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Understanding the Linkages between Climate Change and Inequality in the United States

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OVERVIEW

- The authors conduct a review of the existing academic literature to outline the possible links between climate change and income, wealth, and health inequality in the United States.
- Researchers have shown that the impact of both physical and transition risks may be uneven across location, income, race, and age. This is driven by a region's geography as well as its capacity to adapt.
- The measures that individuals and governments take to adapt to climate change and transition to lower emissions come with the risk of increasing inequality.
- Although federal aid and insurance coverage can mitigate the direct impact of physical risks, their structure may—inadvertently—sustain and entrench existing inequalities.
- This study concludes by identifying open questions and gaps in the literature that could benefit from additional exploration and research.

Although the effects of climate change on economic output and financial stability have received considerable attention in public discourse, scholarly literature, and policy discussions, the interactions between climate change and income, wealth, and health inequality[1] have received far less discussion. However, it is increasingly likely that climate change will not only have important effects on economic output, but it will also have profound effects on the geographic, socioeconomic, and demographic distribution of output. This article presents a literature review of the existing evidence on mechanisms by which climate change can affect economic inequality in the United States (see Appendix). First, we review whether risks from climate change affect populations and regions differently. Second, we consider whether institutions and policies around climate risk may have differential effects in different regions and on different communities. Finally, we identify open questions and gaps in the literature that could benefit from additional exploration and research. Ultimately, we

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use this article to evaluate recent contributions to the rapidly evolving environmental justice literature, bringing together works from often disparate fields such as insurance, financial intermediation, and consumption, as well as others. We frame some discussions in a novel way, using our own expertise in household finance, regulation, federal disaster management, and financial intermediation.

Risks associated with climate change can be decomposed into two categories: physical risks and transition risks. Physical risks refer to the potential for losses as climate-related changes (storms, droughts, floods, rising sea levels, and so forth) disrupt business operations, destroy capital, and interrupt economic activity. Transition risks refer to the potential for losses resulting from a shift in policy (for example, moving toward a lower-carbon economy), consumer sentiment, technological innovation, and other actions taken to resist climate change that will affect the value of certain assets and liabilities. We discuss in the sections below whether these physical and transition risks associated with climate change are uneven across geography, income, race, and age.[2]

We find multiple important channels, highlighted by various strands of the literature, that point to the hypothesis that the heterogeneity in the direct physical impacts of climate change, the differential ability of different regions to adapt, and the effects of climate policy and institutions may work to increase economic inequality. First, the literature on the geographic location of the direct physical impacts of climate change (see, for example, Hsiang et al. [2017]; Hsiang, Oliva, and Walker [2019]; Cruz and Rossi-Hansberg [2021]) suggests that regions of the United States that are home to above-average shares of low-income and minority groups are likely to suffer the greatest meteorological effects of climate change. In particular, the U.S. South, which has the lowest per capita income of the U.S. census regions, is predicted to experience the greatest level of total direct damages from climate change.

Second, a growing literature on household finance presents evidence that low-income and minority Americans are limited in how they may adapt to climate change because they have less access to insurance and are less likely to have access to credit when needed (see, for example, Atreya, Ferreira, and Michel-Kerjan [2015]; Kousky [2018]; Knighton et al. [2021]; Garmaise and Moskowitz [2009]). Moreover, another growing body of work suggests that a major mechanism for adapting to climate change worldwide will be migration to the United States from low-income countries that will be even more affected by climate change. This migration is likely to mechanically increase inequality (the indirect effects through wage pressures are more mixed). The literature on the labor market effects of transitions from high- to low-carbon technologies does not provide hard evidence that additional jobs will be created on net, and there may be some evidence that the jobs created will tend to require higher skills. On the other hand, there is a solid literature showing that adaptation to climate change in the United States so far has improved health outcomes for low-income and minority populations in the U.S. Southeast.

Finally, a large literature documents that institutions (such as the Federal Emergency Management Agency, or FEMA; bank and nonbank financial institutions; and the National Flood Insurance Program) can play an important role in mitigating the impacts of risks, including climate risks, but often provide aid in ways that sustain existing inequalities, even if inadvertently. Such a pattern pertains to the disbursement of disaster insurance, as well as to public policy in urban design and the siting of environmentally hazardous facilities.

1. Do The Physical Effects of Climate Change Increase Inequality?

In this section, we discuss whether the physical risks from climate change affect geographies and populations differently. We start with the geographic distribution of climate risk and find that the incidence of the direct physical impacts of climate change is very heterogeneous across regions. We then discuss whether climate change and disasters affect mortality, location of residence, productivity, conflict by demographics, socioeconomic characteristics, and geography.

1.1 Differences in the Regional Distribution of Climate Risk

Regional disparities in climate risk and natural disasters are undeniable. The Fourth National Climate Assessment (Carter et al. 2018) highlights that the U.S. Southeast is expected to be especially exposed to climate change. That region is home to three of the nation's five large cities with intensifying heat waves along multiple dimensions (including intensity, duration, and so forth)—Birmingham, New Orleans, and Raleigh—and is also uniquely exposed to vector-borne diseases. The U.S. Southeast also has a long ocean coastline that is highly exposed to hurricanes.[3] The National Climate Assessment states that "many Southern cities are particularly vulnerable to the effects of climate change compared to cities in other regions" because southern cities are disproportionately located in floodplains and have older infrastructure. The Southeast is not the only region expected to be affected by climate change. For example, the National Climate Assessment notes that the share of forest area burned by wildfires in the Southwest in 2015 would have been approximately half as large if not for the effects of climate change, while as recently as 1995, climate change accounted for only a small fraction of this share.

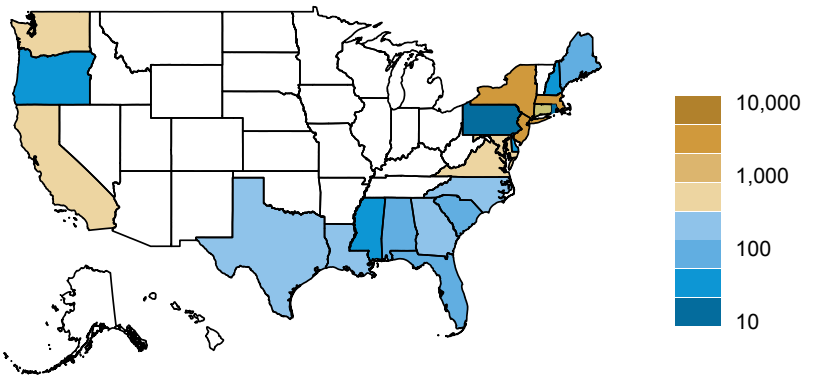
There may be further inequality in the impact of physical risks from climate change within regions if individuals who live in the most detrimentally affected areas also tend to be ex ante disadvantaged. Buchanan et al. (2020) identify the coastal states and cities where affordable housing—both subsidized and market driven—is most at risk of future flooding and rising sea levels (Exhibit 1). They find that residents in low-lying affordable housing, who tend to have low incomes and live in old and poor-quality structures, are especially vulnerable to a rise in sea levels and increased coastal flooding (see also Sisson [2020]). The U.S. Southeast has a longer coastline—from the Chesapeake Bay to the mouth of the Rio Grande—than any other region in the continental United States, making it particularly exposed to coastal flooding. In contrast, California and the mid-Atlantic region—New York, New Jersey, and Connecticut—have shorter coastlines but more dense economic activity on their coastlines.[4]

Evidence also indicates that already disadvantaged neighborhoods are particularly affected by the direct impacts of climate change. Bleemer and van der Klaauw (2017) find that after Hurricane Katrina, declines in homeownership of affected households were markedly smaller for individuals from predominantly white neighborhoods than for households from minority neighborhoods and also for individuals with high credit scores than those with low credit scores. A number of studies have also documented that homes in areas of higher flood risk are often discounted aggressively as a direct consequence of being exposed to this flood risk (see Bin and Polasky [2004]; Bin, Kruse, and Landry [2008]; Kousky [2010]; and Atreya, Ferreira, and Kriesel [2013]).

Exhibit 1

Regions Most at Risk of Flooding and Sea Level Rises

Expected Number of Units Exposed per Year



Source: Adapted from Buchanan et al. (2020), Figure 3, Panel A.

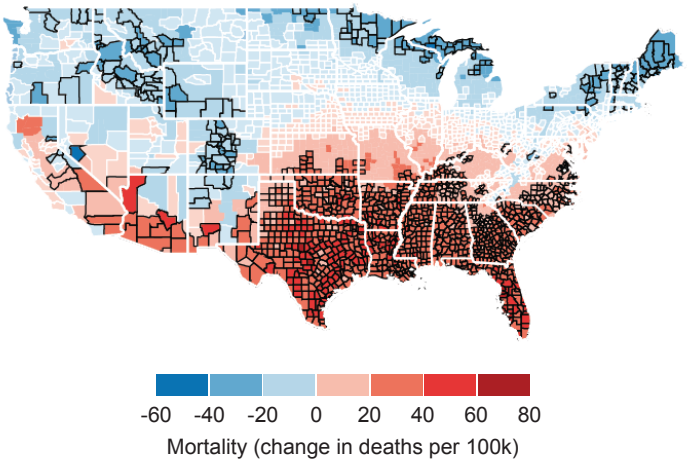
Notes: Using mean sea levels for the year 2000 as a baseline for comparison with future threat, 7,668 affordable housing units were found to be recently at risk of flooding per year in the United States. This map shows the total expected annual exposure of units (integrated across all units with nonzero exposure probability) and shows values for the affordable (subsidized plus market-driven) housing stock.

Lin, Ma, and Phan (2021) provide survey evidence that minorities are also disproportionately more likely to be located near environmentally hazardous sites despite being more worried about pollution. Banzhaf, Ma, and Timmins (2019) also present an excellent review of the literature that links the location choices of polluting industries or waste management facilities to disparate impacts by race and wealth. They help push the rapidly growing strand of "environmental justice" literature.[5] Multiple investigative journalism reports (see, for example, Plumer and Popovich [2020]) document that low-income and minority areas of many U.S. cities have considerably fewer green spaces and considerably more concrete paving than do more affluent and nonminority areas, and that these areas are also considerably hotter. Given that the climate damage function is likely convex (Hsiang, Oliva, and Walker 2019), similar increases in temperature of warmer city localities are likely to lead to greater damages to productivity and health than they would in cooler areas. In particular, Heilmann and Kahn (2019) document that the increased urban heat island effect in minority areas contributes to higher rates of violence in these areas.

Gillingham and Huang (2021) find that air pollution from maritime ports has uneven effects on health outcomes across racial groups. Increases in air pollution stemming from weather-driven vessel stays in port have led to three times as many hospital visits per capita among Black individuals in nearby communities as among white individuals. As climate change has increased the forest area consumed by wildfires in the West (Abatzoglou and Williams 2016), and as forest combustion generates particulate matter that pollutes the air, the health damages from climate change driven air pollution will be distributed unevenly across regions. Pollution from forest fires can affect regions far away from the location of the original fire. For example, pollution from the Bootleg Fire in Oregon reached Chicago and New York in July 2021 (Schwartz 2021), implying that western wildfires will continue to affect not just the Pacific West and the Northwest, but also areas far away from this region.

Exhibit 2A

Geographic Distribution of Effect of Warming on Mortality



Source: Hsiang et al. (2017), Figure 2B. Used by permission.

Notes: Map shows the change in all-cause mortality rates, across all age groups.

1.2 Distribution of Mortality Risks

Human beings are optimized for relatively mild temperatures, so extreme heat or cold tends to result in excess deaths. Climate change may affect mortality through increasing the prevalence of extreme heat, decreasing the prevalence of extreme cold, or increasing the prevalence of extreme temperatures through greater variance in the weather. Hsiang et al. (2017) look at the spatial difference in all-cause mortality rates across the United States. They find that warming reduces mortality in cold northern counties, while it increases mortality in hot southern counties (Exhibit 2A).[6] The resulting pattern induces substantial increases in mortality (up to 80 per 100,000) in the U.S. Southeast as well as parts of the Southwest (for example, southern Arizona), smaller mortality increases (20 per 100,000) at the latitudes of Maryland and Missouri, and mortality *decreases* in most of the Northeast, the northern part of the Midwest, some areas of the Plains and Mountain states, and in the Pacific Northwest.

In addition to extreme heat and cold, air pollution is expected to increase as a consequence of climate change (Abatzoglu and Williams 2016) and can have important distributional consequences. Findings from the large literature on air pollution suggest that even identical changes in the surrounding environment may affect disparate demographic groups differently, with less advantaged groups experiencing greater damages from adverse changes. Chay and Greenstone (2003) evaluate the effects of air pollution on infant mortality by using the variation in pollution reductions caused by the 1981-82 recession. They find that a 1 percent reduction in air pollution (measured by total suspended particulates, or TSPs) leads to a 0.35 percent decrease in the infant mortality rate in an average county.[7] The effects, however, are larger for Black infants: The mortality rate for Black infants at the county level is more sensitive to changes in TSPs. For "big" and "small" changes in TSP, the elasticity for Black

infant mortality is 0.46, whereas the elasticity for white infant mortality is 0.29. The finding suggests that improvements to air pollution are likely to yield substantially greater benefits to Black populations than to their white counterparts.

1.3 Differential Productivity Shocks by Sector

Another way in which climate change could increase inequality is by directly lowering productivity in certain industries that employ the poor and on which the poor rely, for example, agriculture. Declining agricultural yields may result in increased food prices (Crane-Droesch et al. 2019), and given that low-income communities spend a higher proportion of their budget on food, this can have disproportionate effects on them. However, Deschenes and Greenstone (2006) argue that, on average, the effects of climate change on U.S. agricultural productivity are ambiguous, with the best evidence (based on panel data associations between weather and agricultural outcomes) being consistent with very modest declines. Such an average result is reassuring from the point of view of food prices (which, in a frictionless market, should depend only on average agricultural productivity). Nevertheless, the effects of climate change on the agricultural sector may influence inequality through other channels. The Fourth National Climate Assessment (Carter et al. 2018) states that counties in the Southeast will lose the greatest number of labor hours, on average, relative to counties in other U.S. regions, largely because they disproportionately rely on rural economic activity that is particularly sensitive to changes in heat and humidity. More generally, Hsiang et al. (2017) show that climate change will generate improvements in agricultural productivity at higher latitudes and declines in agricultural productivity at lower ones. Exhibit 2B depicts the redistribution in agricultural yields across the United States, where the most negative impact is seen in predominantly lower-income counties in the South.

Like food, energy is an important component of the budget of low-income populations. Hsiang et al. (2017) provide evidence that energy expenditures are likely to disproportionately rise in the Southeast as a consequence of climate change, which may disproportionately affect low-income individuals.

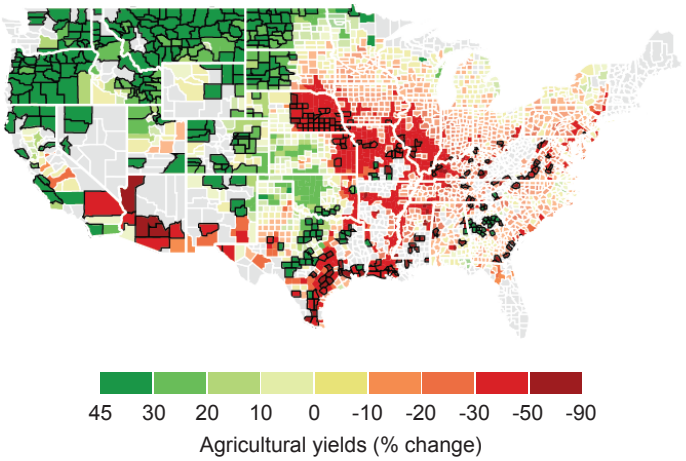
It is worth considering the direct effects of climate change on economic activity more generally. Tran and Wilson (2020) investigate the effect of natural disasters and find evidence of increases in per capita personal income over the long run, although they find considerable heterogeneity in impacts by pre-disaster county income. Differentiating by quartiles of pre-disaster county income, they find that counties with below-median pre-disaster income per capita did not see an increase until six years after the disaster, while above-median counties saw an increase one year after the disaster. Therefore, climate change may make the distribution of economic activity more unequal even without affecting it on average.[8]

1.4 Distribution of Climate Effects on Conflict

Additionally, there is research showing that extreme climate conditions increase conflict and crime. Burke, Hsiang, and Miguel (2015) conduct a meta-analysis of fifty-five studies encompassing developed and developing countries, including the United States. They show that deviations

Exhibit 2B

Redistribution in Agricultural Yields across the U.S.



Source: Hsiang et al. (2017), Figure 2A. Used by permission.

Notes: Map shows percentage change in yields, area-weighted average for maize, wheat, soybeans, and cotton.

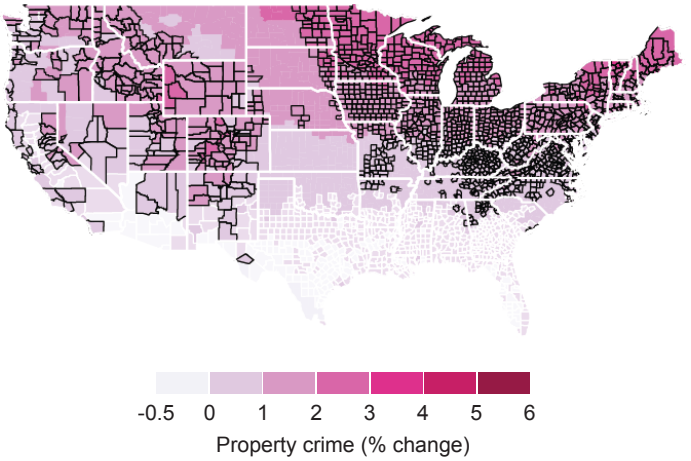
from moderate temperatures and precipitation patterns systematically increase the risk of conflict, with contemporaneous temperatures having the largest average impact on interpersonal and intergroup conflict. They also find that in low-income settings, extreme rainfall events—too much or too little rain—that adversely affect agricultural income are associated with higher rates of personal violence and property crime. Relatedly, Hsiang et al. (2017) present the spatial distribution of the expected effect of climate change on property crime and violent crime rates across the United States (Exhibits 2C and 2D). They find that the effect on violent crimes is uniform across locations, while the effect on property crimes is more concentrated in the North. Hence, rising crime is likely to work *against* the tendency for regional inequality to increase, which we observe from the other channels considered.

1.5 Summary

The literature we reviewed shows that physical risks from climate change exacerbate inequality by income, race, and geography, with the U.S. Southeast experiencing more direct physical risks than other parts of the country. These physical risks from climate change take the form of differences in effects on mortality, housing, consumer finance, conflict, and geography. Taking into account a large number of factors, including agricultural yields, mortality, energy expenditures, risks to labor, coastal damage, property crime, and violent crime, Hsiang et al. (2017) compute a measure of total direct damages from climate change for

Exhibit 2C

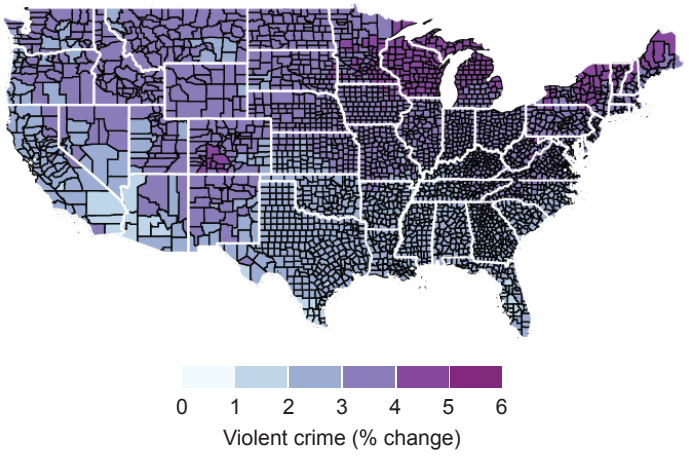
Spatial Distribution of the Expected Effect of Climate Change on Property Crime



Source: Hsiang et al. (2017), Figure 2G. Used by permission.

Exhibit 2D

Spatial Distribution of the Expected Effect of Climate Change on Violent Crime Rates

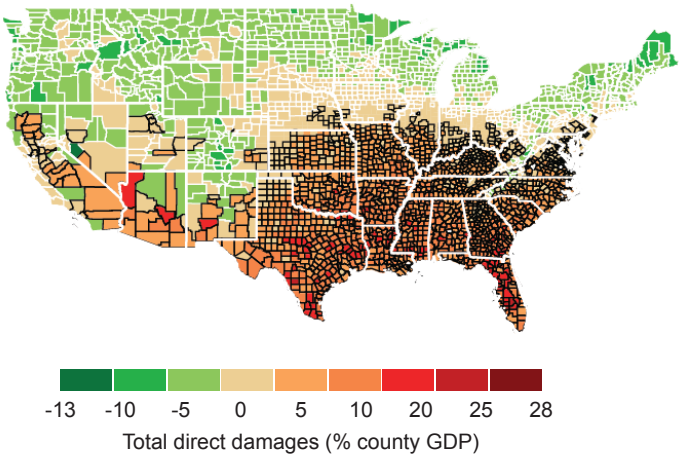


Source: Hsiang et al. (2017), Figure 2H. Used by permission.

U.S. counties, which is illustrated in Exhibit 2E. Warming due to climate change results in a net transfer of value from Southern, Central, and mid-Atlantic regions toward the Pacific Northwest, the Great Lakes region, and the Northeast. This echoes the consensus that damages from climate change will be distributed very unevenly across different parts of the United States. The pre-existing inequality between the U.S. Southeast and the rest of the country will possibly be exacerbated by climate change. We next turn to transition risks and review whether they have unequal effects across populations and geography.

Exhibit 2E

Total Direct Damages from Climate Change for U.S. Counties



Source: Hsiang et al. (2017), Figure 2I. Used by permission

Notes: Map shows median total direct economic damage across agricultural yields, mortality, energy expenditures, low-risk labor, high-risk labor, coastal damage, property crime, and violent crime.

2. Does Adapting to Climate Change Increase Inequality?

Adapting to climate change, according to the Intergovernmental Panel on Climate Change (IPCC), is defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Parry et al. 2007). This could be understood as adjustments made in terms of changing existing technologies or innovating new ones or as a decision to migrate away from areas with higher climate risk.

Besides the unequal distribution of the direct physical impacts of climate change, unequal reaction to these impacts plays at least as large a role in shaping the way in which climate change may affect inequality. In fact, Dell, Jones, and Olken (2012) find that the magnitude of short-run effects of temperature on economic activity is so large that absent adaptation, just eight years of temperature differences across countries would be sufficient to explain present-day cross-country income differences. Dell, Jones, and Olken (2008) find that economic activity in countries with higher GDP shows very little sensitivity to changes in temperature and precipitation because of better adaptation (such as, potentially, air conditioning and other infrastructure to reduce exposure to extreme heat), while poorer countries see considerably larger effects, both to their level of output and to their long-run growth rate. The findings of these studies have implications for U.S. regions, suggesting that poorer regions in the United States—specifically, the South—may see larger level and growth effects from climate change than would richer U.S. regions.

2.1 Innovation

There is evidence that some adaptation to climate change has proceeded in ways that reduced inequality. Barreca et al. (2016) focus attention on the spread of health-related innovations: residential electricity and residential air conditioning. These innovations have helped mitigate the health consequences of hot temperatures, especially for populations that are more vulnerable, for example, individuals age 65 or above and Black residents relative to white residents. Electrification has enabled a wide variety of innovations, including fans, refrigeration, and air conditioning. Air conditioning has made it possible to reduce the stress on health during periods of extreme heat.[9]

The projected increase in electricity consumption naturally necessitates the construction of more power plants; many still use conventional fuel as an energy source. The location choice of these new power plants can have far-reaching implications, however. Work by Davis (2011) suggests that new power plants drive down local house prices. Moreover, power plants appear to change neighborhood composition, with predominantly lower-income households remaining close to operational plants.

Apart from this, increased access to health care has enabled both preventive treatment and emergency intervention, such as the intravenous administration of fluids in response to dehydration. Another innovation that has garnered attention is elevating homes in flood-prone areas to reduce potential damage. However, access to some of these adaptations is likely not equally distributed; rather, they tend to vary markedly by income (for example, it costs nearly $50,000 to elevate an average house, a substantial fraction of median household income).[10]

2.2 Labor Market Effects

As the United States transitions from a high-carbon to a low-carbon economy, changes in the labor market become an important channel through which adapting to climate change may affect inequality. Acemoglu et al. (2012) and Cruz and Rossi-Hansberg (2021) document that such a transition is expected to take place to avoid an environmental disaster or depletion of energy resource. Metcalf and Stock (2020) use the variation in European carbon price adoption across space and time to conclude that the effects of plausible increases in U.S. carbon prices on employment should be minor, while Hafstead and Williams (2018) reach a similar conclusion using a computable general equilibrium model. However, the aggregate result masks considerable variation in job destruction and job creation across industries. Greenstone (2002) and Castellanos and Heutel (2019) show that jobs in fossil-fuel industries are likely to bear the brunt of the job destruction, requiring substantial reallocation of workers if employment overall is to remain steady.[11] Vona et al. (2015) document that environmental regulation will reward "green skills," among which are "high-level analytical and technical know-how related to the design, production, management and monitoring of technology," an outcome that likely may increase inequality by rewarding already highly valued and expensive-to-obtain skills. Popp et al. (2020) consider the impact of the green component of spending under the American Recovery and Reinvestment Act, finding that it created fewer jobs than similar nongreen components of the act, and that while the jobs were mostly in manual labor, they still required some college education and did not change equilibrium

wages. Therefore, the literature seems to provide evidence for only marginal changes to aggregate employment, with gross jobs created likely to require higher skills.

However, the risks that labor markets face from transitioning to a lower-carbon economy need to be balanced with the physical risks of productivity declines from climate change. Isen, Rossin-Slater, and Walker (2017) study the impact of early childhood exposure to pollution on labor outcomes for adults in the United States. They find a significant relationship between early exposure to pollution and lower labor force participation as well as lower earnings at age 30. Hsiang et al. (2017) find noticeably negative effects of warming on productivity across a wide variety of sectors, but especially for occupations that face considerable outdoor exposure. It is reasonable to expect that these productivity risks will also be distributed in ways that disfavor individuals in less advantaged occupations.

2.3 Effects of Climate-Change-Induced Migration on Inequality

Another important factor to consider is migration and how uneven migration patterns following a disaster may be across different social groups. Individuals from high-income areas are more likely to move following a disaster, just as households in predominantly white neighborhoods are more likely to migrate after a disaster (Bleemer and van der Klaauw, 2017; Tran and Sheldon, 2017). Interestingly, Fussell, Sastry, and VanLandingham (2010) show that after Hurricane Katrina, Black residents actually returned to New Orleans at a much slower pace than white residents. The delayed return was driven by the more severe housing damage that Black residents faced because they tended to live in areas that experienced greater flooding. Moreover, climate change may be leading formerly minority communities to gentrify at a more rapid rate. For example, because of their relatively high elevation in the Miami-Dade metro area, traditionally minority neighborhoods, such as Liberty City and Little Haiti, are seeing rising property values that are making homes unaffordable for residents, reflecting the new preference for high elevation (see Harris 2018). This combination of rising prices in higher-elevation neighborhoods and declining property values in more exposed coastal areas may further contribute to the cycle of disproportionate exposures to rising sea levels in low- and moderate-income communities. Bakkensen and Ma (2020) also find clear evidence that low-income and minority residents are more likely to move into high-risk flood zones. These findings highlight the difference by income and race in both the ability to migrate to better outcomes after a negative disaster shock and in being pushed out to locations more susceptible to climate risk.

More generally, migration is likely to be key to mitigating the direct impacts of climate change, so it is important to consider the broad implications of migration for inequality. Cruz and Rossi-Hansberg (2021) find that optimal migration responses to climate change would entail large population flows from the global South to the global North (including to the United States) and would halve the decline in economic activity that would be caused by climate change in the absence of migration. Therefore, it is possible that the United States would receive substantially more immigrants from poorer countries because of climate change, with the U.S. Southwest a likely initial destination for many of them since it is geographically closest to the U.S. land border with Mexico. Mechanically, an inflow of individuals considerably poorer than the average of the receiving population should increase inequality, and

Card (2009) suggests that these mechanical effects create small but positive increases in inequality in general equilibrium. However, there is a debate on whether low-skill immigration lowers wages in low-skill occupations, with, for example, Borjas (2017) and Peri and Yasenov (2015) taking opposing views. Nevertheless, the mechanical effects of immigration alone should contribute to higher inequality within U.S. borders, although they are likely to contribute to lower inequality in the world taken as a whole.

2.4 Summary

Societal and economic adaptations to climate change will take many forms. Although technological innovations and adaptations may improve some communities' resilience to heat and disease, it is the higher-income communities and populations that are more likely to benefit. Many regions of the United States are likely to face labor market disruptions as the economy adapts to new climate and regulatory challenges. Although small in the aggregate, these labor market disruptions are likely to primarily affect poorer households and communities throughout the South. Moreover, as people leave areas in Central and South America that suffer particularly large damages from climate change, large scale migration to the United States is likely to place pressure on—and adversely affect inequality in—the South, which is the region closest to the U.S.-Mexico land border.

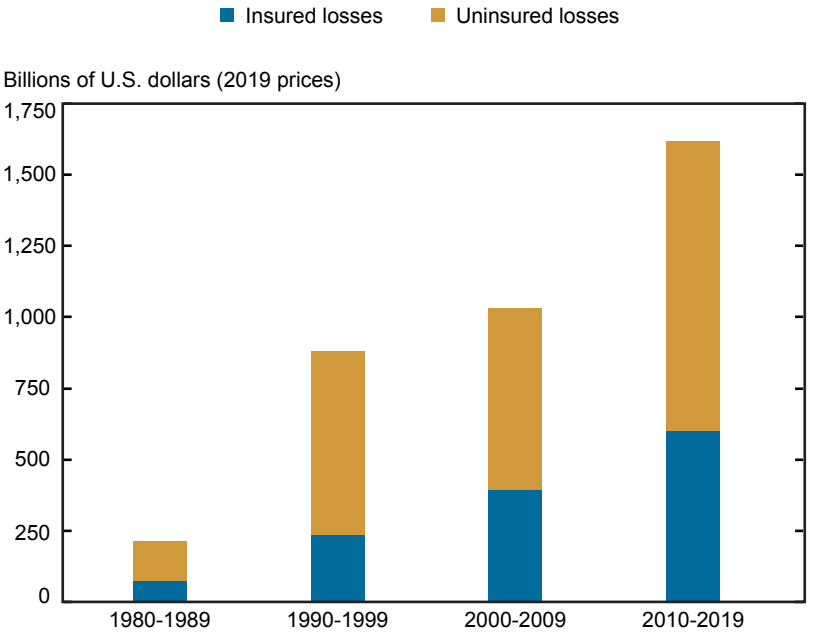
3. Do Institutions Tackling Climate Change Increase Inequality?

Along with the gaps created between different communities due to the direct losses from climate change, the ability to migrate, and access to mitigating technology, another important factor to consider is the role of institutions and policies. The most prominent institution is insurance —both individual and federal disaster insurance. The provision and take-up of both types of insurance, along with the provision of credit, are often correlated with the pre-existing wealth and racial composition of a region. This means that the uneven distribution has the potential to create further imbalance, especially in areas that are ex ante economically depressed.

3.1 Insurance

The availability of private insurance significantly affects the long-term economic costs of natural disasters for individual households. Uninsured losses are a primary driver of the adverse macroeconomic consequences that follow a disaster (von Peter, von Dahlen, and Saxena 2012). In the United States, mortgage lenders are able to require flood insurance in regions designated "flood zones" by FEMA as part of the mortgage contract.[12] However, as Kousky (2018) finds, natural disasters have recently flooded historically safe areas, leading to losses for uninsured households. Chart 1 shows that uninsured losses have been rising globally in recent years as disasters become more frequent and severe. This increase has been most

Chart 1
Global Uninsured Losses over Time Resulting from Natural Disasters



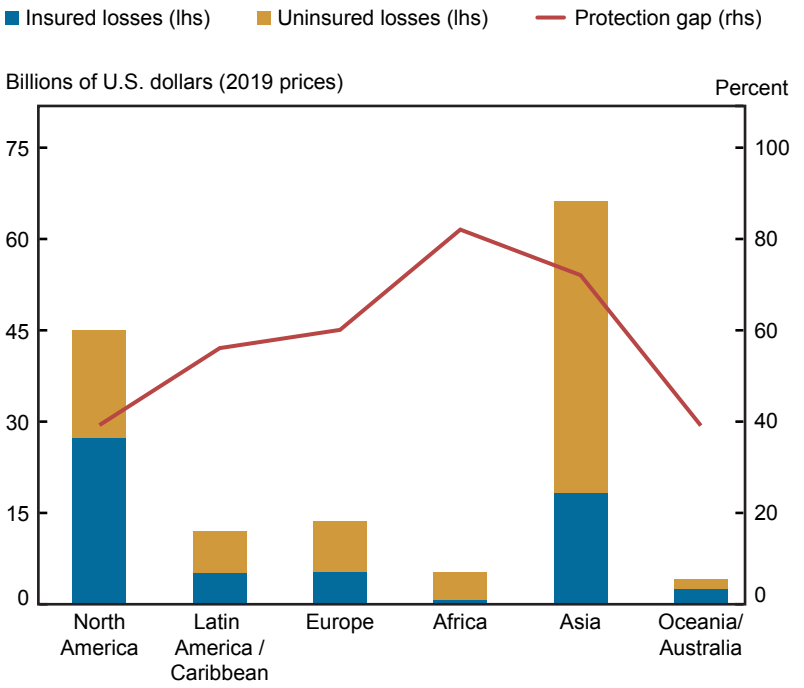
Source: Financial Stability Board. 2020. "The Implications of Climate Change for Financial Stability," November 23, p. 11, citing data from Swiss Re Institute.

severe in less developed countries, where insurance penetration remains much lower than in, for instance, the United States (Chart 2).

Even within the United States, the take-up of insurance varies a great deal and insurance penetration remains relatively low. Atreya, Ferreira, and Michel-Kerjan (2015) analyze flood insurance purchasing behavior using data for Georgia from the National Flood Insurance Program (NFIP), which provides federally subsidized flood insurance to property owners and renters. They find that education plays a significant role in a person's willingness to purchase flood insurance. Households with more education are more likely to purchase flood insurance. Additionally, in the sample of people studied, individuals over the age of 45 and African Americans are, all else equal, more likely to purchase insurance. Another reason for low NFIP take-up may be its pricing. As Kousky (2018) points out, given minimum insurance thresholds, the NFIP is disproportionately overpriced for people insuring low-value properties, inadvertently making such insurance relatively unattractive.

The NFIP helps those households that are able to make use of it to rebuild after a disaster. Unfortunately, this tends to prevent some lower-income households that would wish to relocate to a safer area from doing so. As a consequence, the NFIP frequently rebuilds the same properties several times, although it would have been far cheaper to help the insured family relocate.[13] As a result, some low-income households are inadvertently trapped, since they are unable to move away from areas at risk for natural disasters—or are even drawn to those areas (National Resource Defense Council 2017; Peralta and Scott 2018).

Chart 2
Global Comparison of Uninsured Losses Resulting from Natural Disasters



Source: Financial Stability Board. 2020. "The Implications of Climate Change for Financial Stability," November 23, p. 24, citing data from Swiss Re Institute.

A study by Knighton et al. (2021)[14] examines differences in flood-risk mitigating behavior by race. Using data on flood insurance loss claims and active insurance policy records from fifty U.S. metropolitan areas, they identify two types of communities: "risk-enduring," with lower flood defenses, and "risk-averse," with higher defenses. They find that behaviors are strongly related to the composition of cities—including by race. Risk-averse patterns are found in areas with larger dams and a higher proportion of white residents, while the opposite is true in risk-enduring metro areas. In risk-enduring cities, a steep rise in the purchase of flood insurance policies is seen after flooding, then purchases decline quickly. In risk-averse cities, the number of flood insurance policies tends to be more stable with few fluctuations. Major floods lead to a slight increase in insurance take-up, and the level does not drop off again over time.

It seems natural that the desire to purchase insurance is correlated with risk awareness, which is itself, of course, affected by the occurrence of recent disasters. Ganderton et al. (2000) and Petrolia, Landry, and Coble (2013) show that demand for insurance grows as disasters become more likely. They further show that insurance take-up rises as the cost of insurance falls (relative to the underlying risks), with the price acting as an important determinant of actual insurance take-up. Pricing, however, may be affected by increased risk.[15] Tesselaar et al. (2020) model the take-up—and profitability—of general disaster insurance under various theoretical future climate paths. They find that, as climate risks increase and disaster insurance is priced to reflect these risks accurately, insurance will likely become unaffordable for large groups of people without subsidies. In recent work, Blickle and Santos (2022) find that

accurately priced mandatory flood insurance significantly reduces the ability of low-income or low-FICO-score households to access mortgage credit. The added costs are a deterrent to both borrowers, who cannot make payments, and lenders, who fear borrowers' non-compliance with mandates.

The Risk Management and Decision Processes Center at the University of Pennsylvania has proposed public-private partnerships to promote low-cost micro-insurance with the hope of facilitating an increase in the take-up of insurance.[16] Currently, such projects are not yet ready for wide implementation. Naturally, the state can also help guarantee the provision of private insurance through direct action. For example, California prevented insurers from cancelling or aggressively repricing fire insurance policies in zip codes surrounding the areas affected by the Kincade fire. This primarily affected residents of Sonoma County and prevented insurers from cancelling maturing insurance contracts during or directly following the fire. State governments recognize, however, the limited efficacy of such policies in providing long-term insurance coverage for residents and investors in high-risk areas.[17]

Insurance is an integral mechanism through which communities recover from and adapt to climate change. However, in some communities, insurance take-up is low and too often occurs after a disaster has struck. Moreover, due to pricing, already disadvantaged groups—particularly low-income individuals—may be less able to take advantage of the possibilities that insurance offers or will otherwise be forced out of certain markets in the future.

3.2 Financial Intermediation and Consumer Credit

A number of studies have found correlations between increased disaster risk and lending. It appears, however, that these correlations are further affected by the race and wealth of the individuals and communities affected by climate change. Disasters are usually followed by an increase in the demand for credit. However, insurance market imperfections with incomplete coverage of catastrophic events can restrict the supply of post-disaster credit as banks become less willing to finance certain ventures in high-risk areas (see Garmaise and Moskowitz 2009). The authors show that the higher earthquake risk in California actually led to a decrease in commercial real estate bank loans in the 1990s. Importantly, the authors show that this effect of credit rationing was more severe for Black communities where insurance provision was less prevalent.

Cortés and Strahan (2017) show that banks use their internal capital markets to reallocate mortgage credit to areas affected by disasters. However, they show that banks primarily do this in support of their core markets, withdrawing funds from regions in which they have a smaller or no presence to fund rebuilding efforts. Although long-term effects may depend on the provision of credit by other entities, it is nevertheless evidence of existing bank-funding reallocation following a disaster.[18] Ivanov, Macchiavelli, and Santos (2022) document that a similar reallocation takes place with corporate credit. They also present evidence that the shadow banking system may somewhat attenuate this mechanism for now. Nevertheless, such a reallocation of credit may exacerbate the tendency of economically underdeveloped regions to be underbanked as credit is directed to markets or customers considered "key" for a bank. These effects are not limited to the United States.

Another phenomenon of adverse lending responses to climate change is a practice known as "bluelining," which refers to banks refusing to make loans in areas that they deem susceptible to flooding or being submerged. Bluelining results in the degradation of neighborhoods in flood plains, as poor infrastructure begets more flooding, which begets worse flood scores and zoning, further resulting in less investment and housing opportunities (see Kaufman 2020). Having federal rebuilding assistance funds be linked to the value of the house, as they typically are, further disadvantages low-income communities.

The impacts of increased disaster risk on financial intermediation are not unique to households; entire regions can be negatively affected. Painter (2020) shows that poorer communities with lower credit ratings, which face long-term flood risk, pay more in terms of underwriting fees and initial yields to issue long-term municipal bonds than comparable but more affluent communities. This negatively affects the ability of such communities to issue bonds and, hence, finance important long-term projects (such as infrastructure development). The phenomenon reflects the market's expectation that some—wealthier—communities will be better placed to deal with the impact of climate disasters.

As a result, having access to credit is particularly valuable in the wake of a natural disaster. A number of papers document that credit card use rises after a natural disaster as households attempt to smooth the financial shock through borrowing (Gallagher and Hartley 2017; Tran and Sheldon 2017). However, access to this adaptation mechanism is not uniform across demographic and socioeconomic characteristics. Banked households have better credit access, and minority and low-income households are more likely to be unbanked (Federal Deposit Insurance Corporation 2020). For example, 14 percent of households with incomes of less than $40,000 are unbanked compared to 2 percent of households with incomes between $40,000 and $100,000 and 1 percent of households with incomes above $100,000. Disparities prevail by race as well. While 4 percent of white individuals are unbanked, the numbers are 14 percent and 11 percent, respectively, for Black and Hispanic individuals (Morgan 2021). The most important reason cited by respondents for not having a bank account is that they do not have enough money to meet minimum balance requirements (Federal Deposit Insurance Corporation 2020).

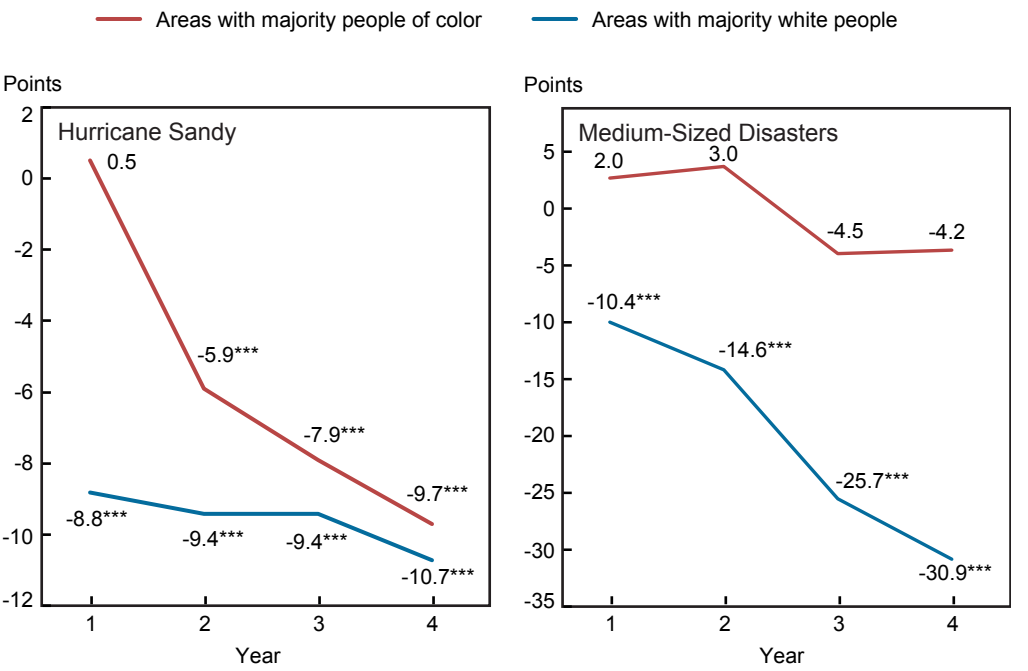
Lack of access to the financial system may lead low-income individuals and people of color to be less equipped to combat the direct physical impacts of climate change. The existing gaps in access to credit can be exacerbated following a natural disaster. Tran and Sheldon (2017) also find a higher incidence of adverse credit conditions following disasters, such as bankruptcies, for low-income households.

Matching FEMA data to the New York Fed Consumer Credit Panel and using a distributed lag model, Avtar, Chakrabarti, and van der Klaauw (2022) study the effect of two types of disasters—hurricanes and floods—on household debt outcomes and investigate whether these outcomes vary by income and race. Their preliminary findings indicate that borrowers from predominantly minority, predominantly Black and low- to moderate-income (LMI)[19] neighborhoods are worse off after disasters, as reflected in the lower probability of taking out auto and mortgage loans, but higher mortgage delinquencies. Borrowers in these neighborhoods had lower credit utilization, yet increases in credit card delinquencies. The authors also find higher migration out of LMI counties after those areas were hit by hurricanes.

Relatedly, Ratcliffe et al. (2019) find that the effects of natural disasters on inequality in credit outcomes are heterogeneous by disaster size because access to FEMA aid is often contingent on disaster size and associated losses. They find that medium-sized disasters are

Chart 3

Change in Credit Score Due to Different Sized Disasters, by Area Composition and Year(s) after Disaster



Sources: Urban Institute calculations based on credit bureau, ACS, and FEMA data, Ratcliffe et al. (2019), p. 24.

Notes: Values represent estimates of average differences in credit scores between individuals affected by the indicated disaster (or set of disasters) and matched individuals from unaffected areas. Effects are estimated separately for each of the four years following the disaster.

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

considerably more likely to widen inequalities compared to large disasters. Specifically, they show that people living in majority-minority communities that are hit by medium-sized disasters experienced, on average, a 31-point decline in credit scores four years after the disaster compared with a 4-point decline for affected people in majority white communities (Chart 3). In contrast, credit scores in majority-minority communities four years after Hurricane Sandy declined less in comparison to that in majority-white communities (10 points versus 11 points).

To summarize, the financial system provides an essential service by reallocating credit to areas experiencing natural disasters. However, the way in which it does so tends to be uneven, with already less affluent, minority-heavy, and underbanked communities benefiting less. The financial system may also disproportionately withdraw credit from such communities unaffected by disasters when a strong need for liquidity arises in a core banking market. Additionally, the literature uncovers substantial inequalities in access to credit, which appear to be softened by disaster relief insurance, such as FEMA aid. The existence of federally provided aid appears to reduce post-disaster inequality considerably relative to the baseline of no aid being distributed. However, this does not imply that the process for distributing FEMA aid is equitable, which will be discussed in the next section.

3.3 Policy

State aid constitutes an important factor in how regions and individuals rebuild after natural disasters. In the United States, FEMA can compensate even uninsured households after certain disasters. FEMA disasters are declared by the president after a natural disaster at the request of the governor(s) of the state(s) in which the disaster takes place. FEMA can then help small businesses and individuals through direct payments and typically allocates funds in accordance with needs.[20] FEMA payouts have, however, been found to be unequal across regions. For example, Billings, Gallagher, and Ricketts (2019), studying the effects of Hurricane Harvey, find that residents of poorer neighborhoods received 5 percent less in FEMA assistance, after controlling for damages, than residents of wealthier neighborhoods. The authors find that this effect may be exacerbated by race. A one standard deviation increase in the share of minority homeowners is associated with a 14.4 percent decline in the probability that the registrant is approved for FEMA assistance. Willison et al. (2019) find that disaster relief aid, as measured by all federal funds allocated to an area, was greater and timelier after hurricanes affecting Florida and Texas than after hurricanes that hit Puerto Rico. This difference is more pronounced after controlling for the damage and death toll of the disasters.

Howell and Elliot (2018, 2019) analyze the long-term wealth implications of natural disasters and their heterogeneity by income and race. They find that FEMA aid may have played a role in widening wealth gaps between white families and families of color. White households living in counties that experienced significant disasters and received substantial FEMA aid accumulated more wealth than their counterparts in counties that received very little FEMA aid. However, Black respondents living in counties that received substantial FEMA aid accumulated less wealth than their counterparts living in unaffected counties. The authors suggest that disaster relief aid, if not implemented with an awareness of existing inequalities, can exacerbate inequalities.

In summary, FEMA payouts or similar state aid may be a crucial way for communities and individuals to recover from a natural disaster. However, the above studies make it apparent that significant disparities exist in FEMA aid across different communities, even conditioning on the level of damages. The disparities in payout may inadvertently widen existing inequalities.

Another channel through which climate change may affect inequality is the measures that national, state, and local governments take to decrease carbon emissions. Fullerton (2011) lists six potential effects of a carbon permit system that could potentially have regressive effects on income distribution, including higher relative prices of carbon-intensive goods, allocations of scarcity rents from permits, and changes in the relative returns to assets in which the rich and the poor invest. Although climate policy need not necessarily be regressive (Pizer and Sexton, 2020), some important existing policies, such as clean energy tax credits, appear to be (Borenstein and Davis 2016). It may also be likely that when choosing between different policy responses to climate change, such policies may give greater weight to the preferences of higher-income individuals than those of lower-income individuals (Bartels, 2018) and follow a direction that places the burden of transitioning to cleaner energy disproportionately on the poor.

Government-sponsored enterprises often provide mortgage forbearance in the wake of natural and other disasters, and federal agencies often encourage mortgage servicers to provide relief to struggling homeowners (see Sorohan [2018]; Coloretti [2012]; Board of Governors of Federal Reserve System [2020]). However, mortgage forbearance can increase inequality.

Mortgagors are typically wealthier, and wealthier households usually have larger mortgage balances. As a result, mortgage forbearance can provide a relatively greater benefit to wealthier households (Chakrabarti et al. 2020).

Also important are the ways in which environmental policy can play a significant role in mitigating inequality. In their study of racial disparities in pollution exposure from 2000 to 2015, Currie, Voorheis, and Walker (2021) find that the $PM_{2.5}$ National Ambient Air Quality Standards (under the authority of the Clean Air Act) explain the convergence in the pollution exposure gap between African American and non-Hispanic white individuals over time.[21] Air pollution regulation and, more specifically, the Clean Air Act (CAA) itself, however, still have much room for improvement. In an extension of their 2019 finding of heterogeneity in the U.S. elderly population's vulnerability to air pollution, Deryugina et al. (2021) show that basing air quality regulation on current pollution levels alone fails to reach areas with the most to benefit from cleaner air, that is, regions with large populations of vulnerable individuals in terms of health and socioeconomic status. Furthermore, Chay and Greenstone (2005) show that for CAA nonattainment counties—counties that exceeded the ceiling set for air pollution (measured by TSPs) by the CAA, there may be heterogeneity in the effect of reduced air pollution on housing values. The authors find that, through the CAA, nonattainment counties experienced large reductions in TSP air pollution and increases in housing prices at the county level.[22] However, they also find some evidence of a decreasing marginal benefit of cleaner air to homeowners in communities with high pollution levels.[23]

3.4 Summary

Institutions attempt to alleviate the impact of climate change in a number of ways. However, these measures can inadvertently increase inequality. Insurance payouts, for instance, help a region recover, though private insurance may be too expensive for some households. Subsidized national insurance suffers from low take-up rates among the most vulnerable. In part, this may be a consequence of the relative mispricing of insurance for low-value properties. Disaster payouts from organizations like FEMA have a large impact. However, FEMA payouts have been shown to exacerbate existing inequalities. Similarly, bank lending is crucial to enable regions to recover after a natural disaster, though banks have been shown to give priority to core markets. Entire low-income communities at risk of climate change, as a whole, have even found it difficult to raise funds. Finally, critical public policies for mitigating climate change may be implemented in ways that miss the groups that are particularly affected by its damages. To avoid exacerbating existing inequalities, programs and public policy that govern payouts and incentives to lend may have to be amended to better respond to the combined challenges of climate change and existing structural issues.

4. Directions for Future Research

The different strands of the literature that we cite provide evidence that climate change is likely to increase inequality, but more research into the precise pathways by which it might do so is needed. Below are several follow-ups that we have identified based on what the most current work in the literature does not yet address.

4.1 Indirect Effects of Credit Chains

The literature in Section 3.2 documents that banks reallocate credit toward areas that suffer natural disasters and away from the rest of their network. It would be important to understand the distributional consequence of these reallocations. Do consumer loans or small business loans shrink in relative terms when another area in the bank network experiences a natural disaster? How is the decline in lending distributed across demographic groups? It is important to understand whether the indirect effects of the rerouting of credit are substantial and whether focusing on areas that experience natural disasters may hide important channels through which climate change affects inequality elsewhere.

4.2 Financial Markets, Climate Risk, and Inequality

There are concerns that climate change may cause a rapid change in asset valuations that may destabilize the financial system (Carney, 2015). Hong, Li, and Xu (2019) present evidence that asset markets, including in the United States, inefficiently price drought risk in agriculture, relating their findings explicitly to these policy concerns. However, Schlenker and Taylor (2019) present evidence that markets incorporate temperature risk into asset prices, concluding: "When money is at stake, agents are accurately anticipating warming trends in line with the scientific consensus of climate models." Although the literature on market efficiency (and inefficiency) is voluminous, the application of this literature to the possibility of systematic underpricing of climate risk is scant. Clearly, if such systematic underpricing were rapidly reversed, this would have important implications for inequality as well as for aggregate growth. On the other hand, establishing that markets efficiently incorporate climate risk would provide important clarity.

4.3 Heterogeneous Impacts of Mechanisms for Awarding Disaster Aid

Section 3.3 discusses evidence that there may be disparities in the way that disaster aid agencies, such as FEMA, allocate funds to individuals affected by climate change. It would be useful to analyze the sources of these disparities, drawing on the literature for the sources of demographic disparities in bank lending, such as Bhutta, Hizmo, and Ringo (2021) and the articles cited therein. It would be useful to distinguish, as the above article does, between disparities created as a function of disparate covariates that enter into algorithms, disparities created through program officers' discretion, and disparities created through aid applicants' differential ability and their willingness to disclose information.

As discussed in Section 2.1, elevating homes in flood-prone areas is key to protecting the property against future disaster damage (Fixr 2021). Such innovations guard against future flooding and, additionally, reduce flood insurance costs. However, there are bureaucratic barriers to obtaining aid approvals and building permit applications, and these may prove more costly for low- and medium-income families, who often hold hourly jobs without flexibility and who also may not be informed about the various options. It would be important to understand these frictions and whether they affect LMI communities differentially.

4.4 Federal Reserve Policies

Turning to Federal Reserve Board policy areas, in October 2020 the Fed released an Advance Notice of Proposed Rulemaking (ANPR) on modernizing the supervisory and regulatory framework related to the Community Reinvestment Act (CRA).[24] This was part of an attempt to get feedback on different approaches in order to more effectively meet the needs of LMI communities. Among the questions in the ANPR, one asked for ideas on whether disaster preparedness and climate resilience investments should qualify as CRA activities in target areas. This is consistent with key connections between climate adaptation and the CRA, within the context of disaster provisions guiding pre- and post-disaster investments, unveiled by Keenan and Mattiuzzi (2019). Some CRA-qualified projects to support LMI communities include developing and constructing energy-efficient and climate-resilient affordable housing; installing energy efficiency improvements in homes and buildings; creating and expanding green jobs with family-sustaining wages and in small businesses; deploying community solar projects; and creating additional green infrastructure, including parks and green spaces (Willingham and Zonta 2020). Causal research aiming to understand the potential impacts of inclusion of climate-resilient investments on economic inequality and equitable growth would be valuable and could guide policy.

4.5 Comparing the Size of Physical Versus Transition Risks

Our review of the literature suggests that not only can the direct effects of climate change exacerbate inequality, but the process of transitioning to a low-carbon economy can do the same. Although the literature has not yet tried to compare the differential effects of physical and transition risks on inequality, such an analysis could inform our understanding of the costs and benefits of transition to a low-carbon economy and can potentially also inform policy. A related promising avenue of research is to investigate whether design changes in policies can reduce disparities in exposure to such transition risks. Such an understanding can provide useful information for policy and can go a long way toward alleviating inequalities during the transition to an environmentally more sustainable economy.

5. Conclusion

We have considered three pathways through which climate change may affect inequality: (1) the unequal impact of direct physical risks, (2) the unequal capacity of different regions to adapt, and (3) the unequal impact of the responses of existing institutions. We reviewed the mechanisms through which climate change may exacerbate existing income and racial inequality as well as other types of inequality, such as inequality by age, education, and health. For both the physical and the transition risks of climate change, we summarized the potential differential impacts that may arise from numerous factors, including race, gender, age, geography, income, and education, among others. We reviewed evidence showing how climate risks impose uneven effects on mortality, housing, consumer finance, social and labor markets, crime, and conflict. These disparate effects were found to exacerbate economic inequality by income and race and disadvantage the U.S. Southeast relative to other regions, thus further exacerbating already existing geographical and socioeconomic inequality. These unequal effects are further intensified by the uneven adaptations to climate change, driven by differential abilities to migrate, adapt, or innovate to protect against climate risk. Disparate access to institutions, such as insurance and the financial system, results in even more negative effects for households. Additionally, public policy may allocate resources such as federal disaster assistance and use urban planning regulations in ways that accentuate these gaps.

With the growing acceptance and understanding of how big a risk climate change poses to our communities and society, we already see new structures and ideas being put into place. The Federal Reserve Board joined the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) in December 2020,[25] so that the Fed can be a part of the exchange of ideas, research, and best practices on managing environmental and climate risks for the financial sector. Not only that, but the Fed is moving to incorporate climate risk into its micro-prudential oversight of banks and its oversight of the stability of the financial system. Even as the Fed is collecting insights on modernizing the framework related to CRA, the Fed's current guidance[26] provides credit for financing renewable energy and energy-efficient and water conservation equipment, or projects that support the development, rehabilitation, improvement, or maintenance of affordable housing or community facilities, such as a health clinic that provides services for LMI individuals. Moreover, the State of New York has recently issued guidance[27] that banking institutions subject to the New York CRA may receive credit for financing activities that support the climate resiliency of LMI and underserved communities. Also, the Biden administration has already prioritized actions on climate change and is sharpening focus on climate policy through multiple measures.[28]

As rapid changes that are bound to have implications for inequality continue to happen, potentially reducing inequalities and bridging gaps, it will be important to understand and continue to monitor how developments unfold. Needless to say, more innovative research using more comprehensive data is essential to understanding the impacts on different communities across the United States and the globe as new policies and practices are unveiled.

Appendix 1: Research Findings Relating Directly to the Exacerbation of Inequality

Atreya, Ferreira, and Michel-Kerjan (2015)

More-educated households are more likely to purchase flood insurance than less-educated households. Counties with a higher share of African Americans have a higher rate of insurance take-up. Similarly, wealth and income are correlated with insurance take-up.

Avtar, Chakrabarti, and van der Klaauw (2022)

Borrowers from predominantly minority, predominantly Black, and low- to moderate-income neighborhoods are worse off after disasters (hurricanes and floods), reflected in the lower probability of taking out auto and mortgage debt, but higher mortgage delinquencies. Despite lower credit utilization, these borrowers also have higher credit card delinquencies.

Bakkensen and Ma (2020)

Low-income and minority residents are more likely to move into high-risk flood zones. White/Asian residents are willing to pay $710 per year to avoid living in a high-risk flood zone.

Billings, Gallagher, and Ricketts (2019)

In the aftermath of Hurricane Harvey, residents from poorer neighborhoods received 5 percent less in FEMA assistance compared to residents from wealthier neighborhoods, all else equal.

Bleemer and van der Klaauw (2017)

A decade after Hurricane Katrina, inundated residents were around 2-3 percentage points less likely to hold a mortgage and 7 percentage points less likely to remain in New Orleans. However, older, higher-income, and white residents were more likely than their counterparts to evacuate New Orleans immediately after Katrina.

Blickle and Santos (2022)

Low-income and low-FICO mortgage borrowers experience more pronounced reductions in lending from mandatory U.S. flood insurance policies.

Borenstein and Davis (2016)

Clean energy tax credits ($18 billion distributed since 2006) have predominantly been given to wealthier Americans. The top 20 percent of Americans by income received 60 percent of credits, whereas the bottom 60 percent received about 10 percent of credits.

Buchanan et al. (2020)

3.7 percent of New Jersey affordable housing, 1.1 percent of New York affordable housing, and 2 percent of Massachusetts affordable housing are exposed to sea level rise under 2050 projections. Affordable housing exposure has more than tripled across the United States from 2000 to 2020.

Appendix 1: (Continued)

Carter et al. (2018)

The Southeast U.S. is more likely to be exposed to severe heat waves; 61 percent of major Southeast cities are experiencing worsening heat waves (highest U.S. percentage). The combined impacts of sea level rise and storm surge in the Southeast can cost up to $60 billion each year in 2050 and up to $99 billion in 2090 under a higher scenario, with Florida being especially at risk. Many people in severely at-risk areas could be classified as some form of vulnerable.

Chay and Greenstone (2003)

A 1 percent reduction in TSPs results in a 0.35 percent decline in the infant mortality rate at the county level (2,500 fewer infants died in 1980-82 than would have if there were no TSP reductions). Effect is largest for minority groups: One could observe a 0.46 percent decline in Black infant mortality, while white infant mortality could decline 0.29 percent.

Cruz and Rossi-Hansberg (2021)

Effects of climate change are unequally distributed: welfare losses up to 15 percent in parts of Africa and Latin America, India, and Australia (global south), and gains up to 14 percent in northern regions (Canada, Alaska, etc.).

Currie, Voorheis, and Walker (2021)

The Clean Air Act is responsible for 60 percent of the decline in the Black-white pollution exposure gap (-1.5 μg/m3 to -0.5 μg/m3) from 2000-2015.

Davis (2011)

Neighborhoods within two miles of power plants experienced a 3-7 percent decrease in housing values and rents in the 1990s. There is evidence of taste-based sorting for neighborhoods near power plants: significant decreases in mean household income, educational attainment, proportion Black or Hispanic.

Dell, Jones, and Olken (2008)

Authors document a large, negative effect of higher temperatures on growth—but predominantly in poor countries. A 1° C rise in temperature reduces economic growth in a given year by 1.1 percentage points—though this rises to 2.4 percentage points in less prosperous countries (agricultural and industrial output declines).

Dell, Jones, and Olken (2012)

The effects of temperature increases are disproportionately negative for low-income countries: A 1° C increase in temperature reduces economic growth in a given year by 1.3 percentage points in low-income countries. In rich countries there is no apparent effect of temperature on economic growth.

Appendix 1: (Continued)

Deryugina et al. (2021)

Elderly Medicare beneficiaries who are vulnerable to air pollution are, on average, 4.5 years older than elderly Medicare beneficiaries who are not vulnerable. They are also 4 percentage points more likely to be male and twice as likely to suffer from Alzheimer's, dementia, lung cancer, congestive heart failure, chronic kidney diseases, or COPD. Indicators of high socioeconomic status are negatively related to vulnerability: high income, high median home values. The U.S. Southeast appears the most affected. Conversely, areas with high levels of government services have a somewhat lower share of vulnerable individuals.

Fajgelbaum and Khandelwal (2016)

Trade favors low-income populations: On average, the real income loss from closing off trade is 63 percent at the 10th percentile of the income distribution and 28 percent for the 90th percentile.

Fussell, Sastry, and VanLandingham (2010)

Post-Katrina, half of white residents returned after three months; less than half of Black residents had returned after fourteen months. There were similar results, respectively, for college graduates and noncollege graduates. Evidence suggests this may be related to housing damage whereby Black residents' homes were damaged more severely from Katrina (or repaired less quickly), delaying their return.

Garmaise and Moskowitz (2009)

The earthquake risk in California decreased provision of commercial real estate loans by 22 percent in the 1990s, with pronounced effects on African American neighborhoods.

Gillingham and Huang (2021)

Vessels idling in ports due to bad weather can create health risks, especially for population groups already at risk. One additional vessel in a port over the course of a year leads to three hospital visits per thousand Black residents within twenty-five miles and only one per thousand for white residents.

Greenstone (2002)

Counties that did not meet the CAA standard lost 590,000 jobs, $37 billion in capital stock, and $75 billion of output in pollution-intensive industries.

Heilmann and Kahn (2019)

Overall crime increases by 2.2 percent and violent crime by 5.7 percent on days with maximum daily temperatures above 85° F (29.4° C) compared with days below that threshold. The authors further suggest that the heat-crime gradient is almost 50x as large at the 25th than at the 75th percentile of the poverty distribution.

Appendix 1: (Continued)

Howell and Elliott (2018, 2019)

Natural disasters and the disaster relief aid provided in their aftermath can exacerbate racial wealth inequality. White residents saw wealth gains after exposure to disaster events, while minority residents did not.

Hsiang et al. (2017)

Combined market and nonmarket damage of climate change in U.S. costs 1.2 percent of GDP per +1° C rise, on average. However, the poorest third of counties will carry the brunt of the impact, with damages from climate between 2.0 and 20 percent of county income.

Keys and Mulder (2020)

From 2013-18, home sales volumes in the most-sea-level-rise-exposed communities declined 16-20 percent relative to less-SLR-exposed areas, even as their sale prices grew in lockstep. This implies a serious reduction in demand for communities actually exposed to SLR.

Knighton et al. (2021)

Divergences in flood-risk-averse and flood-risk-enduring cities are associated with differences in the racial composition of the city: Risk-averse cities have larger proportions of white residents.

Kousky (2010)

Properties in 100-year floodplains are discounted at 3.2-3.9 percent compared with properties outside of the floodplain. Following a severe flood, property prices in the 100-year floodplains did not change, but those in the 500-year floodplains (where costly mandatory insurance is not required) declined 2-5 percent.

Lin, Ma, and Phan (2021)

Minority survey respondents are more likely to be concerned about environmental pollution. Race explains 25-33 percent of the variation in environmental worries in the data, while income correlates negatively with environmental concerns.

Painter (2020)

Compared to wealthier communities, poorer communities with lower credit ratings, which face long-term flood risk, pay more in underwriting fees and initial yields to issue long-term municipal bonds.

Popp et al. (2020)

Authors estimate that fifteen jobs were created per $1 million of the green component of the American Recovery and Reinvestment Act. However, this holds only in the long run, with the short-run effects much less pronounced. The largest employment gains were found for manual laborers with at least some college education, while manual labor wages did not increase.

Appendix 1: (Continued)

Ratcliffe et al. (2019)

Medium-sized disasters are more likely to widen inequalities in credit outcomes compared with larger disasters. Individuals in predominantly minority communities experience a 31-point decline in credit scores four years after the disaster. Individuals in predominantly white communities comparably experience only a 4-point decline.

Tran and Sheldon (2017)

The incidence of adverse credit conditions (for example, bankruptcies), following disasters, is higher for low-income households.

Tran and Wilson (2020)

Following a disaster, the average annual income per capita decreases by -0.1 percent. However, this effect reverts in the longer term. The authors find a positive but insignificant long-run effect of average disasters on poverty rates.

Tesselaar et al. (2020)

Flood insurance is currently more unaffordable in Eastern European countries than in Western European countries, and this is likely to sharpen in projected scenarios for 2050 and 2080.

Willison et al. (2019)

Disaster relief aid was greater and timelier after hurricanes affecting U.S. states (Florida and Texas) than U.S. territories (Puerto Rico).

Notes

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[1] We interchangeably use the term "economic inequality" to describe these inequalities.

[2] See Chakrabarti (2021).

[3] See also Environmental Protection Agency (2017). For a discussion of hurricanes, see Geophysical Fluid Dynamics Laboratory (2021).

[4] For a broader discussion of global sea level rise, see also Thead (2016).

[5] Fowlie, Walker, and Wooley (2020) provide an excellent review of the literature surrounding the discussion of environmental justice and air pollution. They highlight how pollution disproportionately continues to affect historically disadvantaged communities.

[6] These estimates include not only the direct effects of changing temperatures but also the indirect effects of unequal abilities to adapt.

[7] Currie et al. (2015) analyze the effects of openings and closings of 1,600 industrial plants on housing markets and infant health. For the latter, they find that a plant opening is associated with a 3 percent increase in the probability of low birth weight within one mile of the plant.

[8] Fajgelbaum and Khandelwal (2016) look at the gains from trade and demonstrate that low-income households have benefited from trade over the past decades, given the basket of goods they consume (relative to higher-income households). Disruptions to trade due to climate change may have far-reaching and disproportionate impacts.

[9] Newell, Jaffe, and Stavins (1999) show that increasing energy prices as well as government regulation have induced innovation in water heaters, air conditioning, and the like.

[10] Fixr (2021).

[11] Greenstone, List, and Syverson (2012) evaluate the effects of air-quality regulations on the total factor productivity (TFP) levels of manufacturing plants using data from 1972-93 on 1.2 million plant observations. They find a 2.6 percent decline in TFP related to more stringent air-quality regulations and a 4.8 percent decline when correcting for price increases, output declines, and sample selection. This is equivalent to an annual cost of $21 billion (or 8.8 percent) for the manufacturing sector.

[12] Note that only about half of the owner-occupied homes are mortgaged.

[13] See, for example, National Resource Defense Council (2017) for a discussion.

[14] Also see Hancock (2021).

[15] Goldsmith-Pinkham et al. (2021) find that municipal bond yields respond to increases in the share of properties exposed to sea level rise (SLR). They find that in 2015, a one standard deviation increase in the share of homes exposed to six feet of SLR is related to a 5.3 basis point increase in municipal credit spreads.

[16] For a discussion, see the proposed project overview, which includes a proposal for more innovative risk transfer instruments, at: https://riskcenter.wharton.upenn.edu/policy-incubator/innovative-disaster-insurance-tools/.

[17] See Swindell (2019) and Silvy (2021). For a discussion of wildfire risk globally, see also Ross (2020).

[18] Further evidence of such reallocation of funds is also presented by Mahmoudi (2021).

Notes (Continued)

[19] Predominantly minority neighborhoods are defined as counties that fall in the top quartile in the population-weighted distribution of Hispanic and non-Hispanic Blacks. Predominantly Black neighborhoods are counties that fall in the top quartile in the population-weighted distribution of non-Hispanic Blacks. Low- to moderate-income neighborhoods are counties where at least half of the population resides in LMI census tracts, as defined by the Community Reinvestment Act (CRA). For the purposes of the CRA, census tracts in which the median family income (MFI) is less than 80 percent of the MFI of the surrounding geographic area, typically an MSA, are defined as LMI census tracts.

[20] Individuals with insurance will likely have to repay FEMA funds after an insurance payout, while uninsured individuals can, depending on conditions, receive a reprieve from repaying funds.

[21] Currie, Voorheis, and Walker (2021) find that the pollution exposure gap between African Americans and non-Hispanic whites converged from 1.5 $\mu g/m^3$ in 2000 to 0.5 $\mu g/m^3$ in 2015.

[22] Other studies of the effect of climate change on housing prices include the finding by Currie et al. (2015) that the opening of a plant leads to an 11 percent decline in housing values within 0.5 mile of the plant. Furthermore, Keys and Mulder (2020) find that sales of homes that are most exposed to sea level rise experienced a 16 to 20 percent decline from 2013 to 2018.

[23] Using nonattainment status as an instrumental variable for TSPs, Chay and Greenstone (2005) find elasticities ranging from -0.2 to -0.35 for housing values in relation to TSPs. They estimate that nonattainment status led to a $45 billion aggregate gain for homeowners in nonattainment counties.

[24] Call for proposed rule: https://www.federalregister.gov/documents/2020/10/19/2020-21227/community-reinvestment-act.

[25] See the press release from the Board of Governors: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20201215a.htm.

[26] See CRA Interagency Questions and Answers Regarding Community Reinvestment: Guidance.

[27] See the Department of Financial Services press release: https://www.dfs.ny.gov/reports_and_publications/press_releases/pr202102092.

[28] See The White House, Executive Order on Climate-Related Financial Risk.

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