# How will U.S. households adjust their housing behaviors in response to climate change?

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**Abstract**

Americans are moving toward climate risk, even as property damage from climate stresses becomes more salient. Over the coming years, climate change is likely to affect housing decisions through a variety of channels; for instance, by making high-risk locations less attractive both to live and to invest. Households can respond to climate change in multiple ways, reflecting their underlying risk tolerance, financial resources, social networks, lifestyle preferences, and access to information. Private market actors and governments can also alter their engagement with housing markets, including the pricing and availability of property insurance and mortgages and subsidies for climate-friendly retrofits. In this article, I review the literature on how households are incorporating climate risks into their housing decisions, identifying knowledge gaps and priorities for policymakers. A growing body of work suggests that localized climate risks are capitalized into housing prices in high-risk areas, particularly in the recent wake after high-profile storms. Much less is known about consumer knowledge of, and responses to, chronic climate stresses. A notable research gap exists on the climate impacts on renter households and rental markets.

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JEL codes: R1; R2; R3; Q5

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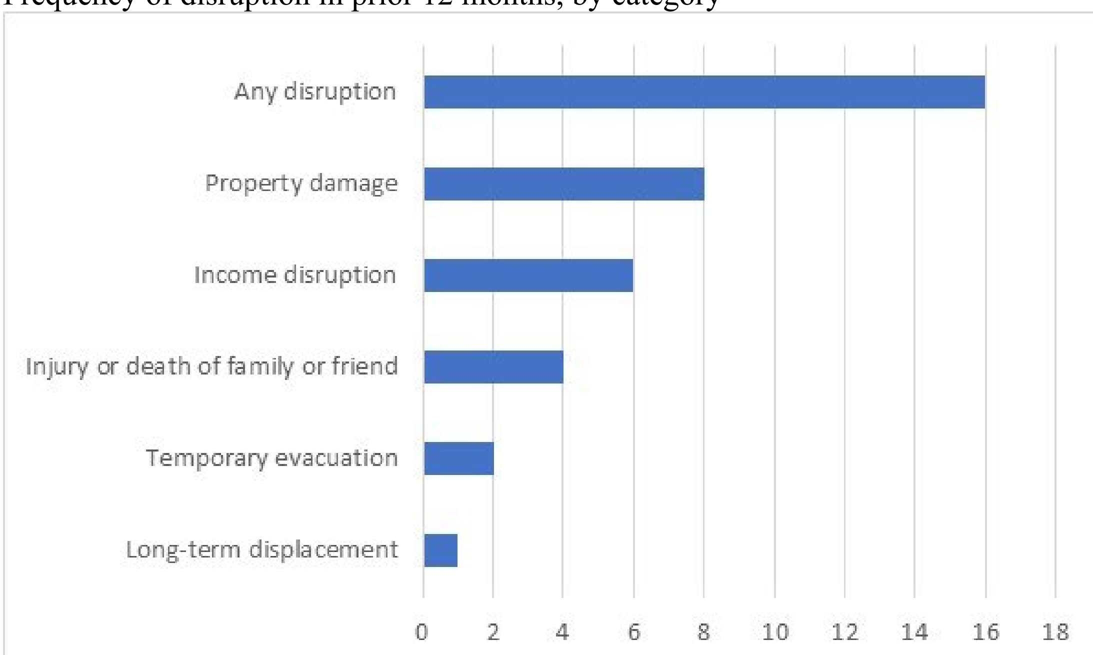
## 1) Introduction

Americans are moving toward climate risk. Over the past 20 years, population has grown rapidly in counties and census tracts facing high risks of heat, water stress, fire, and flood (Katz and Sandoval-Olascoaga 2021, Khater et al 2022). Official statistics (such as NOAA's tracking of billion-dollar disasters[1]) often emphasize the aggregate economic costs of climate events, but for U.S. households, physical damage to homes and neighborhoods is a particularly salient concern. The Federal Reserve Board's (2022) Survey of Household Economics and Decision-making found that16 percent of adults reported experiencing some disruption from natural disasters in the previous 12 months, with property damage cited as the most frequent category of impact.

**Figure 1: Property damage is a common experience from natural disasters**
Frequency of disruption in prior 12 months, by category




Source: Federal Reserve Board Survey of Household Economics & Decision-making (2022).
Note: Graph reports percent of adults. Respondents could select multiple answers.

[1] https://www.ncei.noaa.gov/access/billions/

Individual households cannot substantially alter climate outcomes, but they can take actions that reduce their exposure to risk, or lower the expected physical and financial harm from climate stress. Housing choices offer a range of ways for households to protect themselves and their property, including moving to lower-risk locations, fortifying their homes, or purchasing supplemental disaster insurance.

In this article, I review urban economics literature to develop a framework for how U.S. households can adapt their housing decisions and behaviors in response to changing climate risks. When households choose to buy or rent a home, they are making a complex set of simultaneous decisions, including place-specific amenities, tenure, structure characteristics, upfront and ongoing costs. Climate change is likely to affect housing behavior through a variety of channels; for instance, it makes high-risk locations less attractive places both to live and invest. The paper focuses on four types of housing decisions—location choice, tenure choice, structural characteristics, and spending on operating costs—and discusses how those decisions may interact with household characteristics, market conditions, and policies (Figure 2). Key household characteristics that will influence decisions include financial resources, access to information, risk tolerance, and lifestyle preferences. Private market actors and governments will likely alter their engagement with housing markets, including the pricing and availability of property insurance and mortgages, land use and building codes, and subsidies for climate-friendly housing retrofits.

**Figure 2: Conceptual framework for housing decisions in a changing climate**

| Housing choices | Household characteristics | Market & policy factors |
|---|---|---|
| Location | Income, wealth, access to credit | Mortgage & insurance markets |
| Within & across regions | | |
| Structure | Information & beliefs | Land use policies |
| Building type & materials | | |
| New construction vs retrofit | Preferences & risk tolerance | Housing construction & quality |
| Tenure | | |
| Household preferences | | Local infrastructure resilience |
| Mortgage markets & regulations | | |
| Operating costs | | |
| Insurance | | |
| Utilities | | |
| Maintenance/repairs | | |
| Property taxes & fees | | |

The goals of this paper are: (1) to synthesize existing economic literature on how—and whether—households alter their housing behaviors to reduce exposure to climate risks; and (2) to identify gaps in existing data and research that could inform better policy decisions. The review draws on some core theoretical models in housing economics that provide insight into household decisions—location choice, housing search models, and tenure choice—as well as empirical papers on how real estate markets are changing to reflect local climate risks. I focus primarily on adaptive behaviors that are motivated by self-interest: people acting to protect their personal safety, comfort, property, and financial well-being. Some people may also alter their housing behaviors out of an altruistic or ideological desire to mitigate climate change, for example choosing to live in smaller homes or install solar panels (Kammen et al 2012). Understanding the prevalence of those behaviors, and how market and policy levers could encourage them, is an important area for future research.

Several criteria were used to define the scope of papers reviewed for this study. First, I focus on U.S. households because housing choices reflect policies and institutions (housing finance systems, development regulations, insurance markets) that vary widely across countries.

Similar analysis of other countries should be a priority for future research. Second, papers are drawn primarily from within the economics literature, while noting some overlap with related fields such as urban planning, architecture, and civil engineering (especially around climate-resilient structures). This topic would benefit from interdisciplinary research that combines insights and techniques from other disciplines. Third, the intersection of climate and housing markets is a rapidly growing and changing field; this paper reflects information available at a snapshot in time. New working papers continue to emerge, new data sources become available, and market conditions are changing in real time.[2]

Some key themes emerge from the literature that help explain why Americans are still moving towards climate risk, and highlight both the potential and limitation of policy tools to nudge people away from risk. Household reactions to climate risk are complicated by several market failures and regulatory interventions. In choosing where to live, households balance climate risk against other factors, including housing costs and natural amenities like proximity to beaches and mountains. Household, developers, and other market participants may not have accurate, timely information about local climate risks, or the cost and effectiveness of various adaptation strategies. Partisan polarization around climate change also plays a role in whether people believe available information. Recent empirical papers offer substantial evidence that housing prices decrease in high-risk locations following high-profile disasters, reflecting a decrease in demand for those locations. However, the pricing of mortgages and property insurance in the U.S. are heavily regulated (mortgages by federal rules, insurance by state governments) and thus may not provide consumers with useful signals a priori about spatial

[2] During the course of writing this paper, two major insurance companies stopped offering new homeowners' insurance policies in California. https://www.latimes.com/business/story/2023-06-02/allstate-state-farm-stop-selling-new-home-insurance-in-california

distribution of risk. Households' ability to pro-actively reduce their exposure to risk depends in part on having adequate savings or access to credit; in practice, many low-income households face binding resource constraints that may lead them to live in high-risk places in exchange for cheaper housing. Empirical research is somewhat limited by data availability; for example, more papers examine coastal flooding from intense storms than other types of climate events, especially chronic stresses such as heat and water stress. There is much more attention to sales of owner-occupied homes than to renter households and rental markets. An important area for future research is understanding what households know about climate risks, and how they use information to make housing decisions.

The remainder of the paper is organized as follows. Sections 2 through 5 discuss the intuition and evidence on four types of housing behaviors: location choice, structural characteristics, tenure, and spending on operating costs. These discussions largely take current market and policy conditions as given, but point out areas where future changes could occur that would alter household decisions. Section 6 considers how household characteristics could mediate each of these housing choices. Section 7 sketches out several market and policy levers that could encourage households to reduce their exposure to climate risk, and Section 8 concludes.

## Section 2) Location choice

Climate change will alter the relative amenities and risks of places, thereby influencing where people want to live and how much they are willing to pay for homes. Some of the geographic variation in climate risk is already well-known and reflected in housing prices—for example, coastal areas in Florida face higher risk of hurricanes—but other local climate impacts are more nuanced or less well measured by publicly available data. In this section, I consider how climate change can affect location choice at two different geographic scales: *across* regions of the country (proxied by states or metro areas) and *within* regions. At both scales, two important considerations are: what information do people have when they search for homes, and how strongly do they value climate amenities and risks. There may be asymmetric responses from people who already live in areas with increasing risk compared to people who are planning to relocate and considering a wide set of geographies.

### 2.1) Location choice across regions

In the classic open-city framework, people sort across metro areas based on expected income (a function of regional job markets), housing costs, and the utility they derive from place-specific amenities (Roback 1992, Rosen 1974). In equilibrium, housing costs adjust so that households are indifferent across regions. Climate is primarily incorporated in these models through some measure of weather; "good weather" is an amenity for which people are willing to pay higher prices or accept lower wages. The interaction between climate and geographic features can also be an amenity; locations that are proximate to mountains and have cold, snowy winters offer recreational opportunities like skiing.

Two forms of climate-related regional migration in the U.S. have been extensively documented in empirical research. First, over the course of the 20th century, population has shifted from colder Northeastern and Midwestern regions towards the South and West, specifically towards metro areas characterized by moderate January temperatures and less rainfall (Glaeser et al. 2001, Rappaport 2009). Second, people are increasingly concentrated in high-amenity locations with attractive natural features and outdoor recreation, notably along the coasts and mountains (Lee and Lin 2017). More than 40% of people now live in coastal counties, although these counties make up only 10% of the country's land area (Walls et al. 2018). Exurban areas in the Mountain West have also grown rapidly; from 1990 to 2010, the number of homes in the wildland-urban interface (WUI) increased by 41% (Radeloff et al. 2018). People who move to high amenity regions exhibit a strong place attachment and willingness to pay for these amenities, both in housing costs and higher local tax rates (Brueckner and Neumark 2014).

However, there is a central tension in how climate influences location choice: some of the natural features that create valued amenities—proximity to the coast and other large water bodies, mountain views, access to outdoor recreation—are correlated with higher risk of climate-related disasters, notably floods and wildfires. The Rosen-Roback model can accommodate multiple aspects of climate: it would be a relatively simple modification to estimate cross-metro regressions adding a set of climate risk metrics, such as frequency of intense storms, wildfires, extreme heat, and flooding.

While there is a growing empirical literature on climate migration from high-risk developing countries towards lower-risk wealthier countries (for instance, Kaczan and Orgill-Meyer 2020), relatively little has been written about migration across regions within the U.S. (Partridge et al 2017). Marandi and Main (2021) suggest a typology of U.S. cities: those that are vulnerable to climate hazards and are likely to lose population, those that will receive climate migrants, and those that will actively market themselves as "climate destinations". Martin (2019) estimates that 1.2 million Americans were displaced through weather-related disasters in previous years, including disaster evacuees, recipients of federal buyouts, and those who voluntarily relocate to lower-risk places. He notes that the latter category is difficult to estimate with public data sources.

Some theory papers have attempted to predict climate migration across U.S. regions. Albouy et al. (2016) use climate modeling of future changes in temperature and humidity to predict which regions will become more or less attractive; the focus is still primarily on amenities and quality of life, rather than risk. Because most people prefer moderate temperatures, they predict that rising temperatures will negatively impact utility across all regions. Bunten and Kahn (2014) develop a theoretical framework for household relocation across a system of cities in response to new information about climate risks. A key insight is that households who already live in high-risk places may face stickiness in moving away because of place-based social networks and having already developed adaptive strategies. One limitation of their model is that it does not address the variation in types of climate risks across U.S. regions. For instance, if we measure climate risk only as exposure to sea level rise and coastal storms, Miami is clearly at higher risk than Denver. Incorporating a broader range of climate risks, including wildfires and water stress, makes it more challenging for households to accurately rank cities by risk level.

## 2.2) What do people know about regional and local climate risk?

A key assumption behind the Rosen-Roback model is that most households have or can easily find accurate information about the amenities in various locations—probably a reasonable assumption for features like average January temperature. But does this assumption hold for climate risks? Do most people have ready access to accurate, understandable information about geographic variation in climate risk—including changing climate risks over time? To answer this question, it is helpful to consider different categories of risk and available sources of information for these categories.

Large-scale natural disasters are the most visible source of information: events such as Hurricane Katrina and Superstorm Sandy received extensive national media coverage and raised public awareness of location-specific risks in affected areas. Many empirical papers that try to discern the impact of climate risk on housing prices use the occurrence of high visibility natural disasters as “new news” (for instance, Keys and Mulder 2020; McCoy and Walsh 2018; Ouazad and Kahn 2021). Additionally, public releases of major climate reports, such as the International Panel on Climate Change and the National Climate Assessments, often lead to short-term increases in media stories and greater public awareness. Multiple papers find pronounced short-term declines in housing prices following high-profile events, although some of the changes are short-lived. Giglio et al. (2021) construct a climate attention index which measures the frequency of climate-related words in Zillow listings. They find that the climate attention index increases following high visibility climate events. While properties in a flood zone sell at a premium (due to the amenity value of being near the coast), the premium is smaller during times of higher climate attention.

A more complex question is the extent to which households are aware of and understand chronic climate risks, which may not be accompanied by short-term, high-visibility events. For instance, flooding can occur in different regions of the U.S. from different causes. Hurricanes and other intense storms near large water bodies can lead to coastal flooding. Sea level rise will also lead to persistent flooding in some low-lying coastal areas, even during times with no storms; South Florida and Virginia’s eastern shore are examples of this phenomenon. Intense rainfall can also cause damaging floods (pluvial flooding) in interior parts of the country, including land-locked mountainous areas (Mitchell 2022, Mudd 2023). Similar complexities arise in household perceptions of likely risks for other climate-related events, especially slow-changing, chronic conditions, like extreme heat and water stress.

In theory, households could find information about climate risks in their neighborhoods from a variety of public or private sources. There is a rapidly growing field of climate analytics, consisting of (mostly) private companies that apply climate modeling to create geospatial datasets with metrics of both individual climate risk components (fire, flood, heat) as well as composite risk scores (Schuetz et al. 2023). The best-known data providers include CoreLogic, a private company that combines parcel-level climate risk metrics with structural property characteristics and mortgage information, and First Street Foundation, a non-profit organization that specializes in climate risk analytics for public-sector agencies.[3] Institutional real estate actors, including insurance companies and mortgage lenders, are increasingly acquiring local climate risk data to incorporate in valuation and underwriting decisions. However, parcel-level data are not yet widely accessible to the general public, and require some level of technical expertise to work with. The U.S. Environmental Protection Agency has developed an interactive mapping tool that displays some metrics of flood and wildfire risk at the census tract level, using data from First Street, NOAA, and FEMA.[4]

Researchers are still in early stages of exploring how households might use parcel-level information on climate risks to make housing decisions. A recent experiment conducted by the real estate company Redfin found that when potential homebuyers were shown online listings disclosed to have high flood risk, they shifted their search towards lower-risk properties (Katz et al. 2022). The behavioral change was only seen among customers who initially viewed high-risk properties, suggesting non-linear risk preferences. Potential homebuyers in flood-prone cities, such as Cape Coral, FL, and Houston, were more likely to explore flood risk data when it was

[3] More information about the providers' methodology and data coverage can be found on their websites, https://www.corelogic.com/data-solutions/property-data-solutions/climate-risk-analytics/ and https://firststreet.org/.
[4] https://ejscreen.epa.gov/mapper/

available. Experiments that replicate this work, as well as testing sensitivity to other types of climate risks, are a promising area for future research.

Still another complication in predicting whether people will move to avoid climate risk is the degree to which climate change has become associated with partisan politics. A growing literature finds that climate change skeptics may choose to ignore information on local climate risks (see, for instance, Bakkensen and Ma 2020; Baldauf et al. 2020). Keyes & Mulder (2021) find greater changes in housing sales volume and housing prices in counties where residents are more worried about climate risk, as measured by the Yale Climate Opinion Survey. Bernstein et al (2020) find a correlation between ownership of properties exposed to sea level rise and partisan affiliation, with Republicans more likely to own higher-risk properties.

Even if people have good information, regional variation in climate risk is only one factor that households will consider in choosing where to live. A growing body of work has documented secular trends in declining long-term moves, especially among less-educated households (Molloy, Smith & Wozniak 2011). Moving is expensive, both in direct financial costs and in disruptions to social and professional networks. Transaction costs to moving can lead to mismeasurement in the value households attach to various amenities (Bayer, Keohane, and Timmins 2009). Households place different valuation on place-specific amenities, including good weather and outdoor recreation, as well as industry-specific job opportunities. Whether we see large-scale population movements away from high-climate risk regions, or widespread property value declines in those regions, depends on complex interactions of household preferences, budget constraints, and regional labor markets—along with numerous policy choices (discussed in the final section).

## 2.3) Location choice within regions

A less costly—and therefore more likely—outcome is that households try to reduce exposure to climate risks by moving within regions. For instance, in cities adjacent to the coast, rivers, or lakes, there can be considerable variation in neighborhood flood risk, based both on natural features like elevation and built environment features like drainage and stormwater management systems. Within West Coast and Mountain West metros, neighborhoods on the exurban fringes in the WUI face higher risk of wildfires than the urban core. Relatively short distance within-region moves can mitigate some, but not all, climate risk; coastal flooding from intense storms can reach inland areas quickly, and the smoke from large wildfires can create unhealthy air quality hundreds—or thousands—of miles away (Popovich and Katz 2021).

Conceptually, neighborhood or even property-level climate risk can be accommodated in standard housing location choice models. Like localized air or water pollution, higher risk of floods and fires are an environmental disamenity that will be capitalized into lower land values (Banzhaf et al. 2019). A changing climate also introduces more uncertainty into the future stream of rents that a property can generate (both rent levels and the expected usable life of the structure), implying that investors should apply a higher discount rate when calculating the net present value of properties (Giglio, Kelly, and Stroebel 2021). In practice, factoring localized climate risk into property values is complicated: even with locally specific risk data, the expected harm to any given property reflects the interaction between the probability and severity of a climate event and the structural characteristics of the property (Kousky 2022). For instance, hurricane-force winds will cause less severe physical damage and lower financial losses to a home with high-quality roof that is well secured to the walls. Further, risk levels and amenities are highly correlated even within small geographic areas, making the risk premium difficult to isolate.

There is a rapidly growing body of empirical work attempting to identify small-geography price discounts due to climate hazards. Giglio, Kelly, and Stroebel (2021) provide a detailed review of the recent literature. Many of these papers focus on neighborhood-level variation in flood risk in coastal states, including Florida, New Jersey, and New York (Fan and Bakkensen 2022; Keys and Mulder 2020). Fewer papers examine price impacts relative to wildfire exposure (McCoy and Walsh 2018). The authors use a variety of data sources and empirical techniques to measure climate risk, and there is widespread agreement on top-level findings: within relatively small geographic areas, homes that face higher climate risks sell for lower prices. Many of the papers examine short-term changes in prices and transaction volumes after high-visibility events. There is less evidence on how long these changes last, if climate events do not frequently recur.

While the relationship between local climate risk and housing prices is by far the most developed topic within the broad housing-and-climate space, there are a few questions that could benefit from more empirical work. First, much more attention has been focused on impacts on prices and transactions in owner-occupied markets than in rental markets. One exception is Giglio et al. (2021), who find that annual rents of properties with different levels of risk exposure may not vary over time with climate attention. Lee, Wan, and Zheng (2023) find a negative impact on rents in neighborhoods with more frequent high-tide flooding. As discussed in Section 4, renters and owners (or investors) may not behave symmetrically with respect to climate risk. Second, it would be useful to explore housing market responses to a broader range of climate risks, including lower-visibility chronic stresses such as extreme heat and water stress.

An important extension of the research on housing prices is considering how changing climate risk—or greater awareness of localized climate risk—could result in demographic transitions across neighborhoods. Some advocates and planners have raised the potential for "climate gentrification": as housing costs rise in areas known to have lower climate risks—or fall in risky locations—it could contribute to household spatial sorting based on income (Anguelovski et al 2019 provide an extensive literature review; see also Keenen et al 2018 and Shokry et al 2021 for city-specific case studies). Ratnadiwakara and Venugopal (2020) find that census tracts in Florida that have recently experienced flooding tend to attract new homebuyers with lower incomes than prior residents, suggesting that over time, climate change may exacerbate economic segregation.

2.4) Summary

Spatial variation in climate risk could affect households' location choices both across and within US regions. Historically, urban economics has considered climate primarily as an amenity, not as a risk, in explaining cross-regional choices; more empirical work would be useful to explore population movement and prices adjustments that take into account both risks and amenities. Variation in types of risk across regions, high transaction costs of moving, and a long-run secular decline in mobility raise questions about the probability that large numbers of U.S. households will migrate away from risky regions. Alternatively, the increasing availability of geographically granular climate risk data could lead households to undertake short-distance moves away from risky neighborhoods within regions. More empirical research, including behavioral experiments on risk disclosure, are an important direction for future work.

The next section considers another risk-reduction strategy that would not require households to undertake long-distance moves: purchasing climate-resilient homes, or upgrading resilience of existing homes.

**Section 3) Housing structure choice**

The structural features of a home play an important role in resilience to climate hazards. For example, homes built on an elevated pedestal are less likely to experience damage from floods, while fire-resistant exterior materials can provide greater protection against wildfires. Households that choose to live in high-risk locations—particularly existing residents who cannot or will not relocate—may seek to rent or buy homes with specific safety features or invest in physical upgrades to their current homes, known as "climate hardening." Similar to reducing risk through location choice, investing in climate-resilient structures requires households to have information on localized climate risks, as well as understanding what structural features protect against specific risks. Cost-benefit calculations can be quite complicated, and investments require households to have savings or access to credit—potential obstacles to some households.

Building codes are the primary policy tool that governs safety features of homes, including resilience to natural hazards. Over time, many states and localities with higher climate risk have adopted more stringent building codes. Florida offers a useful case study: following catastrophic damages from Hurricane Andrew in 1992, Florida adopted a new building code in 2001 with provisions developed by the American Society of Civil Engineers to increase the wind load that buildings could stand during hurricanes (Deryugina 2013). Simmons et al (2018) estimate that the new building code reduced property damages due to windstorms by 72% over 10 years.

But building codes apply only to newly constructed homes; they do not require retrofits of existing homes. As of 2022, the median U.S. home is nearly 40 years old; most Americans live in homes that were built under older building codes with different requirements. This suggests that there may be latent demand for residents of older homes to invest in targeted climate hardening projects.

A rational homeowner could be expected to undertake climate upgrades if the expected financial benefits of the project exceed the costs. In practice, these calculations are quite complicated. As discussed in the prior section, climate risk data provides some estimates of the probability of particular climate events in a given location, but with wide confidence intervals, especially over longer time horizons. The expected dollar value of property damage created by those events is also uncertain, and depends on the structure's current physical condition and market value. A technical report drafted for the U.S. Army Corps of Engineers reveals that the cost of climate hardening activities varies widely: one set of estimates for upgrading exterior walls to fire-resistant materials ranges from about $17,300 to $66,800, depending on the type of replacement material used (Napier 2013). The level of complexity in estimating benefits and costs will likely deter even some risk-averse property owners from undertaking financially beneficial retrofits. While some low-cost upgrades could have positive expected net present value for most homes, more extensive investments may not pencil, especially for older, poor-quality homes—a problem observed already in the Department of Energy's weatherization assistance program (Allcott and Greenstone 2017; Fowlie, Greenstone, and Wolfram 2018).

Property owners may also encounter practical obstacles in fortifying homes. Like most home improvements, climate hardening requires owners to pay contractors up front for the labor and material costs of renovations. Owners must either have enough savings to pay out of pocket or be able to borrow, such as through a home equity loan. Some upgrades that improve residents' health and comfort may be relatively inexpensive; for instance, purchasing a window air conditioning unit for use on extremely hot days. But more durable upgrades, such as raising a homes' elevation, will stretch the finances of most property owners. And there is not yet a well-developed market of contractors who have the expertise in doing climate retrofits.

As discussed in Section 5, there are also complicated interactions between investments in climate hardening and property insurance. Rising insurance premiums could encourage more upgrades, but expectations of bailouts by private or public insurance programs could reduce homeowners' incentives to undertake safety precautions (Dehring 2006, Kousky 2022, Dumm et al. 2009).

Prior research on stricter building codes suggests that homebuyers in high-risk locations are willing to pay more for homes with improved safety features. Dumm et al. (2009) find that homes built under the new, stricter 1994 South Florida Building Code sold for about 10% more than similar homes in the region built under the previous, more relaxed codes. Simmons and Sutter (2007) find that consumers in tornado-prone Oklahoma were willing to pay 4% more for homes with an internal shelter or safe room. Households who were recently exposed to tornadoes showed a higher willingness to pay. More empirical work on the price premium associated with specific safety features in the context of local climate risk would be helpful in scoping whether this could become a profitable business niche for specialized contractors.

In summary, households that choose to live in climate-risky locations can reduce their expected damages by purchasing or renting resilient homes, or upgrading structural features of their existing homes. Potential obstacles include lack of information and credit constraints; as discussed in Section 6, lower-income households and renters are most likely to be constrained by financial resources. In the next section, we consider whether households' decision of whether to buy or rent may also be endogenous to climate risk.

## Section 4) Tenure choice

The tension between wanting to live in high-amenity, high-risk locations for lifestyle preferences and increasing financial risk of owning that property raises the question of whether some parts of the country could see aggregate tenure shifts. That is, are there places where many people want to live—and are willing to pay high rent for current consumption—but do not want to own a primary residence? Most of the empirical research on high-risk locations has focused on prices and transactions of owner-occupied homes; little is known so far about whether rents and rental transaction volume react in the same way to increasing awareness of climate risk. Tenure decisions could also be influenced as mortgage markets incorporate future climate risk into the pricing and availability of loans. Further, the U.S. explicitly encourages and subsidizes homeownership through federal tax policy, mortgage market regulation, and disaster relief programs; changes to these policies could substantially alter the attractiveness of homeownership in high-risk locations.[5]

### 4.1) Household preferences

Standard tenure choice models frame the household's decision of whether to purchase or rent their primary residence as a function of financial market conditions and household characteristics (Henderson & Ioannides 1983, Mills 1990). Among the most important financial

[5] There is an extensive literature on explicit federal tax subsidies for owner-occupied homes, notably the mortgage interest deduction and capital gains exclusion; see Gale, Gruber, and Stephens-Davidowitz (2007) for an overview. Researchers have also documented the implicit subsidies built into mortgage interest rates provided by the government-sponsored entities, Fannie Mae and Freddie Mac, and related features of U.S. mortgages, such as the absence of pre-payment penalties for qualified mortgages (Jaffee and Quigley 2013, Passmore and von Hafften 2017). Unequal treatment of homeowners and renters in disaster relief programs is discussed later in this section.

market conditions are mortgage availability and costs, expectations of future home prices and rents, and the transactions costs of buying—all of which could be impacted by changes in local climate risks.

A key determinant of households' decision to buy or rent is the expectation of future housing prices/rents relative to the expected returns on non-housing assets, such as the stock market. If housing prices and rents are anticipated to rise more than other assets, adjusted for risk, then households will find it more attractive to invest their savings in a downpayment for a home than to rent their home while investing in non-housing assets. While all sectors of the economy face climate risk, the physical, place-based nature of real estate makes it one of the higher risk sectors (Giglio, Kelly, and Stroebel 2021). Uncertainty over regulatory changes to mortgage markets and banks (discussed more below) also creates substantial transition risk. Owner-occupied housing by definition is not a diversified investment; it is more akin to investing a substantial portion of one's net wealth in a single stock, rather than a broad-based mutual fund. Further, housing is a relatively illiquid asset with high transactions costs of buying and selling. Both owner-occupants and investors may worry about future ability to sell the property and extract their equity in locations perceived to be at high risk.

As discussed in Section 2, there is already considerable empirical evidence that housing prices and sales volumes are lower in high-risk locations—a trend that may increase as local risk data becomes easier for consumers to access. To date there is very little research on whether climate risk has affected rental housing markets, due in part to the limited availability of timely, geographically granular data on metrics such as rent levels, turnover in rental units, or vacancy rates. However, the potential for asymmetric impacts on owner-occupied and rental markets raises important questions for researchers and policymakers. Might some high-amenity, high-risk locations support healthy (or at least functional) rental markets, even if owner-occupants are reluctant to invest? Could these areas see demographic turnover, based on different risk preferences? For instance, younger households with shorter expected duration or low-income households who are price-sensitive may be more interested in renting in high-risk locations. Are there some places where few households are willing to rent or own—and what will happen to people who currently live or own property in those places?

### 4.2) U.S. mortgage markets are guided and constrained by federal policies

In well-functioning credit markets, the availability and cost of capital should reflect expectations of future harm from climate events. Homes in high-risk locations are more likely to sustain property damage, lowering the value of the collateral. Intense storms create at least short-term disruptions to household income, increasing the likelihood of default (Ratcliffe et al 2020). That suggests that mortgage lenders should set stricter underwriting standards or pricing schedules for loans in risky areas, such as charging higher interest rates or lower loan-to-value ratios. So far, however, mortgage terms do not systematically incorporate geographic or property-specific variation in climate risk, due in part to federal government policies.

Roughly two-thirds of U.S. mortgages are securitized through the government-sponsored enterprises (GSEs), Fannie Mae and Freddie Mac, or their smaller public counterpart, Ginnie Mae (Urban Institute 2020). Securitization transfers most of the default risk from originating mortgage lenders to investors who hold mortgage-backed securities. Fannie and Freddie do require borrowers in flood-prone areas to purchase federal flood insurance, but they do not use climate risk (or other geographic criteria) to determine which loans to securitize (Hurst et al. 2016). Since the Great Recession, the GSEs have been under federal conservatorship, and are subject to supervision from Congress and the Federal Housing Finance Agency (Federal Housing

Finance Agency 2022). Under this status, it is unclear whether the GSEs have the authority to introduce climate-risk-based pricing without explicit permission from FHFA, Congress, or both.

A few empirical papers have examined the extent to which mortgage lenders have restricted credit to borrowers in high-risk locations, or are otherwise altering their lending behavior to reduce climate risk. Keys and Mulder (2020) find that high-risk Florida tracts see similar reductions in both mortgage origination volume and cash purchases, inferring that buyers' preferences, rather than lender restrictions, is driving their results.

The most-cited paper on this topic argues that mortgage lenders deliberately try to shift climate risk onto the GSEs, but the results have been contested. Ouazad and Kahn (2021) investigate post-disaster lender behavior in places that were struck by large hurricanes between 2004 and 2012. They look at the volume of loans originated and securitized within narrow bands around the county- and year-specific conforming loan limits set by the GSEs; loans above this dollar value are not eligible for GSE purchase, so are typically held in portfolio by lenders. Their analysis finds that after major climate events, lenders are more likely to originate and securitize loans just below the conforming loan limit, and interpret this as intentional efforts by lenders to shift climate risk onto the GSEs. However, LaCour-Little et al. (2022) replicate Ouazad and Kahn's analysis, and find that they are using incorrect county-year conforming loan limits. Re-estimating the regressions using correct loan limits, LaCour-Little et al find no evidence of greater securitization. Given the importance of understanding the interactions of lender behavior and the GSEs, further empirical work in this area is needed.

Property insurance and federal disaster recovery programs further reduce homebuyers' financial incentives to avoid high-risk locations. Mortgage lenders require borrowers to purchase homeowners' insurance, which at least partially compensates owners for damages caused by natural disasters—with significant exceptions for floods and earthquakes (Kousky 2022). Lacking a similar requirement, fewer than half of renter households have any property insurance. Public programs, such as the National Flood Insurance Program (NFIP) and Community Development Block Grant Disaster Recovery (CDBG-DR), cover some of the gaps left by private insurance. These programs have been widely criticized for their regressive design, providing more assistance to affluent homeowners than low-income renters, and for incentivizing or requiring owners to rebuild homes in disaster-prone locations (General Accounting Office 2010; General Accounting Office 2019; Spader and Turnham 2014).

### 4.3) Summary

Increasing climate risk could alter households' decision whether to purchase or rent their home in some locations, by altering the expected financial risks and returns to owning property. Real estate as an asset class faces particularly high physical and transition risks from climate change. So far, the availability and pricing of mortgages does not reflect local variation in climate risk, due to federal regulation of mortgage markets. Property insurance, which is regulated by state governments, also diffuses financial risks of owning homes in high-risk places, discussed in the next section. Policy changes to introduce climate risk-based-pricing into either mortgages or insurance faces considerable political uncertainty.

The next section considers how increasing climate risks could impact spending on several categories of operating costs, including mortgage and insurance payments.

## Section 5) Spending on operating costs

Climate stresses on properties could nudge households to increase spending on several categories of operating costs. The largest components of operating expenses (both for owner-occupied and rental housing properties) are typically mortgage payments, insurance, property taxes, utilities, and routine maintenance and repairs. Rental properties also typically set aside funds monthly for capital reserves. In some instances, property owners could face tradeoffs between upfront investments in climate hardening and increased monthly operating costs. For low-income homeowners, non-mortgage costs often account for more than half of monthly costs, so it is worth considering these components separately (Begley and Palim 2022). Housing expenditures account for roughly one-third of the typical household's income, and well over half of monthly income for the poorest quintile (Larrimore & Schuetz 2017); increased operating costs due to climate stress could increase housing insecurity among low-income owners and renters.

In well-functioning markets, we would expect the cost of property insurance—whether through annual premiums, deductibles, or caps on payouts—to increase in locations with higher expected losses from climate events. In practice, state governments regulate insurance markets, setting the parameters for pricing, availability, and coverage of property insurance (Kousky 2022). State insurance regulators in high-risk states, such as California and Florida, have intervened to support widespread availability of property insurance below actuarially fair prices, even as the size and frequency of payouts due to climate-related events has put pressure on insurance providers. Standard homeowners' insurance policies exclude floods and earthquakes, and generally do not cover the full amount of damages. One option for risk-averse homeowners is to purchase separate disaster insurance policies; the market for these policies is still quite small and not well understood by most consumers.

Expenditures on utilities could change in multiple ways that are difficult to predict. In areas that experience more days with extreme temperatures (both heat and cold), residents may need to run heating and air-conditioning systems more often. However, higher usage could be offset by lower energy costs, depending on the progress towards expanding production of electricity through renewable sources (Bogdanov et al. 2021; Carley & Konisky 2020). There are also clear tradeoffs between households making upfront investments in energy efficiency (e.g., switching to electric heat pumps, adding insulation and air sealing, upgrading windows and doors) and ongoing energy usage. New federal tax incentives through the Inflation Reduction Act should encourage greater uptake of climate retrofits among income-eligible homeowners and some rental property owners (Wagner 2022).

The need for routine property maintenance and repairs could increase, as both extreme weather events and chronic stresses increase wear-and-tear, especially for older buildings. This category of operating costs will likely vary by household characteristics; Begley and Lambie-Hanson (2015) find that older homeowners tend to reduce property maintenance over time, leading to declining conditions. Low-income owners and renters live in poor quality homes with high levels of deferred maintenance. These groups also have limited liquid savings and weak credit, making it difficult to access funds to undertake home repair projects (Wallace, Divringi, and Wardrop 2019).

How local governments adapt to climate risks will influence both the quality of locally provided public services and the cost passed on to property owners through taxes and fees. Communities that are grappling with persistent, chronic physical risks such as sea level rise and extreme temperatures will need to undertake climate hardening of their water, sewer, and transportation infrastructure, in order to continue providing basic services (Mann, Pearson, and Schuetz 2022; Rojas, Krueger, and Cromwell 2022). While federal and state funding sources may offset some of these costs, local governments will likely need to raise local revenues through increased property tax rates, user fees, or other mechanisms. Municipal bond markets have begun factoring in climate risk into the availability and cost of long-term lending (Four Twenty Seven 2018; Goldsmith-Pinkham et al 2019); communities that face higher physical risk may face higher borrowing costs.

In summary, both severe natural disasters and chronic climate stresses are likely to ongoing costs of property maintenance and operations, including insurance premiums, utility costs, property taxes, and building repairs. The ability to absorb higher operating costs, or to offset these costs through upfront investments, will vary depending on household characteristics—discussed in the next section.

## Section 6) Household characteristics mediate housing behaviors

Understanding how different types of households will adapt to climate stress is a promising area for future empirical research. In this section, I propose three broad sets of household characteristics that may impact adaptive behaviors, motivated by recent survey data. First, households with fewer financial resources (income, wealth, and access to credit) will have more difficulty undertaking expensive adaptations, such as long distance moves or substantial home retrofits. Second, households who are skeptical of climate change or lack detailed information about localized risks will be less likely to engage in any risk mitigation. Third, household choices will reflect lifestyle preferences, including relative demand for climate-related amenities and risk tolerance.

Exposure to climate risk—like pollution, crime, and other neighborhood disamenities—is higher among low-income, Black and brown communities. An extensive empirical literature documents how financial constraints and long-standing racial discrimination in housing markets has restricted location choices for Black, Latino, and Native households (Bakkensen and Ma 2020; Banzhaf et al. 2019; Pindus et al. 2017; Rothstein 2017; Thomas et al. 2018; Trounstine 2018). Consistent with this literature, the Federal Reserve Board's Survey of Household Economics and Decision-making (2022) finds that 20% of adults in families earning less than $25,000 reported a disruption from natural disaster, compared to 13% of those in high-earning households (Figure 3). Black and Hispanic adults were 5-7 percentage points more likely to have been impacted by natural disasters than non-Hispanic white adults.

**Figure 3: Low-income, Black, and Hispanic adults experience more disruptions from natural disasters**

Frequency of disruptions by family income and race/ethnicity

| Family income | Percent | Race/ethnicity | Percent |
|---|---|---|---|
| Less than $25,000 | 20 | Asian | 15 |
| $25,000-49,999 | 18 | Black | 19 |
| $50,000-99,999 | 14 | Hispanic | 21 |
| $100,000 or more | 13 | White | 14 |

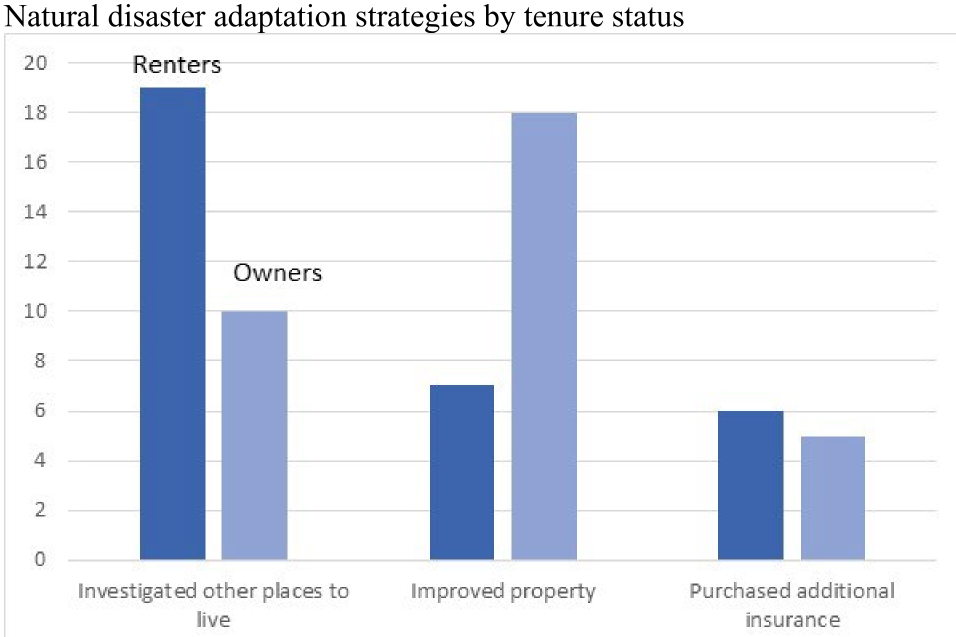
Source: Federal Reserve Board Survey of Household Economics & Decision-making (2022).
Note: Graph reports percent of adults.

Limited financial resources—current income, wealth, and access to credit—will also limit the ways in which many households can adapt to climate change. Moving is expensive; relocating from high-risk to low-risk neighborhoods is likely to come with higher housing rents or prices. Low-income households tend to live in older, poorer quality homes, even before accounting for structures' climate resilience (Wallace, Divringi, and Wardrip 2019). Further, because more low-income households rent their homes, they may not have the legal authority to undertake climate upgrades, even if they could afford it.

Bunten and Kahn's (2014) model of cross-city search assumes that long-standing residents of a city have greater frictions to moving, due to locally-based social networks, and thus are less likely to relocate. They also derive different propensities to move based on household income. High-income households with strong preferences for coastal lifestyles and the ability to self-insure (essentially, to rebuild after a disaster) may choose to live in high-risk cities, as do low-income households who cannot afford to move to lower-risk locations, while middle-income households sort into cities with lower climate risks.

While there has been little empirical research on how climate risk impacts renter households and rental markets, the Federal Reserve Board's survey offers some preliminary insights into how climate adaptation may vary by tenure (Figure 4). Renters face lower transaction costs in moving than homeowners, but are often restricted by their lease in the types of structural modifications they can make. Consistent with these constraints, about 19 percent of renters reported that they had investigated other places to live because of natural disasters, compared to 10 percent of homeowners (Figure 4). Conversely, homeowners were more than twice as likely to say they had improved their property to reduce climate risks. Both groups reported low rates of purchasing additional insurance, such as flood or earthquake insurance.

**Figure 4: Homeowners and renters take different approaches to climate risk**
Natural disaster adaptation strategies by tenure status




Source: Federal Reserve Board Survey of Household Economics & Decision-making (2022).
Note: Graph reports percent of adults.

For policymakers hoping to encourage climate adaptation, it will be important to understand what kind of information disclosure could prompt households to act. Climate risk modeling is often presented in complex and technical language, which could hinder households from understanding how to interpret it. Moreover, climate change skeptics may discount or ignore key information. The Federal Reserve Board (2022) survey found large differences in adaptive behaviors based on educational status, for both renters and owners. Among renters, adults with a BA or more were twice as likely as those with less than a high school degree to think about moving (22% versus 11%). Similarly, 20 percent of college-educated homeowners had improved their property to reduce risk, compared to 12 percent of homeowners without a high school degree. It is unclear what drives these differences—knowledge or information gaps, financial resources, or other factors that correlate with education. Further research would be very useful to inform outreach strategies.

In summary, without substantial policy interventions, it seems likely that climate change will exacerbate existing economic and racial disparities in housing well-being. Low-income and non-white households already face higher exposure to climate risks. Most of the adaptive strategies require some amount of financial resources upfront, which will be challenging for households with lower income, wealth, and access to credit. The structure of insurance and disaster recovery programs is currently quite regressive, providing more protection and greater payouts to high-income homeowners than low-income renters.

The next section considers the types of policy levers that could encourage households to reduce their exposure to climate risk.

**Section 7) Policy and market levers to encourage risk reduction strategies**

All of the housing behaviors discussed in this paper—location choice, structure choice, tenure choice, and expenditures—are influenced by both external market factors and public policies. Policymakers therefore have numerous levers with which to nudge households to reduce their exposure to climate risk. Policy options range widely in the degree of intervention, from relatively light touches (better information disclosures) to financial carrots (subsidies for home retrofits) to heavy regulatory "sticks" (declaring "no build zones"). This section briefly outlines four areas in which markets and policies could improve housing resilience. Each type of policy intervention offers ample scope for future research to explore potential policy designs and implementation strategies.

Mortgage and insurance markets

Two of the most important factors in household location choices—especially for owner-occupied homes—are the availability and pricing of mortgages and property insurance. Because both markets are highly regulated, policy changes that encourage or require prices to reflect local climate risk could have potentially large impacts on where households choose to buy homes and/or structural resilience. Less directly, financial regulations that consider climate risk of banks' balance sheets could also discourage capital flows into high-risk real estate (this might matter more for multifamily development and acquisition, which is less directly tied to the GSEs).

Land use policies

State and local governments could use their authority over land use regulation to discourage new development in risky locations, using a variety of tools. Among the lighter touch options, public agencies could provide greater information to developers and households about locally specific climate risks—and use that information to guide their own decisions about investments in local infrastructure. Land use regulations, from zoning laws that designate how land can be used to requirements for environmental review of construction projects, could be used to restrict or prohibit development in high-risk locations. Ideally, land use policies should protect environmentally risky or vulnerable areas while allowing sufficient development in low-risk areas to accommodate the demand for additional housing and commercial uses. In practice, many states and localities have struggled to achieve either of these goals. For example, the seminal California Environmental Quality Act enables existing residents to block climate-friendly projects like bike lanes while allowing continued sprawl into wildfire prone areas (Dillon 2014). Research that compares the outcomes and effectiveness of state and local environmental protections could inform better policy design and implementation.

Federal disaster recovery and planning programs could also be better designed to address local differences in climate risk (General Accounting Office 2010; General Accounting Office 2019; Spader and Turnham 2014). Although some funding is available to buy out homeowners in high-risk locations, the amount of funding is small relative to demand, resulting in years-long waiting lists. Some federal disaster recovery programs provide reimbursement for homeowners to rebuild in the same location—even in high-risk areas. Policymakers could change program rules to encourage or require relocation.

<u>Housing construction technology and quality</u>

Both private market actors and policymakers could reduce risk through better housing construction materials and techniques. Building codes for new construction continue to incorporate additional safety features; understanding what features offer the greatest additional protection against specific types of risks, and the cost effectiveness of various features, would help inform decisions by the construction industry and housing consumers. An understudied area is how to encourage climate-hardening retrofits of existing homes. Are there economies of scale (such as reductions in per-home labor and materials costs) in undertaking similar retrofits to clusters of nearby homes? Could local governments or non-profits coordinate this activity to increase resilience in low- or moderate-income neighborhoods? How could owners of low-cost rental housing be encouraged to retrofit their buildings? Is there a sufficient supply of contractors with appropriate expertise, as well as parts and materials?

Local infrastructure resilience

While the primary focus of this piece is on households and individual homes, similar considerations also apply to neighborhood-serving infrastructure, including streets, sidewalks, public transit, water and sewer systems, and parks. Local and regional governments must decide on the level and type of investments they make in infrastructure systems to protect against climate stresses, such as where to improve stormwater runoff or install neighborhood cooling features. Localities are also responsible for disaster planning and recovery efforts, such as developing evacuation strategies and setting up emergency shelters.

But local governments vary widely in their capacity to carry out these tasks; federal or state agencies may need to provide additional staff, expertise, or financial resources, especially for lower-income communities (Schuetz 2022, Chapter 7). Additionally, some planners have raised concerns over "climate gentrification"—the expectation that undertaking resilient infrastructure projects in lower-income neighborhoods could raise housing costs and lead to displacement of lower-income households (Shokry et al. 2022).

How communities can and will engage in city- or neighborhood-level risk reduction strategies offers several interesting topics for future research. A few of these include: How does climate stress impact local taxes (property tax rates, user fees, or special assessments)? How salient are local governments' climate strategies in local elections? What are the implications for municipal bond markets?

## 8) Conclusion and directions for future research

Climate-related events pose an increasing risk to U.S. homes and neighborhoods, and are gradually gaining salience among a wider set of households, real estate industry groups, and policymakers. Households can reduce their exposure to climate risk through a variety of housing decisions, including moving to lower-risk locations, upgrading the safety features of their homes, renting rather than buying in high-risk locations, and adjusting their spending on operating costs. How they choose to act will reflect household resources, knowledge, risk tolerance, and lifestyle preferences. At this point, there is considerable uncertainty about reactions from mortgage lenders, insurance providers, and policymakers at all levels of government. Currently, public policies are not well designed to encourage risk reductions, but a wide range of policy levers could be used to nudge consumers and market actors towards less risky choices.

There is a rapidly growing urban economics literature on the interactions of housing and climate, but there is still wide scope for empirical work on timely, policy-relevant questions. What information do households need to make better choices? What entities should provide that information, and how? How can public policies support and nudge private industry responses? What are the most cost-effective and politically feasible adaptive strategies for individual homes, neighborhoods, and cities? What are the pros and cons of reducing climate risk through regulatory policies (e.g., mortgage market and financial regulations) versus fiscal policies? While the focus of this paper is on U.S. households and market contexts, comparative research on other countries could be useful in exploring the effectiveness of other market structures and policies.

Most of the empirical work on pricing of climate risk into real estate has focused on owner-occupied housing. Similarly, research on climate hardening of structures usually assumes that the costs will be borne by homeowners. Much less thought has been paid to risk reduction strategies for the one-third of Americans who rent their homes, and the owners of low-rent properties.

Finally, researchers and policymakers should consider the equity implications of various risk-reduction strategies. Policies such as local climate disclosure risk could exacerbate existing economic and racial disparities by lowering property values in poor and/or non-white communities. Equity implications should be explicitly part of discussions on which structures and neighborhoods should receive funding (private or public) for climate-resilient retrofits, and which ones to demolish or retreat from.

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