INVITING DANGER

How federal disaster, insurance and infrastructure policies are magnifying the harm of climate change

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Executive Summary

Many government policies create incentives for people to make economically detrimental decisions, including settling and building on land exposed to hurricanes, floods, and wildfires. These policies already cost taxpayers tens of billions of dollars annually and may cost a lot more by distorting the allocation of trillions of dollars of capital into danger-prone areas. Market forces that are normally powerful arbiters of risk are blunted by the assumption that losses, if they happen, will be repaid by government. Worse, where these policies amplify dangers that effect is likely to become more severe due to the impacts of global warming.

We introduce a framework for analyzing how federal spending patterns under current and possible future policies may shield or remove individuals, firms and local governments from some of the financial harm created by decisions they take—what economists often call "moral hazard." Whereas these actors are often in a good position to make decisions that reduce exposure and damage from natural perils, in the presence of moral hazard they could make different decisions that, in effect, shift the cost of their choices.

What's new in this paper is a framework for looking at individual policies and government programs according to how they affect the damages associated with natural disasters. We focus on the subset of those disasters that could be affected by climate change and thus exclude earthquakes, tsunamis and others whose incidence is unlikely to change in a warmer world. We distinguish between those that merely aim for simple recovery after peril hits—thus prone to create moral hazard if they discourage efforts to reduce dangers—and policy programs that aim to improve resilience against future perils. While there are many diverse domains of federal policy, we focus on policy programs in three areas: a) disaster response, b) building and maintenance of infrastructure; and c) subsidization of insurance for perils such as flood and crop losses.

Such a framework is essential because these policies are often highly complex, with varied goals that implicate agency action that are diffused across the whole of the federal government. For example, even within a single agency implementing a common core set of statutes—the Federal Emergency Management Agency (FEMA)—some programs aim at resilience while most focus only on recovery. In FEMA's case, we find that just 14 percent of the 81 billion dollars in total disaster grant funding spent since 2005 have gone to programs that aim to advance resilience to climate related disasters—smart building and rebuilding. Outside that tiny fraction, most of FEMA spending has gone into activities, such as rebuilding, that have the unintended effect of encouraging risky siting decisions and other behaviors that may discourage those best prepared to address these risks from being fully responsible for adverse outcomes. Loans and grants managed by Housing and Urban Development (HUD) also exhibit funding differences that can propagate behavior that could invite risk rather than build resilience. Flood and crop insurance programs can create similar incentives that insulate homeowners, farmers, and businesses from the consequences of risky behavior. Federal infrastructure investments also, for the most part, focus on recovery and response to today's patterns of disasters rather than planning for the changing climate of the future.

The value of a framework is the ability to look across the entirety of the federal government. Quantifying the exact impact of the misallocation of risk costs, or moral hazard aspects of these programs is very difficult not just because they are diffused across government but also because the programs that create these adverse incentives co-mingle worthy policy goals (e.g., protecting vulnerable populations that are living on the edge already) with unintended consequences that can

create moral hazard and shift the costs of that hazard to the federal government. Assessing how spending affects behavior—ultimately by individual homeowners and others—is outside the scope of this paper. Our purpose is to take the first step in such a full blown analysis, understanding the allocation of policy effort, that can create the conditions for moral hazard.

A central finding from applying this framework is that there is currently a 7:1 ratio of disaster recovery to resilience funding across the federal government. While there is substantial evidence that resilience funding generates large social returns, in practice federal spending on climate-related disasters appears to be heavily weighted away from resilience. We find this ratio can be as high as 40:1 depending on the accounting system used. The exact size of this cost differential is hard to pin down, but a central estimate today suggests that the federal government currently spends at least about $46 billion per year responding to and recovering from large natural disasters, and only $6 to 7 billion on resilience towards future perils. However, that number does not account for the full federal backstop—the implicit promises of assistance that are widely assumed to exist when massive losses, such as extreme hurricane seasons, arrive. That backstop has been tested periodically—for example, by superstorm Sandy—and found robust (and thus valuable and costly but hard to measure).

The practice of focusing federal disaster policy on recovery reflects many political forces, including support for important humanitarian goals. However, there are three reasons to expect that the cost will grow and, plausibly, become unsustainable politically and also more distortionary economically. First, population migration already trends toward dangerous areas—such as hurricane-beset Florida and Texas. Second, property values rise as these more crowded populations get wealthier. These two factors alone explain the majority of the rise in extreme storm losses over the last 3 decades, and that trend is likely to continue. The third factor—climate change—is newer and will magnify these effects. By mid-century, it is plausible that the flow of annual federal expenditures on climate related disasters will need to rise significantly, and by later in the century the increases due to climate change will exceed the effects from population and economic growth. We compare current average annual payments for FEMA declared disasters over the last decade against the expected economic loss in 2012 if the climate conditions projected for last decades of the century existed in 2012 and find the latter to be 1000 times greater on average, with lots of variation across the country. The Congressional Budget Office (CBO), Government Accountability Office (GAO) and other agencies, along with some academics and many state policy makers and experts in the corporate sector, have begun to look closely at this because it is so fundamental to public finance and to expectations for the size and character of future natural hazard policies.

Policy reform will be challenging. At present, federal policies are shrouded in deep layers of political defense, which is why these widely known problems with the current arrangements have not led to much durable reform. There are many encouraging pilot efforts to re-align incentives and reduce moral hazard—for example, FEMA's efforts to buy out properties that suffer repeated losses rather than simply funding rebuilding that leads to repeated cycles of loss. Such efforts, overall, have only small effects on overall expenditure and many come unglued politically when they operate as intended. Reforms to raise flood insurance premiums in 2012, a good idea, came unglued politically when homeowners and the real estate industry balked; Congress rolled the premiums back just two years later.

Mindful of the political challenges, it is essential to pursue policy reforms in advance of accelerating impacts of climate change. We explore scenarios that could open a window of opportunity for reform. A massive event is one such scenario, for such shocks allow for a reordering of political forces. This happened briefly after superstorm Sandy when special Congressional appropriations allocated between one-third and one half of funding for smart rebuilding—a share much larger than normal disaster recovery programs. The probability of such an event is rising, and the country needs to

recalibrate and plan for how it might respond not just immediately but in terms of larger disaster policy reforms. When Hurricane Andrew hit Florida in 1992 it caused $26.5 billion in total economic damages; the same event today, with more people and value at risk, would be $80-100 billion. And it's not just large events that can create a crisis. Other scenarios see multiple small and medium size events over a short period of time that ripple through the insurance markets and create cascading financial stress. Florida, even with one of the most sophisticated private-public frameworks for funding disasters in the U.S., is primed for such an unravelling. With its $2.6 trillion of exposed insured residential values through public and private insurers, the Florida economy would be dependent on the viability of post event financing and assessments of policyholders and taxpayers to recover financially from an unusually severe hurricane season.

We outline reforms, with an emphasis on the value of tracking the difference of recovery vs. resilience spending so that the full picture (and its potential imbalances) can be understood. Such improved situational awareness will require more action in Congress to account for spending along with more analysis of how moral hazard may be amplifying the nation's exposure to natural disasters. No regular government accounting activity tabulates the full extent of programs that may create moral hazard through federal policy. We also see a role for the US National Climate Assessment, a regular analysis of the possible impacts of climate change on the country, as one of the places where better understanding of how federal and state policies are affecting behavior could alter the actual damages the country suffers from climate change and the response strategies that might reduce those damages. In addition to better awareness of the effects of these federal policies, we identify ways for the whole of the federal government to operate more strategically in this domain. Finally, we suggest that major reforms of disaster assistance, while politically challenging, would benefit from more explicit political design so they contain interlocking elements that are likely to be more durable. A policy commission, similar to the commissions that help design policies for closure of military bases (a politically fraught topic with many of the zero sum dynamics that make disaster reform difficult) could be helpful. We also suggest that reforms are most likely in the context of crisis, and thus there is a need for realism about when reforms can be accomplished—laying the foundation of more situational awareness and more politically savvy reform packages will lay the groundwork for change when the opportunity arises.

Over the last few cycles of executive control, it has become apparent that neither political party has a strategy for realigning disaster assistance in ways that make it more financially sustainable nor create the right incentives to make society more resilient in the face of climate change. Most policies have focused on "building back the same," and the public for the most part has been supportive. While that might have been tolerable in an era of modest impacts from natural disasters, that era is ending. An urgent national priority is creating the right incentives so that private and public sector investments reduce the future damages from climate change and make the country more resilient.

INTRODUCTION

For thirty years diplomats have been holding regular negotiations on climate change and have forged three global agreements on the problem—the latest in Paris in 2015. Meanwhile, emissions have risen one-third over that period. While many firms and governments are now engaged in more serious efforts to cut warming pollution and the Paris Agreement is auspicious, momentum in the system all but assures that the climate will keep changing apace and goals to keep warming in check at just 2 degrees will tumble as impractical.[1] As such, the world is in for a lot of climate change.

For years, among climate activists and many governments, there was a taboo on talking about adaptation to climate impacts for fear that that a focus on preparing for the harms of a warmer planet would signal the defeat of emissions mitigation efforts and weaken political pressure to cut the drivers of global warming (Pielke et al, 2007). Whether that theory of politics was ever sound is debatable—many armchair theories of politics are based on little real analysis. But the taboo was harmful, and only about a decade ago political debates expanded to include sustained attention to the many ways that society must brace for a lot of climate change. In a few places this shift is on display already: in Miami, where climate impacts are embedded into urban planning, and in California, where the powerful Coastal Commission vets building permits with an eye to possible extreme rises in sea levels.[2] At the federal level, a regular National Climate Assessment (NCA) now looks, every 4 years, at the potential impacts of warming and, to a lesser degree, adaptation strategies.[3] The federal government itself manages $1.2 trillion dollars worth of military real estate around the world and 650 million acres of climate exposed land domestically (GAO, 2019a; GAO, 2013). It has also begun to factor climate impacts and adaptation into its work—although only one agency (the Pentagon) has done this systematically and extensively (Office of the Under Secretary of Defense for Acquisition and Sustainment, 2019). Four out of five of the largest federal natural resource management agencies, including the Forest Service, the National Fish and Wildfire Service, the National Oceanic and Atmosphere Administration, and the National Park Service also have strategic plans in place for climate adaptation (GAO, 2013).

The taboo is eroding, but not fast enough. The next frontier for climate policy must involve breaking another taboo: moral hazard.

For decades analysts have known that many federal and state policies don't just ignore the need for adaptation to the impacts of climate change. They make those impacts bigger by shielding investors from the consequences of doing dangerous things, such as building hotels on fragile barrier islands. The federal government has built infrastructure to make it easier to do such dangerous things; many

List of Acronymns	
Federal Emergency Management Agency	(FEMA)
National Disaster Response Framework	(NDRF)
Recovery Support Function Leadership Group	(RSFLG)
National Flood Insurance Program	(NFIP)
Federal Crop Insurance Corporation	(FCIC)
Small Business Association	(SBA)
Department of Housing and Urban Development	(HUD)
Community Development Block Grants-Disaster Relief	(CDBG-DR)
Department of Defense	(DOD)
US Army Corp of Engineers	(USACE)
Department of Agriculture	(USDA)
Department of Commerce	(DOC)
Government Accountability Office	(GAO)
Congressional Research Service	(CRS)
Congressional Budget Office	(CBO)
Department of Homeland Security	(DOHS)
Department of Health and Human Services	(HHS)
Department of Transportation	(DOT)
Department of the Interior	(DOI)
Federal Highway Administration	(FHA)
Federal Transit Administration	(FTA)

state investment and regulatory policies have had similar effects, including through insurance subsidies and implicit promises to backstop risks (Flavelle, 2018). While these problems have been known to analysts and a few brave political administrative leaders have attempted reforms, most reform efforts have failed.

In principle there are very compelling social needs for a federal backstop when it comes to the impacts of natural disasters. For example, the deadliest and most destructive regular disasters are hurricanes (Office of Coastal Management, n.d.). Over the last few decades, typically only about 40 percent of the losses from hurricane events are covered through non-governmental sources such as private insurance (GAO, 2020a). The rest of those losses are a combination of uninsured private assets and damages to a variety of public assets such as infrastructure.

These federal backstops can create what economists call moral hazard because they incentivize people take on risks they otherwise would not because they do not bear the full cost of those risks. It is a kind of subsidy. And for that reason, politicians treat this topic as a third rail of policy reform—intriguing to talk about, important for the nation, and yet politically dangerous to address seriously.

We note that there is a wide body of literature that exists today on both the problem of moral hazard in disaster assistance, and on disaster policy reform more generally. The Wharton Risk Management and Decision Process Center at the University of Pennsylvania in particular has provided valuable scholarship on disaster policy and reform efforts at all level of government.[4] Much of the academic literature is focused on specific programs or sectors such flood insurance and the National Flood Insurance Program (NFIP)—a particularly important program because of its breadth of coverage and the fact that homeowners are often compelled to purchase NFIP policies.[5] Other studies look at how federal programs interact with each other, such as how receipt of disaster assistance from FEMA affects future behavior of homeowners in flood insurance markets.[6]

Further research has documented both the conceptual phenomenon, and supporting empirical evidence, around how federal disaster policies invite risky behavior that can create moral hazard. Research has focused on moral hazard conceptually, as a governance or political economy problem, and examined the institutional forces that shape drivers of moral hazard.[7] Empirical work has looked at, and found, evidence of risk invitation in specific federal programs that address distinct climate hazards, including wildfire and flood.[8]

Beyond academic research, key federal agencies are also focused on risk invitation and disaster policy reform. The GAO and CBO have both looked closely at the large costs incurred to the government from hurricanes and opportunities to reform programs that incur these costs (GAO 2020a: CBO, 2016).[9] The NCA as well, while not focused specifically on moral hazard, does comprehensively look at drivers of climate risk to communities across the United States (USGCRP, 2018).

This paper is about the size of the potential moral hazard problem in climate-related federal and state policies today. We are mindful that there are other moral hazards in federal policies that intersect with nature (e.g., regarding earthquakes), but the climate-facing portion is of special importance as the size of the problem will soon get much bigger at an accelerating pace. We find that there are large differences in the allocation of current spending between recovery versus resilience. Triangulating the available evidence, we suggest this difference creates a potential imbalance that overweights "building back the same" and underweights known cost-effective strategies for making society more resilient. This difference represents a plausible imbalance because there are well documented cost savings captured from resilience investments, along with the rapidly emerging impacts of climate change will plausibly grow in the coming decades. We focus on the federal level, because thanks to its sheer size and its ability to spend in deficit, federal spending is much larger than at the state levels. Additionally, much of what occurs in Washington sets the frame for the states.[10]

We proceed in three steps. First, we assess the difference in federal spending for response versus resilience, and use this to suggest the creation of possible distortionary incentives, offering a new framework for analysis and applying that framework to the federal budget. Second, we project forward how today's policies, weighted towards recovery instead of resilience, could get much costlier in the future. Third, we look at reform—at the kinds of mega-events that could trigger the need for reform and, depending on the ability and motivation of reformers, what could be done to fix the system. In light of the long history of failed reforms, we are not optimistic, which is why particular care is needed to craft politically viable strategies that address the ever-growing problem.

PART I: HOW BIG IS THE PROBLEM OF POTENTIAL CLIMATE-RELATED MORAL HAZARD?

One of the central challenges in assessing the size of the moral hazard problem is that there is no federal office of moral hazards—no single agency whose budget sits ready for audit and where policies, if found faulty, can be changed. Instead, actions are diffused widely across government. Moreover, while it is possible to observe spending—which, in this paper, is our central contribution—it is much harder to observe the relationship between spending on diverse federal programs and human behavior, which is what's needed for a full blown assessment of moral hazard. Conceptually, our goal then is to identify those policies (and their associated costs) that could have the effect (intended or otherwise) of encouraging behavior through which people and firms incur risks whose costs are accrued to the government. This is, of course, difficult to do because it requires a degree of counterfactual thinking, as one must identify what actions individuals would take in absence of a federal program and compare it with real world behavior. Additionally, many federal programs actively seek to achieve important distributional goals for they, by design, benefit populations that do not, on their own, have the resources to protect against all natural hazards. Those worthy goals of policy must be kept in mind alongside the more pernicious effects, those that may change the behavior of individuals, communities, or firms who have the ability to make different decisions but choose not to because of federal backstops.

To get a first fix on the size of the problem we will focus on existing policy strategies and the agencies that are oriented around likely impacts of climate change—especially the extremes. These impacts often take the form of natural disasters and can be mitigated by disaster preparedness. They also include possible failures to crops and harm to public lands. With that perspective, the following agencies and programs are most important:

Agency	Programs	Brief Description, and issues to consider in analysis
The Federal Emergency Management Agency	Disaster assistance and mitigation programs	The largest source of programs responsible for disaster relief provision in the US.
State emergency agencies	Local level disaster assistance programs	Vary widely depending on state context.
Federal Emergency Management Agency	The National Flood Insurance Program	The largest federal insurer of climate-related hazards as measured by its $20.5 billion in outstanding and $16 billion in canceled debt beyond collected premiums. (Congressional Research Service, 2019a).

Federal Crop Insurance Corporation	National annual crop insurance provision	The nations primary source of federal crop insurance. The FCIC reported a negative $7.3 billion balance sheet as of 2018 and is estimated to cost the federal government $8 billion annually through the end of this decade (GAO, 2019c).
The Department of Defense	The Army Corp of Engineers	The largest federal builder of public infrastructure. There are, in addition, other federal sources of disaster recovery infrastructure funding such as the Department of Transportation's (DOT) grants provided through the Federal Highway Administration (FHA)
The Department of Housing and Urban Development	Community Development Block Grant programs	Manages several multi-billion-dollar funds supporting under-served communities post disaster and has provided up to $16 billion in disaster relief after events such as Sandy and Harvey (Department of Housing and Urban Development, n.d.).
The Small Business Association	Direct relief programs and loans for households and businesses	Offers millions of dollars in disaster recovery loans to households and businesses and can be the primary source of rebuilding funds to individuals besides insurance (FEMA, 2020).
State sponsored insurance pools	Wind, fire, and other hazards	Operates with different forms of subsidy, including implicit or explicit backstops if available state and private insurance mechanisms fail.

In terms of total budget, federal funding for disaster assistance (mainly FEMA) is the most visible and costly. All told, from 2005 to 2018, total federal funding for disaster related spending was $430 billion—concentrated on perils such as hurricanes, flooding and wildfires that are all emblematic of impacts that will get worse in a warming world (GAO, 2019d). In addition to these on-budget disaster expenses, careful research that looks more widely beyond FEMA finds between five to seven times the federal costs are paid to communities hit by disaster, such as through unemployment claims and medical expenses (Deryugina, 2016).

While FEMA is the dominant agency in federal disaster-related spending, its exact role is hard to pin down. Measuring the exact share of the total costs of these disasters paid through FEMA is complex and varied, but a typical share is between half and two thirds.[11] For example, from 2005 - 2015, the CBO reports that the Federal government (mainly FEMA) paid on average 62 percent of hurricane damages (CBO, 2016). Of course, not all this funding results from moral hazard. The moral and political needs for disaster support are clear enough. Ironically, the accounting for costs that create moral hazard is compounded in difficulty. Often when disaster strikes, the local economy, in the immediate aftermath of the disaster sees a surge in economic benefits such as higher sales tax revenues and employment due to rebuilding (South Texas Economic Development Center, 2018).

Because of these accounting difficulties, it is very difficult to measure the real extent of moral hazard. At best, we can triangulate at answers. To help in that triangulation, we have adopted a conceptual framework shown in Table 1. Along the rows we show the two major routes by which federal policy strategies, expressed through programs, may affect behavior. First is how these federal programs affect response and recovery during the immediate response to a climate-related disaster. Second is how existing programs affect investments before a climate-related disaster hits that could lead to reductions in future damages through actively building resilience to the kinds of hazards expected as climate change advances.[12] Put differently, the first is about whether individual owners of assets or communities think they will be kept whole (or partly whole) in the face of disaster. The second is whether they help these individuals and communities prepare

TABLE 1
Federal Programs that Increase Moral Hazard

Policy Strategy	Federal Programs		
	Disaster Response	Infrastructure Building and Maintenance	Subsidized Insurance
Recovery (financial recovery and physical recovery)			
Resilience (financial risk resilience and physical risk resilience)			

better for those disasters by hardening against exposure or moving away altogether.

The presence of federal and state policy strategies, funneled through agencies and programs that affect beliefs about repayment and decisions on where to invest, can in turn, alter the incentives for firms, households and communities to take risks they otherwise would not. They can alter, as well, what the "market" thinks about those risks—for example, the decisions that credit ratings agencies (CRAs) make about whether a climate-exposed community that is raising debt for infrastructure will repay its bonds if climate-related disasters strike (Bolstad et al, 2020). It is ultimately the totality of these effects—disaster response, resilience, and broader market responses—that determine whether federal policies are amplifying or dampening climate dangers. And the broader market effects are probably the most important, for they are seen in investments that will be measured in trillions of dollars whereas the annual costs of relevant federal policies will be in the tens of billions.

In Table 1, the columns are the three major areas of federal programs that affects these outcomes. These include programs supporting disaster assistance and disaster response directly. The programs largely fall under FEMA but also include other relevant agencies and actions such as the use of the Department of Agriculture (USDA) for temporary food benefits. In the second column are policies around infrastructure spending, which are sprawling and include infrastructure trust funds for roads and airports, spending on federal rail lines, and the varied activities of the Army Corps of Engineers. In the last column are subsided insurance provisions—at the federal level the most important instantiation being flood insurance followed by crop insurance. [13]

What follows is an effort, with this framework in mind, to triangulate some answers about the size of the climate-related moral hazard problem today. As we will see, any conceptual framework is very difficult to apply to the actual federal budget because so many programs comingle different functions. For example, in 2016 the GAO did a big survey of all disaster assistance in an attempt to organize the entire federal budget into a common framework (GAO, 2016). That effort proved difficult at the time and has not been replicated since. One of the many challenges is the large number of judgement calls needed around the purpose of different federal programs. An additional challenge is language, because the concept of "disaster assistance" can mean just the narrow responses to actual disasters or a larger set of programs to prepare for disasters plus long-term spending after disasters to make rebuilding more effective. These difficulties are a reminder that any attempt to assess the totality of federal intervention around climate related perils must examine them from many different perspectives.

Triangulation part 1: What we observe in the Federal Budget

In terms of fiscal cost, we can look at total expenditures on climate-related disasters across all agencies, which is shown in Figure 1. Tracking expenditures across the entire Federal budget is difficult, given the separate departmental mandates and functions of each agency involved in the disaster resilience and response process.

Given this inherent complexity, The National Disaster Recovery Framework (NDRF) was first introduced through FEMA in 2011 as the nation's primary framework for identifying the mission areas and core capabilities needed to mobilize a collaborative response effort across federal, state, local, and tribal jurisdictions (DOHS, 2016). Fortuitously for our purposes, the Recovery Support Function Leadership Group (RSFLG) a multi-agency coalition made up of the key players involved in the NDRF's six Recovery Support Functions (community

FIGURE 1
Federal disaster response funding by agency (2017–2019)

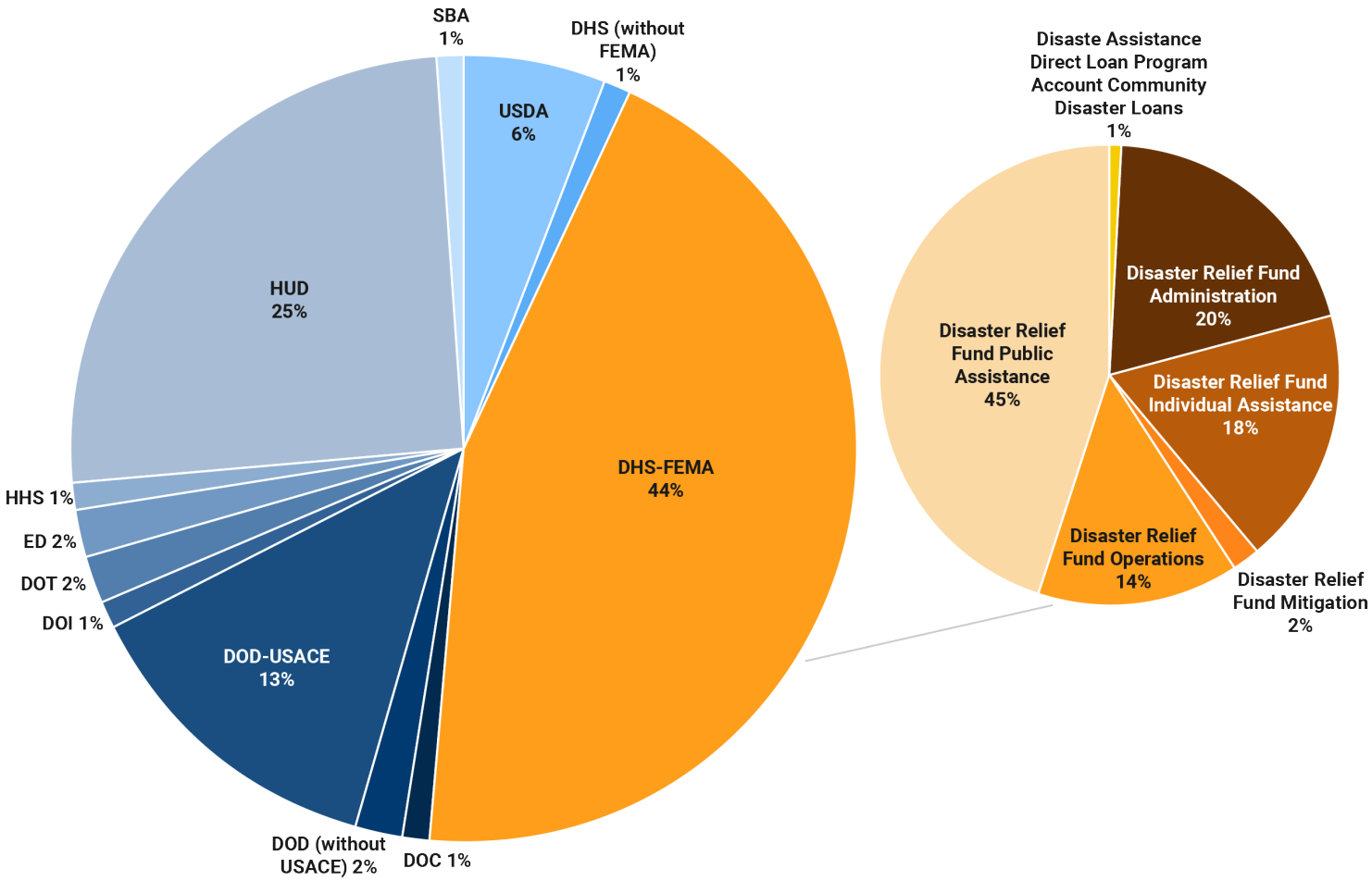


Figure 1 analysis by authors. This data is sourced from the Recovery Support Function Leadership Group, a federal multi-agency disaster response coalition, and is maintained by the Federal Emergency Management Agency (FEMA). The main pie chart shows percentage breakdown by agency appropriations from 2017-2019, while the secondary pie chart shows the breakout in obligations for the largest source of federal appropriations, which is FEMA itself. While the majority of FEMA funds are appropriated into the Disaster Relief Fund (DRF), FEMA also maintains a loan program to support the continuation of community services in the wake of a disaster (the Disaster Assistance Direct Loan Program).

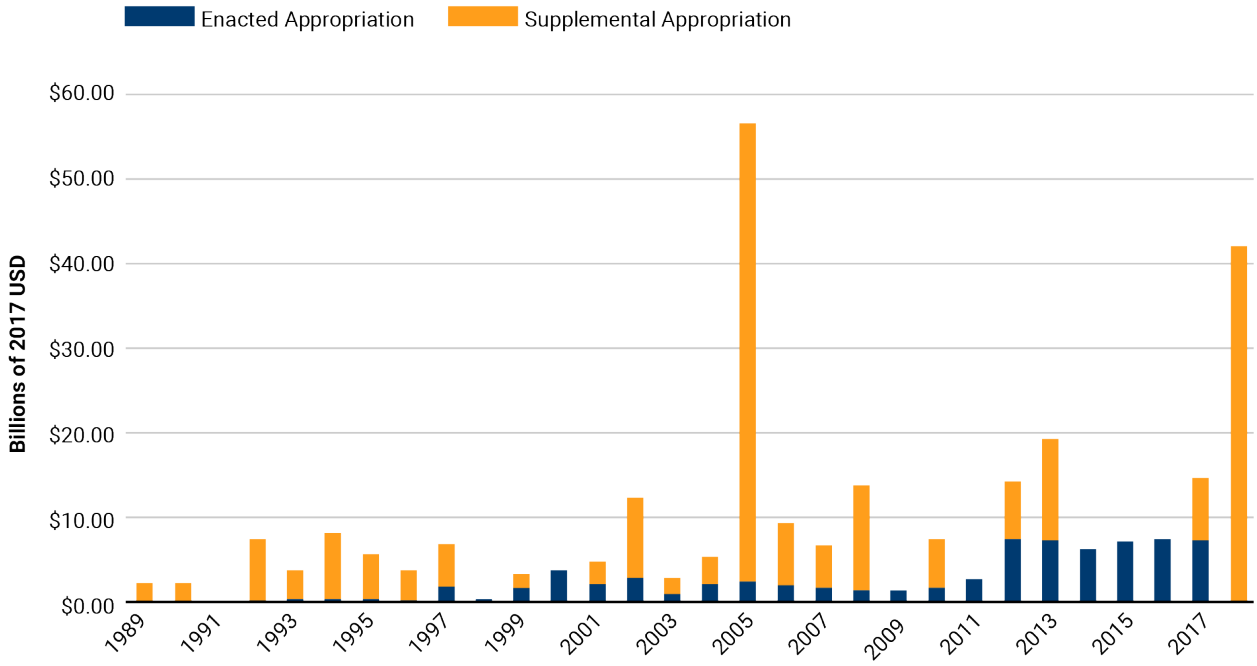
planning and capacity building, economic recovery, health and social service, housing, infrastructure systems and natural and cultural resources) has been publicly tracking large disaster spending since 2017 (FEMA, n.da). RSFLG's strategic focus is on better agency collaboration and transparency, and thus it also compiles the most complete set of budgetary data across the federal government. Using that data, we have accessed federal appropriations and obligations by department, agency, and program for the over $159 billion provided by Congress in the last three years for disasters including the devastating 2017-2018 hurricane and wildfire season.

What is clear from Figure 1 is that while federal disaster support is provided by a broad group of agencies, FEMA makes up the largest single source of federal disaster funding, with 44 percent of overall federal appropriations going towards the agency's operations and main relief programs.[14] Other agencies involved in disaster response include the Department of Housing and Urban Development (HUD), the Army Corp of Engineers (DOT-USACE), the Department of Agriculture (USDA), the Department of Defense (DOD), the Department of Transportation (DOT), the Small Business Association (SBA), the Education Department (ED), the Department of Commerce (DOC), the Department of Health and Human Services (HHS), and the Department of the Interior (DOI).

Given FEMA's outsized role in the federal disaster budget, in Figure 2 we focus there. We show the main source of funding for FEMA's disaster response and recovery programs, the Disaster Relief Fund (DRF) appropriations since 1989. Although called "relief" in fact the DRF is the funding vehicle for the vast majority of FEMA activities that implicate relief or preparedness. Annual DRF appropriations through the normal budgeting process are small (a few billion dollars per year, although the most recent federal budget included a $19.4 billion-dollar funding request) (DOHS, 2020). Thanks to the political gridlock in Washington and the unpredictable nature of big disasters, nearly all DRF funds come from supplemental appropriations, for instance, the three supplemental assistance bills signed into law by President Trump to address the damage of the 2017 hurricane season provided nearly $50 billion in funding for the DRF (CRS, 2018). Such appropriations rarely face much opposition and typically proceed without the need for offsets to keep them below the quaint concept of an agreed budget cap. A more orderly budget process would be politically challenging because it is hard to undertake the politically difficult process of appropriating funds when big disasters are abstract but relatively straightforward to do the same thing once families are flooded.

Once appropriated through the DRF, where have FEMA funds primarily gone? The answer is that nearly all go to paying the immediate costs of disasters, including rebuilding and disaster response management. Figure 3 below shows that from 2005-2017, about 46 percent of the agency's total grant funding went into Public Assistance (PA) and Individual Assistance (IA) grants (FEMA, n.db.). FEMA's largest program, Public Assistance, provides recovery dollars for debris removal, and state and county level repairs of public utilities and public infrastructure.[15] Individual Assistance, making up 1 percent of grants, provides direct support to households and individuals in the form of home repairs and immediate housing needs. Fire and Preparedness grants, which made up an additional 40 percent of total FEMA grant funding, are utilized for capacity building and emergency management response, such as procuring equipment for first responders, and enhancing state and local emergency preparedness systems. This is reflective of FEMA's broad disaster response mandates, for instance, FEMA is heavily involved in COVID19 response, and a majority (7/8) of the FEMA preparedness grants are focused on terrorism.[16] In contrast to those grants supporting response and rebuilding in the wake of a disaster, FEMA's hazard resilience (termed mitigation) grants, including the Hazard Mitigation Grants program, Flood Mitigation Assistance program, and Pre-Disaster Mitigation program, all of which target climate related hazards such as hurricanes and floods, made up only 14 percent of overall grant funding during that 13 year period. Put differently, there is a historical 6:1 difference between FEMA spending on the

FIGURE 2
Annual Appropriations to the Disaster Relief Fund (1989-2018)



Lingle et al., 2018

immediate response and consequences of disaster and funding that goes towards mitigating future risks from natural hazards to communities.

Does the difference between resilience and response revealed in the FEMA budget hold when looking across the whole of federal spending? That question is much harder to answer because federal spending is dispersed and the fact that resilience data is limited and not tracked systematically across the federal government, with the most complete data coming from FEMA itself (Pew, 2018).

The conceptual framework we offered in Table 1 can help answer this question. Using the same list of agencies and programs as shown in Figure 1, and additional sources where needed, particularly for the federal insurance programs, we allocated all the spending that the RSFLG tabulated across the conceptual recovery and resilience categories in Table 1. That complex process is detailed in an accompanying supplemental index and summarized below in Table 2 which shows where we think each federal program belongs in the framework.

In terms of expenditure, from 2017 to 2019 total funding for recovery from disasters was about $137 billion dollars.[17] By contrast, total resilience spending—all of which is devoted in various ways to reducing hazards for the future—totaled about $20 billion. That also suggests a difference of 7:1 across the totality of federal funding, a finding roughly in line with the historical FEMA grant data we report above.[18] The imbalance in this ratio matters because as we discuss below, there is strong evidence that investments in resilience can provide large cost savings benefits, and cost reductions. Table 2 shows how we allocated each program into our conceptual framework, while Table 3 reports the total funding for each category organized into the same conceptual framework. While there are hundreds of grants that FEMA identifies as relevant for disaster recovery resources, from agencies as different as the National Endowment for the Humanities and NASA, here we show just the agencies and their respective programs that

FIGURE 3
FEMA all hazards grant funding from 2005-2017 favored immediate disaster needs by 6:1

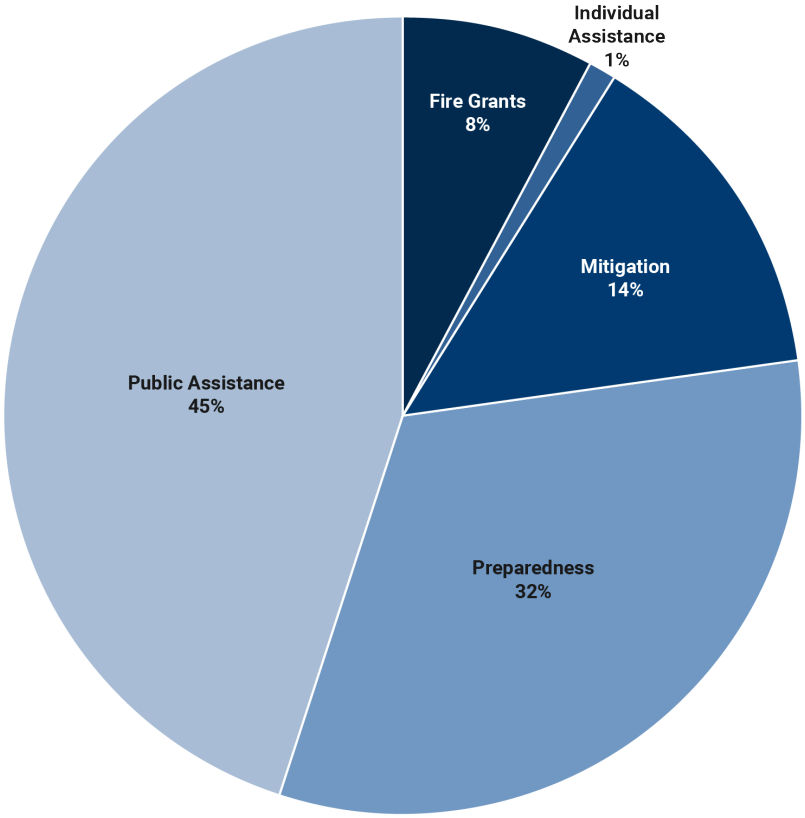


Figure 3 analysis by authors. While analogous to the analysis in figure 1 this data is sourced from FEMA's public summary of disaster declarations and grants website, which includes historical grant specific funding beyond the appropriations included in the RSFLG dataset. The summary tool that FEMA provides is compiled across multiple datasets and aggregates data across grant programs. We note that this data is inclusive of all disasters, such as terrorism and earthquakes, not just climate related natural disasters such as wildfires, although FEMA's mitigation programs are primarily focused on natural hazards to communities.

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account for the largest spending categories (>1 percent of total) as reported by the RSFLG, and the major federal insurance programs.[19]

It is very hard to pin down the exact level of difference, because most programs have multiple functions. For the tabulation in Table 2 we assigned programs based on their primary purpose and function identified through publicly available information. Changing the accounting methods, which we explore in more detail in the appendix, will change the ratios. Narrowing the accounting focus, for example, to just the permanently authorized risk resilience programs at USDA and FEMA would lift the ratio as high as 40:1. In other scenarios, when looking very broadly at resilience (e.g. including one off's like the HUD-MIT program and more generic flood damage reduction funds specified in individual legislation), alternative accounting methods can yield a ratio as low as 3:1. For more on each specific accounting method, see the supplemental information posted online with this paper.

This difference has huge implications for the nation's resilience to disasters—even before we begin to worry about climate change. A widely cited report, funded by HUD and sponsored by FEMA yet written by the National Institute of Building Sciences—a highly credible multisector NGO authorized by Congress since 1974—found that federal mitigation grants exhibit a 6:1 benefit cost savings ratio (National Institute for Building Science, 2018). Despite this, the HUD-CDBG-MIT program, which was announced in 2018 to fund resilience

and mitigation actions for disasters from 2015, 2016, and 2017, is the only multi-billion-dollar fund that has been specifically earmarked for resilience building (Department of Housing and Urban Development, n.d.).

Triangulation part 2: How private markets respond to these signals

It is very hard to measure how moral hazard affects what ultimately matters: levels of investment and economic activity in harm's way. The level of federal spending is one way to take the pulse of potential incentives that enable moral hazard, and one of the core contributions of this paper is a new framework and tabulation of that expenditure.

Before looking to the future—at the possible

TABLE 2
Federal programs allocated into our Conceptual Framework

Policy Strategy	Federal Programs		
	Disaster Response	**Infrastructure Building and Maintenance**	**Subsidized Insurance**
Recovery	Individual Assistance (FEMA) Disaster Recovery Loans (SBA) Wildfire and Hurricane Indemnity Program (USDA) Commodity Assistance (USDA) Emergency Conservation Program (USDA) Supplemental Nutritional Assistance Program (USDA) Emergency Forest Restoration Program (USDA) Disaster Education Recovery (ED) College Housing and Academic Facilities Loan Program (ED) Military Construction (DOD) Health Resources and Support Programs (HHS) Community Disaster Loans (FEMA)	Public Assistance (FEMA) Emergency Relief (FHA/DOT) Public Transportation Emergency Relief (FTA/DOT) Community Development Block Grant- Disaster Relief (HUD) Economic Development Disaster Assistance (DOC) Army Corp of Engineers (USACE) Rural Development Grants-Community Facilities and Water and Waste Disposal (USDA) Airport Trust-fund (DOT) Economic Development Fisheries Assistance (DOC) Construction and Resource Support Programs (DOI)	NFIP FCIC Rural Housing Insurance Fund
Resilience	Pre-Disaster Mitigation Grants (FEMA) Watershed and Flood Prevention Operations (USDA) Hazard Mitigation Grants (FEMA)	Community Development Block Grant-MIT (HUD) Building Resilient Infrastructure and Communities (FEMA, replaced the Pre-disaster Mitigation Grants in 2020)	Flood Mitigation Assistance (FEMA)

This tabulation represents the exhaustive list we utilize for our analysis. This list is inclusive of all reported RSFLG agency appropriations making up >1% of total funding and the federal insurance programs, excluding funds for wilderness forest fighting, and those designated operations, maintenance, and administration ext. In practice, as we elaborate on in footnote 7, many of these programs do have the ability to fund resilience in addition to recovery activities. However, the difference in policy strategy is salient regardless of accounting methods utilized.

TABLE 3
Federal funding organized into our conceptual framework

Policy Strategy	Federal Programs			
	Disaster Response	Infrastructure Building and Maintenance	Subsidized Insurance	Total
Recovery	$18.4b	$69.6b	$48.5b	$136.5b
Resilience	$2.7b	$16.5b	$0.6b	$19.8b
Funding Ratio				7:1

Cases in which data was sourced beyond the 2017 RSFLG dataset are FEMA's individual mitigation programs for which we use data reported by the Government Accountability Office from 2014-2018, and several newer programs, such as the Department of Housing and Urban Development (HUD) Community Development Block Grant (CDBG) MIT program, and FEMA's Building Resilient Infrastructure and Communities (BRIC) program, both of which were launched after 2017. HUD's grants are also not identified specifically in the RSFLG dataset and we report the data sources for both the MIT and CDBG-DR program separately in the appendix. The major federal insurance programs are accounted for according to the deficit covered by each program from 2017-2019. In the case of NFIP we use money borrowed from the Treasury plus debt cancelled. For the FCIC, we use total yearly subsidies for existing policies. Where possible, and for most of the programs, federal appropriations were used, however due to reporting limitations, in some cases obligations and allocations were utilized. The differences footnoted between appropriations and obligations , whereby the political nature of appropriations leads to greater funding announcements than actual obligations mean this analysis may exhibit an upwards bias (as larger programs are biased towards larger appropriations).

impacts of climate change (Part II) and policy responses (Part III) we must pause, briefly, to examine how the presence of large federal programs could create moral hazards that cause worrisome behavior by state and local entities that are one of the major beneficiaries of federal disaster-related spending. Similarly, that literature suggests that the behavior of private entities—such as homeowners and financial investors—also do not reflect adequately the real nature of the risks they face such as from floods and wildfires.

The central result from this literature is that it is often hard to find the signal of climate-related disasters in private market behavior. This has been studied most closely in mortgage markets. For example, one study using a large data set from the realty site Zillow found that houses exposed to sea level rise are now trading at prices 7 percent lower than those that aren't (Bernstein et al, 2018).[20] Yet other studies suggest the effects are harder to observe. For example, recent academic research finds no impact of sea-level rise on home prices (Murfin and Speigel, 2020). The implications of the mixed evidence on market signals regarding climate impacts have been studied as well. One important new paper finds that existing climate risk information asymmetries between local private banks and federal institutions Fannie Mae and Freddie Mac result in public risk offloading through mortgage securitization (Keenan and Bradt, 2020). In extreme cases effects can be seen for some perils. For example, careful work looking at the effects of multiple fires separated by many years in southern California suggests that the first fire cuts home prices about 10 percent and a second fire cuts prices 23 percent (Mueller et al, 2009). So far, no study has yet identified the "right" level of market response if, for instance, insurance costs were actuarially fair and the people most able to manage exposures to extreme events—homeowners and investors—were fully exposed to the consequences.

The muted impacts on public and private sector behavior plausibly reflect three factors at work—all consistent with a substantial moral hazard that could be created by existing federal policy. First, as shown in our earlier research, prices and allocation of capital in financial markets, overall, do not signal concerns about the physical impacts of climate change (Bolstad et al., 2020). The picture for U.S. municipal debt, we found, is particularly important

because municipalities, as a whole, are often on the front lines of climate-related weather hazards. In that portion of the market there is zero relationship between the level of potential exposure to climate impacts by communities and the information they disclose to the markets about actual risks (Bolstad et al, 2020). Other, much smaller studies find similar results (Government Accountability Institute, 2019; Deese et al 2019, Cooper 2019; Norton, 2019). By this logic, hazard-inviting policies can create additional risk because the markets don't have the information needed to discourage such behavior. Such earlier work suggests that markets for equities also have little reliable information about the physical impacts of climate change on traded equities, and reviews of the relevant literatures show, indeed, prices and capital allocation do not seem to reflect concerns about impacts of climate change (Bolstad et al., 2020).

Second, there is substantial and growing evidence that credit rating agencies (CRAs) are not taking more credit-related actions due to dangers of climate-related perils. In our earlier research we found that they are developing some of the tools that might be useful for identifying these dangers but they also, for the most part, continue to believe that extreme risks will be compensated by FEMA and other agencies (Bolstad et al, 2020). This phenomenon, known as the "FEMA put" has also been documented by a variety of analysts from large firms like BlackRock to local market players in exposed geographies like Sarasota, Florida (Deese et al, 2019; Healy, 2019). So long as that belief system prevails then the most powerful market forces affecting municipalities—the cost of borrowing—will be nonresponsive. That reality, rooted in today's federal policies and the assumption that the politics of reforming those policies are intractable, is one of the reasons we wrote the present paper. Indeed, recent work shows that these assumptions are already softening (Jerch et al, 2021). The strong interlocking political forces that have prevented meaningful reform of disaster response strategies—the presence of those forces can give the CRAs confidence that their assumptions around full repayment and lack of reform are robust.

Third, a contributing factor that amplifies the first two is that while disaster causes many harms—the generation of anxiety and loss of life and livelihoods among them—when the assumption of a "FEMA put" holds true it is also likely that disasters yield substantial boosts to local revenues during the rebuilding process. Numerous studies have documented these effects, such that some of the actors that might be expected to invest heavily to avoid the harms of disaster have a weaker incentive to do so. Looking at New Orleans after Katrina, for example, found that sales taxes in every parish rose during the worst period of the disaster (The rising effect was greatest in the parish hit hardest and needing the most rebuilding) (Hildreth, 2009). While the immediate effect of the disaster was to raise questions about the ability of New Orleans to honor its debt service—a point bolstered by local analysts stating the need to allow the already economically fragile city to declare bankruptcy—within two years the size of economic aid provided by outside agencies was so substantial that New Orleans debt was upgraded out of junk status by Moody's.

In Houston after Hurricane Harvey brought massive flooding to the city, overall economic activity nearly everywhere had rebounded within one quarter (South Texas Economic Development Center, 2018). Because money floods into disaster areas in many different ways—loans, grants, special loan conditions and other programs spread across federal and state and other programs—it can be hard to track all the effects. One careful study done in the aftermath of Harvey did that, showing that not only did relief funds contribute to substantial economic activity—not just repairs but also purchasing of many new vehicles and other capital equipment—but that many households used these infusions of support to reduce debt as well (Hartley et al, 2019).

PART II: HOW BIG WILL IT GET?

A core finding from the previous section is that the US federal government currently spends approximately $46 billion per year (as a central

estimate) on large disaster response and just one-seventh that amount (~ $7 billion/yr) to develop resilience to the next disaster. Those are big numbers for the federal government and the communities on the front lines, but they are plausibly quite small compared with how they might grow over time and with mounting climate change. This second section looks at the potential rise in climate-related damages in the coming decades.

It is hard to offer any precision on how big the US exposure to climate-related disasters could get because disaster size is the result of several compounding forces: rising population and migration; incomes, which drive up the cost and price of the built environment and thus the value of assets at risk; and climate change. In this section we assume no adjustment in the policy framework—a proposition that will become increasingly untenable in the face of plausibly massive disaster assistance needs—and in the next section we look at policy reform.

Population and migration

People like warmth and good weather, Florida and the west in particular. In 1800 the mean center of the US population, as counted by the Census, was 18 miles west of Baltimore. By 1900 it has moved to Indiana, and in the 2000s the center of the US population has been walking southwest across Missouri (United States Census Bureau, n.da)

Figure 4 shows this migration with more granular county-level data. Over the period 1970-2010 the center of the country has been emptying out and the coasts have been getting more populous. Florida, Texas, and most of the urban West have grown, while a few established urban footholds in the rest of the country have swelled in size as well (e.g., the Washington DC area). Texas and Florida, among the most highly climate exposed states in the nation, continue to be two of the fastest growing states in the US, and have grown in population at 15 percent and 14 percent since 2010, respectively (World Population Review, 2020) (United States Census Bureau, n.db).

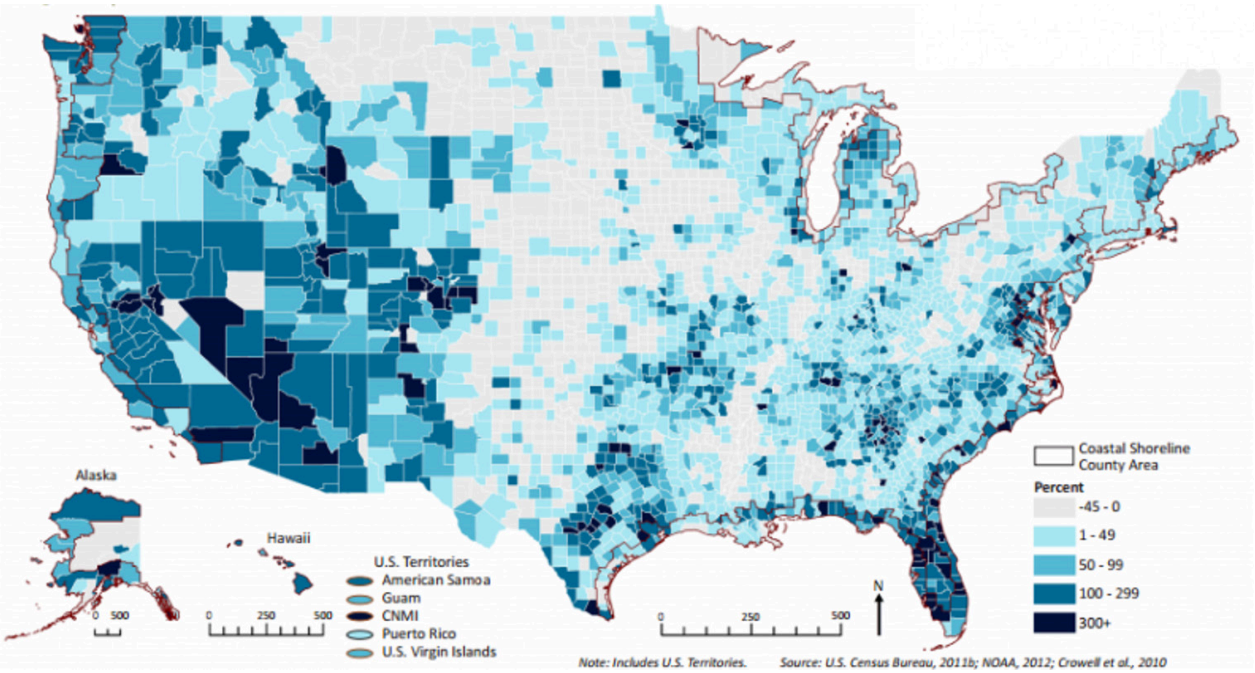
This migration, by itself, is extremely important in bringing people closer to danger. For example, under contract to FEMA and the Federal Insurance and Mitigation Administration (FIMA), the research arm of AECOM (a large and credible engineering firm) did a thorough study analyzing the twin impacts of population growth and climate change on the National Flood Insurance Program through the end of the century (AECOM, 2013). [21] That study looked just at climate and flooding dangers along rivers and coastal geographies when interacted with projected population changes. Climate change, by itself, contributed 70 percent of the rising danger; while population growth added 30 percent.[22]

Rising incomes and values at risk

In addition to migration there are income effects. Overall, US national income has been rising for the last fifty years despite periodic recessions- for instance the growth rate of US household income dropped from a three decade long average of 1.2 percent annually to 0.3 percent from 2000 - 2018, however since 2015 that rate has climbed back to 2.1 percent (Horowitz et al, 2020). Those averages, however, obscure huge disparities that affect climate dangers. As a general rule, income growth has favored urban and migratory segments of the population and disfavored rural places. Some of the nation's most valuable and exposed properties are in coastal areas, and as more people with higher incomes flood into those areas that remain geographically fixed in size (notwithstanding Miami condo high-rises) property values rise as well.

These trends are stark. From 2012-2018, AIR, a leading catastrophe modeling firm reports that the value of coastal exposures in the US grew 27 percent (Grenier et al, 2020). Catastrophe modeling tools allow us to quantify both the size of hazard exposures, and the likelihood of a hazard occurring. This roughly decadal increase in exposure value translates into a compound annual growth rate (CAGR) of about 4 percent and makes up the largest contributing factor to increasing hurricane risk across the country. In some of the most exposed

FIGURE 4
US coastal population change from 1970-2020



NOAA National Coastal Population Report, 2020

geographies, like Florida, this trend is even more pronounced. In the period leading up to the housing market crash from 2002 to 2009, the Florida residential property insurance market (private and public insurer Citizens), saw an increase in values insured by a 12 percent CAGR. While the values insured remained practically unchanged until 2017, the insured values started increasing again at a CAGR of 4 percent from 2017 to Q1 2020 producing a CAGR of 5 percent over the 18-year period.[23]

Impacts on the costs of disasters

The confluence of these two factors—population and income—are already having a very large impact on the cost of disasters. As the cost of the disasters goes up, so does the cost of federal policies and the degree of concern about moral hazard and risk invitation. This can be seen in two ways.

First, as documented extensively in prior research, disasters are costing more over time.[24] Figure 5 below shows the total cost of weather-related disasters and the frequency of those disasters since 2000. Often this chart and others like it are used to make the case that disasters are becoming more frequent and more costly. In fact, these data show neither. Discerning a trend in frequency in noisy phenomena is difficult, especially when incentives to report disasters (and the clumping of reports) vary with time. Careful research suggests that essentially all that trend, possibly until recently when California wildfires will be added, is due to rising values at risk, not climate change (Weinkle et al, 2018). Some efforts to detrend these data and suggest a climate-related signal are fraught with difficulty—for example, removing trends in the consumer price index (CPI), which is one measure of rising costs, leave a trend. But the CPI is the wrong metric for detrending because it measures costs from the vantage point of consumers whereas what matters for most natural disaster costs are the trends in property values and public infrastructure costs at risk, not the CPI.[25]

Second, we can examine what would happen if

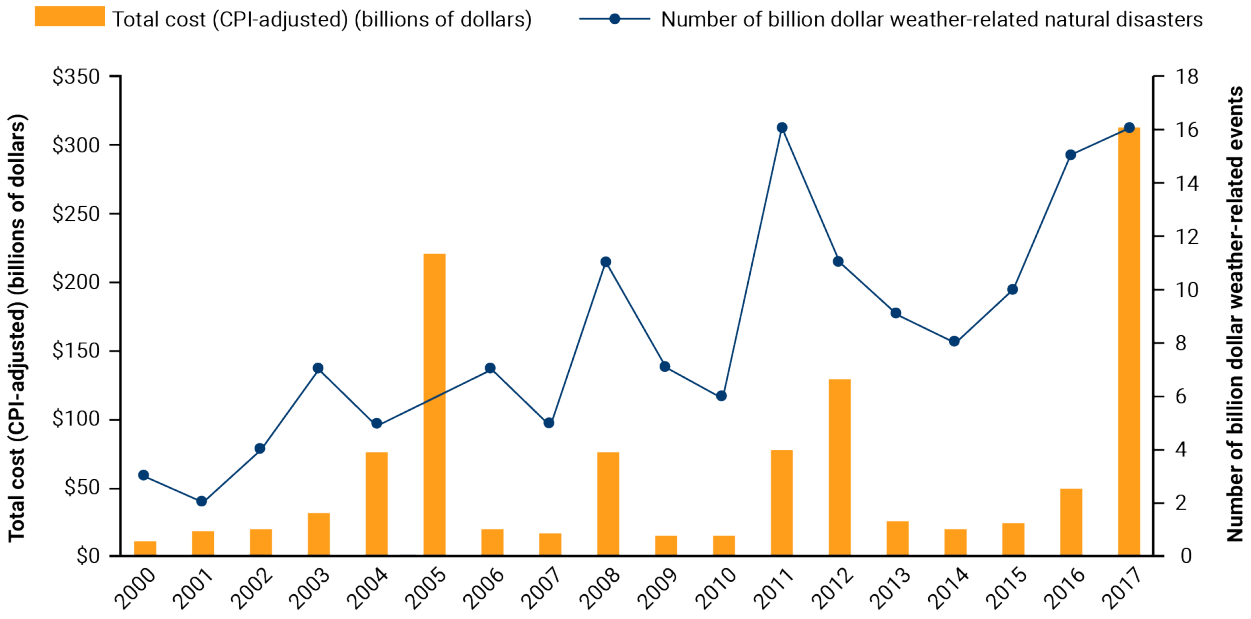
events from the past were to happen today (or in the future). Table 4, drawn from an authoritative study of the largest hurricanes to hit the US, illustrates what's at stake. What's striking is that the insured losses alone from events with probability on the scale of 1 in 30 years far exceed anything in recent memory. For instance, Hurricane Andrew struck in 1992 causing unprecedented losses in Florida at the time, rendered 11 insurers insolvent, and helped trigger major reforms in the Florida insurance market. If Hurricane Andrew repeated itself today it would cost $50-60 billion in insured losses alone and between $80-100 billion in total economic losses (triple the $26.5 billion total economic losses suffered in 1992) (Swiss Re, 2017). Even with reforms, the Florida insurance market is still not robust against stress tests that simulate the impact of giant hurricane events. (Nicholson et al, 2018) (Bailey, 1999). Indeed, recent modeling of hurricanes shows that events of the $100 billion dollars in scale are becoming more probable (Grenier et al, 2020).

In addition to the much higher exposure today, what's also interesting is how the details of a storm track affect damages. If the 2017 Hurricane Irma had hit downtown Miami, as forecast for a period, the damages would have been about $180 billion in insured losses. Combined with uninsured losses, which are often equal or larger in size, total damages would have exceeded $300 billion. If Hurricane Andrew had followed a track just 20 miles further north insured damages would have been $60 billion instead of $15 billion (Nicholson, 2018).

What's surprising in all this is the modern rarity of $100 billion plus events in the US (roughly $50 billion of insured plus $50 billion of non-insured losses). The historical record over the past 120 years suggests that the frequency of events of this magnitude for Atlantic basin hurricanes, once new values in population growth are factored in, are at least once every 15 years (9 times in the past 120 years).[26]

Looking into the future, even absent climate change, the impact of population and income on overall hazard risk is expected to continue to be salient. The compounding effects from increasing climate change and increasing exposure values only ramp up overall risk. For instance, one study looking at the interaction of coastal development (defined as

FIGURE 5
Weather related disasters cost more over time



Maplecroft, 2019

population plus income) and climate change on future US hurricane risk found that total hurricane damages are projected to increase at a rate greater than the entire US economy, with 54 percent of the overall $120 billion increase in average expected hurricane damages coming just from population and income factors (Dinan, 2017). Looking forward, the chances of not having at least a $100 billion event over the next 15 years is nearly zero.

Adding climate change

Now we add an additional level of unknown: climate change. When looking backwards in time at actual weather-related disasters—events that may become more common or more intense with a changing climate—one observes the stochastic processes of weather. Miami may be at severe risk, but when big hurricanes come at the US, only a few actually hit Miami. By contrast, when looking forward over long time horizons the climate models, for the most part, don't represent individual climate-related events stochastically. Instead, they estimate mean damages. Some new modeling work is filling in this gap but modeling stochastic events (e.g., a hurricane track) using catalogs of possibilities selected with an eye to how climate change will make certain types of events more likely or more intense or both (Greiner et al, 2020). Such work remains rare, however.

We approach this question from two angles and rely on estimates of plausible future damages from climate change as outlined by the Climate Impacts Lab (CIL). CIL reports estimates on the full range of impacts of climate change—including sector level damages such as impacts on worker productivity, death from heat stress, and violence (Hsiang et al, 2017). We will focus on a subset of those perils most aligned with the area where federal programs have the largest impacts on moral hazard as listed on table 2; CIL defines those perils as "coastal damages."[27] In effect, we will treat the CIL analysis as a picture of what is likely to happen with climate

TABLE 4

Estimated insured losses from the top 10 largest hurricanes in US history selected on basis of current exposures

Date	Event Name	Category	2017 Insured Loss*
September 18, 1926	Great Miami Hurricane	4	USD 128 billion
September 17, 1928	Great Okeechobee Hurricane	4	USD 78 billion
August 29, 2005	Hurricane Katrina	3**	USD 64 billion
September 17, 1947	1947 Fort Lauderdale Hurricane	4	USD 62 billion
September 9, 1965	Hurricane Betsy	4***	USD 57 billion
August 24, 1992	Hurricane Andrew	5	USD 56 billion
September 10, 1960	Hurricane Donna	4	USD 50 billion
September 21, 1938	The Great New England Hurricane	3	USD 50 billion
September 9, 1900	Galvesto Hurricane of 1900	4	USD 49 billion
August 17, 1915	Galveston Hurricane of 1915	3	USD 25 billion

AIR, 2017

*Modeled loss to onshore property, contents, and business interruption and additional living expenses for residential, mobile home, commercial, and auto exposures as of December 31, 2016, using the indexed take up rates provided in the 2017 CATRADER® release. Losses include demand surge and account for storm surge.

**This refers to Katrina's strength at second landfall in Louisiana.

***This refers to Betsy's strength at second landfall in Louisiana.

change and then see how actual climate-related disasters might unfold in light of that.

One way to look at the data is spatially. What are the spatial relationships between the places where FEMA already spends large resources on disasters and where costly climate impacts are likely to occur in the future? Figure 6 shows the FEMA data for 2010-2020, and the same counties but from the perspective of coastal climate losses at the end of the century.[28] Mindful that we are measuring two different things—for FEMA we are measuring federal share of actual obligated payouts for coastal storm related disasters, and for CIL we are estimating projected county-level losses in income due to flooding and wind, the patterns are similar. This suggests that FEMA is already a good early warning indicator of the places where, with climate change, these same kinds of perils are more likely to occur. One implication of that insight, important for policy (the subject of the next section) is that FEMA processes that identify properties for resilience through observed losses could be a good screening mechanism for future resilience investments—especially if other mechanisms like modeling and mapping are too fraught with political or technical difficulties. The other implication is that if we could develop a function to describe how damages could rise from current to future levels as a result of climate change then we could apply that function to observed FEMA data to understand that rate at which FEMA-covered losses could rise. While that particular analysis is beyond the scope of this paper, the mathematical function, as reported by the CIL and visible in a figure we include in the appendix, is quadratic, indicating that damages actually accelerate over time periods.

A second angle aims to estimate the total level of climate-related damages. This is extremely difficult to do. One way to get a fix is to look at the relationship between FEMA spending on coastal hazards today (average annual over the last 10 years) and then compare it with the magnitude of likely damages from wind and flood as estimated by CIL. Again, we are measuring two different things: FEMA is actual losses, but the CIL data are estimates of expected losses to whole counties if projected end-of-century climate conditions occurred 'today' (data for 2012). These are illustrative measures of impact although not directly comparable for a variety of reasons. For example, FEMA spending is contingent on being a declared disaster for the Public Assistance program, while the CIL estimates are total economic losses whether or not they take the particular form of a disaster. A lucky county could have a high median estimated loss and then suffer few declared disasters—although with a loudly ticking clock each disaster season. Among other things, the multiple orders-of-magnitude differences between the two measures suggests that modest shifts in events that are disaster-worthy (either by impact or definition of "disaster") could have massive impacts on FEMA cost exposure.

That comparison is shown in Figure 7, with annual average FEMA payouts over the past ten years. Today, there isn't much relationship between the two. While the earlier Figure 6 suggested that there would be a broad geographical relationship between the places that have disasters and those that will suffer similar perils under climate change, this figure shows that numerically there will be lots of variation. Not only are disasters themselves stochastic events (the vertical axis) but the level of total damage to communities from climate change in the future also varies enormously. The outliers make sense—New York is most at risk in total cost because the built environment in that dense urban core is so costly (and thanks to Sandy it has had big payouts). Motley, Texas, a remote town far from the seashore and flooding dangers is the opposite.

Perhaps most important from Figure 7 is that the orders of magnitude in FEMA payouts are much lower than total exposure from climate change. Looking to the rough center of the cloud of data, the damages already being paid to communities, as a whole, are a factor of 1000 lower than the full economic cost of the likely damages that will come end century to those same communities as a whole.

There is hope that these challenges can be reformed via state level apparatuses, however, when we look closely, we see that even the best efforts

FIGURE 6

Geographic distribution of existing FEMA funding and projected future coastal economic damage

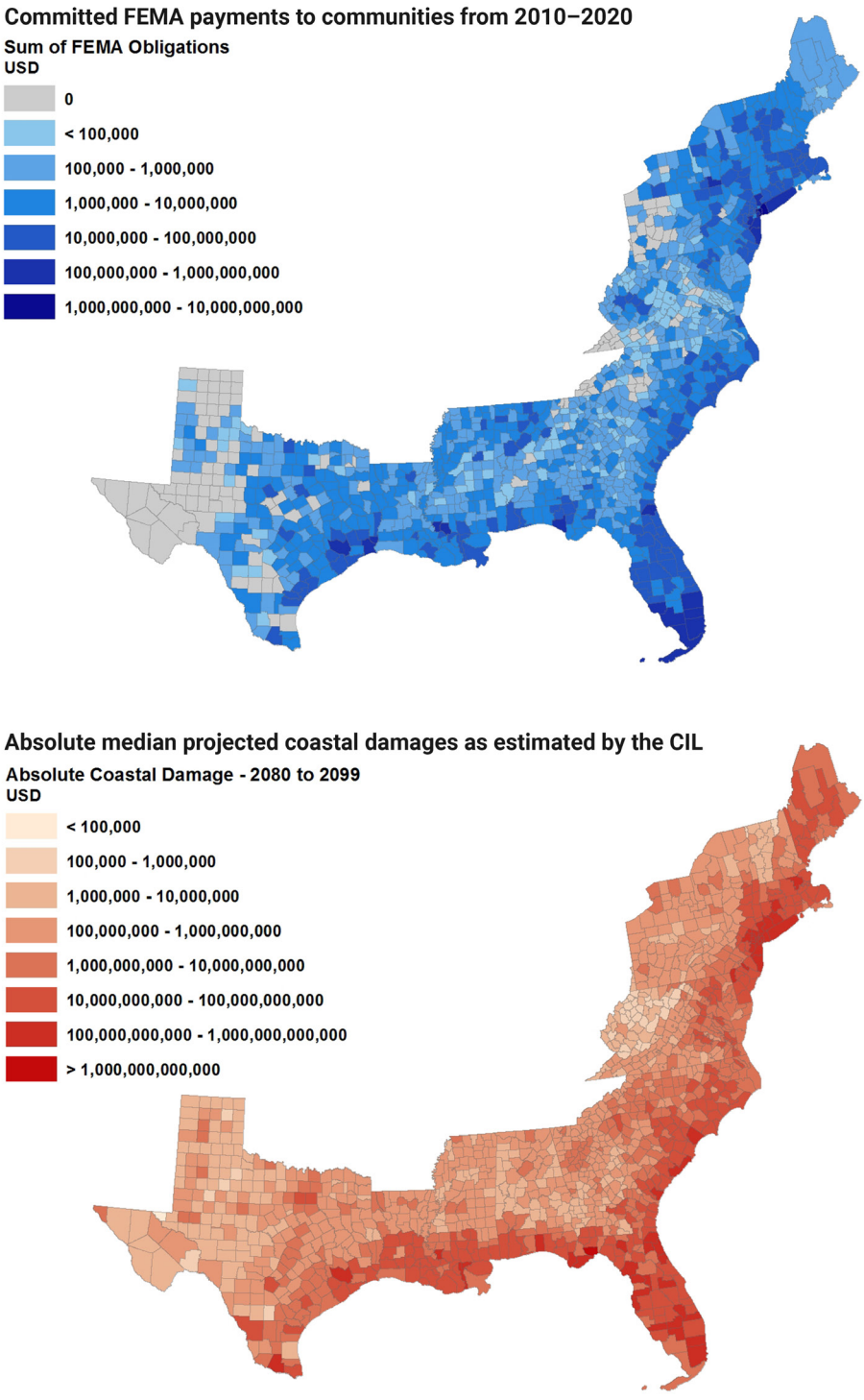


Figure 6 data by authors, and imaging provided by AIR Worldwide. This data is sourced from FEMA's Public Assistance dataset, and includes the sum of the federal share obligated for all county level projects resulting from damages that most closely match the CIL hazards, including damages from hurricanes, coastal storms, severe storms, and floods between 2010-2020. As noted above, projected economic damage data is sourced from the Climate Impacts Lab (CIL) sector level damages dataset and represents expected economic loss by county if climate conditions projected for end-of-century existed in 2012.

to enact changes at the subnational level don't alter the underlying mechanisms.[29] For example, Florida, a highly exposed state with a long history of hurricanes is in many ways an indicative vanguard when it comes to spreading natural hazard risk between the private and public sector. The state has several large public funds for pooling catastrophic risk, including Citizens Property Insurance Corporation and the Florida Hurricane Catastrophe Fund (FHCF) which both rely on post event funding to continue operations through policyholder assessments and raising debt, and the need to access these post event funds has occurred in the past. In addition, the Florida residential market relies on thinly capitalized local firms, which are ultimately backed by taxpayers for capital shortfalls post event through the state guaranty fund, The Florida Insurance Guaranty Association (FIGA). However, this public-private innovation does not alter the facts: a whopping $2.6 trillion residential insured value (Citizens Property Insurance Corporation, 2020) as of today still stands in the way of a number of scenarios that create at least a $50 billion insured event (which has occurred several times over the last 100 years once exposures are adjusted to current values with increasing chances once climate change is factored in) that could result in insufficient funds pre-event to pay those claims and have enough assets left over to prepare for future years without raising additional funds.[30] The Florida solution merely shifts the risk burden of sufficiently large events to future tax payers and consumers, leaving them and their future economic wealth directly in the path of large hurricanes.

PART III: HOW TO FIX IT?

Nearly everyone deeply involved in federal disaster assistance knows that the system is broken and must be reformed. The level of spending is not sustainable—as revealed, among other places, by the periodic need for emergency appropriations

FIGURE 7

Projected coastal county damages and existing committed average annual FEMA payments to communities

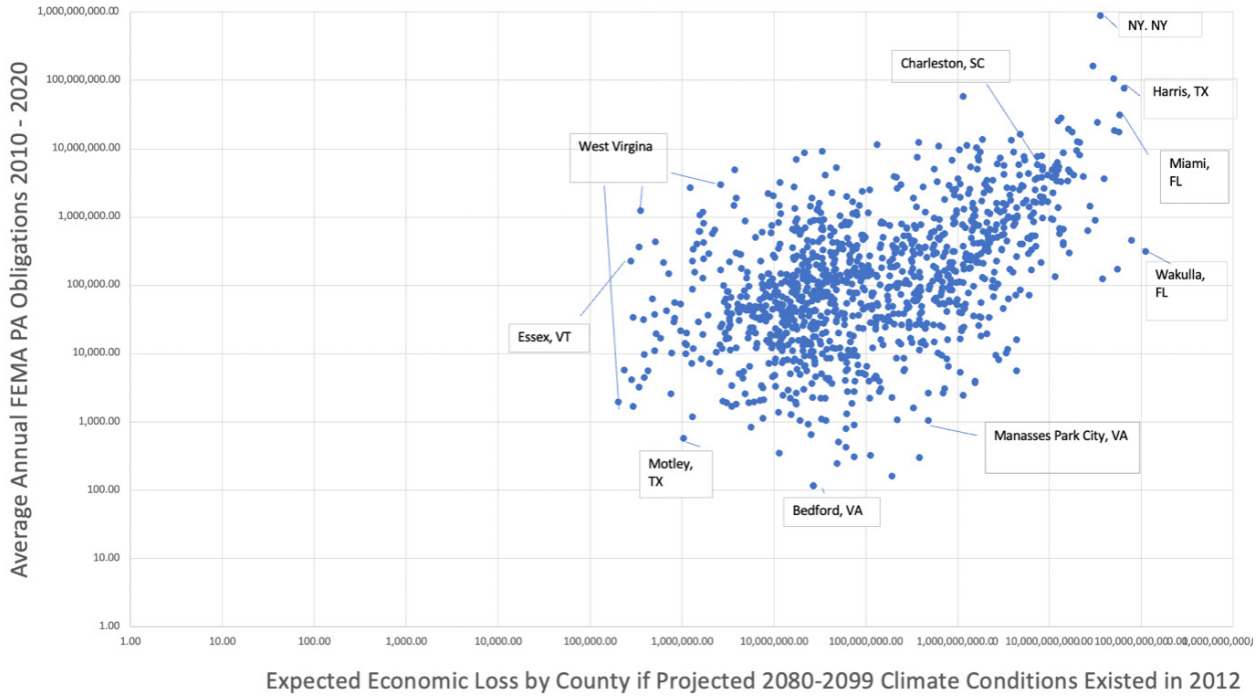


Figure 7 analysis by authors. This data is sourced from the same CIL sector level damages dataset and FEMA's Public Assistance dataset utilized above. We note that a line of best fit run through this data suggests roughly a factor of 1000 between the two variables, with lots of variation present.

to FEMA and the ongoing large deficit at NFIP that would be much larger if not for recent loan forgiveness. Worse, the system creates unintended consequences through incentives that magnify the dangers of weather-related perils in the US already today and will further magnify those dangers as climate change makes storms, flooding and wildfires worse in the future.

Yet the politics of reform are fraught with difficulty. Good polling studies show that people are averse to having government tell them what to do, especially when it involves costly changes in personal behavior and assets such as the location of a family home or upgrades in building codes (MacInnis and Krosnick, 2020). Instead of mandates, they favor positive incentives to help reduce dangers. (Who doesn't favor something when the cost can be shifted to the government?) But incentives can be expensive for the public purse and benefit groups that are not well organized politically. Yet, at the same time, those polls also show that people strongly favor helping localities when disaster strikes. This simple alignment of political forces helps explain the huge difference in natural disaster policies today, with the vast majority of the funds devoted to programs that help people when harmed rather than build resilience to disaster in the first place.

These differences in what people want and the incidence of the costs helps to explain the politics of reform. Major reform episodes tend to occur during crisis—when the system can't withstand more spending or has failed patently (Kingdon, 1984). Absent such a crisis the only kinds of reforms adopted are those that are politically "easy," relatively speaking. Yet what is easy isn't relevant to solving the underlying problem. And what's relevant isn't easy.

Here we look at this problem from two angles. First, we document what has been tried so far in terms of reforms and show how some of the most promising reforms are later reversed when they work as intended—and thus create political backlashes that are predictable. Second, we outline reform packages that could work, if adopted during the right window of opportunity. We don't know when that opportunity opens—it seems more likely to accompany a major disaster than the publication of this paper—so our purpose is to chart how the opportunity can be used to effect change.

What has been tried?

Because the problem of moral hazard creation in disaster policy is so well known, there are many ideas for reform and, to a more limited degree, actual episodes of reforms over history. In terms of cost, the most expensive reform activities have not been aimed at addressing moral hazard at all—instead, these have been costs that arise when disaster assistance programs run out of money and, politically, there is no real option but to provide more funds. This is most evident in the history of NFIP which ran roughly in balance until faced with a major event—Katrina and Rita that hit New Orleans and swelled NFIP's debt from about zero to $20 billion (figure 8). Within six months the GAO put NFIP on its list of high-risk programs that need careful ongoing scrutiny—a place it has occupied ever since. More big events follow—among them Sandy (2012), Matthew (2016) and a string of events in 2017 (Harvey, Irma, Maria) that compounded to a doubling of NFIP's debt. When long-term authorization for the program ran out in September 2017, coincidentally about a month after Harvey ran in to Houston, Congress cancelled half the debt, bringing NFIP back to its $20 billion average (GAO, 2020b). Among other things, this history shows that the really big reforms are triggered by big budget holes, not a serious grappling with the micro-level incentives and distortions created by the program and that $20 billion of NFIP-covered damage is roughly the scale of a reform triggering event. If so, events on that scale should become quite commonplace based on population and income effects alone—let alone climate change—as we suggested earlier.

The reforms that could matter are those that alter incentives and cause the misallocation of risk costs. These kinds of reforms, in turn, could affect the total cost of disaster assistance and the exposure of the US population and its built environment to weather- and climate-related hazards.

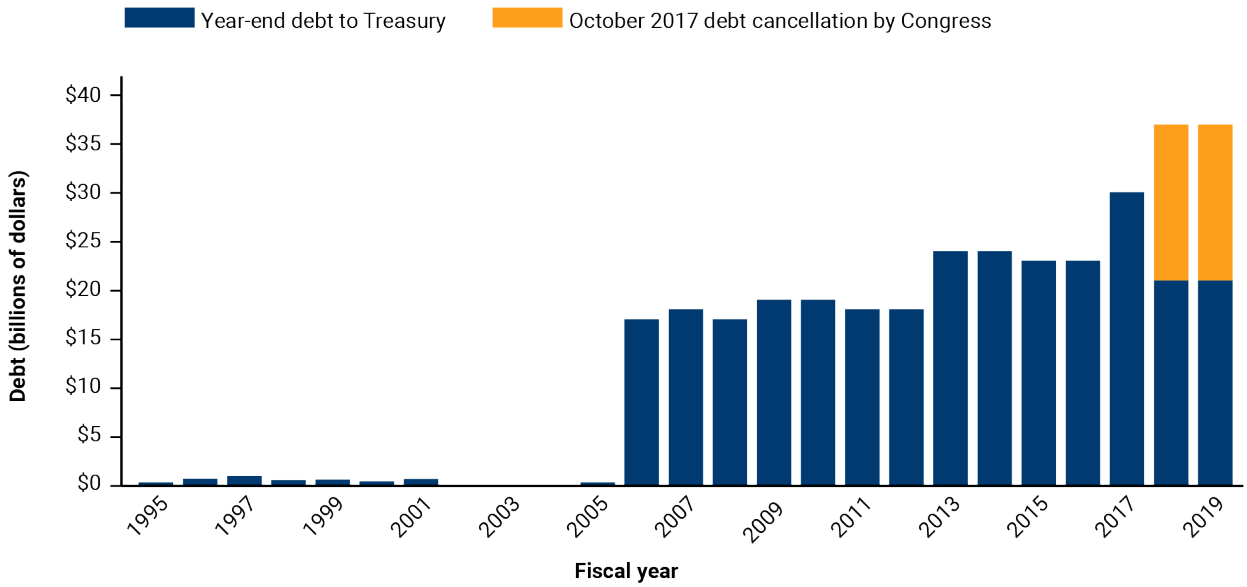
Recalling the conceptual framework in Table 1, our interest in examining reforms is to understand where and how those reforms have led to more emphasis on resilience across all three of the programmatic buckets that make up the identified recovery and resilience policy strategies- disaster response, insurance and infrastructure. We are also interested in where, if at all, reforms might alter the types of payouts that follow extreme events—so as to send a more credible signal for the future that any and all damages will not be compensated.

To reduce selection bias—that is, the tendency to talk about reforms that are most visible, which tends to mean those that get enacted by Congress and thus those that are pre-selected for their political feasibility—we sample a cluster of reforms that have been enacted and a cluster (necessarily less well specified) that have been proposed but not enacted. Table 5 shows those real and imagined reforms organized according to the framework used in this paper.

Perhaps more interestingly, Figure 9 shows them on a two-dimensional space with our assessments of the political feasibility of the reforms (horizontal axis) and impact on moral hazard (vertical axis). For completeness, we also include here the 2014 rollback of the Biggert-Waters reforms, which we discuss below.

What is useful to recognize about many of these reforms is that they have, in several important ways, tried to take real steps towards reducing the problem of moral hazard. Notable are the reform measures in the top left, those "low hanging fruit" that exhibit low levels of overall moral hazard impact and low levels of political difficulty. FEMA's Flood Mitigation Assistance program, which seeks to mitigate the presence of repetitive loss, and severe repetitive loss properties or SRL's (the worst offenders in the disastrous and costly cycle of flood, rebuild, flood again two years later) is an example of successful recognition of these entrenched moral hazards, and attempts to correct them.[53] While that program has been identified by a recent audit as ineffectively administered, and recent studies show that the number SRL's on FEMA's books are actually increasing, it at least exists (GAO, 2020c)(Office of Inspector General, 2020). Just this year as well, FEMA announced funding for the Building Resilient Infrastructure and Communities (BRIC) program,

FIGURE 8
NFIP annual year-end debt from 1995–2019



GAO, 2020b

which has been hailed as critical step forward in resilience efforts, as this program allows for the allocation of up to 6 percent of annual disaster funding to be set aside for resilience building (Federal Register, 2020b) [54]

Beyond individual programs, the most recent, and most instructive example of an attempt to tackle moral hazard comprehensively was the 2012 Biggert-Waters Flood Insurance Reform Act. This act (uncontroversial at the time) passed with bipartisan support and the goal of reforming NFIP to reflect actuarial risk through gradually increasing premiums and reducing subsidies for policy holders. Yet just two years later, in the wake of Hurricane Sandy, this effort was significantly hamstrung by the 2014 Homeowner Flood Insurance Affordability Act, which was passed after strong push-back against the resulting premium hikes from policy holders and the real estate industry (Wriggins, 2014). Sandy made highly visible the adverse consequences for individual homeowners of Biggert-Waters' reforms, and thus they were no longer politically sustainable. While many key parts of the original bill have stuck, including the gradual phase out of subsidies on SRL's and second homes, other subsidies, such as those for "grandfathered" properties (those homes that find themselves in a new risk designation after an updated flood map process) were reinstated, and many policy holders actually refunded.[55] Additionally, the original desire to improve flood mapping through best available science in order to reduce political influence in the mapping process was perhaps blunted by the 2014 Act's increased Congressional oversight and affordability consideration requirements. [56]

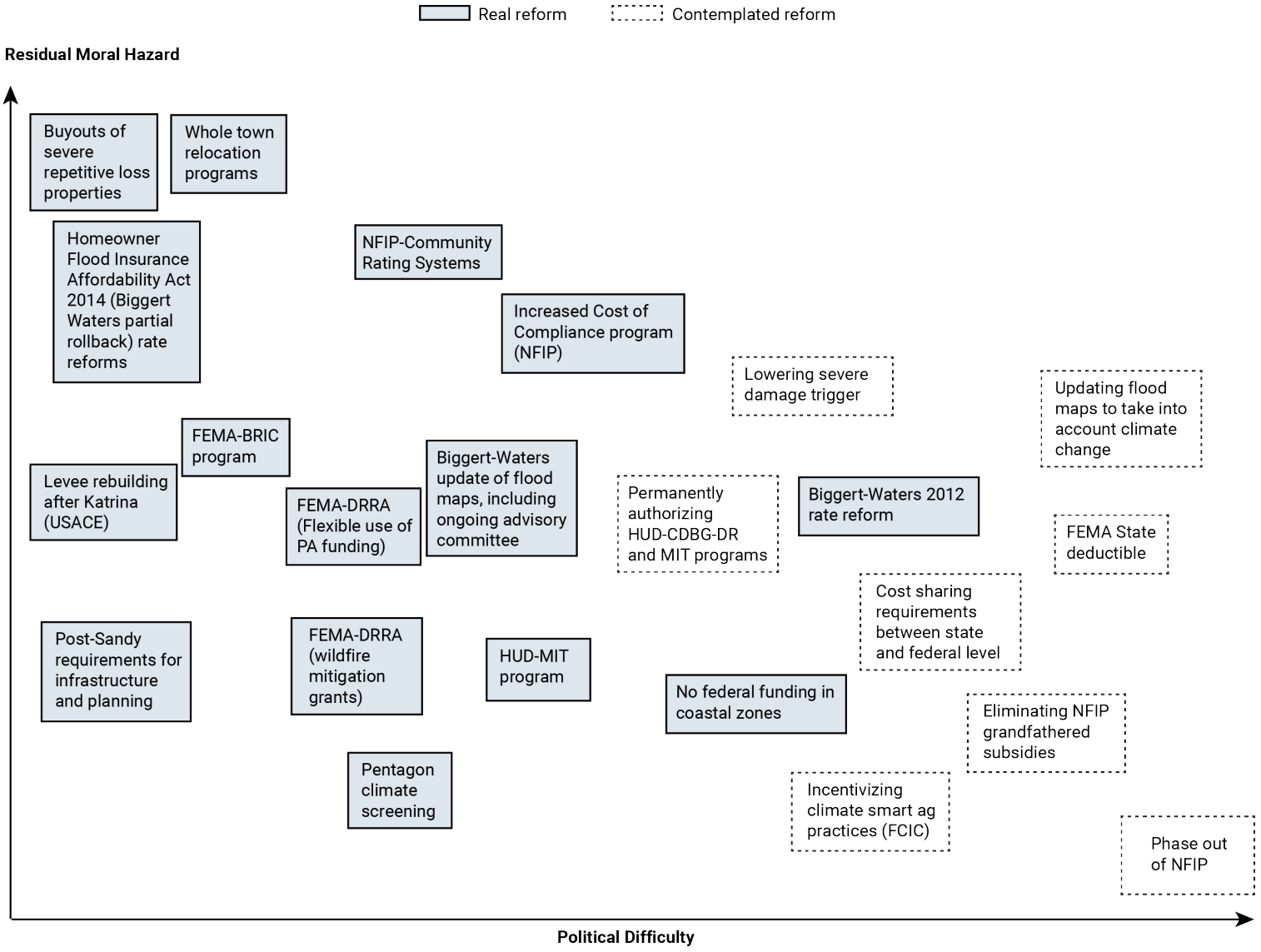
Why is there widespread awareness of the problems

TABLE 5
Real and contemplated policy responses intended to reduce moral hazard

Recovery	**Real**: Buy-outs of severe repetitive loss properties[31] **Real**: No federal funding in certain coastal zones[32] **Contemplated**: Phase out of subsidies for grandfathered properties and others[33]	**Real**: post-Sandy requirements for infrastructure hardening and planning[34] **Real**: Flexible use of FEMA Public Assistance funding for updated codes through the 2018 Disaster Recovery Reform Act (triggered in part by 2017 hurricane season).[35] **Real**: Army Corp levee rebuilding post Katrina[36] **Contemplated**: Permanently authorizing the Department of Housing and Urban Development's Community Development Block Grant funding[37]	**Real**: NFIP's increased cost of compliance program[38] **Contemplated**: lowering the severe damage trigger for bringing structures up to code[39] **Contemplated**: Updating flood maps to reflect climate change[40]
Resilience	**Real**: Enhancements in FEMA mitigation grants, e.g wildfire prevention through the 2018 Disaster Recovery Reform Act (triggered in part by the 2017 wildfire season)[41] **Contemplated**: cost sharing requirement shifts between state and federal level[42]	**Real**: whole town relocation programs[43] **Real**: Department of Housing and Urban Development-MIT grants[44] **Real**: FEMA's Building Resilient Infrastructure and Communities program.[45] **Real**: Pentagon climate screening[46] **Contemplated**: FEMA State level disaster deductible[47]	**Real**: Biggert-Waters premium reforms[48] **Real**: National Flood Insurance Program community rating system[49] **Real**: Biggert-Waters update of flood maps, including ongoing advisory committee[50] **Contemplated**: Phase out of NFIP[51] **Contemplated**: Incentivizing climate smart ag practices at the Federal Crop Insurance Program[52]

FIGURE 9

Real and contemplated policy responses, political difficulty of implementation, and residual potential moral hazard after implementation



Here we show each policy response placed along two axis: political difficulty and level of moral hazard. This is a conceptual map based on authors judgment and is not intended to reflect a rigorous quantitative analysis of cost or benefit. The degree of distance between each reform effort is not indicative of any specific distance increment. Given the temporal aspects of policy reform, we consider political difficulty as ex post for real reforms and ex ante for contemplated reform (i.e. the level of political difficulty required to pass). Likewise for potential moral hazard, we consider each policy by the degree to which it creates risk invitation, again using our own judgment regarding the effectiveness of the program, and overall scale of the program itself. As such, moral hazard is only conceptualized after a policy (real or contemplated) has been implemented. To illustrate, looking at the extremes, phasing out NFIP displays very high degrees of political difficulty, yet would completely eliminate invitation of unwarranted risk—it would leave homeowners exposed to the full costs of their choices. At the opposing end, FEMA's efforts at whole town relocation demonstrate low levels of political difficulty (if your town is underwater, it's easy drum up support for someone paying you to move) and high levels of risk invitation/low levels of risk reduction, given the very small scale the programs have operated on (<700 people to date). We set the reform environment at the median level of political difficulty, or in a normalized governance process.

with current federal disaster policies and yet persistent failure to reform? The central challenges for reform lie with tensions between three key facts. One, is that disaster assistance policy almost intrinsically shifts the costs of risky behavior at least partly away from the parties that should be in the best position to control that risk. A second tension is that those parties are citizens who, in the middle of disasters, are suffering enormous pain and it is both politically and morally impractical to impose yet more distress onto them. And a third is that when the market 'sees' these mechanisms operate, the markets on their own do not reveal accurate information about the costs of insurance and other financial instruments that could be used to both measure and manage these risks better.

What can we learn from history?

The past suggests at least five sets of political insights that can help guide a future program.

First, when reforms focus principally around tangible costs and abstract benefits, they are prone to fail. One of the strengths of Biggert-Waters was its bipartisan nature. But the practical effect of the legislation was to generate perceived harm for the roughly 20 percent of homeowners whose rates were subsidized—a harm that was not offset by any benefit that generated a powerful political force that would countervail those harmed. Bipartisanship was abstract; the impacts of rising rates, even as those rate increases were delayed, motivated political opposition.

Second, directionally correct reforms have been possible when Congress is focused on a larger tangible problem. After iconic disasters, more attention has been paid to enshrining resiliency requirements during recovery. For example, after Hurricane Sandy, HUD's $15.2 billion in Community Development Block Grant (CDBG) funds, which target under resourced urban communities (and was the largest single program appropriation), came with requirements for infrastructure hardening assessment in consideration of future sea level rise (Gurian, 2013).[57] This money, along with Congressional resiliency funding mandates for the public transportation and flood reduction projects of the Department of Transportation ($5.5 billion) and Army Corp ($5 billion, of which the largest amount went to risk reduction) made up over 1/3, but still less than ½ of the total $58 billion in federal disaster relief (Gurian, 2013). In addition, the huge disasters associated with Hurricane Katrina forced changes in federal policy, particularly with regard to preparedness planning, and the recent wildfires will have similar affects.

Third, even for people who follow these issues closely it is extremely difficult to take the pulse of the overall suite of programs oriented around weather- and climate-related disasters. The GAO is now focused regularly on these issues, but its evaluations tend to focus on key programs rather than the system as a whole. The National Academy of Sciences has never been asked to look at disaster assistance as a whole. In the past it has looked, at the request of Congress at some challenges in FEMA flood maps, and has looked recently at supply chains following major hurricanes (a topic that intersects with FEMA), the reliability of the electric grid (including after major storms), and at related topics on climate change impacts (National Research Council, 2009; National Academies of Sciences, Engineering, and Medicine, 2017). But, as with GAO, it has not been asked to look at the system as a whole. This lack of situational awareness may help explain, at least in part, where reforms tend to be piecemeal and focused on programs.

Fourth is the matter of social justice. While it has proved possible to adopt some reforms to disaster assistance when substantial new resources are being appropriated—for example, the special legislation in the aftermath of Sandy—a central challenge for any reform is that the public very strongly supports assistance to communities in need (MacInnis and Krosnick, 2020). Indeed, poorer communities and families are much less well insulated from economic shocks, less likely to have insurance, and more likely to live in vulnerable areas (Krauss and Reeves, 2017). This central role for disaster assistance as a matter of social policy—a role that is fitting and proper—needs

to be disentangled from the other functions that FEMA could perform such as resilience planning.[58] Comingling them means they often compete for the same budgetary resources—a political arrangement that almost guarantees failure, as revealed for example in the caps on allowable co-spending of FEMA funds on resilience.

The fifth political insight is that meaningful solutions require engaging with government as it is actually organized. Much of the current disaster related response at the federal level is organized in line with Presidential Policy Directive 8 (PPD8), an Obama era issuance that established a National Preparedness Goal and a resulting system architecture in support of that goal (Department of Homeland Security, n.d.). Since 2011, PPD8 and its mandated annual report has tracked the five mission areas that span this National Preparedness System, which include Prevention, Protection, Mitigation, Response and Recovery. These five mission areas provide the organizational framework for governmental response to risks such as chemical spills, terrorism, and natural disasters (Department of Homeland Security, 2019). The reforms discussed here need to be channeled through this existing framework. Assessing the balance of resources and current capabilities across these five mission areas, with the purpose of channeling more effort towards mitigation, prevention and protection is a good first step. There is a need as well to update PPD8 and put climate change squarely in conversation with the existing federal organizational architecture it established.

It is hard to summarize the full political history of disaster program creation and reform, but those five lessons from the past are helpful guides for what might be done in the future. And if the argument in the previous section is compelling, the opportunities for future reform will be growing as the number of large events—with total costs at $100 billion or above, and with NFIP-only costs of $20 billion or above—will rise, offering more opportunities for reform if used properly. It is possible that even smaller events could have precipitating effects—for example, an event with insured Florida losses of $50 billion or less might trigger a cascading set of failures that would require federal and state action that could open the door for larger reforms.

Toward a plan that could work

Given the long history of failed and marginal attempts at policy reform, some realism is needed about just what can be achieved and exactly how it can be achieved. Rather than sketch out a detailed plan for policy reform only to see that plan founder when it makes contact with political reality, we instead outline three major clusters of activities that can help prepare the ground for reform—activities that can help open the door to successful reform efforts and, more importantly, ensure that when a political shock, such as an extreme storm, does occur that the elements of good reform are present and ready for adoption.

First, it is vitally important to improve situational awareness. We have benefitted in this paper from the ability to draw data and analysis from numerous federal institutions—notably GAO, CBO and FEMA. Each, in different ways, has documented the scale and allocation of federal spending and programs that affect moral hazard. Congress should encourage continuation of these efforts, with specific funding and requests where needed. In particular, it would be helpful for such accounting efforts to identify expenses according to purpose—building on and refining the framework we offer here so that the nation can obtain much more systematic information about the balance of investment between recovery and resilience and also comparisons between costs and social returns for investments in each category. Such a program would notably build on the capabilities already developed at the GAO, which is looking, regularly, at some of the biggest programs that create moral hazard (e.g., NFIP and other FEMA programs). Within the executive branch this would build on the budgeting tool that FEMA maintains through the Recovery Support Function Leadership Group (RSFLG) but would organize that information not just programmatically but also according to function—resilience versus recovery response. FEMA has already sponsored important studies

that evaluate, periodically, the efficacy of different resilience programs; these need more regular and systematic evaluation because, at present, it isn't known which kinds of resilience efforts will perform best and experiments to learn quickly are needed.

An additional element of situational awareness is much better understanding of how federal policies might be affecting the nation's actual exposure to climate impacts. The place where this could be done is the National Climate Assessment (NCA) —an activity that occurs every four years, managed by the federal government, to evaluate the nation's exposures to climate change. At present the NCA, on matters of disasters, focuses heavily on the disasters themselves and not on how the nation's exposure to and impacts from disasters are, themselves, a function of federal policy. The next NCA should do that explicitly and should opine on how disaster assistance affects the nations resiliency to the impact of climate change; within the limits of the NCA's authority, the Assessment should also explore how revisions to disasters assistance might improve how the nation readies itself for climate change.[59] In many areas of climate policy there has been close attention to "win-win" policies that are likely to be politically more durable; improved disaster strategies could be one such area. A partial model for this closer look at disaster policy may be efforts at some of the states—ranging from California to North Carolina—that are showing how science about climate impacts can be combined with more situational awareness of which policy levers—including policy levers that implicate moral hazard (North Carolina Department of Environment Quality, 2020). In California, for example, the state's exposure to wildfires is not merely a matter of climate change but also the ways that state land use, insurance and planning policies have amplified some fire dangers (Syphard et al, 2019).

Second, the federal government would benefit from the capacity to approach climate-related disasters in a more strategic "whole of government" approach. In this regard, there is already encouraging news with a greater government emphasis on preparedness for disasters. Much of that framework has been developed and advanced with respect to terrorism, but FEMA has led a whole-of-government effort to improve preparedness to natural (including climate-related) disasters that is encouraging (FEMA, 2019). Making this approach effective will require the capacity to commission needed supplies of information and assessment. For example, in our earlier research looking at how climate change might affect municipalities we found that the nation would benefit from more extensive infrastructure audits to allow a more systematic assessment of how climate-related disasters may affect national infrastructure. Such information could help allocate effort within a whole-of-government approach to climate change impacts.

Much of climate science is a centralized activity oriented around scientific elites. More attention to climate impacts and preparedness will require more systematic engagement with local practitioners who are on the front lines—a point that is true for government-wide efforts to address climate-related disasters as well as impact assessment activities such as the NCA. To this end, federal assessors and responders to climate-related disasters would benefit from more focus on local practitioners as partners—such as floodplain managers, local water managers, land managers, and local officials responsible for infrastructure.

Third, while the exact moment of opening for reform is hard to predict, the contours of a federal reform strategy can be shaped already—in part with the five lessons from prior reform efforts, discussed above, in mind.

Federal disaster policy, while special in its own ways, is hardly unique in the history of policy reform challenges where the politics are mis-aligned with needs—where there are large collective gains from a better policy but many narrow interests that prevent reform. One area where this problem has been addressed somewhat successfully is the closure of excess military bases—for example, at the end of the cold war. A Base Realignment and Closure (BRAC) process helped the government plan five rounds of base closures that totaled about 350 installations and save, now, $12 billion annually (Historical Office of National Defense, n.d)

(Congressional Research Service, 2019b). If left to normal congressional processes no bases would have been closed, for no member of Congress wants their own base gone even as they knew that the total number of bases was financially unsustainable. The solution was deference to BRAC to form balanced packages of base closures that could be voted on up or down as a whole.

A similar commission could be created to frame options for disaster policy reform. Timing for this commission might coincide with the end of the next NCA, which will help frame the scale of the challenge. By then, further work by GAO and others can provide additional situational awareness about the scale of federal spending, its purposes, and some roadmaps for areas of reform that are easier and harder. A commission yielding a reform plan might not have immediate success, but it would allow considered and politically vetted ideas to sit ready for the next Sandy or other event that reveals greater political willingness to act.

Over the long term, the goal of this approach is not just reform of US federal policy. It is also to signal the market—to investors, municipalities, the credit rating agencies and others that the assumption that all disaster costs will be compensated is no longer robust. And once the market has that signal it will respond quickly with its own powerful incentives—in the form of insurance prices, bond ratings and prices, and flow of capital—that will encourage safer behavior.

CONCLUSION

A wide array of federal government policies has resulted in unintended consequences—incentives that can create moral hazard—that have raised the exposure of the U.S. to weather-related disaster. We have suggested that there is already a huge difference in disaster policy weighted toward rebuilding rather than building resilience to disasters. This difference, already, creates severe distortions in the society. As the effects of climate change become more apparent those distortions could grow substantially, along with the cost of responding to climate-related disasters. On the cusp of huge changes in climate the nation should be investing in resilience and adaptiveness; policies that may create moral hazard provide the opposite incentive.

One contribution of this paper is a theoretical framework for thinking about how different types of policies create moral hazard, along with a first application of that framework to the federal budget. While we have tried to emphasize the “knowns” in this paper, what is perhaps most striking are the profound unknowns. As a matter of accounting, it is hard to assign different programs to the correct categories. Even harder is learning how the incentives from these programs affect behavior and thus risk. The policy reforms we have offered begin, first and foremost, with a more regularized program to map the adverse impacts of federal disaster policies and to understand how that mapping may shift and magnify with climate change.

Politically, the prospects for reform of these programs are, during normal times, bleak. That suggests a strategy for reform that is grounded in political realism. It should be a strategy that takes advantage of political windows of opportunity, which open periodically. And it should focus more on policy reforms that are directionally correct and build upon each other. And it must be a strategy that raises awareness in key interest groups—insurance companies, infrastructure companies, homeowners, and organizations that focus on fiscal probity—by documenting the level of spending, the rise in exposure, and the potential imbalance that leads the nation to under-invest in resilience despite huge social returns from such investments. Such a strategy, while long overdue, must not wait longer.

ENDNOTES

[1] For the auspicious nature of Paris see (Victor, 2015). For more on why 2 degrees is an impractical goal see (Peters, 2017).

[2] Miami-Dade County has invested in a comprehensive and ongoing seal-level rise resilience and adaptation process. For more see (Miami Dade, n.d.). For the California Coastal Commission's 2018 sea-level rise policy guidance document see (California Coastal Commission, 2018). Of course, the success of investments in resilience are dependent on local context – for instance, investments in sea walls in places like Miami may not ultimately protect due to the specifics of sea-floor geography.

[3] This is a reporting requirement under the UNFCCC and was signed into law by Congress in the Global Change Research Act of 1990 (USGCRP, n.d.)

[4] For example, see notably (Kousky et al, 2020; Kunreuther, 2018: Kunreuther et al, 2013).

[5] Research has looked behaviorally at individual decision making (one reason NFIP policies are mandated is because people tend to not voluntarily buy them) and found that external factors such as consumption of FEMA flood maps, past storms and perceived risks play a significant role in the decision to purchase flood insurance (Shao et el, 2017).

[6] One important paper found that receiving non-insurance federal disaster assistance such as FEMA grants led to lower amounts of flood insurance purchased, though there was no reported impact on insurance take up rates (Kousky et al, 2018).

[7] For example see (Burby, 2006; Nickerson and Husted, 2014). We note that (Burby, 2006) distances himself from the term moral hazard and refers to the risk invitation issue as the "safe development paradox" whereby the federal government, in seeking to make hazardous areas safe, actually make them more dangerous.

[8] Two recent empirical studies show that the presence of federal disaster programs increases risk exposure. The first study, currently published as a seminar paper, focuses on NFIP and suggests that flood insurance availability increases population in flood-prone counties by 5 percent for every one standard deviation in flood risk (Peralta and Scott, 2019). The second paper looks closely at federal wildland fighting expenditures and residential development, and finds, among other more granular metrics, that the majority of wildland fighting funds goes towards protecting private homes, sometimes incurring net present values greater than 10% of the actual transaction value of the home itself (Baylis and Boomhower, 2019)

[9] Through it's high-risk list, which is produced every two years, the GAO regularly assess the fiscal threat of climate change to the federal government from disaster aid and poorly designed federal insurance programs, among others.

[10] We note that in addition to federal funding patterns that can increase risk, there are numerous implementation challenges in federal disaster mitigation assistance related to state level cost share that are outside the scope of this paper. These challenges can result in mitigation dollars remaining unspent even when allocated, creating additional barriers to communities in need and further complicating the tracking of disaster spending on a granular level. For more see (Frank, 2021)

[11] This is a general estimate that encompasses both individual program cost shares and overall disaster cost shares. We note that each individual disaster declaration and grant program can have distinct and waivable cost share requirements that change over time. For instance, the CBO reports that overall government spending on hurricanes can range from 9 – 80%, while FEMA's public assistance program federal assistance share is "not less than 75 percent of the eligible cost" (CBO, 2016; FEMA, n.df)

[12] While the term of art used in many of these programs is mitigation, we define the second policy investment strategy as resilience in order to draw a semantic distinction with emissions mitigation, and also to capture the important need to build with a sustainable future in mind, not just prevent future damages.

[13] We note that there are other important federal policy programs that can create moral hazard beyond disaster assistance. This includes, for instance, government sponsored mortgage agencies that do not require earthquake insurance when taking on a mortgage.

[14] Federal appropriations are the primary method through which Congress announces disaster funding, and in many ways are essentially political statements, while obligations are the less glamorous legally binding spending commitments. The distinction between obligations and appropriations can change the overall picture depending how each is assessed. For instance, in the appendix we report this same data by obligation, where the difference between the USACE's 20 billion dollar appropriation and only 3 billion dollars in obligation causes its overall percentage to shrink to 5 percent from 13 percent. HUD follows a similar pattern, while in contrast, the SBA's share of overall funding expands to 13 percent from 1 percent when viewed by obligations.

[15] FEMA's Public Assistance program is the largest single disaster relief program in the entire federal budget when measured by obligations, where it makes up ¼ of committed federal obligations since 2017.

[16] For more on these grants see: (Barnosky, 2015).

[17] In appropriations, unless otherwise noted. For more on appropriations versus obligations, see footnote 3. In the appendix, we provide a data key for understanding when different units were used.

[18] The years covered by this analysis were all big disaster years, including the 2017 flood and 2018 wildfire season. Thus, these numbers may be upwardly biased when viewed over longer historical time horizons. However, the fact that recent history displays such historically expensive costs is already indicative of the trends and future climate impacts that are the focus of this paper.

[19] Many of these programs, such as FEMA's PA program, HUD's Community Development Block Grants (CDBG) the USACE, and the SBA, have discretionary ability to fund mitigation and resilience projects on a smaller scale in addition to their core mandates that focus on recovery. For example, FEMA's PA program was reported to fund up to 2 billion dollars in mitigation related projects after Superstorm Sandy (Pew, 2018). However these projects are not tracked comprehensively or systematically, making it difficult for analysts to track spending fluctuations inside existing programs. As such, we categorize them analytically according to their primary function as determined by name and public information on prima facia purpose, which we assess through program title and description.

[20] Recent reporting has also examined the growing visibility of the threat that climate-related disasters pose to home mortgages (Flavelle, 2020).

[21] A fuller analysis would need to accommodate the reality that after extreme events, often there is outmigration from people seeking to avoid a repeat. For more see (Boustan et al, 2017)

[22] Other findings include vulnerable flood areas swelling by 45 percent in riverine floodplains and 55 percent in coastal floodplains, particularly increasing vulnerability for the Atlantic and Gulf Coasts. In turn, the AECOM report finds that NFIP policies could grow by 80-130 percent depending on shoreline management, and rates would need to adjust between 40-70 percent to accommodate the increasing vulnerability.

[23] Calculations are authors own using historical data from (Citizens Property Insurance Corporation, 2020).

[24] We note that there is a large body of literature on estimating the costs of disasters and thank Adele Morris for her comments. For more see (Bakkensen et al, 2017; Kousky et al, 2019; Eckhardt, 2019)

[25] For more on CPI detrending see (Smith, 2019).

[26] This estimate is based on data reported in (Nicholson et al, 2018)

[27] The CIL coastal damages are calculated from the interaction of wind and storm surge modeling with sea level rise, mapped onto a property database maintained by Risk Management Solutions. The CIL coastal damages are reported in logbase10 percent of median 2012 county level per-capita income. Our analysis relies on transformation of this data from log to aggregate county level income from reported 2012 population. As such, this analysis is intended to be used as an illustration and not as a rigorous modeling exercise.

[28] Going further back in time this data could also extend to the 2005 hurricane season (Rita, Wilma and Katrina), which would plausibly create new outliers in terms of FEMA expenditure, though not change the geographical distribution.

[29] Among the many examples of this, states have the ability to report their public housing infrastructure as "self-insured" against flood risks.

[30] Historical events restated to 2017 values from (AIR, 2017).

[31] See GAO, 2020b

[32] See Coastal Barriers Resources Act, n.d.

[33] See CBO, 2017

[34] See Gurian, 2013

[35] See FEMA, n.de

[36] See Army Corp of Engineers New Orleans District website, n.d.

[37] See H.R. 3702

[38] See FEMA, n.dd

[39] See Adler and Scata, 2017

[40] U.S. House of Representative Committee on Science, Space, and Technology, 2020

[41] See FEMA, n.dc

[42] See Conrad and Thomas, 2013

[43] See GAO, 2020c

[44] See HUD, n.d.

[45] See Frank, 2020

[46] See Office of the Under Secretary of Defense for Acquisition and Sustainment, 2019

[47] See Scata, 2017

[48] See FEMA, 2013

[49] See U.S. Climate Resilience Toolkit, n.d

[50] See Federal Register, 2020a

[51] See Office of the Under Secretary of Defense for Acquisition and Sustainment, 2019

[52] See NRDC, n.d.

[53] These properties also engender a disproportionate share of costs, accounting for 1 percent of total policies and around 1/3 of claims. See (Pew, 2016).

[54] Other examples of positive reform efforts, small scale though they may be, can be found in the 2019 National Preparedness Report, which we include in the references.

[55] The 2013 AECOM study on climate change and NFIP found that these grandfathered properties would contribute the largest source of exposure by 2100.

[56] The battle over NFIP rates is very much alive today. As of this writing, FEMA's long awaited Risk Rating 2.0, which would update the methodology used for calculating NFIP premiums, has already been delayed and is expected to be an ongoing source of contention.

[57] Beyond designating funds or setting in place requirements, actual enforcement and implementation of mitigation efforts is often very hard to ascertain. For instance, federally sponsored rebuilding projects often takes years to complete, and there is no systematic way to track whether or not mitigation requirements were reflected in actual project implementation. Instead efforts often rely on audits or one-off project assessment, for example see (Office of Inspector General, 2020).

[58] For more see (Vajjhala, 2017)

[59] This idea would build on the concept of a 'sustained climate assessment' discussed in (Moss et al, 2019).

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