocks (stocks of alcohol, tobacco, and gaming companies).[10]

Another important issue is that investors may not only suddenly price in climate change risks when facing climate risk-related events but also overreact to them due to a salience bias, the tendency to overestimate the risk of events based on their vividness, proximity, or emotional impact. For instance, Alok, Kumar, and Wermers (2020) find that professional money managers within a major disaster region underweight disaster

10. Hong and Kacperczyk (2009) hypothesize that there is a societal norm against funding operations that promote vice and that some investors pay a financial cost in abstaining from these stocks. Consistent with this hypothesis, they find that sin stocks are less held by norm-constrained institutions such as pension plans as compared to mutual or hedge funds that are natural arbitrageurs, and sin stocks receive less coverage from analysts than stocks with otherwise comparable characteristics. The authors also show that sin stocks have higher expected returns than otherwise comparable stocks.

zone stocks much more than distant managers. They argue that this aversion to disaster zone stocks is related to a salience bias rather than superior information held by managers nearby, citing the following evidence. First, the post-disaster change in the return on assets or sales growth of firms in the disaster zone relative to firms close to the disaster zone is statistically indistinguishable from zero. Second, disaster zone stocks that are most underweighted by disaster zone funds subsequently outperform stocks that are overweighted by those funds, indicating a potential price pressure effect due to the misjudgment and overreaction of the funds. Huynh and Xia (2023) quantify firms' exposure to physical risk using establishment-level data on subsidiaries, branches, and plants, combined with disaster damage data in the United States. They find that, when firms are exposed to disasters, both corporate bond and stock prices tend to overreact, leading to higher ex-post returns. This effect is more pronounced for firms with weaker environmental profiles and higher levels of institutional ownership.

Finally, many studies examine the impact of climate-related disclosure in the stock market. Using a survey on institutional investors, Ilhan et al. (2023) find that many institutional investors consider climate risk reporting to be at least as important as financial reporting. Several studies on voluntary disclosures suggest that stocks tend to be undervalued in the absence of disclosure. Matsumura, Prakash, and Vera-Muñoz (2014), for example, find that firm value decreases as carbon emissions increase using carbon emissions data voluntarily disclosed by S&P 500 firms. They also find that the median value of firms that disclose their carbon emissions is higher than that of comparable non-disclosing firms. This result indicates that a penalty is imposed on firms that do not disclose. Further, Flammer, Toffel, and Viswanathan (2021) document that firms voluntarily disclosing climate risks in response to environmental shareholder activism experience valuation increases.

However, establishing causality between firms' disclosure activities and stock price reactions is inherently challenging. For instance, firms with favorable private information may be more inclined to disclose voluntarily, leading to potential self-selection bias. Although the studies mentioned above apply bias correction methods, they do not necessarily solve the issue. One solution to mitigate self-selection bias is examining the impact of mandatory disclosure requirements. Given the global trend toward enhancing mandatory climate disclosure based on advanced frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD), the literature increasingly exploits such opportunities.[11] However, Matsumura, Prakash, and Vera-Muñoz (2024) suggest that mandatory disclosure is not necessarily a panacea. In the United States, while firm managers are required to disclose material climate risks, their disclosure decisions are confounded by the lack of consensus on materiality and by uncertainty surrounding the enforcement of disclosure regulations. The authors find that the cost of equity is lower for disclosing firms than for non-disclosing firms, particularly in industries where climate risks are deemed material. This result suggests that markets use information of industry-level materiality to evaluate the credibility of managers' disclosure decisions.

11. See, for example, Ichiue (2025).

C. Green Bonds

Another type of asset on which much research has focused is green bonds and many studies estimate the premium—or "greenium"—on such bonds. Many of these studies focus on municipal green bonds in the United States. As highlighted by Larcker and Watts (2020), U.S. green municipal bonds are identical to ordinary municipal bonds in all ways except that the use of proceeds is allocated to environmentally friendly projects. They argue that any differences in security pricing are attributable to investor preferences for non-monetary security features, rather than differences in expectations about future cash flows or risk. Even if their argument is correct, it is still important for us to understand this growing market related to climate change risks.

The empirical results on the greenium are mixed. Using data on secondary market yields, Karpf and Mandel (2018), for example, find that green bonds display a positive premium. However, their result is questioned by Baker et al. (2022), who observe that Karpf and Mandel (2018) compare taxable and non-taxable securities, although pricing in the U.S. municipals market is highly sensitive to tax features. To address this problem, Baker et al. (2022) focus on after-tax yields. They find a minus 5–9 basis points premium. Meanwhile, focusing on the period from 2013 to 2017, Zerbib (2019) uses observations for green bonds traded in the secondary market and for which the counterfactual yields of ordinary bonds with the same characteristics, such as the issuer and the currency, can be estimated. He finds a statistically significant green bond premium of minus 2 basis points after controlling for the difference in liquidity between green and ordinary bonds using bid-ask spreads. Moreover, negative premiums are larger in absolute terms for financial and lower-rated bonds.[12] Pástor, Stambaugh, and Taylor (2022) examine German government's green bonds and find that these bonds trade at lower yields than virtually identical non-green bonds.

In contrast, other studies find little evidence of a greenium. For instance, comparing green securities to nearly identical securities issued for non-green purposes by the same issuers on the same day, Larcker and Watts (2020) find essentially no premium on municipal green bonds. Moreover, using the certification by the Climate Bonds Initiative, which ensures that issuers of green bonds are actually using the financing proceeds for environmentally friendly purposes, they also show that the lack of an observed premium is unlikely to be driven by the presence of greenwashing (the practice of trying to make people believe that an entity is doing more for sustainability than it really is). Since investment banks appear generally to charge fees to issue green bonds in part due to the cost associated with certification processes, the authors argue that their results suggest that the borrowing costs of municipalities increase if they issue green bonds. Another study that finds little—or at best mixed—evidence on a greenium is that by Tang and Zhang (2020). Examining green bonds issued by firms in 28 countries, they do not find a consistently significant premium for green bonds.

D. Other Assets

We now turn to the literature on other asset classes: corporate and municipal bonds, syndicated loans, and weather derivatives.

12. The author argues that these findings can be linked with the literature on the liquidity premium, which shows that the liquidity premium is higher for financial bonds and lower-rated bonds.

Several studies examine corporate bonds. For example, Huynh and Xia (2021) use Engle et al.'s (2020) negative climate change news index and estimate the beta of bond returns with respect to the index. They find that bonds with a higher climate change news beta earn lower future returns, consistent with the idea that investors are willing to pay a premium to hedge climate risk. The effect is more pronounced for longer-term bonds, suggesting higher concern about the longer-term risk.

Further, studies suggest that municipal bond markets also reflect climate change risks. For instance, Painter (2020) finds that U.S. counties with greater exposure to sea level rise pay higher underwriting fees and initial yields to issue long-term municipal bonds, although no such relationship is observed for short-term bonds. He also finds that the effect of sea level rise risk on issuance costs is driven by bonds with low credit ratings, which suggests that lower rated counties are more likely to be susceptible to climate change risks, as they generally have weaker infrastructure and smaller fiscal capacity. Meanwhile, Goldsmith-Pinkham et al. (2023) obtain somewhat different results from Painter (2020). Discussing potential reasons behind the difference in results, they highlight that they measure sea level rise exposure at the school district level, while Painter (2020) uses a measure of climate risks for 17 major metropolitan areas that does not differentiate among coastal and inland municipalities in the same region. Goldsmith-Pinkham et al. (2023) find that municipal bond markets began pricing sea level rise exposure in 2013, coinciding with upward revisions to worst-case sea level rise projections. The effect is larger for long-maturity bonds, suggesting that the premium is primarily attributable to the long-term risk of gradually rising oceans, rather than the near-term risk of flooding from increased storm frequency and intensity.

The literature also examines syndicated loans. Ehlers, Packer, and de Greiff (2022) find a significant "carbon premium" across a wide range of industries since the Paris Agreement in December 2015. However, they argue that the premium appears to be low given a plausible estimate of a future carbon tax. In addition, only Scope 1 carbon emissions (i.e., emissions directly produced by the firm) are priced. Furthermore, the authors find no evidence that syndicated loans arranged by green banks, which are defined as those participating in the United Nations Environmental Programme Finance Initiative or adhering to the Equator Principles, factor in more climate risk than loans arranged by other banks.

Turning to studies on weather derivatives, Schlenker and Taylor (2021) argue that the market for weather futures is accurately anticipating rising temperatures in line with scientific predictions. Weather futures are products whose prices are determined by how much average daily temperatures fall below or above a certain benchmark in a month. Weather futures have been traded on the Chicago Mercantile Exchange since 2001, and there are products for eight different cities across the United States. Schlenker and Taylor (2021) show that weather futures prices indicate that the market is anticipating an increasing number of hot days in the summer and a decreasing number of cold days in the winter. Moreover, the authors find that this price trend approximates the projections of scientific models and is not influenced by year-to-year temperature fluctuations. This result suggests that market participants fully internalize the scientific forecasts and do not myopically update their predictions based on short-term weather outcomes.

E. Key Takeaways of Section III

While many studies show that prices of assets, such as stocks and bonds, factor in climate-related risks to some extent, many other studies show that real estate prices in particular do not adequately reflect such risks. Several studies provide evidence that investor behavior and asset prices have changed due to revised perceptions of risks as a result of disasters or local signs of the impact of climate change. Consequently, there are concerns that asset prices could fall substantially as climate-related risks materialize. When asset prices do not adequately factor in risks, they can hinder adaptation and mitigation actions, for instance, through excessive lending to high-risk areas and deterring financing by companies with low carbon emissions. Many studies demonstrate the effects of information disclosure, for example, by providing evidence that property prices do not sufficiently factor in climate risks in the absence of adequate information disclosure. Meanwhile, the empirical findings on green bond premiums remain mixed.

IV. Natural Disasters and Bank Behavior

We now turn to the literature on how banks are affected by and respond to natural disasters. In particular, we focus on whether the banking sector is sufficiently resilient to supply credit to satisfy liquidity needs and aid in the recovery after a severe disaster. In the conventional banking literature, natural disasters are often used as a natural experiment, where the disaster is regarded as an exogenous shock. As climate change advances and concerns over the growing frequency and intensity of natural disasters rise, these studies are becoming increasingly relevant in understanding the threats that natural disasters pose to the financial system. Furthermore, an increasing number of studies investigate the relationship between banks and natural disasters with specific reference to climate change. Our survey finds that banks' solvency and their role as credit suppliers are adversely affected by natural disasters (Section IV.A). We also review the rich literature on how the geographical expansion of banks leads to the transmission of adverse shocks to distant, unaffected regions (Section IV.B). We next investigate the heterogeneous responses of banks, areas, and loan types to natural disasters (Section IV.C). We then consider the benefits and side effects of public support related to the banking sector (Section IV.D). Finally, we summarize this section (Section IV.E).

A. Damage to Banks and Credit Constraints

Natural disasters affect banks' solvency through various channels: disasters can lead to a deterioration in the balance sheets of affected lenders, reduce the value of collateral, and directly damage banks' assets, such as their offices and system infrastructure. For instance, in a cross-country analysis covering more than 160 countries, Klomp (2014) finds that large-scale natural disasters adversely affect commercial banks' z-score (a measure of bank soundness or, more accurately, the inverse distance to default). Gramlich et al. (2023) examine data on 9,928 banks across 149 countries and find that natural disasters have a negative impact on banks' capital ratios. Similarly, using county-level data on natural disasters such as thunderstorms, hurricanes, floods, wildfires, and tornados in the United States, Noth and Schüwer (2023) show that property damages from weather-related natural disasters significantly weaken the stability of banks as reflected

in lower z-scores, higher non-performing asset ratios, higher foreclosure rates, lower returns on assets, and lower bank capital ratios. Meanwhile, Schüwer, Lambert, and Noth (2019) find that the z-scores of banks affected by three hurricanes that hit the U.S. Gulf Coast decreased and that these banks became significantly riskier than banks that were not affected. Further, Koetter, Noth, and Rehbein (2020) examine the effects of a major flood in Germany in 2013. Their main analysis disregards banks in flooded counties to avoid confounding loan supply and credit demand responses in those counties. They compare exposed banks, which are defined as banks with a critical share of corporate borrowers located in flooded counties, with unexposed banks. They find evidence for a relative increase in the share of non-performing loans for exposed banks that are not part of geographically diversified banking groups.

The literature also examines the impact of natural disasters on financial outcomes for borrowers. For example, Gallagher and Hartley (2017) find that following Hurricane Katrina, overall delinquency rates on credit cards increased, and credit scores decreased for the most flooded residents, although these changes were modest in size and short-lived. Using loan-level data from Mexico, Aguilar-Gomez et al. (2024) find that unusually hot days (with maximum temperatures above 35°C) lead to higher firm delinquency rates, especially in the agricultural sector, but also in nonagricultural industries that rely heavily on local demand. Ho et al. (2023) investigate the impact of the 2016 Fort McMurray Wildfire in Canada and find that it led to increased mortgage arrears in severely affected areas.

When natural disasters strike, affected firms' and households' credit demand often increases because they need to rebuild destroyed or damaged physical capital, bridge financing gaps until they receive monetary support from the government or payments from insurance firms, or secure their liquidity positions. The increase in credit demand is illustrated in several studies. For instance, Brown, Gustafson, and Ivanov (2020) show that firms, particularly solvent small firms, draw on their credit lines and increase the size of credit lines in response to a significant cash flow decline after unexpectedly severe snow cover in the United States. Meanwhile, Collier et al. (2019) find that, one year after Hurricane Sandy, negatively affected firms in New York were more likely to report that they had applied for credit than other firms. Similarly, in their study on the 2013 flood in Germany mentioned earlier, Koetter, Noth, and Rehbein (2020) find evidence that credit demand increased. Using data on lending to micro, small, and medium-sized enterprises in Ecuador, Berg and Schrader (2012) find that the number of loan applications increased after volcanic eruptions. Dessaint and Matray (2017) show that after hurricane events in the United States, unaffected firms located in the neighborhood of the disaster area substantially increased cash holdings, and their managers expressed greater concern about hurricane risk. The authors also find that the amount of cash increases during the first four quarters following the disaster and then reverts to pre-hurricane levels over the year. Based on such findings, they argue that firm reaction is consistent with a salience bias.

Whether banks can meet the heightened credit demand after a natural disaster is critical for the affected economies. The literature indicates that natural disasters limit both banks' ability to lend and firms' ability to borrow. For example, using data from a survey conducted for several years after the Great East Japan (Tohoku) Earthquake

in Japan in 2011, Uesugi et al. (2025) find that both damage to firms' tangible assets and to the net worth of their primary bank increased the probability that firms faced borrowing constraints after the disaster, providing evidence of the existence of both a so-called collateral and a bank lending channel. They also show that firms that faced a tighter credit constraint after the earthquake saw a fall in the level of production and sales activities. Meanwhile, in their study on Ecuador, Berg and Schrader (2012) show that volcanic activity restricts access to credit. Other studies find that natural disasters, such as hurricanes, snow, and high temperatures, increase credit constraints through higher interest rates and less borrower-friendly revisions of non-price loan terms, such as shorter maturity, flexible interest rates, and requirements to secure loans (Collier et al., 2019; Brown, Gustafson, and Ivanov, 2020; Aguilar-Gomez et al., 2024).

B. Reduction in Credit Supply in Unaffected Areas

As reviewed in the previous subsection, natural disasters lead not only to higher lending demand from firms and households but also to restrictions in the lending supply by banks. Clearly, this is bad news because firms may not be able to access credit when they need it the most. We next take a more granular look at banks' credit supply and review how banks propagate the impact of natural disasters to distant regions (we will refer to this propagation as "network effects" hereafter). Several studies suggest that the geographical expansion of banks has both harmful aspects, such as the propagation of adverse shocks, and beneficial aspects, such as risk sharing and new business creation (Demyanyk, Ostergaard, and Sørensen 2007; Morgan, Rime, and Strahan 2004; Black and Strahan 2002). Our survey shows that these findings in the literature are also relevant in the context of natural disasters.

Several studies find that banks reduce credit supply in unaffected regions after a natural disaster. For instance, like Koetter, Noth, and Rehbein (2020), Rehbein and Ongena (2022) examine the effects of the 2013 flooding in Germany. While Koetter, Noth, and Rehbein (2020) focus on lending within the affected region after the flood, Rehbein and Ongena (2022) examine the impact on unaffected regions. To this end, they define disaster-exposed banks as banks that provided credit to corporate borrowers in flooded counties to a large extent. They then find evidence that firms in non-disaster areas but connected to disaster-exposed banks reduced total borrowing, employment, and tangible assets. They also show that in a non-flooded area, the more firms were connected to disaster-exposed banks, the greater the reduction in GDP was. A similar result is provided by research on an earthquake in Japan. Hosono et al. (2016) examine the impact of the Great Hanshin-Awaji Earthquake in 1995 on firms located outside of the affected area. They find that the investment ratio (investment per capital stock) of firms whose main banks were inside the area was lower than that of firms whose main banks were outside of the area. Further, using U.S. disaster data, Cortés and Strahan (2017) find that mortgages in unaffected but connected markets decline by a little less than 50 cents per dollar of additional mortgage lending in affected areas after properties in these areas are damaged due to natural disasters. As for the reason why banks propagate the shocks of natural disasters to unaffected areas, Garbarino and Guin (2021) argue that the reallocation of lending from unaffected areas to affected areas may be due to a failure to mark-to-market property collateral against declining

market prices, preventing a tightening of credit supply in the affected areas.

While so far, we have focused on natural disasters—i.e., physical risks—as sources of network effects, transition risks, for example, through regulatory and technological changes, can also have network effects. For instance, if a carbon tax is introduced, the market value of fossil fuels may drop significantly as they become unusable, rendering them stranded assets. Consequently, the balance sheets of firms that own those assets may be greatly damaged, adversely influencing the lending capacity of branch networks of banks exposed to those firms. In this regard, Gilje, Loutskina, and Strahan (2016) examine the impact of an unexpected technological breakthrough that made vast amounts of shale oil and natural gas economically profitable in the United States. They find evidence that the resulting increase in deposit supply leads to higher growth in mortgages. Hence, it is plausible that a drop in the market value of fossil fuels could have the opposite effect—i.e., result in a significant decline in the supply of loans.

C. Heterogeneity

There is likely to be considerable heterogeneity in the impact of a natural disaster, depending on a range of circumstances. The literature identifies several factors that affect the size of the adverse impacts following natural disasters, such as capital regulation and supervision, bank-borrower relationships, age and size of firms, and alternative funding sources. For instance, Klomp's (2014) country-level analysis finds that the impact of a natural disaster is negatively associated with the stringency of capital regulation and supervision, in addition to the level of financial and economic development. Studies also find that the presence of bank-borrower relationships prior to natural disasters reduces credit constraints. In their study using Ecuadorian data, Berg and Schrader (2012) find that repeat clients already known to the financial institution are about equally likely to receive loans after volcanic eruptions as before, while new clients face difficulty in receiving financing. The importance of relationship banking is also highlighted by Koetter, Noth, and Rehbein (2020), who find that after the 2013 flood in Germany, firms located in flooded counties on average increased their borrowing if they were connected to banks in unaffected counties. Another source of heterogeneity is firm characteristics. Collier et al. (2019) show that younger and smaller firms were less likely to receive all of the credit financing that they requested after Hurricane Sandy. Aguilar-Gomez et al. (2024) find that the increase in delinquency rates on unusually hot days is concentrated among small and medium-sized firms. A further source of heterogeneity is access to non-bank credit. For instance, using zip-code level data for California, Morse (2011) finds that foreclosures increase after a natural disaster but access to high-interest credit (payday loans) mitigates the impact when disasters are not covered by homeowner insurance.

Several studies examine the impact of natural disasters, focusing on differences between local and non-local banks. Theoretically, local banks in affected areas should be more vulnerable to the shock and potentially tighten credit supply to a larger extent. On the other hand, local banks may also be more willing to continue lending after a natural disaster because borrowers in the disaster area are more important to them than to non-local banks or because local lenders face lower costs of monitoring borrowers in the reconstruction phase. In fact, the literature suggests that local banks have a com-

parative advantage in accessing soft information about borrowers (Berger et al. 2005; Agarwal and Hauswald 2010).

Empirical studies generally find that local banks in affected areas are more likely to continue lending than non-local banks. Gallagher and Hartley (2017) find that after Hurricane Katrina hit New Orleans, mortgage reductions were larger in areas where homeowners were likely to have a home loan originated by non-local lenders. Furthermore, two years after Katrina, local banks' lending returned to the pre-Katrina level, while a large share of non-local banks exited from the market. Schüwer, Lambert, and Noth (2019) find similar results and further show that affected counties with a relatively large share of local banks and relatively high average bank capital ratios show higher growth in total personal income and employment than other affected counties following Hurricane Katrina. Meanwhile, Chavaz (2016) examines the effects of hurricanes in the United States in 2005 including Katrina. He finds that compared to geographically diversified banks, local banks originated a higher share of new mortgage and small business loans in affected areas while cutting lending to unaffected counties and selling a higher share of the new mortgages into the secondary market. These results indicate that local banks have special abilities or incentives to seize opportunities in a distressed market, while loans in affected areas are increasingly transferred to agents that can better support the associated risk. On the other hand, he finds that local banks did not accept more loans in an affected area in which they owned a higher share of outstanding mortgages, suggesting that local banks did not aim to influence local house prices and economic activity.

Other factors that create heterogeneity in the impact of a natural disaster include bank, area, and loan characteristics. In particular, many studies show that bank characteristics are an essential determinant of the network effects. As mentioned above, Schüwer, Lambert, and Noth (2019) find that local banks increase new lending in the local market only when they are highly capitalized. Bank capitalization is an important determinant of network effects, too. For example, Rehbein and Ongena (2022) find that low bank capital amplifies network effects. They show that the impact of the 2013 flood in Germany was transmitted to firms in non-disaster areas via their banks: firms connected to banks with high exposure to the flood and ranking into the bottom quartile in terms of their capitalization experienced a significant decline in borrowing, employment, and tangible assets relative to similar firms connected to a well-capitalized bank. Meanwhile, Cortés and Strahan (2017) suggest that bank size is another factor determining the network effects. Specifically, they find that exogenous shocks to credit demand are transmitted to distant regions through the reallocation of funds only in the case of small banks but not large banks. Hosono et al. (2016) find that the network effects differ depending on whether main banks' headquarters or branches are damaged. While the impact of damage to main banks' headquarters emerged immediately after the Great Hanshin-Awaji earthquake, the impact of damage to main banks' branches emerged only with a one-year lag.

Turning to studies on area characteristics as a determinant of the strength of bank network effects, Cortés and Strahan (2017) find that a reduction in lending is mainly observed outside banks' core markets in which they own branches. Somewhat in contrast, the study by Gilje, Loutskina, and Strahan (2016) on shale boom windfalls finds

that banks exposed to the shale boom grew mortgages faster than similar non-exposed banks only in counties where the banks had branches. This suggests that if those windfalls disappear, banks may shrink their lending again in counties where they had increased their mortgage lending due to the shale boom. Meanwhile, Rehbein and Ongena (2022) find that, following a disaster, banks reduce their exposure to areas that, although currently unaffected, are generally disaster-prone.

Finally, studies examining the role of loan characteristics suggest that whether loans are easy or difficult to securitize matters. For instance, Gilje, Loutskina, and Strahan (2016) show that banks exposed to the shale boom expanded lending more in segments that were less likely to be securitized. This suggests that if banks were to experience a tightening in liquidity constraints due to, for example, a natural disaster, they might find it more difficult to extend loans that are hard to securitize.

D. Benefits and Side Effects of Public Support

Many governments provide direct or indirect public support for banks, firms, and individuals in the event of a disaster. While such support can have positive effects on lending and the economic conditions of firms and individuals, it can potentially also have adverse side effects by distorting the behavior of banks and borrowers.

In this context, several studies examine the positive and negative effects of public support from government-sponsored enterprises (GSEs) in the United States. For instance, Cortés and Strahan (2017) find that after natural disasters, banks originate more small loans that can be sold to the GSEs. This result suggests that GSEs meet the legislative goal of promoting access to mortgage credit for low- and moderate-income households.

Meanwhile, in a study on the Tohoku earthquake in Japan, Uchida et al. (2015) show that the injection of public capital into damaged banks appears to have distorted resource allocation. To extract the impact of purely exogenous financial shocks on bankruptcy, they focus on firms located outside the affected area but transacting with banks located inside the area. They obtain some evidence that the capital injection reduced the probability of firm bankruptcy and weakened the natural selection mechanism, whereby less efficient firms are more likely to go bankrupt.

Some studies examine the impact of public support on individuals after natural disasters. Gallagher, Hartley, and Rohlin (2023) find evidence that federal disaster assistance ameliorates the negative impact of devastating tornadoes on household finance, businesses survival, and employment. The effects on business survival and employment are concentrated among small non-manufacturing establishments that rely on local demand. On the other hand, Bleemer and van der Klaauw (2019) show that public support distorts resource allocation. They find that, ten years after Hurricane Katrina, credit scores and homeownership among flooded residents of New Orleans are lower than among their non-flooded neighbors. They also find, however, that residents of areas surrounding New Orleans, who were eligible for various federal programs like residents of New Orleans, had higher rates of consumption, credit scores, and homeownership and lower rates of bankruptcy and foreclosure than residents outside the area

a decade later.[13]

E. Key Takeaways of Section IV

The review of the literature presented here suggests that when the area in which banks operate is affected by a natural disaster, banks' health deteriorates, and the demand for borrowing increases while the supply of loans, especially to young and small businesses, falls. The supply of bank credit also declines in unaffected areas. Further, there is considerable heterogeneity in the impact of natural disasters, with factors determining this impact including bank, area, and loan characteristics. For instance, local banks in affected areas are more likely to continue lending, and the effects are less severe when banks have high capital ratios. Finally, while public support mitigates the impact of a disaster, it has the negative side effect of distorting resource allocation.

V. The Role of Insurance and Related Challenges

Another essential part of the financial system that is significantly relevant to climate change is the insurance sector. On the one hand, insurance (and economically equivalent public support) serves as a means for policyholders to mitigate the impact of negative shocks caused by climate change: if losses caused by weather-related natural disasters are covered by insurance, the payouts provide an important source of funding for recovery. On the other hand, the insurance sector may become a source of financial instability if large payouts impair insurers' solvency or lead to fire sales of assets. Furthermore, insurance can introduce moral hazard, potentially delaying adaptations to reduce the costs of climate change. In this section, we start with the role of insurance in mitigating disaster risk and complementing bank finance (Section V.A). We then consider three challenges related to insurance: increasing the coverage of insurance (Section V.B), maintaining the solvency of insurance firms when climate-related risks materialize (Section V.C), and avoiding the problem of moral hazard (Section V.D). Finally, we sum up the key takeaways (Section V.E).

A. The Role of Insurance

Insurance can mitigate the adverse effects of natural disasters on economies. According to a survey by Kousky (2019) focusing on catastrophe insurance for housing in advanced economies, the literature indicates that insurance speeds up post-disaster recovery at both the household- or small business-level and the level of the economy as a whole, although she cautions that rigorous empirical work on these topics is limited. Billings, Gallagher, and Ricketts (2022) investigate the impact of flooding caused by Hurricane Harvey, which struck Houston in August 2017. They find that credit-constrained homeowners experienced increases in bankruptcies and in the share of debt in severe delinquency in flooded blocks outside the flood plain, relative to non-flooded

13. Relatedly, Deryugina (2017) shows that U.S. hurricanes lead to substantial increases in non-disaster government transfers, such as unemployment insurance and public medical payments, in affected counties in the decade after a hurricane. The present value of this increase significantly exceeds that of direct disaster aid. This implies that without counting this increase, the fiscal costs of natural disasters are significantly underestimated.

areas. In contrast, this pattern was not observed inside the floodplain, where households were required to insure against flood risk. This result suggests that flood insurance mitigates the financial impact of flooding.

Insurance also influences the availability of, repayments on, and demand for bank credit. As we saw in Section IV, the literature finds that following natural disasters, borrowing constraints tighten, delinquency rates rise, and credit demand increases. Insurance can alleviate these impacts to some extent. For instance, Uesugi et al. (2025), using the Tohoku Earthquake in 2011 as a natural experiment, find that earthquake insurance payouts and government subsidies for recovery investment alleviated firms' borrowing constraints or reduced the probability that firms were unable to obtain the desired amount of loans following the disaster. Meanwhile, Gallagher and Hartley (2017) find that after Hurricane Katrina hit New Orleans in 2005, the greater the flood damage households experienced the larger was the reduction in their total debt because they used flood insurance to repay their mortgages rather than to rebuild. Collier et al. (2019) find that after Hurricane Sandy, businesses that suffered large losses and were not covered by insurance were significantly more likely to apply for credit than businesses that experienced large losses that were fully covered by insurance. In addition, Morse (2011), in her study on natural disasters in California, finds that access to payday loans reduces foreclosures after natural disasters only when disasters are not covered by homeowner insurance.

While the studies mentioned so far examine the effect of insurance on credit *after* a disaster has struck, insurance can also influence credit provision even *before* a disaster occurs. Garmaise and Moskowitz (2009) find that insurance market imperfections can restrict credit supply in particular to non-wealthy individuals, who rely on credit to purchase a property. They theorize that with a perfect insurance market, there should be no link between earthquake risk and loan provision since insurance can cover all of the risk. Their empirical analysis on earthquake and hurricane risks in the United States, however, indicates that properties with higher earthquake risk were less likely to be financed with bank debt, suggesting that the insurance markets are imperfect.

B. Insurance Coverage

The preceding section discussed the important role insurers play in cushioning the financial impact of natural disasters on households, firms, and the economy overall. Given this crucial role, an important question is the current level of insurance coverage. Extensive coverage would imply that more people and firms enjoy protection against natural disasters and hence the economy would be more resilient to the adverse effects of such disasters. However, existing evidence suggests that insurance coverage is low. According to Swiss Re, worldwide, more than 70 percent of natural disaster losses are not covered by insurance, and this ratio is particularly high for floods and earthquakes (Holzheu and Turner 2018).

Even if a household or firm has insurance of some kind, the loss may not be covered by that insurance. Collier et al. (2019) find that while Hurricane Sandy damaged firms' assets and disrupted their operations (e.g., through utility outages and customer relocation), 29 percent of the negatively affected firms had no insurance of any kind. Moreover, even insured businesses often did not have coverage for the kinds of losses

that Sandy created: 74 percent of businesses with property insurance, 72 percent with business interruption insurance, and 52 percent of businesses with flood insurance reported that none of their losses from the event had been covered by their policies. The low level of insurance payments is likely because the types of losses created by the hurricane differ from the types of losses that are protected by the most common forms of insurance. For instance, flood insurance from the National Flood Insurance Program (NFIP) protects against flood-related property losses but does not cover flood-related business interruptions. On the other hand, all the businesses with flood insurance that did not receive any insurance payments reported that they did not have property damage. These facts suggest that the insurance policies poorly match the losses stemming from customer and utility disruptions commonly reported by negatively affected firms.

Moreover, existing studies also show that there is heterogeneity in coverage and indicate that insurance fails to cover those who need it the most. For instance, Botzen, Kunreuther, and Michel-Kerjan (2019) find evidence that homeowners with lower incomes were less likely to buy flood insurance than those with higher incomes due to affordability concerns. Collier et al. (2019) find that younger and smaller firms were significantly less likely to be insured. These results suggest that the most vulnerable groups—low-income homeowners as well as younger and smaller firms—were least likely to be covered by insurance.

The literature also finds that international risk-sharing through reinsurance is low. Ito and McCauley (2022) find that international sharing of disaster losses is generally very limited. For example, they document that earthquake insurance covered only 16 percent of Japan's direct losses from the Tohoku earthquake, and less than a quarter of this 16 percent was reinsured internationally, implying that only 3.6 percent of total losses were ultimately shared with the rest of the world. Using data on cross-border reinsurance payments for 93 disasters across 44 economies from 1982 to 2017, they show that this limited international risk-sharing stems from both low participation in primary insurance and the limited use of reinsurance. Moreover, they find that those most in need of risk-sharing receive the least support: countries with lower levels of economic or financial development tend to insure a smaller share of disaster losses, and among advanced economies, less fiscal space is associated with lower levels of international risk-sharing.

The literature suggests that both demand and supply factors are responsible for the low insurance coverage. Several studies find that there is heterogeneity in the demand for insurance. For instance, Gallagher (2014) suggests that demand for flood insurance is positively related to the flooding experience. Using U.S. data, he finds that the take-up of insurance spikes in the year following a flood and then steadily declines back to the pre-disaster level over the next decade, indicating that the infrequent nature of natural disasters may be one reason for the low demand for insurance, and raising awareness of risks may help increase insurance demand. Botzen and van den Bergh (2012) use data from a survey among homeowners in the Dutch river delta. The survey asks whether respondents would be willing to purchase flood insurance and how much they would be willing to pay (WTP) under the current flood probability of 1 in 1,250 years and under higher probabilities as a result of climate change. The survey is hypothetical in the sense that flood insurance was not available in the Netherlands at that

time. The authors find that even when the flood probability increased to 1 in 400 years, at most around 50 percent of respondents would purchase flood insurance. On the other hand, the WTP of those who would purchase is on average considerably higher than the expected value of the flood risk they face. The authors also find evidence that risk communication increases risk awareness of respondents.

Another reason why insurance coverage is low is supply constraints. Supply of catastrophe insurance may be constrained for several reasons, such as information asymmetries (and adverse selection resulting from such asymmetries) and limited availability of reinsurance. A defining characteristic of disasters is that large numbers of people, properties, and businesses are impacted simultaneously, meaning that the law of large numbers does not work well. Under these circumstances, insurance firms build up reserves, purchase reinsurance, or issue catastrophe bonds. However, the literature shows that such steps by insurers make disaster insurance more expensive. For instance, Froot (2001) documents that although theory suggests that risk sharing against severe, low-probability events is most valuable, most insurers do not purchase reinsurance against such events, and that reinsurance premiums are high relative to expected losses. He argues that the most compelling explanation is supply restrictions associated with capital market imperfection facing reinsurers and market power enjoyed by the relatively small number of reinsurers.

C. Insurance Firm Losses and Their Implications

It is important to note that insurance firms themselves may be made vulnerable by climate change risks. If they underestimate natural disaster risks *ex ante*, collected premiums may not be sufficient to pay out for covered damages *ex post*. A deterioration in the financial health of insurers may result in a fire sale of assets, higher insurance fees, and a reduced supply of insurance.

The solvency of insurance firms has indeed been affected by large disasters. For instance, following Hurricane Andrew, which landed on the eastern coast of the United States in 1992, a number of insurance firms became insolvent. Even if insurance firms remain solvent, they may conduct a fire sale of assets to meet insurance claims, which could undermine financial stability. The effects of insurers' fire-sales on financial markets are illustrated by Massa and Zhang (2021), who examine the impact of the liquidation of corporate bond holdings by (re)insurance firms in the wake of Hurricane Katrina. They find that property insurance firms with large exposure to Katrina reduced their corporate bond holdings by 14 percent, while other property insurers reduced theirs by only 1 percent. The authors further show that, as a result, firms whose bonds were held by Katrina-exposed property insurers faced a larger decline in their risk-adjusted bond returns. Moreover, these affected firms shifted from bond financing to bank loans at least for three years after Katrina.

Another concern is that insurers may raise premiums to cover expected losses, likely resulting in lower participation. Indeed, Froot (2001) shows that reinsurance of catastrophic event risks became considerably more expensive following Hurricane Andrew, which led to a decline in reinsurance purchases. He further shows that the amount of reinsurance purchased fell by more, and the premium paid rose by more for insurers with large exposure to hurricanes.

It is also possible that insurers consider the costs of natural disasters too large to insure and consequently stop providing insurance. Existing evidence finds that this has indeed happened in the past. For example, following the 1994 Northridge earthquake in California, insurers paid more in claims than they had collected in earthquake premiums over the preceding 30 years. Consequently, many insurers began to withdraw from offering homeowners insurance coverage, since California state law requires insurers providing homeowners coverage to also offer earthquake coverage. This retreat of insurers triggered a housing market crisis in California (Insurance Information Institute 2025).

D. Moral Hazard

Another critical issue in the context of insurance is moral hazard. Insurance may cause the policyholders to engage in risk-taking activities because they know that they will be compensated for a loss by the insurance. In the context of climate change, insurance may discourage policyholders from taking measures that reduce the costs of climate change and natural disasters. As a result, it is possible, at least in theory, that the social costs of induced risk-taking activities exceed the benefits brought about by insurance. In addition, moral hazard could lead to higher premiums and lower insurance supply.

Existing empirical studies find some evidence of moral hazard induced by public insurance. For instance, Annan and Schlenker (2015) examine the impact of the Federal Crop Insurance Program in the United States on the incentive to adapt to extreme heat using county-level data. They find that insured corn and soybean yields decline more significantly than uninsured yields when exposed to extreme heat, implying that public insurance acts as a disincentive for farmers to engage in adaptation strategies to cope with extreme heat. Relatedly, Bakkensen and Barrage (2022), referencing a report by the U.S. Government Accountability Office, point out that the NFIP, the dominant public flood insurer, is fiscally unsustainable, suggesting that it fails to provide households with sufficient incentives to fully internalize flood risk.

Moral hazard may pose a problem, but theory suggests that well-designed insurance programs can reduce it. For instance, many insurance policies involve deductibles, based on the expectation that if the insureds must bear part of the losses, they will be encouraged to engage in risk-reducing activities. Moreover, insurance can play a critical role in improving resilience to natural disasters not only by supporting recovery but also by providing incentives for climate adaptation or investment in hazard alleviation.

While studies often find a positive correlation between having disaster insurance coverage and investing in hazard alleviation among individuals, Kousky (2019) cautions that the correlation may be driven by common underlying factors, such as high risk aversion and high risk perceptions. She concludes that rigorous empirical evidence on this topic remains limited. The correlation could also reflect adverse selection: individuals who are more exposed to disaster risk tend to purchase more insurance coverage.[14] However, she argues that for many disasters, insurers possess more accurate risk information than policyholders, which may mitigate concerns about adverse selection.

Botzen, Kunreuther, and Michel-Kerjan (2019) find conflicting evidence on moral

14. See Cohen and Siegelman (2010) for a survey on the empirical literature on adverse selection in insurance markets, including methods for distinguishing between moral hazard or adverse selection.

hazards. The authors survey more than 1,000 homeowners in New York City after they experienced Hurricane Sandy. On the one hand, those who had purchased insurance were more likely to undertake loss reduction measures, such as installing water-resistant walls, before the disasters. On the other hand, however, those people were less likely to undertake emergency loss reduction measures, such as moving contents to higher floors to avoid them suffering flood damage.

E. Key Takeaways of Section V

Insurance mitigates the negative impact of natural disasters and also influences the availability and repayment of, and demand for, bank lending. However, several challenges remain. Insurance coverage is particularly low among low-income households and young and small businesses, with some studies pointing to both supply and demand factors as underlying reasons, suggesting that risk communication could help expand insurance coverage. Natural disasters can lead to a deterioration in the financial health of insurers, potentially triggering fire sales of assets, higher insurance fees, and a reduced supply of insurance. While there is some evidence that public insurance programs have resulted in moral hazard, there is a lack of rigorous empirical studies that show whether private insurance mitigates or induces moral hazard.

VI. Conclusion

This paper attempted to provide a comprehensive literature survey on the interaction between climate change and the financial system. While our survey covered a broad range of issues, we conclude by highlighting three policy implications of the findings in the literature.

First, our survey finds that asset prices, particularly real estate properties, do not adequately price in climate risks. It also finds that investors update their risk perceptions when they experience the impacts of climate change. These findings indicate that asset prices may decline significantly as climate change risks materialize. Moreover, mispricing can distort incentives for financial institutions, households, and firms to take mitigating and adapting actions against climate change. Meanwhile, many studies provide evidence that disclosure of climate change risks helps alleviate these problems. While these findings do not immediately warrant stricter regulations on disclosure since there are associated costs and limits on market participants' ability to process information, they nonetheless provide useful guidance for policymakers seeking to encourage asset markets to price in more climate change risks.

Second, natural disasters restrict credit supply from affected banks, adversely affecting the real economy, even in unaffected areas. Public support can unintentionally distort resource allocation. On the other hand, some studies argue that the impact of a natural disaster on banks—and hence credit supply and the economy overall—is less severe for banks with a higher capital ratio and located in countries with stricter financial regulations and supervision. These results imply that regulatory frameworks, including capital requirements, which were originally intended to maintain the resilience of banks and the financial system against non-climate shocks, are also effective with regard to climate change risks.

Third, while insurance plays a critical role in mitigating the adverse effects of climate change, the literature also highlights several challenges: increasing coverage, maintaining insurers' solvency when climate change risks materialize, and avoiding the problem of moral hazard. Policymakers need to be aware of the benefits and challenges when designing monitoring and supervisory frameworks for the insurance sector as climate risks grow.

Our survey highlights that the literature on the interaction between climate change and the financial system has grown rapidly in recent years. While our understanding of this subject has advanced considerably as a result, significant research is still needed to fill the gaps in our knowledge. Moreover, it is essential to ensure that future policy discussions are evidence-based and incorporate the growing body of research findings in this area.

References

Agarwal, Sumit, and Robert Hauswald, "Distance and Private Information in Lending," *The Review of Financial Studies*, 23(7), 2010, pp. 2757–2788.

Aguilar-Gomez, Sandra, Emilio Gutierrez, David Heres, David Jaume, and Martin Tobal, "Thermal Stress and Financial Distress: Extreme Temperatures and Firms' Loan Defaults in Mexico," *Journal of Development Economics*, 168, 2024, 103246.

Alok, Shashwat, Nitin Kumar, and Russ Wermers, "Do Fund Managers Misestimate Climatic Disaster Risk," *The Review of Financial Studies*, 33(3), 2020, pp. 1146–1183.

Anderson, Sarah E., Terry L. Anderson, Alice C. Hill, Matthew E. Kahn, Howard Kunreuther, Gary D. Libecap, Hari Mantripragada, Pierre Mérel, Andrew J. Plantinga, and V. Kerry Smith, "The Critical Role of Markets in Climate Change Adaptation," *Climate Change Economics*, 10(1), 2019, 1950003.

Annan, Francis, and Wolfram Schlenker, "Federal Crop Insurance and the Disincentive to Adapt to Extreme Heat," *American Economic Review*, 105(5), 2015, pp. 262–266.

Ardia, David, Keven Bluteau, Kris Boudt, and Koen Inghelbrecht, "Climate Change Concerns and the Performance of Green vs. Brown Stocks," *Management Science*, 69(12), 2023, pp. 7607–7632.

Aswani, Jitendra, Aneesh Raghunandan, and Shiva Rajgopal, "Are Carbon Emissions Associated with Stock Returns?" *Review of Finance*, 28(1), 2024, pp. 75–106.

Baker, Malcolm, Daniel Bergstresser, George Serafeim, and Jeffrey Wurgler, "The Pricing and Ownership of US Green Bonds," *Annual Review of Financial Economics*, 14, 2022, pp. 415–437.

Bakkensen, Laura A., and Lint Barrage. "Going Under Water? Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics," *The Review of Financial Studies*, 35(8), 2022, pp. 3666–3709.

Baldauf, Markus, Lorenzo Garlappi, and Constantine Yannelis, "Does Climate Change Affect Real Estate Prices? Only If You Believe in It," *The Review of Financial Studies*, 33(3), 2020, pp. 1256–1295.

Bartram, Söhnke M., Kewei Hou, and Sehoon Kim, "Real Effects of Climate Policy: Financial Constraints and Spillovers," *Journal of Financial Economics*, 143(2), 2022, pp. 668–696.

Batten, Sandra, Rhiannon Sowerbutts, and Misa Tanaka, "Let's Talk about the Weather: The Impact of Climate Change on Central Banks," Staff Working Paper No. 603, Bank of England, 2016.

———, ———, and ———, "Climate Change: Macroeconomic Impact and Implications for Monetary Policy," in *Ecological, Societal, and Technological Risks and the Financial Sector*, Cham: Palgrave Macmillan, 2020, pp. 13–38.

Bauer, Michael D., Daniel Huber, Glenn D. Rudebusch, and Ole Wilms, "Where is the Carbon Premium? Global Performance of Green and Brown Stocks," *Journal of Climate Finance*, 1, 2022, 100006.

Berg, Florian, Julian F. Kölbel, and Roberto Rigobon, "Aggregate Confusion: The Divergence of ESG Ratings," *Review of Finance*, 26(6), 2022, pp. 1315–1344.

Berg, Gunhild, and Jan Schrader. "Access to Credit, Natural Disasters, and Relationship Lending," *Journal of Financial Intermediation*, 21(4), 2012, pp. 549–568.

Berger, Allen N., Nathan H. Miller, Mitchell A. Petersen, Raghuram G. Rajan, and Jeremy C. Stein, "Does Function Follow Organizational Form? Evidence from the Lending Practices of Large and Small Banks," *Journal of Financial Economics*, 76(2), 2005, pp. 237–269.

Bernstein, Asaf, Matthew T. Gustafson, and Ryan Lewis, "Disaster on the Horizon: The Price Effect of Sea Level Rise," *Journal of Financial Economics*, 134(2), 2019, pp. 253–272.

Billings, Stephen B., Emily A. Gallagher, and Lowell Ricketts, "Let the Rich Be Flooded: The Distribution of Financial Aid and Distress after Hurricane Harvey," *Journal of Financial Economics*, 146(2), 2022, pp. 797–819.

Bin, Okmyung, Thomas W. Crawford, Jamie B. Kruse, and Craig E. Landry, "Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk," *Land economics*, 84(3), 2008, pp. 434–448.

Black, Sandra E., and Philip E. Strahan, "Entrepreneurship and Bank Credit Availability," *The Journal of Finance*, 57(6), 2002, pp. 2807–2833.

Bleemer, Zachary, and Wilbert van der Klaauw, "Long-Run Net Distributionary Effects of Federal Disaster Insurance: The Case of Hurricane Katrina," *Journal of Urban Economics*, 110, 2019, pp. 70–88.

Bolton, Patrick, and Marcin Kacperczyk, "Do Investors Care about Carbon Risk?" *Journal* of *Financial Economics*, 142(2), 2021, pp. 517–549.

———, and ———, "Global Pricing of Carbon Transition Risk," *The Journal of Finance*, 78(6), 2023, pp. 3677–3754.

Botzen, WJ Wouter, Howard Kunreuther, and Erwann Michel-Kerjan, "Protecting against Disaster Risks: Why Insurance and Prevention May Be Complements," *Journal of Risk and Uncertainty*, 59(2), 2019, pp. 151–169.

———, and Jeroen CJM van den Bergh, "Risk Attitudes to Low-Probability Climate Change Risks: WTP for Flood Insurance," *Journal of Economic Behavior and Organization*, 82(1), 2012, pp. 151–166.

Brown, James R., Matthew T. Gustafson, and Ivan T. Ivanov, "Weathering Cash Flow Shocks," *The Journal of Finance*, 76(4), 2020, pp. 1731–1772.

Carney, Mark, "Breaking the Tragedy of the Horizon—Climate Change and Financial Stability," Speech at Lloyd's of London, on September 29, 2015. (available at https://www.bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf)

Chatterji, Aaron K., Rodolphe Durand, David I. Levine, and Samuel Touboul, "Do Ratings of Firms Converge? Implications for Managers, Investors and Strategy Researchers," *Strategic Management Journal*, 37(8), 2016, pp. 1597–1614.

Chavaz, Matthieu, "Dis-Integrating Credit Markets: Diversification, Securitization, and Lending in a Recovery," Staff Working Paper No. 617, Bank of England, 2016.

Choi, Darwin, Zhenyu Gao, and Wenxi Jiang, "Attention to Global Warming," *The Review of Financial Studies*, 33(3), 2020, pp. 1112–1145.

Cohen, Alma, and Peter Siegelman, "Testing for Adverse Selection in Insurance Markets," *Journal of Risk and Insurance*, 77(1), 2010, pp. 39–84.

Collier, Benjamin L., Andrew F. Haughwout, Howard C. Kunreuther, and Erwann O. Michel-Kerjan, "Firms' Management of Infrequent Shocks," *Journal of Money, Credit and Banking*, 52(6), 2019, pp. 1329–1359.

Cortés, Kristle Romero, and Philip E. Strahan, "Tracing Out Capital Flows: How Financially Integrated Banks Respond to Natural Disasters," *Journal of Financial Economics*, 125(1), 2017, pp. 182–199.

de Bandt, Olivier, Laura-Chloé Kuntz, Nora Pankratz, Fulvio Pegoraro, Haakon Solheim, Gregory Sutton, Azusa Takeyama, and Fan Dora Xia, "The Effects of Climate Change-related Risks on Banks: A Literature Review," *Journal of Economic Surveys*, 2024, pp. 1–42.

De Haas, Ralph, Ralf Martin, Mirabelle Muûls, and Helena Schweiger, "Managerial and Financial Barriers to the Green Transition," *Management Science*, 71(4), 2025, pp. 2890–2921.

———, and Alexander Popov, "Finance and Green Growth," *The Economic Journal*, 133(650), 2023, pp. 637–668.

Demyanyk, Yuliya, Charlotte Ostergaard, and Bent E. Sørensen, "U.S. Banking Deregulation, Small Businesses, and Interstate Insurance of Personal Income," *The Journal of Finance*, 62(6), 2007, pp. 2763–2801.

Deryugina, Tatyana, "The Fiscal Cost of Hurricanes: Disaster Aid versus Social Insurance," *American Economic Journal: Economic Policy*, 9(3), 2017, pp. 168–98.

Dessaint, Olivier, and Adrien Matray, "Do Managers Overreact to Salient Risks? Evidence from Hurricane Strikes," *Journal of Financial Economics*, 126(1), 2017, pp. 97–121.

Diaz-Rainey, Ivan, Becky Robertson, and Charlie Wilson, "Stranded Research? Leading Finance Journals Are Silent on Climate Change," *Climatic Change*, 143, 2017, pp. 243–260.

Dyck, Alexander, Karl V. Lins, Lukas Roth, and Hannes F. Wagner, "Do Institutional Investors Drive

Corporate Social Responsibility? International Evidence," *Journal of Financial Economics,* 131(3), 2019, pp. 693–714.

Ehlers, Torsten, Frank Packer, and Kathrin de Greiff, "The Pricing of Carbon Risk in Syndicated Loans: Which Risks Are Priced and Why?" *Journal of Banking & Finance*, 136, 2022, 106180.

Engle, Robert F., Stefano Giglio, Bryan Kelly, Heebum Lee, and Johannes Stroebel, "Hedging Climate Change News," *Review of Financial Studies,* 33(3), 2020, pp. 1184–1216.

Flammer, Caroline, "Corporate Green Bonds," *Journal of Financial Economics*, 142(2), 2020, pp. 499–516.

———, Michael W. Toffel, and Kala Viswanathan, "Shareholder Activism and Firms' Voluntary Disclosure of Climate Change Risks," *Strategic Management Journal*, 42(10), 2021, pp. 1850–1879.

Froot, Kenneth A, "The Market for Catastrophe Risk: A Clinical Examination," *Journal of Financial Economics*, 60(2–3), 2001, pp. 529–571.

Gallagher, Justin, "Learning about an Infrequent Event: Evidence from Flood Insurance Take-Up in the United States," *American Economic Journal: Applied Economics*, 6(3), 2014, pp. 206–233.

———, and Daniel Hartley, "Household Finance after a Natural Disaster: The Case of Hurricane Katrina," *American Economic Journal: Economic Policy*, 9(3), 2017, pp. 199–228.

———, ———, and Shawn Rohlin, "Weathering an Unexpected Financial Shock: The Role of Federal Disaster Assistance on Household Finance and Business Survival," *Journal of the Association of Environmental and Resource Economists*, 10(2), 2023, pp. 525–567

Garbarino, Nicola, and Benjamin Guin, "High Water, No Marks? Biased Lending after Extreme Weather," *Journal of Financial Stability*, 54, 2021, 100874.

Garmaise, Mark J., and Tobias J. Moskowitz, "Catastrophic Risk and Credit Markets," *The Journal of Finance*, 64(2), 2009, pp. 657–707.

Giglio, Stefano, Bryan Kelly, and Johannes Stroebel, "Climate Finance," *Annual Review of Financial Economics*, 13(1), 2021, pp. 15–36.

———, Matteo Maggiori, Krishna Rao, Johannes Stroebel, and Andreas Weber, "Climate Change and Long-run Discount Rate: Evidence from Real Estate," *The Review of Financial Studies*, 34(8), 2021, pp. 3527–3571.

Gilje, Erik P., Elena Loutskina, and Philip E. Strahan, "Exporting Liquidity: Branch Banking and Financial Integration," *The Journal of Finance*, 71(3), 2016, pp. 1159–1184.

Goldsmith-Pinkham, Paul, Matthew T. Gustafson, Ryan C. Lewis, and Michael Schwert, "Sea-Level Rise Exposure and Municipal Bond Yields," *The Review of Financial Studies*, 36(11), 2023, pp. 4588–4635.

Gramlich, Dieter, Thomas Walker, Yunfei Zhao, and Mohammad Bitar, "After the Storm: Natural Disasters and Bank Solvency," *International Journal of Central Banking*, 19(2), 2023, pp. 199–249.

Hallstrom, Daniel G., and V. Kerry Smith, "Market Responses to Hurricanes," *Journal of Environmental Economics and Management*, 50(3), 2005, pp. 541–561.

Hino, Miyuki, and Marshall Burke, "The Effect of Information about Climate Risk on Property Values," *Proceedings of the National Academy of Sciences*, 118(17), 2021, pp. 1–9.

Ho, Anson TY, Kim P. Huynh, David T. Jacho-Chávez, and Geneviève Vallée, "We Didn't Start the Fire: Effects of a Natural Disaster on Consumers' Financial Distress," *Journal of Environmental Economics and Management*, 119, 2023, 102790.

Holzheu, Thomas, and Ginger Turner, "The Natural Catastrophe Protection Gap: Measurement, Root Causes and Ways of Addressing Underinsurance for Extreme Events," *The Geneva Papers on Risk and Insurance-Issues and Practice*, 43(1), 2018, pp. 37–71.

Hong, Harrison, and Marcin Kacperczyk, "The Price of Sin: The Effects of Social Norms on Markets," *Journal of Financial Economics*, 93(1), 2009, pp. 15–36.

———, G. Andrew Karolyi, and José A. Scheinkman, "Climate Finance," *The Review of Financial Studies*, 33(3), 2020, pp. 1011–1023.

———, Frank Weikai Li, and Jiangmin Xu, "Climate Risks and Market Efficiency," *Journal of Econometrics*, 208(1), 2019, pp. 265–281.
Hosono, Kaoru, Daisuke Miyakawa, Taisuke Uchino, Makoto Hazama, Arito Ono, Hirofumi Uchida, and Iichiro Uesugi, "Natural Disasters, Damage to Banks, and Firm Investment," *International Economic Review*, 57(4), 2016, pp. 1335–1370.
Howe, Peter D., Matto Mildenberger, Jennifer R. Marlon, and Anthony Leiserowitz, "Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA," *Nature Climate Change*, 5(6), 2015, pp. 596–603.
Hsu, Po-Hsuan, Kai Li, and Chi-Yang Tsou, "The Pollution Premium," *The Journal of Finance*, 78(3), 2023, pp. 1343–1392.
Huynh, Thanh D., and Ying Xia, "Climate Change News Risk and Corporate Bond Returns," *Journal of Financial and Quantitative Analysis*, 56(6), 2021, pp. 1985–2009.
———, and ———, "Panic Selling When Disaster Strikes: Evidence in the Bond and Stock Markets," Management Science, 69(12), 2023, pp. 7448–7467.
Ichiue, Hibiki, "Negative Stock Market Reactions to Climate Disclosure Framework Endorsements," SSRN working paper, 2025 (available at http://dx.doi.org/10.2139/ssrn.5120286).
Ilhan, Emirhan, Philipp Krueger, Zacharias Sautner, and Laura T. Starks, "Climate Risk Disclosure and Institutional Investors," *The Review of Financial Studies*, 36(7), 2023, pp. 2617–2650.
———, Zacharias Sautner, and Grigory Vilkov, "Carbon Tail Risk," *The Review of Financial Studies*, 34(3), 2020, pp. 1540–1571.
Insurance Information Institute, "Background on: Earthquake Insurance and Risk," 2025. (available at https://www.iii.org/article/background-on-earthquake-insurance-and-risk)
Ito, Hiro, and Robert N. McCauley, "A Disaster Under- (Re) Insurance Puzzle: Home Bias in Disaster Risk-Bearing," *IMF Economic Review*, 70(4), 2022, pp. 735–772.
Karpf, Andreas, and Antoine Mandel, "The Changing Value of the 'Green' Label on the US Municipal Bond Market," *Nature Climate Change*, 8(2), 2018, pp. 161–165.
Klomp, Jeroen, "Financial Fragility and Natural Disasters: An Empirical Analysis," *Journal of Financial Stability*, 13, 2014, pp. 180–192.
Koetter, Michael, Felix Noth, and Oliver Rehbein, "Borrowers under Water! Rare Disasters, Regional Banks, and Recovery Lending," *Journal of Financial Intermediation*, 43, 2020, 100811.
Kousky, Carolyn, "The Role of Natural Disaster Insurance in Recovery and Risk Reduction," *Annual Review of Resource Economics*, 11, 2019, pp. 399–418.
Laeven, Luc, and Alexander Popov, "Carbon Taxes and the Geography of Fossil Lending," *Journal of International Economics*, 144, 2023, pp. 103797.
Lagarde, Christine, "Climate Change and the Financial Sector," Speech at the Launch of the COP 26 Private Finance Agenda in London on February 27, 2020 (available at https://www.bis.org/review/r200302c.pdf).
Larcker, David F., and Edward M. Watts, "Where's the Greenium?" *Journal of Accounting and Economics*, 69(2–3), 2020, pp. 101312.
Li, Qing, Hongyu Shan, Yuehua Tang, and Vincent Yao, "Corporate Climate Risk: Measurements and Responses," *The Review of Financial Studies*, 37(6), 2024, pp. 1778–1830.
Liang, Hao, and Luc Renneboog, "On the Foundations of Corporate Social Responsibility," *The Journal of Finance*, 72(2), 2017, pp. 1–59.
Massa, Massimo, and Lei Zhang, "The Spillover Effects of Hurricane Katrina on Corporate Bonds and the Choice between Bank and Bond Financing," *Journal of Financial and Quantitative Analysis*, 56(3), 2021, pp. 885–913.
Matsumura, Ella Mae, Rachna Prakash, and Sandra C. Vera-Muñoz, "Firm-Value Effects of Carbon Emissions and Carbon Disclosures," *The Accounting Review*, 89(2), 2014, pp. 695–724.
———, ———, and ———, "Climate-risk Materiality and Firm Risk," *Review of Accounting Studies*, 29(1), 2024, pp. 33–74.
Meng, Kyle C., and Ashwin Rode, "The Social Cost of Lobbying Over Climate Policy," *Nature Climate Change*, 9(6), 2019, pp. 472–476.
Morgan, Donald P., Bertrand Rime, and Philip E. Strahan, "Bank Integration and State Business

Cycles," *The Quarterly Journal of Economics*, 119(4), 2004, pp. 1555–1584.
Morse, Adair, "Payday Lenders: Heroes or Villains?" *Journal of Financial Economics*, 102(1), 2011, pp. 28–44.
Murfin, Justin, and Matthew Spiegel, "Is the Risk of Sea Level Rise Capitalized in Residential Real Estate?" *The Review of Financial Studies*, 33(3), 2020, pp. 1217–1255.
Nguyen, Duc Duy, Steven Ongena, Shusen Qi, and Vathunyoo Sila, "Climate Change Risk and the Cost of Mortgage Credit," *Review of Finance*, 26(6), 2022, pp. 1509–1549.
Noth, Felix, and Ulrich Schüwer, "Natural Disaster and Bank Stability: Evidence from the U.S. Financial System," *Journal of Environmental Economics and Management*, 119, 2023, 102792.
Ortega, Francesc, and Süleyman Taşpınar, "Rising Sea Levels and Sinking Property Values: Hurricane Sandy and New York's Housing Market," *Journal of Urban Economics*, 106, 2018, pp. 81–100.
Painter, Marcus, "An Inconvenient Cost: The Effects of Climate Change on Municipal Bonds," *Journal of Financial Economics*, 135(2), 2020, pp. 468–482.
Pástor, Lubos, Robert F. Stambaugh, and Lucian A. Taylor, "Dissecting Green Returns," *Journal of Financial Economics*, 146(2), 2022, pp. 403–424.
———, ———, and ———, "Sustainable Investing," NBER Working Papers Series No. 33252, National Bureau of Economic Research, 2024.
Ramelli, Stefano, Alexander F. Wagner, Richard J. Zeckhauser, and Alexandre Ziegler, "Investor Rewards to Climate Responsibility: Stock-Price Responses to the Opposite Shocks of the 2016 and 2020 US Elections," *The Review of Corporate Finance Studies*, 10(4), 2021, pp. 748–787.
Rehbein, Oliver, and Steven Ongena, "Flooded Through the Back Door: The Role of Bank Capital in Local Shock Spillovers," *Journal of Financial and Quantitative Analysis*, 57(7), 2022, pp. 2627–2658.
Sautner, Zacharias, Laurence Van Lent, Grigory Vilkov, and Ruishen Zhang, "Firm-level Climate Change Exposure," *The Journal of Finance*, 78(3), 2023, pp. 1449–1498.
Schlenker, Wolfram, and Charles A. Taylor, "Market Expectations of a Warming Climate," *Journal of Financial Economics*, 142(2), 2021, pp. 627–640.
Schüwer, Ulrich, Claudia Lambert, and Felix Noth, "How Do Banks React to Catastrophic Events? Evidence from Hurricane Katrina," *Review of Finance*, 23(1), 2019, pp. 75–116.
Shive, Sophie A., and Margaret M. Forster, "Corporate Governance and Pollution Externalities of Public and Private Firms," *The Review of Financial Studies*, 33(3), 2020, pp. 1296–1330.
Tang, Dragon Yongjun, and Yupu Zhang, "Do Shareholders Benefit from Green Bonds?" *Journal of Corporate Finance*, 61, 2020, 101427.
Uchida, Hirofumi, Daisuke Miyakawa, Kaoru Hosono, Arito Ono, Taisuke Uchino, and Iichiro Uesugi, "Financial Shocks, Bankruptcy, and Natural Selection," *Japan and the World Economy*, 36, 2015, pp. 123–135.
Uesugi, Iichiro, Daisuke Miyakawa, Kaoru Hosono, Arito Ono, and Hirofumi Uchida, "The Collateral Channel versus the Bank Lending Channel: Evidence from a Massive Earthquake," *Journal of Banking and Finance*, 170, 2025, 107315.
Vyshnevskyi, Iegor and Wook Sohn, "Central Banks' Support for Climate Action: A Literature Review and Key Issues," *Journal of Economic Surveys*, 2025 (available at https://doi.org/10.1111/joes.12709).
Zerbib, Olivier David, "The Effect of Pro-Environmental Preferences on Bond Prices: Evidence from Green Bonds," *Journal of Banking and Finance*, 98, 2019, pp. 39–60.
Zhang, Shaojun, "Carbon Returns Across the Globe," *The Journal of Finance*, 80(1), 2025, pp. 615–645.