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THE HAMILTON PROJECT

EPIC
ENERGY POLICY INSTITUTE
AT THE UNIVERSITY OF CHICAGO

Protecting Urban Places and Populations from Rising Climate Risk

Matthew E. Kahn

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We believe that today's increasingly competitive global economy demands public policy ideas commensurate with the challenges of the 21st Century. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments.

Our strategy calls for combining public investment, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine — to introduce new and effective policy options into the national debate.

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NOTE: This policy proposal is a proposal from the author(s). As emphasized in The Hamilton Project's original strategy paper, the Project was designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. The author(s) are invited to express their own ideas in policy proposal, whether or not the Project's staff or advisory council agrees with the specific proposals. This policy proposal is offered in that spirit.

BROOKINGS

Abstract

Climate change has already produced a range of risks that confront Americans cities; even under optimistic projections for carbon dioxide (CO_2) emissions mitigation, these risks will continue to increase. Moreover, key choices must now be made regarding public investments in infrastructure. Ensuring that infrastructure investments help build climate change resilience is therefore an urgent necessity. This paper proposes three complementary policies for enhancing urban resilience to new climate risk. The first focuses on improving key urban infrastructure. The second addresses the urban poor, who are the most vulnerable in the face of climate change risks. The third proposal aims to reduce the cost of adaptation through better-functioning markets, and to allow prices of natural resources, energy, and coastal insurance to reflect true conditions.

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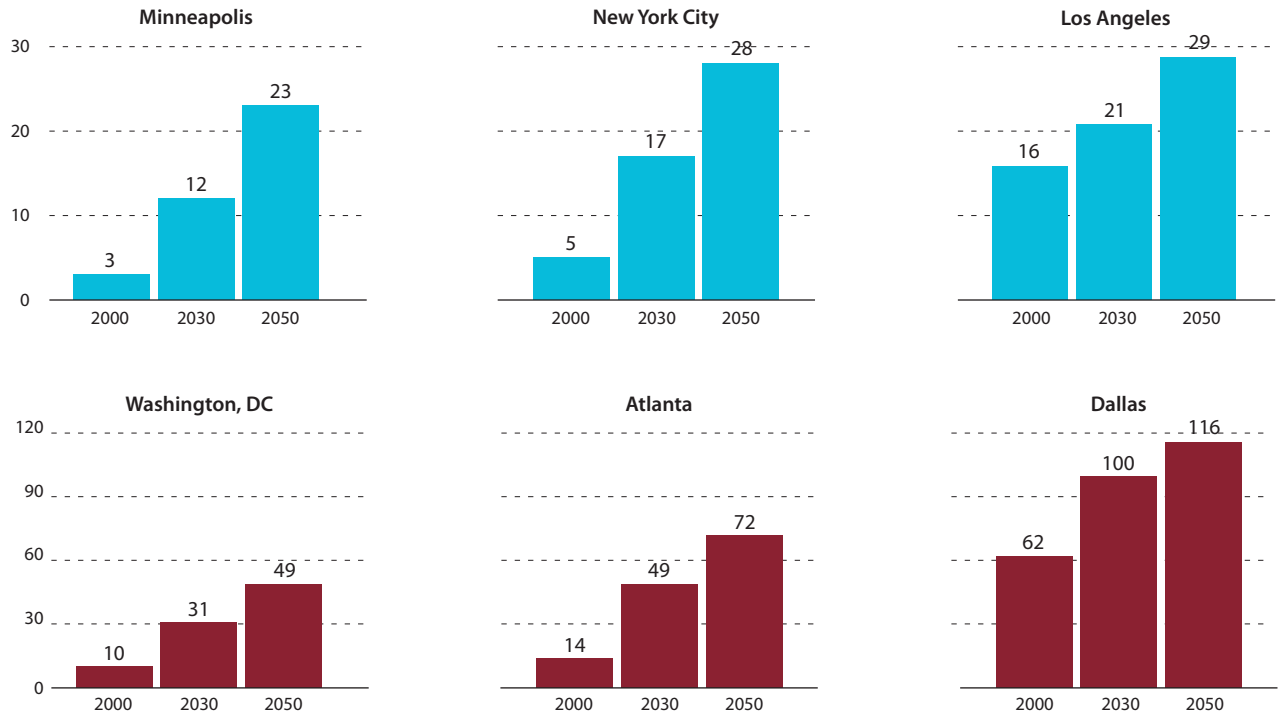
Chapter 1. Introduction

The year 2016 was the hottest summer in modern times; much of the Southwest faced drought, and the effects of Hurricane Sandy on the Northeast coast in 2012 persisted. Despite the fact that per capita CO2 emissions generated by the United States have been constant for more than 20 years, the world's ambient carbon dioxide level has now risen to 401.0 parts per million, up from 362.6 in 1996 (NOAA n.d.). And though a global climate change agreement was achieved, global temperatures are still expected to rise 3.5°C (6.3°F) degrees by 2100 even under the terms of the agreement. In the absence of a more aggressive approach to mitigation, the world's greenhouse gas (GHG) emissions are likely to continue to rise as the developing world's population and per capita income increase.

Basic climate science predicts that the United States will face increased risk from heat, drought, and natural disasters as global CO_2 concentrations increase (Field et al. 2007). These risks will vary by region, state, and even neighborhood, with the degree of exposure depending on investments that are made in advance. For example, figure 1 shows that while the number of days per year for which the heat index reaches 104°F for Los Angeles should increase by only about 13 days, that number is projected to increase by 39 days for

FIGURE 1.

Projected Number of Days per Year with Heat Index Above 104°F for U.S. Cities



Source: Climate Central 2016.

Note: Blue bars are on a y-axis with a maximum of 30 days. Red bars are on a y-axis with a maximum of 120 days. Days with a heat index above 104°F are referred to as "danger days" in Climate Central report. Annual average danger day count based on current emissions trends. Projected temperature and humidity calculations come from Climate Central analysis of CMIP5 multi-model ensemble dataset.

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Washington, DC and by 58 days for Atlanta. This paper will focus on introducing cost-effective strategies to protect city dwellers from these new risks.

As of early 2017 the United States is also engaged in a vigorous discussion of potential infrastructure investments that could be initiated in the near future (Summers 2016). At a time when interest rates are near historic lows, such investments appear particularly desirable. It is especially important to ensure that infrastructure investment plans take account of climate change risks and build resiliency. The impact of climate change will be expensive and wide-ranging, with potentially devastating costs for our communities, but timely action now can minimize these costs and leave the United States better prepared for an uncertain future.

There is a growing awareness of the risks associated with climate change. As many as 2 million properties might be submerged by the year 2100 (Rao 2016a). Although we must be cautious about interpreting such long-run predictions, as well as mindful that adaptation can lower the cost of this development, Rao predicts that this would lead to a $900 billion loss (Rao 2016b). Importantly, a majority of America's population and per capita earnings are located in coastal counties (Rappaport 2003).

At the same time that the United States faces new risks, we have the capacity as individuals and as a society to build up our resilience to these risks.

At the same time that the United States faces new risks, we have the capacity as individuals and as a society to build up our resilience to these risks. Relative to other nations, the United States has a number of advantages in adapting to climate change: a wide range of climates with many possible locations for building cities, an educated and wealthy populace, strong institutions, an active free media, and advanced technology (including communications). Although weather shocks certainly have a random component such that we cannot predict with certainty when a heat wave or a major rainstorm will occur, we also have an increasing ability to predict which geographic areas face greater risk. This information allows for resilience planning and strategic investments that together reduce our collective risk exposure.

There are two broad types of policies that can protect urbanites from risk. The first aims at improving climate-relevant infrastructure. Cities will need higher-quality transportation networks, water treatment systems, and electricity generation and transmission networks, all of which face risks related to climate change. Many older cities currently rely on dated infrastructure that needs to be upgraded and retrofitted to prepare for new risks. Key decisions that must be made now include how to invest in resilience and how to finance those investments.

A second type of policy aims to improve the quality of life of the most vulnerable. The urban poor will face the greatest challenges in coping with new climate risks because they live in the lowest-quality housing in the parts of cities that are most vulnerable to climate-change shocks, and because they possess limited resources to fund individual adaptation.

Higher-income people are able to use markets to protect themselves from emerging risks. They can move to safer areas within their current city or to new, safer cities, and they can obtain housing and transportation that are more climate-resilient, as well as better air conditioning and health care. As new challenges arise and higher-income people seek solutions to those challenges, markets will respond by supplying solutions. This induced innovation is a hallmark of capitalism: the third policy proposal will speak directly to ways to encourage the unleashing of such innovation.

This paper focuses on introducing cost-effective policies that increase the resilience of our cities and improve the quality of life of the urban poor during a time of increased climate risk. The three proposed policies also aim to create efficient markets for insurance, water, and electricity that encourage conservation and induce entrepreneurs to design new products that facilitate adaptation:

1. **Improve and invest in the resilience of infrastructure.** Many cities, especially older, poorer cities, have aging infrastructures that have not been maintained consistently. Infrastructure ranging from the transportation network, to the electricity grid, to sewerage systems now face greater risk from severe storms, extreme heat, and sea-level rise. At

a time when the United States is preparing to increase its infrastructure investments, it is crucial to invest in lasting, climate-resilient infrastructure.

2. **Protect the urban poor.** The poor face greater limits on their options to respond to new threats. They tend to live in older housing and in neighborhoods that are at greater risk. Many do not own a car and have limited access to air conditioning. This group is thus likely to face greater exposure to extreme heat and pollution, have worse work conditions, and have worse access to high-quality food and health care. This combination of unique risks means that policy must separately address the effects of climate change on low-income households.
3. **Correct the mispricing of insurance and commodities, thereby inducing innovation.** Climate change will increase sea levels and cause droughts and heat waves. Given that millions of people live in current floodplains and in areas at risk of future flooding, real estate insurance prices in such areas should reflect this risk. Current flood insurance pricing creates perverse incentives that pricing reforms can mitigate. In addition, the prices of water and electricity should reflect evolving conditions of scarcity associated with rising temperatures and recurrent drought.

Together these three policies will help cities to prepare and adapt to increased climate risk—and will do so in a way that acknowledges the unique needs of low-income urban residents.

Chapter 2. Background

In late October 2012 Hurricane Sandy made landfall in New Jersey and New York, where it devastated coastal communities and urban infrastructure. The storm, which affected the entire eastern seaboard from Florida to Massachusetts, caused more than $71 billion in damages, making it the second-costliest tropical cyclone in the U.S. since 1900, after Hurricane Katrina in 2005 (NOAA 2014).

Hurricane Sandy spurred significant action at the federal level. The Disaster Relief Appropriations Act of 2013, which included the Sandy Recovery Improvement Act of 2013, allocated $50 billion for hurricane relief. The bill's provisions included $9.7 billion for the National Flood Insurance Program (NFIP) to cover claims filed by individuals whose homes had been damaged or destroyed (GPO 2014).

In the wake of Hurricane Sandy, the Hurricane Sandy Rebuilding Task Force (U.S. Department of Housing and Urban Development [HUD] n.d.) delivered a rebuilding strategy for areas affected by the storm. The Task Force launched the Rebuild by Design competition to encourage innovative, locally contextual, and regionally scalable projects to enhance climate resilience. In addition, the Department of Transportation's Federal Transit Administration dedicated $5.7 billion to four of the area's most impacted transit agencies; nearly a quarter of those funds were allocated to make transit systems more resilient to future disasters (White House 2013).

As part of broader efforts to address climate change, President Obama issued an executive order in October 2009 requiring every federal agency to identify risks and vulnerabilities posed by climate change, and to develop and implement actions to address these concerns (White House 2009). In 2013 President Obama further directed federal agencies to develop, update, and implement their Climate Change Adaptation Plans. Also in 2013, the president issued a Climate Action Plan outlining the federal government's steps toward climate change mitigation and adaptation, and international cooperation on climate change. With this plan President Obama directed agencies to support climate-resilient investments and fully integrate climate risk management considerations into infrastructure and natural resource management planning (White House 2013). The Climate Action Plan included outreach to a variety of stakeholders, including state, local, and tribal leaders.

BOX 1.

The National Flood Insurance Program (NFIP)

The NFIP allows homeowners, business owners, and renters to purchase insurance against losses from flooding. Through elected officials, communities can volunteer to join NFIP, and can separately join the Community Rating System (CRS) to receive discounts on premiums. These discounts depend on flood risk–reduction measures taken by communities, such as preservation of floodplains as open space and development of a comprehensive floodplain management plan. Furthermore, residents and business owners who live or work in a Special Flood Hazard Area are required to purchase flood insurance if they have acquired a loan from a federally regulated and insured lender.

The Biggert-Waters Flood Insurance Reform and Modernization Act of 2012 was passed by Congress to increase NFIP premiums to better align with the actuarial risk of flood damage, and to gradually decrease federal subsidies to homeowners. However, Congress subsequently elected to delay or eliminate these increases in NFIP premiums.

This flip-flop on allowing insurance prices to properly reflect risk appears to be consistent with Mancur Olson's famous prediction that when interest groups are tightly organized and have low transaction costs to meeting, the small group with much at stake (in this case, the coastal property owners) can win a political battle against a large number of people (here, the inland taxpayers) who have less to gain from reforms and who face transaction costs to organize (Olson 1971).

The plan also directed federal agencies to update flood-risk reduction standards for federally funded programs, and to incorporate recent science on expected rates of sea-level rise. In addition, the plan sought to develop actionable climate change science to improve understanding of the impact of climate change, explore risk and catastrophe modeling, and

develop tools for policy makers to respond to long- and short-term effects of extreme weather.

Among the federal agency plans, HUD's latest Climate Change Adaptation Plan (2014) is particularly relevant to this proposal. To confront the impact of climate change, HUD's adaptation plan proposed several actions to address rising sea levels, temperature shifts, and extreme weather events. For example, the plan recommended updating the Targeted Lending Initiative, expanding it to promote investment in properties with improved disaster relief and sustainability features. To address shifts in temperatures, HUD proposed updating utility expense levels, allowances, and surcharge formulas in order to decrease the financial burdens associated with rising utility expenses that low-income tenants would experience due to more-frequent temperature extremes. Finally, the plan also called for the development of toolkits and training materials for HUD grantees, including updated guidelines on natural disaster and climate resilience (HUD 2014).

In a progress report published in the summer of 2015, the White House highlighted various federal actions to improve climate resilience (White House 2015):

- Resilience standards: The president signed Executive Order 13690 in January 2015, establishing a federal flood-risk management standard and requiring all future federal investments to meet higher flood-risk standards, thereby reducing the risk of future flood disasters.
- Green infrastructure: In February 2015 HUD issued a report, "Green Infrastructure and the Sustainable Community Initiative," outlining resources, best practices, and lessons learned to improve green infrastructure. Additionally, the United States Army Corps of Engineers (USACE) released a report assessing how natural and nature-based features such as wetlands, beaches, and dunes could improve coastal resilience (USACE n.d.). Finally, at the time of the USACE report's publication, the Federal Emergency Management Agency (FEMA) was assessing ways green infrastructure projects could be eligible under the Hazard Mitigation Assistance programs that would reduce future risk and ameliorate the impacts of climate change.

Policy makers at the state level are also working to enhance climate change resiliency. California is a notable example: in 2015, a number of bills were passed that aim to better prepare the state for the impacts of climate change. Specifically, policy makers acted to improve the coordination of adaptation efforts across state agencies, directed local government to incorporate adaptation efforts into their planning, and created an initiative within the state's Office of Planning and Research to provide information and technical assistance related to climate adaptation (California State Legislature 2015).

Chapter 3. The Challenge

There is much that we do not know about new climate risks. Specifically, we do not know how higher temperatures will impact the economy and our quality of life. How will agriculture be affected? How will senior citizens be affected? How will specific cities (e.g., Newark or San Francisco) be affected?

The negative impact of climate change will vary considerably across the United States. Historically, natural disasters have occurred in some states at disproportionate rates. Figure 2 shows the share of all FEMA-declared disasters experienced by states between 1953 and 2016 (FEMA 2011). These data are useful for seeing which geographic areas are over-represented with respect to past disaster risk. For example, Louisiana and Kentucky experience more disasters than would be predicted if disasters occurred with equal probability across the states (USACE n.d.).

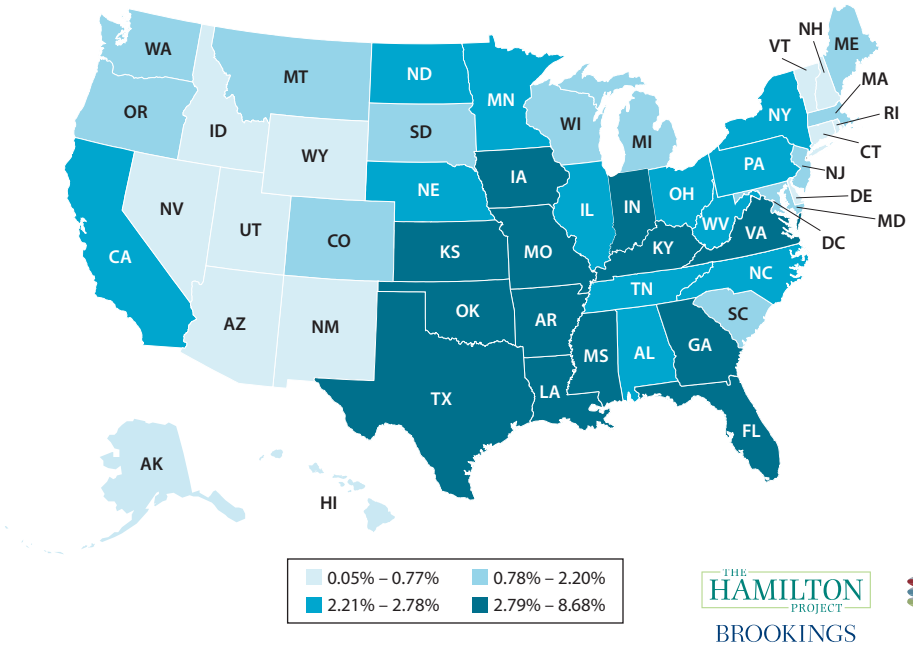
Climate change will likely cause some combination of extreme rainfall events, sea-level rise, and extreme heat for long stretches of time. If sea levels rise 0.9 meters by 2100, which is within the range of scenarios considered by climate scientists, then 4.2 million Americans would be put at risk of inundation (Hauer, Evans, and Mishra 2016). If sea levels rose by 1.8 meters, 13.1 million Americans would be put at risk. The greatest population at risk of rising sea levels is concentrated in counties that border the Gulf of Mexico.

Every day, residents of U.S. cities take for granted that they can access electricity, flush the toilet, and use public roads and transport to get to work. Yet in each of these cases, public infrastructure plays a critical role in providing these necessities. People notice infrastructure only when it breaks. There is an element of "out of sight, out of mind" in infrastructure. When shocks occur such as water pipes bursting in Los Angeles or the Metro system shutting down in Washington, DC, people are reminded of the key role basic infrastructure plays in our lives. Such infrastructure is durable, but not infinitely so.

Much of our current infrastructure was built decades ago and some has fallen into a state of disrepair. For example, the

FIGURE 2.

Share of FEMA Disasters by State, 1953–2016



Source: FEMA 2016.

BOX 2.

Sea-Level Rise in San Francisco

The city of San Francisco faces a high level of uncertainty with regard to rising sea levels. Surrounded on three sides by the San Francisco Bay to the east and the Pacific Ocean to the west, the city is particularly vulnerable to sea-level rise by comparison with other major cities in the country. General estimates for sea-level rise over the next century range from 36 inches to 120 inches (Brinklow 2016).

Because it borders the Bay as well as its importance to the city's economy, the San Francisco International Airport (SFO) is of particular note. According to the San Francisco Sea Level Rise Action Plan, in a worst-case scenario sea levels would rise so much as to nearly submerge SFO by the end of the century. More likely than this scenario, however, is the increased potential for storm flooding, which would occur in even the most optimistic climate change scenarios (City and County of San Francisco 2016).

Possible preventive measures include improving infrastructure, such as barricades around SFO's perimeter and seawalls that act as dams. Unfortunately, this infrastructure will likely be insufficient for combating the rising sea levels. The airport has launched a Shoreline Protection Program with the goal of mitigating the risks that exist in current defensive measures. For example, the current seawalls are extremely vulnerable to significant sea-level rise. Existing infrastructure would be replaced with equipment designed specifically to deal with floods, in contrast to the current rudimentary retaining walls.

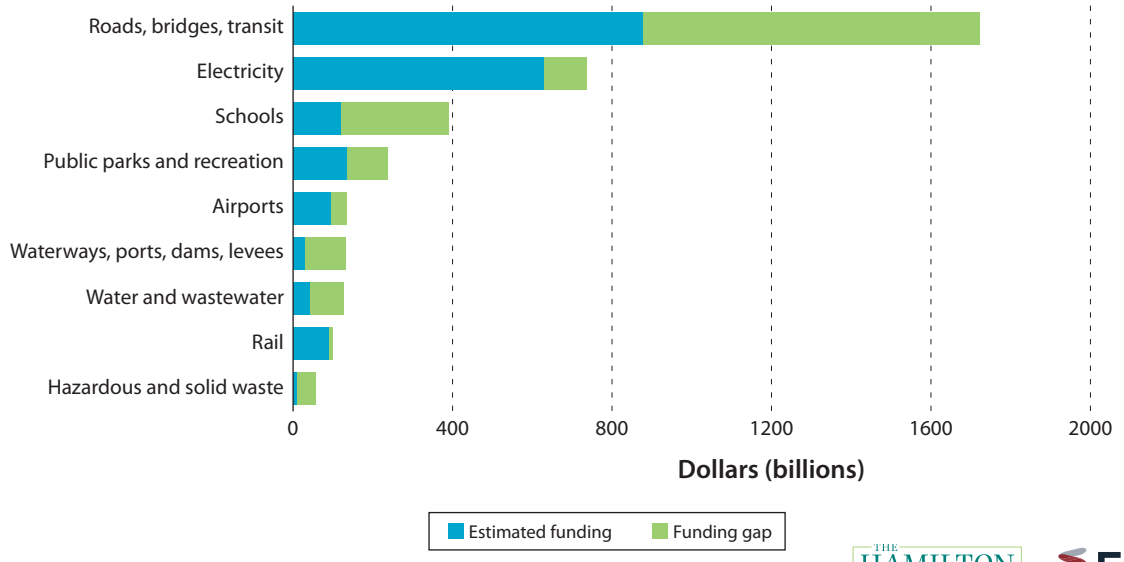
Roughly two-thirds of the public property value at risk in the city is that of SFO. In the case of a 66-inch rise in sea level, damage to SFO could amount to $55 billion (City and County of San Francisco 2016). The Airport Shoreline Protection program, to be carried out over the next several years, plans to eliminate this risk.

Metro transit system in Washington, DC, which opened in 1976, has developed numerous problems that are partly related to deferred maintenance spending (FTA 2015). Figure 3 depicts the gaps in needed infrastructure, showing that deficits in transit, the electrical grid, and water infrastructure (including levees) are particularly pronounced. The need for these investments represents an opportunity to put in place infrastructure that is more climate resilient.

Climate change necessitates a broad-based research and infrastructure investment response, but it also creates particular problems for the poor, who are both exposed to disproportionate risk and particularly poorly equipped to adapt. Low-income households tend to live in older center cities, in older housing, and in neighborhoods with few resources. Low-income households often do not have easy access to air conditioning or safer housing that can withstand extreme heat or flooding. For example, the

FIGURE 3.

Infrastructure Needs, Funded and Unfunded, 2013–20



Source: Center on Budget and Policy Priorities 2016; ASCE 2013.

Note: The funding gap does not take into account climate change needs.

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Chicago heat wave in 1995 disproportionately killed older African Americans living in high poverty areas (Klinenberg 2015). Many of these individuals lived in housing without working air conditioning. Indeed, figure 4 shows the uneven distribution of both heat-related mortality and air conditioning use for the city of New York. Many of the neighborhoods facing the highest mortality during extremely hot days are also neighborhoods that have low air conditioning ownership and use.

Preparation for and adaption to climate change requires investments in infrastructure that make full use of relevant research, as well as targeted assistance to low-income households with a reduced ability to adapt. However, adaptation will also require that individuals face the correct incentives, as expressed in market prices for insurance and scarce commodities. Real estate investors in areas facing flood risk, water consumers in drought-plagued areas, and hot-weather electricity consumers are all less likely to make the socially efficient decisions, given the current distortions in the pricing of electricity, water, and insurance.

It is very difficult to calculate the probability of significant flooding in any year or how this flood risk changes over time (Soper 2016). Though new statistical approaches are being taken to model coastal flood risk, markets for flood insurance continue to suffer from two problems. First, if community residents have better information about flood risk than outsiders, insurers might be reluctant to offer protection from flood risk. Similarly, uninformed outsiders might underestimate the likelihood of flood damage, especially if they over-rely on past experience and neglect to account for the growing impact of climate change. Second, if an expectation emerges that the government will recompense property owners for damages from climate change-related events, individuals and businesses could ignore the possibility of these events and locate themselves in unsafe places, which would impede adaptation to climate change.

In addition to the problems of flood insurance, individuals often face prices for commodities—water and electricity—that do not reflect actual conditions of scarcity. Typically, prices are kept artificially low, which encourages overuse and discourages conservation. Prices can also be inflexible, failing to rise when circumstances temporarily cause increased scarcity.

FIGURE 4A.

Mortality Rate Ratios for Seniors during Days of Extreme Heat, New York City

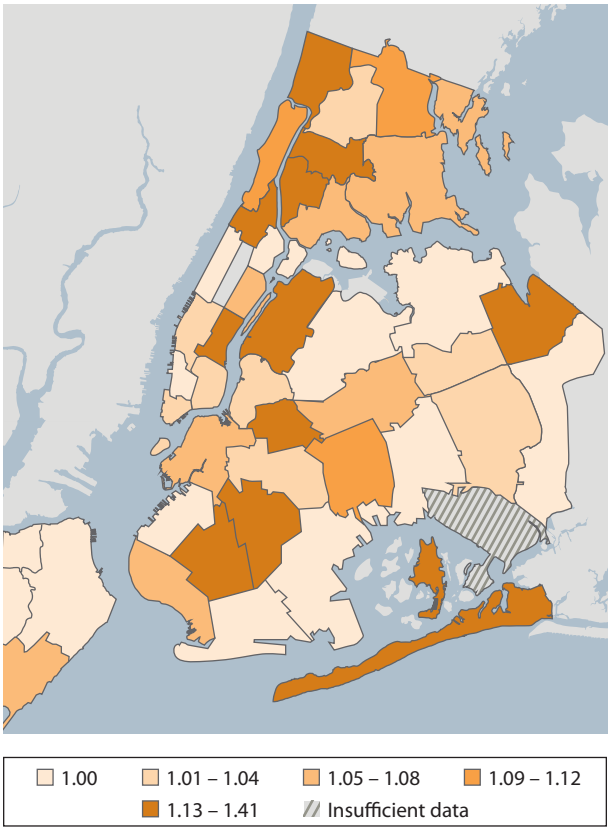
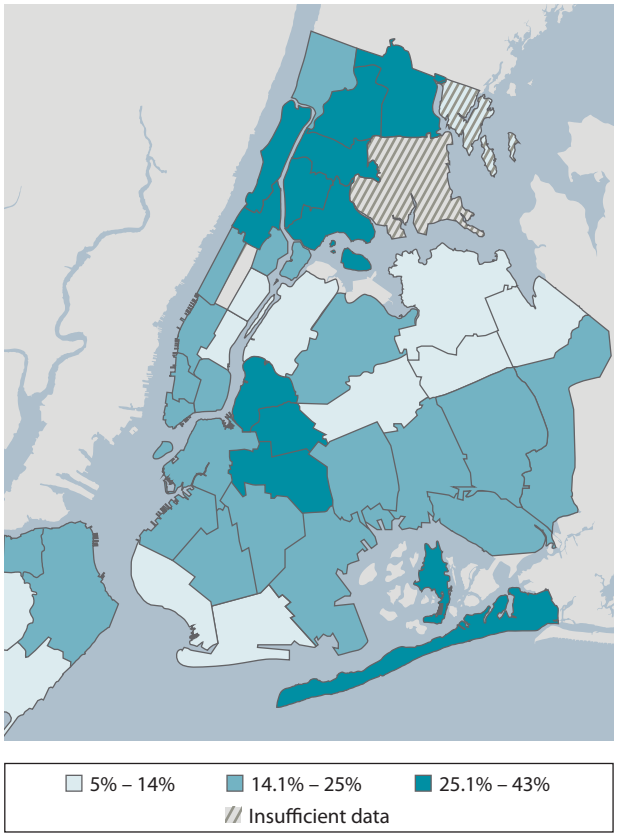


FIGURE 4B.

Percent of Seniors Who Do Not Use Air Conditioning, New York City



Source: Klein-Rosenthal, Kinney, and Metzger 2014.

Note: Senior is defined as age 65 and older. The Mortality Rate Ratio for seniors age 65 and older (MRR65+) shows excess mortality (ratios above 1.00) during very hot days (maximum heat index = 100 °F +) compared to all May through September days, 1997–2006. Regions are divided by New York City United Hospital Fund (UHF) neighborhoods (n=42).

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Chapter 4. Proposal: Invest in Urban Infrastructure Resilience

The first proposal seeks to harness needed investment to improve urban quality of life by reducing the probability of severe, disruptive risks caused by extreme climate change events.

DIAGNOSING INFRASTRUCTURE RESILIENCE RISK

At the height of the Great Recession, the Federal Reserve Board conducted analyses—typically referred to as stress tests—of different banks to measure their ability to avoid bankruptcy in the midst of financial shocks. This same approach can be applied to identify cities at risk.

Big data—very large administrative data sets generated by firms and government agencies—has enabled fine-tuning of investments based on local data, better focusing on areas that are at greater risk. The Chicago city government has been working with engineers and data scientists to install 500 information-gathering nodes throughout the city (Computation Institute 2016). By measuring data on air quality, climate, traffic, and more, this sensor network will provide useful real-time information. The city will post these data in an open-data format to allow concerned citizens, the media, and researchers to have real-time access to the data. Such information holds urban leaders accountable if clear evidence emerges that certain neighborhoods and groups of citizens are suffering significant reductions in local quality of life related to climate change. Other easy-to-access sources of useful data are 311 calls (such as in Chicago and New York City) and social media usage. In a city featuring millions of people who have constant Internet connectivity, people can easily supply information about emerging risks.

The creation of such a real-time database is a necessary but not a sufficient condition for bringing about accountability for infrastructure gaps. If nobody analyzes the data—or if they are in a format such that they cannot be compared across cities at a point in time or for a given city over time—then such data will not provide a benchmark for quality-of-life dynamics. To address this concern, the federal government could subsidize a type of X-Prize competition for both the collection of urban risk information and for creative programs for disseminating and encouraging urban leaders to act on this information (X-Prize.org n.d.). The federal government's investment in standardized data will allow for benchmarking such that the media can publicize valid cross-city comparisons. Such information will inform voters, and thus will affect elected officials' behavior (Ferraz 2008). A growing development in economics literature has documented that report cards encourage elected officials to change their behavior and help to mitigate principal-agent problems.

In addition to using information from sensor networks, cities should be required to contract with federal engineering experts to inspect key infrastructure. Disinterested experts would produce annual status reports for each city, focusing on the quality and resilience of key infrastructure ranging from transportation, to water treatment, to flood control.

These annual reports will resemble the analyses (or stress tests) that the Federal Reserve Board has conducted to predict whether major banks can withstand shocks to financial markets (Federal Reserve Board of Governors 2016). As part of the same climate change resiliency reports, and similar to current infrastructure report cards, the USACE or the American Society of Civil Engineers (ASCE) will conduct thorough reviews of the infrastructure of each city to inspect its electricity grid, water treatment facilities, highways, and airports, thereby determining which infrastructure is at risk from extreme heat, flooding, natural disasters and sea-level rise (ASCE n.d.). Such reports should be posted on a well-publicized website to create public accountability. These reports will allow cities to be compared at a point in time, and will also allow progress for a single city to be measured over time.

Infrastructure problems are often hidden until they are thrust into the open when something breaks. But by conducting infrastructure assessments and broadly publicizing the results, local elected officials will face new public pressure to address infrastructure problems. The sunshine created by these reports would nudge elected officials to investigate these challenges, with the local media playing a key role in spreading the information in these reports (Neidell 2008).

Moreover, assessments will provide a source of information that can help shape and refine ongoing efforts to build resilience. Economic research studying choice under uncertainty has generated a key insight: when an investor faces risk but is aware that she will soon learn relevant information, she wisely delays

making an irreversible decision. To be clear, this is not an argument for inaction in the face of climate change, and in fact many investments are less expensive and more beneficial when made early. But the option value approach to investment stresses the importance of making investments that can be reconfigured as we learn about the evolving conditions and risks.

In this age of big data, we have increased access to real-time data for identifying threats to quality of life. Cities around the world are facing similar challenges. This demand for solutions creates a marketplace for entrepreneurs and opens the possibility of beneficial social learning such that any given coastal city can learn from other coastal cities that have attempted different local approaches. Cities can experiment, and spread the news about what efforts have and have not been effective in protecting the urban population.

New investments in infrastructure will be most effective if they flow to areas that both face the largest new risks from climate change and have the most difficulty in funding the protective investments on their own.

Next, I propose a set of federal financing programs to encourage the lender to prioritize the projects that are found to be effective.

FINANCING RESILIENCE INVESTMENT

Although cities will differ with respect to the investments they will require to protect their infrastructure against climate change, many will need to tap into new capital to finance these investments. Research on local public finance offers several relevant insights. First, since land owners are the major beneficiary of improvements in local quality of life, they collectively have a strong interest in implementing such investments. If a city does not make the required investments and so remains highly vulnerable to the negative impacts of climate change, rents and land prices will be lower than they would otherwise be. Of course, local land owners would prefer that the federal government pay for costly investments in resiliency, but a government facing a balanced budget constraint must raise taxes to cover new expenditures. One way to finance needed investments is to raise local property taxes and to earmark the tax revenue to infrastructure improvements. A second way to finance such investments would be to issue bonds. Cutler and Miller (2006) have documented that such bonds played a key role in the early decades of the 20th century, allowing major U.S. cities to finance their construction of water treatment systems. Such investments sharply reduced mortality from infectious disease (Costa and Kahn 2015). To encourage this approach, the federal government could offer a subsidy for bond issues focused on climate resilience, thus reducing the expense incurred by cities looking to invest in resiliency.

The federal government faces important choices regarding how to allocate its support across different types of investment. New investments in infrastructure will be most effective if they flow to areas that both face the largest new risks from climate change and have the most difficulty funding the protective investments on their own. In addition, if a geographic area faces climate change risk but has only a small population, then protecting such an area yields few benefits. This discussion highlights that in developing criteria for how to allocate resilience investment, the federal government must consider the following questions: How much less risk does a geographic area experience per dollar invested? How many people would be exposed to the risk if the investment is not made? Would the location have financed the same infrastructure investment without federal intervention?

An objective criterion for judging the merits of investing federal funds would depend on the number of people who will be protected by an infrastructure investment as well as the extent of protection conferred. A second criterion would be to evaluate the percentage of poor people affected: greater weight would be given to projects that benefit a larger percentage of poor people.

One standard approach to implementing this vision would be for the federal government to set up competitive grants to states that are judged according to the previous criteria. To further raise the likelihood that cities submit only meritorious projects, the federal government would require that cities pay for 50 percent of the infrastructure project. This requirement that the cities have "skin in the game" would lead them to more carefully plan their investment choices. Alternatively,

BOX 3.

Green Infrastructure in Camden, New Jersey

Local governments addressing flood and storm risk sometimes choose to set aside land as wetlands to provide basic flood prevention that cannot occur with impenetrable surfaces (EPA n.d.). The federal government can assist in this effort to create new public parks, augmenting local government efforts and private land conservation trusts.

Camden, New Jersey, has seen sharp population decrease since the mid-20th century. With the tax base eroding, infrastructure investments were neglected for decades. In recent years, neglect of water and sewerage infrastructure has led to backups and flooding across the city.

To address these issues, local community-based organizations such as the Cramer Hill Community Development Corporation have partnered with county and city authorities, including the Camden County Municipal Utilities Authority. Using grants from the U.S. Environmental Protection Agency (EPA) and the New Jersey Department of Environmental Protection Green Acres Program, these organizations will restore natural drainage patterns to allow rainwater to flow to the Delaware River, decreasing the strain on the sewerage system.

In Camden's Waterfront South neighborhood that was once part of Camden's industrial hub, frequent flooding raised concerns about contamination from scrapyards and contaminated sites. Partnering with the community, the Camden Stormwater Management and Resource Training (SMART) team transformed the site into a public community park featuring a series of rain gardens. Without this development, 470,000 gallons of stormwater would have entered the sewerage system annually, contributing to sewage overflow events (New Jersey Future 2014).

the federal government could simply cosign loans for cities, such that the federal government would bear default risk and cities could borrow at a lower interest rate. In return for access to federal loan guarantees, the localities would face auditing conditions and other oversight rules that would reduce the likelihood of malfeasance and corruption.

Finally, a more sophisticated federal funding mechanism would involve subsidized loans to cities, where the extent of the subsidy increases with specific proposed resilience investments. For any given piece of infrastructure, the USACE could create a metric of investments that would yield a resilience bonus; in other words, the federal government would offer a subsidy that is proportional to the project's resilience score. One feasible approach would be to mimic the Department of Energy's Energy Star program or Leadership in Energy & Environmental Design (LEED) certification program. These certifiers use criteria to determine the environmental performance of a building—energy consumption, water consumption, and other resource use—and then determine if the building qualifies for a standard of excellence status. A similar approach would help focus cities' investments in resiliency.

EVALUATING THE EFFECTIVENESS OF NEW INFRASTRUCTURE INVESTMENT

The benefits from investments in resiliency can be measured using data, for example by the sensor networks that Chicago and other cities are introducing. Measures of flooding and transportation disruption could be constructed annually for each city. Evidence of increased resilience would be demonstrated by the extent to which urban areas can increasingly handle heat waves, heavy rainfall, and sea-level rise without negative consequences for citizens. If there are fewer public transit delays, deaths, hospitalizations, or flood insurance claims filed in the wake of a subsequent disaster, that would be evidence that the city's resilience has increased. To refine this type of evaluation, a control group will be helpful in judging whether the resilience investments have truly been effective at causing reduced risk. The control group here would be similar to coastal cities that have not made such new resilience investments. Each city would be notified that its likelihood of receiving future federal resilience investments will be tied to such evaluation reviews. This approach will help to create accountability and raise the likelihood that cities will use scarce public funds effectively.

Chapter 5. Proposal: Protect the Urban Poor against Climate Shocks

The second set of proposals seeks to enhance the quality of life of the urban poor during a time of rising risk.

INFORMATION PROVISION AND SHORT-RUN FORECASTS

In this smartphone era, the local authorities can use satellite information to quickly provide information about storm flood risk, heat wave risk, and air pollution risk to citizens as events unfold. A 2014 Pew Research Center survey found that half of U.S. adults earning less than $30,000 per year owned a smartphone (Pew 2014). In practice, people do respond to such information alerts, with the educated most likely to respond—likely because they have access to more resources that allow them to take action such as evacuating a flooding area (Neidell 2009). The remote sensing data discussed previously will allow spatial researchers to make high-quality maps of evolving conditions, thereby communicating more effectively with the public about the nature of the risks. Research in behavioral economics has argued that people are more likely to have behavioral biases and thus to make mistakes in making choices if they have lower cognitive abilities (Benjamin, Brown, and Shapiro 2013). Given that the poor tend to be over-represented in this group, this raises the concern that the poor will disproportionately face challenges of responding to the new climate risks as those risks arise. These challenges will be due both to lack of awareness of some of the challenges posed by climate change and the low-income population's limited resources for responding to the challenges they do perceive. Thus, I propose a variety of cost-effective strategies for protecting the poor.

SHORT-RUN PROTECTION

Climate models predict that major American cities will face sharp increases in the count of hot days as climate change unfolds. While there is considerable uncertainty associated with these predictions—because future global CO2 concentrations will be determined by policy choices, and because the link between concentrations and the average temperature distribution is subject to uncertainty—it is clear that days over 90 degrees Fahrenheit will increase in some areas by more than 40 per year, as shown in figure 1.

Higher-income people in cities such as Phoenix and Las Vegas routinely face extreme summer heat and respond by staying inside during peak heat hours and making extensive use of air conditioning. Unfortunately, low-income individuals often do not have the resources to own and operate an effective air conditioner, though it is true that fans and room air conditioning units are less expensive than they used to be. Many electric utilities have lower electricity rates for low-income people, but this might not be sufficient for protecting poorer people and homeless people from extreme heat. The city of Los Angeles has addressed this issue by establishing designated cooling centers where people can go to cool down. Houston has made similar investments.

Other cities should provide similar services, keeping a record of the demand for such centers by measuring peak heat and counting how many people show up on different days. Researchers could survey the people who choose to visit the centers to learn about their ability to cope with the heat. A common concern with the efficacy of such cooling centers is the transportation challenge of transporting people from their homes to the centers. Many poor people do not have private cars, and bus routes can require transferring to and from many buses or even walking the last half mile. Ride-sharing services could play a key role here: the city government would pay a contractor to provide rides to the cooling center on hot days. Researchers could then study the origin and destination of such trips to help the city government better understand the demand for cooling centers and to tailor government services such as public transportation to these neighborhoods. This combination of government services, survey research methods, and big data technology is likely to be effective for a variety of adaptation challenges.

MEDIUM-TERM ADAPTATION

Migration is a critical adaptation strategy: if people can migrate to higher ground, then they can continue to prosper even when their original location suffers (Kahn 2013). This type of adaptation depends on whether individuals are aware of their migration options, whether they can afford to live in potential destinations, and whether they can finance their migration.

MIGRATION INCENTIVES

A key idea from urban economics is that neighborhoods with attractive amenities will feature higher rents and home prices. The demand to live in these neighborhoods is higher than that for other neighborhoods, which causes a price differential between the areas. The urban poor often cannot afford to pay these rents, which limits their ability to move to these more-attractive areas. Unfortunately, children in low-income families suffer from this limited access to high-quality public schools and other aspects of desirable neighborhoods. HUD's Moving to Opportunity for Fair Housing (MTO) research demonstration, which encouraged randomly selected low-income households to move to lower-poverty areas, provided some of the best evidence about the effects of neighborhoods on economic mobility (Chetty, Hendren, and Katz 2016).

The fact that neighborhoods matter has implications for climate change adaptation. A new MTO program should be implemented, but this time with provisions that encourage movement to neighborhoods that have lower flood risk, less exposure to high temperatures, and a higher-quality housing stock. Low-income people who are given a federal housing voucher contingent on moving to these areas will be exposed to less climate change risk. Future research would then use both income data and mortality data to study whether this treatment group experienced less risk and a higher quality of life than a control group who received vouchers that were not contingent on moving to low-risk areas.

More generally, migration costs can limit the ability of people to move to areas that would improve their overall quality of life. A 2010 Hamilton Project paper by Ludwig and Raphael proposed a mobility bank for financing migration (Ludwig and Raphael 2010). Their logic is that many low-income people have insufficient savings to finance their move to a new place even if this new place offers a better labor market and housing opportunities that would eventually pay the costs of the move. The Ludwig and Raphael proposal intends to help households finance such investments in a way that it is self-sustaining and that allows the lender to recoup the upfront investment. Their proposal is directly relevant here for helping the poor to adapt to spatial climate risks through migration, and should be considered in this context.

LAND USE POLICY

Reform of land use policy represents another opportunity to enhance the mobility of all households, including those with low incomes. Current land use regulations in cities play a role in limiting the poor's housing options (Bunten 2015). Suppose that climate scientists can identify geographic areas within cities and across cities that face less climate risk. For example, there are areas within Los Angeles that are close enough to the ocean to continue to be cool in summer but far enough from the beach to avoid flooding. In such areas, changes in the zoning code allowing for increased housing density could allow millions more people to live in Los Angeles while facing less risk from climate change. In addition, increased density would facilitate the broader use of public transit. Changes in the zoning code to allow for high-rise buildings in safer places would therefore achieve both CO2 mitigation and climate adaptation goals (Glaeser and Kahn 2010).

Recently, the Obama administration put forward a set of principles to increase housing supply in American markets. These principles include reducing the role of city planning commission discretion in approving new developments, taxing vacant land, and providing exceptions to density limits contingent on development of affordable housing units, among other proposals (White House 2016). A similar approach should be taken to encourage increased density in places that are resilient to climate change.

Chapter 6. Proposal: Reduce the Cost of Climate Change Adaptation through Better-Functioning Markets

RISK DISCLOSURE AND RISK UPDATING

One straightforward way to improve the availability of information about flood risk would be for the federal government to pass laws requiring that real estate purchasers receive flood zone risk assessments. Such information would resemble California's rules about earthquake risk disclosure, which requires sellers to inform buyers about known home weaknesses and natural disaster hazards (California Department of Conservation 2011).

In addition, companies that provide the Multiple Listing Service (MLS)—a commonly used repository of real estate information used by buyers and sellers—could be required to supply climate risk information as another attribute of a home's location. If this information is not already incorporated in prices, areas that are objectively riskier will experience a drop in value as insurance rates rise. Indeed, congressional representatives whose jurisdictions contain such at-risk homes have tried to minimize the introduction of such information where they could cause insurance rates to rise (e.g., Abraham 2016).

Experts have suggested that coastal property insurance should be reconfigured to more closely resemble life insurance (Richards 2016). In the case of life insurance, those with a lower life expectancy pay more each year for life insurance. This same approach could be used for coastal real estate insurance (Richards 2016). The challenge will be to improve the science of flood forecasting to offer more-accurate actuarial tables of the probability that a structure will experience significant flooding over the next year. The insurance industry would use these models to more closely tailor the pricing of flood insurance to individual conditions.

If coastal real estate investors are fully aware of the emerging risks from sea-level rise, and if they are aware that they will face rising insurance costs, then their demand for coastal real estate will diminish. They will then be more likely to seek out properties featuring greater natural flood-risk resilience and properties featuring defensive investments that protect the structure. This reallocation of investment is useful in that it increases our overall coastal resilience.

EVALUATE THE EFFECTIVENESS OF THE CURRENT NFIP PROGRAM

Under the current rules of the National Flood Insurance Program (NFIP), participating communities are able to purchase subsidized insurance from the government. The size of the subsidy depends on actions the community has taken to reduce its risk exposure. As currently designed, a key piece of the NFIP program is its Community Rating System (CRS). Earlier in this paper, I discussed the details of the NFIP system and CRS (see box 1).

Perhaps surprisingly, FEMA's records reveal that participating communities are not investing in low-hanging fruit that would sharply increase a city's resilience in the face of flooding. Relative to the maximum possible score, the average community's score is very low for the following categories: hazard disclosure, flood insurance provision, open space preservation, flood data maintenance, stormwater protection, flood protection, and levee and dam safety (FEMA 2015). This suggests that the CRS might not be achieving its stated goal, and is providing subsidies to at-risk communities without inducing productive investment in resilience. This suggests that the CRS criteria need to be better tied to objective measures of resilience. The challenge here is to carefully tie the CRS point score to objective risk reduction because communities will seek to maximize their subsidy while paying as little as possible for investment in resilience.

The best way to investigate whether the current CRS program is effective would be to implement the following experimental design: Consider a set of coastal communities that are at risk of flooding, using the FEMA CRS criteria to determine each of these communities' CRS score. Suppose that each geographic area's objective flood risk can be estimated each year. Consulting firms such as Coastal Risk Consulting are designing such risk assessments. Controlling for an area's objective risk of flooding, a test of the effectiveness of the current CRS system would be to study whether those communities with a higher CRS score suffer less damage when natural disasters occur. If the prepared communities are really equipped to handle such events, they should suffer less damage from the same climate shock.

INSURANCE PRICING REFORM

If the current CRS system is not inducing communities to make effective investments in resilience, then reforms must be

implemented. Such reforms should focus on incentivizing those who live in flood-prone areas to make investments that actually shield them from new risks. The most direct way of achieving this would be to expose such residents to a greater portion of climate risks; for example, residents could pay an increased flood insurance deductible. This would mean that real estate owners have more incentives to seek out safer building materials and to work with local officials to make the community more resilient to shocks (Kousky 2010). To the extent that the federal government is part of the effort to encourage increased skin in the game for property owners, this would reduce concerns about an implicit promise of federal bailout impeding adaptation to climate risks.

EXPAND AND REFINE FLOOD INSURANCE REQUIREMENTS

Individuals could be more comprehensively required to buy flood insurance. Currently, there are sharply delineated flood maps that determine whether a homeowner is required to buy flood insurance in order to access federal benefits such as housing loan guarantees, which lower mortgage costs (McCoy and Zhao n.d.). These flood maps imply that homes just outside of the map face no flood risk, but this is not accurate. A more realistic approach would be to acknowledge that more homes face flood risk under climate change, but different areas face different risks and these risk probabilities will evolve over time as climate change unfolds and our knowledge about climate science increases.

Each property owner would be required to hold at least a minimum flood insurance policy set at 25 percent of the property's assessed value. Insurers would now have a larger market of policy demanders, which would create an incentive for them to invest in excellent climate science predictions to determine the evolving risk probabilities. To reduce the probability that insurers declare bankruptcy when a major flooding event occurs, such flood insurance sellers could be mandated to purchase catastrophe bonds, thereby hedging their risk exposure (*The Economist* 2013).

WATER AND ELECTRICITY PRICING

Climate change has increased drought risk in the American West and hot weather demand for air conditioning. If allowed to rise in response to these changing conditions, water and electricity prices can induce conservation and contribute to adaptation. However, there has been some political resistance to exposing consumers to price volatility for goods such as water and electricity (Daniels 2016). Nevertheless, water and electricity markets should be restructured to provide consumers with more information about changing conditions of resource scarcity.

INCENTIVIZING EXPERIMENTATION WITH DYNAMIC PRICING

More information is necessary regarding how consumers respond to flexible water and electricity prices. The federal government should therefore subsidize randomized field experiments by water and electric utilities that expose customers to dynamic pricing.

Recent experiments at the Sacramento Municipal Utility District in California have yielded useful information (Potter, George, and Jiminez 2014). That municipal utility district enrolled a group of randomly chosen residential customers in a dynamic pricing program that imposed higher prices for electricity at certain times of the day. These customers were aware of this price premium and were observed to delay some consumption activities until electricity prices were much lower. This improved the ability of the electric utility to engage in load management, reducing the occurrence of blackouts on extremely hot days.

With the rise of smart thermostats and similar devices, households can preprogram software to implement their choices automatically in response to temperature and price conditions. This reduces the time and effort required for households to optimize their behavior. If electricity prices are allowed to rise in response to increased scarcity, then residential and commercial customers will be more likely to demand energy-efficient air conditioners and energy-efficient real estate such as Energy Star–certified housing and commercial structures. The increased use of more-efficient products further contributes to both increased resilience and CO_2 mitigation.

BOX 4.

Introducing Flexible Water Pricing

The same principles underlying dynamic pricing for electricity can be used to address water scarcity related to drought. Two recent Hamilton Project papers (Ajami, Thompson, and Victor 2014; Culp, Glennon, and Libecap 2014) provide useful details. These authors stress the importance of creating water markets that allow those with property rights to trade with urban water consumers. They propose that state and local governments facilitate these markets by setting up clearinghouses and encouraging market-driven risk-management strategies.

Together these policies would encourage water conservation and would allow areas that demand more water—perhaps because of population growth—to identify areas that are willing to trade. Farmers, who historically have had property rights to large amounts of water, would have reduced incentive to produce low-value but water-intensive crops such as alfalfa.

Chapter 7. Questions and Concerns

How can firms be encouraged to adapt to climate change?

In recent years more of the business community is recognizing the new risk that climate change poses. The Risky Business Project housed under the Paulson Institute brings together business leaders to publicize these risks (Paulson Institute 2015). For-profit firms lose profit if climate change impacts supply chains or extreme heat affects such firms' operations.

Recognizing the new risks posed by climate change, the Securities and Exchange Commission (SEC) has issued guidance encouraging companies to disclose not only their carbon positions (because this might be a cost if carbon pricing and regulation is enacted) but also, where appropriate, a discussion of factors related to climate change that make investment in these firms risky (SEC 2010). This guidance should have two effects. First, the SEC disclosure documents are meant to alert investors and to reduce asymmetric information issues and thus to increase the accountability of management to its shareholders and bond holders.

A second dimension of the SEC guidance is related to climate change adaptation and business resilience. Consider an extreme example: suppose there is a banana exporter who sells bananas to consumers in Los Angeles. If the bananas are grown in a single location in Central America and if this location now faces increased heat waves, the production of bananas will become more volatile; there are climate scenarios in which the revenue from the banana sales would fall sharply. The SEC guidance is meant to inform investors about the new risk that heat waves, natural disasters, drought, and heavy rains and sea-level rise will all cause for business.

Those who lend to businesses at risk will lend at a higher interest rate if the loan becomes risky (as the lender fears default). If borrowers can borrow at a lower interest rate, such as when the geographic area where they operate is safer, then this creates a profit motive for companies to lobby local officials to invest in resilience.

Does strengthening urban infrastructure in at-risk places encourage more risk-taking?

Investment in infrastructure resilience can encourage individuals and businesses to locate in places that face significant climate risk, potentially raising the total risk exposure of the population. If people become convinced that a coastal area is less risky because of defensive infrastructure investments, those who enjoy coastal living will move to that area. This effect would be compounded even further if individuals and businesses assume that—now that more people live in the area—a federal bailout is likely in the event of a disaster.

While this possibility must be taken seriously, this proposal has introduced several features ensuring that investors retain some risk exposure as well as increased access to information about the risks they face.

What can be done for those unwilling to leave climate-impacted neighborhoods?

In every neighborhood with long-term residents, friendships form and people grow familiar and comfortable with their surroundings. Such social networks and connections offer numerous benefits but they also tend to reduce the likelihood that incumbents will want to move away (Glaeser et al. 2011). This matters because migration to safer areas or safer cities represents an important adaptation strategy.

The federal government could invest in upgrading multifamily apartment housing through lead paint removal, installation of central air conditioning (especially in places likely to experience extreme heat), and flood-risk control on lower floors of buildings.

One consequence of such investments is that rents will rise and the poor might eventually not be able to afford their original neighborhood. Although local real estate owners would gain from such improvements, renters might actually lose out. One way to address this is for the federal government to require longer-term rental contracts in return for subsidizing resilience upgrades.

Chapter 8. Conclusion

This paper has proposed a set of policies that together reduce the risk that urban places and residents will face as climate change unfolds. I have proposed a research design for identifying areas that are high risk due to geography or inadequate infrastructure, and for updating infrastructure in these affected areas.

In particular, these proposed policies address the unique challenges faced by low-income households, pinpointing at-risk populations and appropriately directing state assistance. My final set of proposals seeks to build up urban resilience by harnessing free-market capitalism. The heart of this proposal combines dynamic pricing for water and electricity with continually updated spatial maps to properly price coastal flood insurance, thereby incentivizing real estate investors to invest wisely in beautiful but increasingly risky areas.

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References

Abraham, Ralph. 2016, July 11. "Abraham Blocks Obama Floodplain Expansion Order." Press release, Office of U.S. Congressman Ralph Abraham, M.D., Washington, DC.

Ajami, Newsha K, Barton H. Thompson Jr., and David G. Victor. 2014, October. "The Path to Water Innovation." Discussion Brief 2014-06, The Hamilton Project, Brookings Institution, Washington, DC.

American Society of Civil Engineers (ASCE). n.d. "State Facts." American Society of Civil Engineers, Reston, VA.

Benjamin, Daniel J., Sebastian A. Brown, and Jesse Shapiro. 2013. "Who Is 'Behavioral'? Cognitive Ability and Anomalous Preferences." *Journal of the European Economic Association* 11 (6): 1231–55.

Biggert-Waters Flood Insurance Reform and Modernization Act of 2012, Pub. L. 112-141 (2012).

Brinklow, Adam. 2016. "City Prepares for Sea Level Rise, Epic Storms, Constant Flooding, General Unease." Curbed.com, San Francisco, March 11.

Bunten, Devin. 2015. "Is the Rent Too High? Aggregate Implications of Local Land-Use Regulation." Working Paper, University of California–Los Angeles, Los Angeles, CA.

California Department of Conservation. 2011. "Natural Hazards Disclosure: Alquist-Priolo Earthquake Fault Zones." California Department of Conservation, Sacramento, CA.

California State Legislature. 2015, November. "Summary of Oversight and Informational Hearings of the California State Senate Committee on Environmental Quality." Hearing, Senate Environmental Quality Committee, California State Legislature, Sacramento, CA.

Chetty, Raj, Nathaniel Hendren, and Lawrence F. Katz. 2016. "The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment." *American Economic Review* 106 (4): 855–902.

City and County of San Francisco. 2016, March. "San Francisco Sea Level Rise Action Plan." City and County of San Francisco, San Francisco, CA.

Computation Institute. 2016, August 29. "Chicago Becomes First City to Launch Array of Things." Computation Institute, University of Chicago, Chicago, IL.

Costa, Dora, and Matthew Kahn. 2015, April. "Death and the Media: Asymmetries in Infectious Disease Reporting During the Health Transition." Working Paper No. 21073, National Bureau of Economic Research, Cambridge, MA.

Culp, Peter W., Robert Glennon, and Gary Libecap. 2014. "Shopping for Water: How the Market Can Mitigate Water Shortages in the American West." Discussion Paper 2014–05, The Hamilton Project, Brookings Institution, Washington, DC.

Cutler, David M., and Grant Miller. 2006. "Water, Water, Everywhere: Municipal Finance and Water Supply in American Cities." In *Corruption and Reform: Lessons from America's Economic History*, edited by Edward Glaeser and Claudia Goldin, 153–83. Chicago, IL: University of Chicago Press.

Daniels, Steve. 2016, October 12. "Run Your Dishwasher at the Wrong Time, Watch Your Electric Bill Soar?" Crain's, Chicago, IL.

Disaster Relief Appropriations Act of 2013, Pub. L. 113-2 (2013).

The Economist. 2013. "Perilous Paper: Bonds That Pay Out When Catastrophe Strikes Are Rising in Popularity." *The Economist*, October 5.

Federal Emergency Management Agency (FEMA). 2011, May. "Fact Sheet: Disaster Declaration Process." Federal Emergency Management Agency, Washington, DC.

———. 2016. "Disaster Declarations Summary." Federal Emergency Management Agency, Washington, DC.

———. 2015, May. "Community Rating System: A Local Official's Guide to Saving Lives, Preventing Property Damage, Reducing the Cost of Flood Insurance." National Flood Insurance Program, Federal Emergency Management Agency, Washington, DC.

Federal Reserve Board of Governors. 2016, June. "Dodd-Frank Act Stress Test 2016: Supervisory Stress Test Methodology and Results." Board of Governors of the Federal Reserve System, Washington, DC.

Federal Transit Administration (FTA). 2015. "Washington Metropolitan Area Transit Authority (WMATA) Safety Management Inspection." Report, Federal Transit Administration. U.S. Department of Transportation, Washington, DC.

Ferraz, Claudio, and Frederico Finan. 2008. "Exposing Corrupt Politicians: The Effects of Brazil's Publicly Released Audits on Electoral Outcomes." *Quarterly Journal of Economics* 123 (2): 703–45.

Field, Christopher B., Linda D. Mortsch, Michael Brklacich, Donald L. Forbes, Paul Kovacs, Jonathan A. Patz, Steven W. Running, and Michael J. Scott. 2007. "North America." In *Climate Change 2007: Impacts, Adaptation and Vulnerability*, edited by Martin L. Parry, Osvaldo F. Canziani, Jean P. Palutikof, Paul J. van der Linden, and Clair E. Hanson, 617–52. Cambridge, UK: Cambridge University Press.

Glaeser, Edward L., and Matthew E. Kahn. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67 (3): 404–18.

Glaeser, Edward L., Matthew Resseger and Kristina Tobio. 2011. "Urban Inequality." In *Justice for All: Promoting Social Equity in Public Administration*, edited by Norman J. Johnson and James H. Svara, 76–99. Armonk, NY: M.E. Sharpe.

Government Printing Office (GPO). 2014, July 30. "The Flood Insurance Claims Process in Communities after Sandy: Lessons Learned and Potential Improvements." Statement of Craig Fugate, Administrator, Federal Emergency Management Agency, U.S. Department of Homeland Security, before the Committee on Banking, Housing, and Urban Affairs Subcommittee on Housing, Transportation, and Community Development, U.S. Senate, Washington, DC.

Hauer, Mathew E., Jason M. Evans, and Deepak R. Mishra. 2016. "Millions Projected to Be at Risk from Sea-Level Rise in the Continental United States." *Nature Climate Change* online.

Kahn, Matthew. 2013. *Climatopolis: How Our Cities Will Thrive in the Hotter Future*. New York, NY: Basic Books.

Klein-Rosenthal, Joyce Ellen, Patrick L. Kinney, and Kristina B. Metzger. 2014. "Intra-Urban Vulnerability to Heat-Related Mortality in New York City, 1997–2006." *Health Place* 30: 45–60.

Klinenberg, Eric. 2015. *Heat Wave: A Social Autopsy of Disaster in Chicago*. Chicago, IL: University of Chicago Press.

Kousky, Carolyn. 2010. "Learning from Extreme Events: Risk Perceptions after the Flood." *Land Economics* 86 (3): 395–422.

Ludwig, Jens, and Steven Raphael. 2010. "The Mobility Bank: Increasing Residential Mobility to Boost Economic Mobility." Discussion Paper, The Hamilton Project, Brookings Institution, Washington, DC.

McCoy, Shawn J., and Xiaoxi Zhao. n.d. "Risk, Salience and Investment in Residential Housing" Working Paper.

National Oceanic & Atmospheric Administration (NOAA). 2014. Atlantic Oceanographic & Meteorological Laboratory. Hurricane Research Division. 2014. "The Thirty Costliest Mainland United States Tropical Cyclones 1900–2013 Unadjusted Dollars." National Oceanic & Atmospheric Administration, U.S. Department of Commerce, Washington, DC.

———. n.d. "Trends in Atmospheric Carbon Dioxide, Mauna Loa, Hawaii." Earth System Research Laboratory. Global Monitoring Division, National Oceanic & Atmospheric Administration, U.S. Department of Commerce, Washington, DC.

Neidell, Matthew. 2009, March 31. "Information, Avoidance Behavior, and Health: The Effect of Ozone on Asthma Hospitalizations." *Journal of Human Resources* 44 (2): 450–78.

Neidell, Matthew, and Bowman Cutter. 2009. "Voluntary Information Programs and Environmental Regulation: Evidence from 'Spare the Air'." *Journal of Environmental Economics and Management* 58 (3): 253–65.

New Jersey Future. 2014, May. "Camden: Rising Above the Floodwaters." Case study, in "Ripple Effects: The State of Water Infrastructure in New Jersey Cities and Why it Matters," 12–50. Report, New Jersey Future. Trenton, NJ.

Olson, Mancur. 1971. *The Logic of Collective Action*. Cambridge, MA: Harvard University Press.

Patient Protection and Affordable Care Act (ACA), Pub. L. 111-148, 124 Stat. 119 through 124 Stat. 1025 (2010).

Paulson Institute. 2015. "The Risky Business Project." Paulson Institute, Chicago, IL.

Potter, Jennifer M., Stephen S. George, and Lupe R. Jiminez. 2014. "SmartPricing Options Final Evaluation." Sacramento Municipal Utility District (SMUD), Sacramento, CA.

Rao, Krishna. 2016a, August 2. "Climate Change and Housing: Will a Rising Tide Sink all Homes?" Zillow Research, Zillow, Seattle, WA.

———. 2016b, August 2. "Rising Sea Levels Threaten to Put Nearly 2 Million U.S. Homes Underwater." Press Release, Zillow, Seattle, WA.

Rappaport, Jordan and Jeffrey D. Sachs. 2003. "The United States as a Coastal Nation." *Journal of Economic Growth* 8 (1): 5–46.

Richards, Edward P. 2016. "Applying Life Insurance Principles to Coastal Property Insurance to Incentivize Adaptation to Climate Change." Boston College Environmental Affairs Law Review, Chestnut Hill, MA.

Sandy Recovery Improvement Act of 2013 Pub. L. 113-2 (2013).

Securities and Exchange Commission (SEC). 2010. "Commission Guidance Regarding Disclosure Related to Climate Change." Securities Exchange Commission, Washington, DC.

Soper, Shawn. 2016 (August 18). "FEMA Reps Roasted Over Costly Flood Map Error In Ocean City; 'Disagreement' Between City, Feds Still Being Worked On." *The Dispatch* online.

Summers, Lawrence. 2016. "The Next President Should Make Infrastructure Spending a Priority." *Washington Post*, September 11.

U.S. Environmental Protection Agency (EPA). n.d. "What Is Green Infrastructure?" U.S. Environmental Protection Agency, Washington, DC.

U.S. Department of Housing and Urban Development (HUD). 2014, October. "Climate Change Adaptation Plan." Report. U.S. Department of Housing and Urban Development, Washington, DC.

———. "Green Infrastructure and the Sustainable Community Initiative." HUD Exchange, U.S. Department of Housing and Urban Development, Washington, DC.

———. n.d. "Hurricane Sandy Rebuilding Task Force." U.S. Department of Housing and Urban Development, Washington, DC.

United States Army Corps of Engineers (USACE). n.d. "Sustainable Solutions to America's Water Resource Needs." Report. United States Army Corps of Engineers, Washington, DC.

White House. 2009, October. Exec. Order No. 13514. "Focused on Federal Leadership in Environmental, Energy, and Economic Performance." White House, Washington, DC.

———. 2013, June. "The President's Climate Action Plan." Report. Executive Office of the President, White House, Washington, DC.

———. 2015, July. "Progress Report: Highlighting Federal Actions Addressing the Recommendations of the State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience." Report. White House, Washington, DC.

———. 2016, September. "Housing Development Toolkit." Report. White House, Washington, DC.

X-Prize. n.d. "Who We Are." Culver City, CA. http://www.xprize.org.

THE HAMILTON PROJECT

ADVISORY COUNCIL

Highlights

Matthew Kahn of the University of Southern California proposes to implement a series of policies to improve urban climate change adaptation strategies, including investing in infrastructure, assisting those who are most vulnerable to climate risks, and allowing markets to accurately reflect potential climate threats.

The Proposal

Invest in urban infrastructure resilience. This proposal seeks to diagnose disruptive risks caused by extreme climate change events and to finance resilience investments. Kahn proposes that the effectiveness of these infrastructure investments should be tested through empirical evaluation.

Protect the urban poor against climate shocks. Kahn suggests that local authorities focus on disseminating information about short-run risks, providing services that some urban poor might not have access to, incentivizing migration to lower-risk areas, and relaxing zoning restrictions to allow more people to live in lower-risk areas.

Reduce the cost of climate change adaptation through better-functioning markets. This reduction can be achieved by allowing the prices of natural resources, energy, and flood insurance to reflect true risks and conditions.

Benefits

Implementation of Kahn's three proposals would benefit individuals who face significant risks related to climate change and would improve the nation's resilience in the face of serious threats from climate change. In particular, low-income urban residents who currently have minimal ability to adapt to these risks would be better protected.

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