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Issue Analysis

# Hurricane Damage and Global Warming

## How Bad Could It Get and What Can We Do about It Today?

*By Daniel Sutter*

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### Executive Summary

Climate experts and policy makers have debated the existence of a potential link between global warming and increased hurricane activity since the record-setting 2005 Atlantic hurricane season. While claims that hurricanes are already stronger due to climate change are highly controversial, research demonstrates that increases in societal vulnerability to hurricanes—the number of persons and amount of property in coastal areas—goes a long way toward explaining the increases in hurricane losses over time.

This paper focuses on hurricane damage projections, reviews them in detail, and critiques the projections. It details how existing public policies have helped increase hurricane losses. In its final section, the paper recommends specific policies to reduce populations' vulnerability to hurricanes.

Existing public policies—including insurance regulation, government-subsidized flood insurance, improper mitigation, and faulty building code enforcement—contribute to unnecessarily risky and inefficient development along coastal areas by shifting the cost of hurricane damage ultimately onto third parties—mainly taxpayers. Poor policies lead to excessive vulnerability to hurricanes and would exacerbate the cost of any increase in storm activity, whether due to climate change or any other factor. Insurance subsidies and mitigation may not be normally considered part of the climate change debate, but within that debate reform of these policies now will constitute a "no regrets" strategy. In other words, reforms will yield benefits in all circumstances—especially if adverse climate change does occur.

## Introduction

The United States endured a record Atlantic hurricane season in 2005, with 27 named storms, including Hurricane Katrina, which killed over 1,000 people and was the costliest natural disaster in U.S. history. Since then, the debate on the effects of climate change on hurricanes has intensified.

*The future is not nearly as stormy as NRDC projects.*

The United Nations Intergovernmental Panel on Climate Change (IPCC) describes the intensification of hurricanes due to greenhouse gas emissions as "likely."[1] In an oft-cited study, the Natural Resources Defense Council (NRDC), one of the biggest U.S. environmental groups, warns that the cost of more intense hurricanes could be staggering—it projects that climate change will *increase* the annual cost of hurricanes by $422 billion and lead to an extra 756 deaths each year by 2010. Consequently, NRDC recommends that the U.S. drastically reduce its carbon emissions, by 80 percent by 2050.[2] However, the future is not nearly as stormy as NRDC projects, even if climate change were to lead to more intense hurricanes.

This paper focuses on hurricane damage projections, reviews them in detail, and critiques the projections. It details how existing public policies have helped increase hurricane losses. In its final section, the paper recommends specific policies to reduce populations' vulnerability to hurricanes.

The increased hurricane damages stem from three factors:

- A very short and unrepresentative period for base damage;
- Questionable extrapolations of the impact of stronger winds on damage; and
- An extreme sea level rise scenario with no adjustment of coastal development to accommodate rising seas.

All three of these components are questionable. A more realistic projection is that more intense hurricanes would at the extreme double current damages, which would be less than one quarter of the increase NRDC projects.

An alternative policy path is available for addressing any potential global warming-related increase in hurricane intensity. Research to date, discussed in later sections, demonstrates how increases in societal vulnerability leads to the escalation of hurricane losses over time. Societal vulnerability refers to the number of persons and amount of property in coastal areas vulnerable to hurricanes. Some of the increase in coastal development is worthwhile. Coastal development is necessary to sustain the

*Current public policies encourage risky and inefficient coastal development by shifting the cost of hurricane damage to third parties.*

ports that are essential to world trade. In addition, Americans enjoy living and vacationing at the beach, and economic prosperity allows us to bear property losses which a generation or two ago would have been devastating.

However, current public policies encourage risky and inefficient coastal development by shifting the cost of hurricane damage to third parties. State property insurance regulations and state-run residual markets (or "wind pools"), the National Flood Insurance Program (NFIP), disincentives for mitigation, and poor enforcement of building codes all increase hurricane losses. These government policies shift the cost of otherwise private decisions to live along the coast to other insurance policy holders and taxpayers, and reduce the quality of the built environment. The combination of these policies could easily account for half of current hurricane damages, and their combined cost will rise if hurricanes become stronger.

The final section argues that while insurance reform and building code enforcement are not normally considered as polices to address potential adverse effects from global warming, they should be. Policy reforms eliminating insurance subsidies and improving incentives for mitigation represent a very prudent investment to counter global warming. These policy reforms are sure to yield gains to society, as hurricanes will continue to occur regardless of whether climate change occurs. And if hurricanes happen to become more intense in the future, the benefits of these reforms will automatically increase manifold.

### Hurricane Losses and Global Warming

In its oft-cited study (*The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked*), NRDC estimates that damages from hurricanes will increase by $422 billion by 2100 relative to expected damage without climate change. The NRDC study assumes, consistent with IPCC projections, that hurricanes will become more intense but not more frequent if the climate warms.[3] The increase in hurricane damage due to global warming is a function of four factors:

- The baseline level of annual damage prior to global warming;
- A development factor for growth in population and GDP per capita;
- A storm intensity factor based on the atmospheric concentration of greenhouse gases; and
- A sea level rise factor, since an increase in sea level will worsen the impact of storm surge.

The NRDC study uses expected, normalized damage estimates based on damages from land-falling hurricanes between 1990 and 2006 of $12.4 billion (in 2006 dollars). The application of a development factor for the growth of population and GDP per capita is reasonable, since analysis has found that hurricane damages increase roughly proportionally with increases in population and wealth.[4] However, NRDC does not state the exact projections for population and GDP growth employed. This analysis will focus on projected damage as a percentage of GDP, because damage increases with population and per capita GDP.

NRDC projects the $422-billion increase in damage to be 0.41 percent of U.S. GDP in 2100. America's GDP was $13.18 trillion in 2006, so 0.41 percent of current GDP would amount to $54 billion in hurricane damage in today's economy. Thus, NRDC's projected *increase* in damage due to climate change is more than four times the current annual baseline damage of $12.4 billion. For perspective on what $54 billion in annual hurricane damage would constitute, consider that Katrina, the costliest hurricane in U.S. history, and Wilma, the third costliest, produced $81 billion and $20 billion in damage in 2005, respectively. Therefore, the NRDC study assumes that by 2100, global warming will result in damage slightly greater than Katrina and Wilma combined every two years, *on top of* the damage each year due to natural forces.

*The NRDC study assumes that by 2100, global warming will result in damage slightly greater than Katrina and Wilma combined every two years, on top of the damage each year due to natural forces.*

The NRDC study's sea level rise and increased storm intensity factors result in this quadrupling of damage due to climate change. It projects a doubling of atmospheric carbon to increase the wind speed of hurricanes by 9 percent by 2100. This means that a hurricane that would have made landfall with 100 mph winds in 2000 would make landfall with winds of 109 mph in 2100.[5] This might seem like a modest effect at first glance, but economist William Nordhaus has calculated the damage caused by a hurricane to increase with the eighth power of wind speed at landfall.[6] Thus, a hurricane that makes landfall with 150 mph winds would do 256 times ($2^8$) the damage as a minimal hurricane with 75 mph winds. This estimate is based on historical data from hurricanes in the U.S., not potentially stronger future hurricanes. Based on this, the NRDC report uses a storm intensity adjustment equal to the ratio of atmospheric carbon in 2000 to 2100, so the projected doubling of greenhouse gases would double hurricane damage.

The final adjustment is for sea level rise. The study follows Nordhaus and assumes that a one-meter rise in sea level would double hurricane damage, in addition to the intensity effect. The business-as-usual scenario of the NRDC study uses a projected sea level rise of 45.3 inches by 2100, and this increases damage by a factor of 2.2.

*The Pielke et al. analysis suggests that changes in hurricane damage over time are largely due to changes in societal vulnerability.*

### A Closer Look at the Alleged Increase in Damage

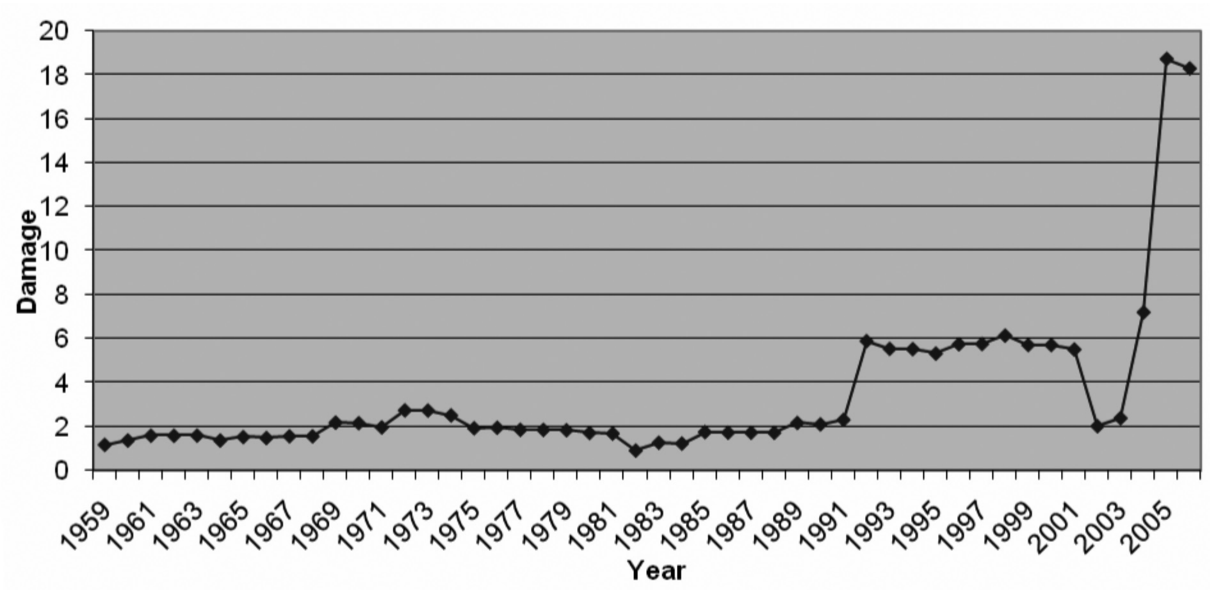
How plausible are the NRDC study's damage projections? We can evaluate the projections by comparison with academic analyses of hurricane damages. Roger Pielke Jr., of the University of Colorado, and colleagues examined damages during the period 1900-2005, normalized for inflation, population growth, and wealth, on the grounds that hurricanes will naturally cause more damage if more people and property move into their path.[7] In essence, the Pielke normalizations estimate the damage we might expect if any 20$^{th}$ century hurricanes were to make landfall today. Importantly, they find no trend in normalized damage; we would expect a positive time trend if hurricanes were indeed becoming stronger or more destructive. The Pielke et al. analysis suggests that changes in hurricane damage over time are largely due to changes in societal vulnerability. Meanwhile, Nordhaus estimates hurricane damage to increase by $8 billion annually—from $7 billion annually to $15 billion—in 2006 dollars, much lower than the $54-billion increase estimated in the NRDC study.[8]

Three components of the NRDC's damage projections are questionable: the base period damages, storm intensity factor, and sea level rise factor. The NRDC study uses the years 1990 to 2006 as a base period, a short and unrepresentative time period. This choice of this base period increases future damage projections, since 1990-2006 had a high level of hurricane activity and included the powerful hurricanes Andrew and Katrina, which struck highly populated and vulnerable areas of the U.S. coastline.

#### *Base Period and Storm Intensity*

Figure 1 presents a moving average of inflation-adjusted hurricane damage per year since 1950 to illustrate the unrepresentative damage from the period 1990 to 2006. Between 1990 and 2005, inflation-adjusted property damage from hurricanes averaged $13.9 billion per year (in 2005 dollars). By contrast, over the period 1970-2005, which still includes Andrew and Katrina, property damage averaged $7.25 billion per year, about half the level of the shorter, latter period. The NRDC storm intensity and sea level rise factors multiply the base period damage, so a higher base loss leads to higher climate change-induced losses. To see the effect of base period

**Figure 1. Hurricane Damage over Time**




Damage is a ten year moving average of inflation adjusted annual damage from hurricanes. Source: Author's calculations based on data reported in Pielke et al., "Normalized Hurricane Damage in the United States: 1900-2005."

selection, if the 1970-2005 average damage of $7.25 billion is used in place of the NRDC base damage, the increase in damage due to global warming is $262 billion by 2100, not $422 billion—or, in 2006 dollars, $34 billion rather than $54 billion. Therefore, the base period choice accounts for 40 percent of the projected increase in damage.

The NRDC storm intensity factor is based on William Nordhaus's eighth-power relationship between wind speed and damage. Nordhaus's result is somewhat misleading, at least for very powerful hurricanes. Damage escalates with wind speed or Saffir-Simpson scale category (the familiar hurricane strength scale that ranges from Category 1 to Category 5) because of two distinct factors: stronger winds and larger storms. Stronger winds result in greater damage to buildings already damaged by hurricane-force winds, while larger storms result in more property being exposed to hurricane winds. Damage to any property within the hurricane wind field has an upper limit, namely total destruction of the building. Atmospheric scientists believe that a maximum size for hurricanes exists, which Nordhaus acknowledges. Thus, the eighth-power rule may not apply as the winds of large, powerful hurricanes intensify. For instance, Katrina could not have done any more damage along the Mississippi shoreline even if it came ashore with 160 mph winds, because the destruction of the beachfront was total.

*Sea levels today are much higher than they were thousands of years ago, and this has not affected hurricane losses.*

The relationship between wind speed and damage is affected because hurricanes Andrew and Katrina struck highly populated areas. Andrew was the only hurricane since 1970 to make landfall in the U.S. as a Category 5 storm, and it struck the Miami metropolitan area, resulting in much greater damage than if it had struck, say, Kenedy County, Texas (population 414).[9] Katrina inflates damage for Category 3 hurricanes by deluging the only city on the Gulf and Atlantic coasts located below sea level and especially vulnerable to flooding due to levee failure in a hurricane storm surge. To illustrate the unrepresentative nature of the areas struck by these two hurricanes, consider that six coastal counties in states from Texas to North Carolina—the states most at risk for major hurricanes—had population densities greater than 1,000 persons per square mile in 2000. Three of these six counties—Dade County in Florida and Orleans and Jefferson parishes in Louisiana—were struck by Andrew and Katrina, respectively. The nation was unlucky in that both Miami and New Orleans suffered major hurricane strikes over this period. By contrast, 36 of 81 coastal counties had population densities of less than 100 persons per square mile. Hurricane losses during 1990-2006 were above the more likely long-run level with a more normal distribution of landfall locations. Damages for Category 3, 4, and 5 hurricanes were unusually high during 1990-2006.

***Sea Level Rise***

The NRDC sea level rise factor is also questionable for two reasons. First, a sufficiently slow sea level rise may have little or no impact on hurricane losses, since coastal development will shift as the coast line shifts. Sea levels today are much higher than they were thousands of years ago, and this has not affected hurricane losses. Over the course of a century, coastal communities could adjust, as most of today's building stock is gradually replaced.[10] In 2100, communities could be at the same location relative to the coast as today.[11]

Second, much of the sea level rise adjustment is derived from the magnitude of rise of 45.3 inches assumed by NRDC. The upper bound of sea level in the 2007 IPCC report's A-2 scenario is 18 inches (0.51 meters) by 2100, which, based on the functional relationship assumed by the NRDC report, would increase damage by 42 percent.[12]

An alternative estimate of the impact of possible intensification of hurricanes on damage can be generated by constructing a new distribution of landfalling storms expected per year with NRDC's own estimate of a 9-percent increase in wind speed.[13] When calculated in this manner, global

## Hurricane Intensification and Fatalities

This report focuses on the hurricane damage projections offered by the NRDC report. But the study also predicts that climate change will lead to 756 additional deaths each year in hurricanes by 2100. NRDC's projections regarding fatalities are on even weaker ground than its economic damage projections.

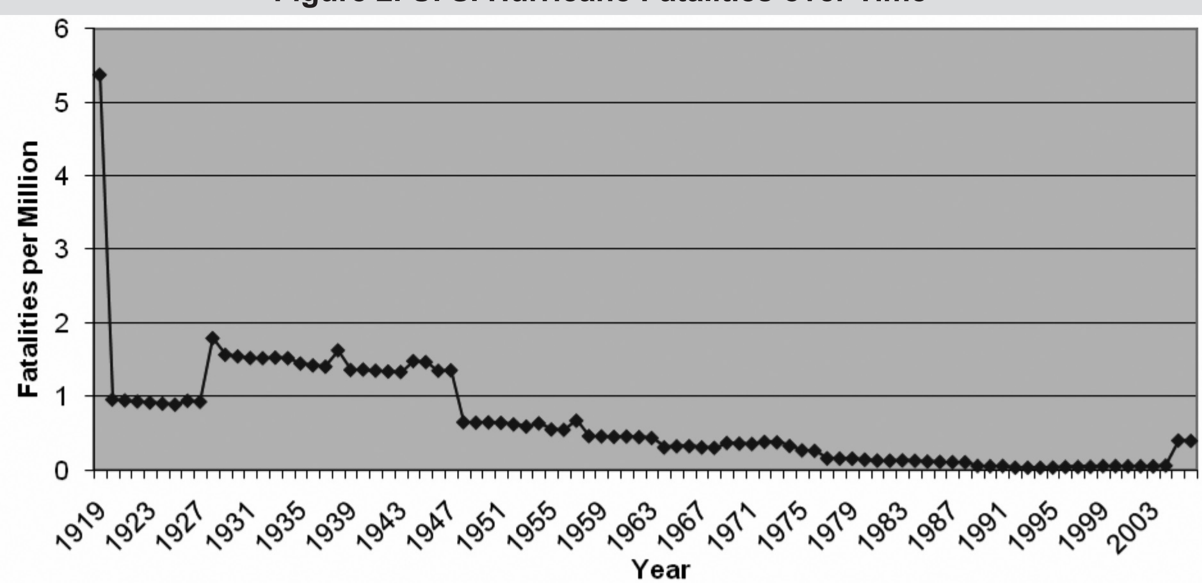
The NRDC study estimates that an *additional* 756 average deaths due to hurricanes per year will occur by 2100 because of global warming. That is about half of the number of lives lost in Hurricane Katrina. NRDC arrived at this estimate by applying the development, storm intensity, and sea level rise adjustment factors to the number of deaths.

The NRDC study applies William Nordhaus's storm intensity and sea level rise adjustments for hurricane damages to deaths. Applying these factors without demonstrating their applicability to fatalities is inappropriate. Hurricane fatalities had been falling for decades prior to Katrina, despite escalating damages. Figure 2 reports a 20-year moving average of U.S. hurricane fatalities per million residents, and illustrates the long-run decline, at least up to Katrina. Researchers understand that different processes drive hurricane fatalities and damages.[24] International research has found strong support for an inverse relationship between income and national disaster fatalities.[25] Satellites, radar, and hurricane hunter aircraft now detect tropical cyclones at sea, and improved forecasts allow evacuation prior to landfall. Indeed, the majority of hurricane fatalities occur in freshwater flooding, often inland, which demonstrates the life-saving effects of hurricane warnings and response. A repeat of the destruction of Galveston, Texas, in 1900, by a hurricane that struck without warning, seems inconceivable today.

Powerful hurricanes are not necessarily deadly. Since 1990, the U.S. was struck by one Category 4 (Charley 2004) and one Category 5 hurricane (Andrew in 1992). Charley resulted in 10 deaths and Andrew 23, with eight of these deaths during Andrew's second landfall in southern Louisiana.[26] Andrew and Charley demonstrate by example that an increase in the number of Category 4 and 5 hurricanes will not necessarily lead to significantly higher death tolls, even if the storms strike highly populated portions of the coast.

Hurricane Katrina now distorts any statistical analysis of U.S. hurricane fatality trends. Katrina represented a unique vulnerability—a city below sea level subject to rapid inundation if its levees failed. To put the NRDC projection of 756 extra hurricane deaths in perspective, the U.S. suffered 754 hurricane fatalities between 1968 and 2004. Even post-Katrina, Figure 2 shows that the U.S. hurricane fatality rate is lower now than in the 1950s. The last hurricane to result in 100 or more deaths was Agnes in 1972; prior to Agnes, 15 different hurricanes had killed 100 or more people in the U.S. in the 20th century, with never more than 12 years between such hurricanes. Katrina was a tragic statistical outlier event, obscuring a decades-long downward trend in U.S. hurricane fatalities. The decline in fatalities occurred despite an increasing coastal populations and property, factors which *The Cost of Climate Change* assumes *increase* fatalities. Since our ability to forecast hurricanes is likely to improve, there is no reason to expect any substantial increase in hurricane fatalities in the future, even if hurricanes become more intense.

**Figure 2. U. S. Hurricane Fatalities over Time**




Fatalities per million is a 20 year moving average of annual hurricane fatalities. Source: Author's calculations based on data reported in Pielke et al., "Normalized Hurricane Damage in the United States: 1900-2005."

warming can be expected to increase hurricane damage by 55 percent, since the NRDC base period of 1990-2006 would then translate into a $7-billion increase in hurricane damage, not the $54-billion increase projected by the NRDC report.

*If owners of high-risk properties pay adequate premiums each year for coverage, insurance does not involve a subsidy, even if a particular homeowner files a claim greater than all the premiums he or she has paid to date.*

### Mitigation and Insurance Regulation: Prudent Policies that also Insure against Global Warming

Hurricanes are a force of nature, but their impact on society depends in large part on human actions. Damage depends on the number of persons who live, work, and vacation in coastal areas most exposed to hurricanes. Coastal areas provide significant benefits to the nation, and the potential for occasional hurricanes to damage property only partially offsets these benefits. In addition to enjoying access to resources and to maritime shipping, an increasingly wealthy nation will likely trade off some additional damage when hurricanes do strike to enjoy waterfront living. The critical economic question is whether coastal development generates sufficient benefits to offset the full cost of development, including the extra cost due to hurricane damage. A secondary issue is whether coastal development is done using cost-minimizing construction techniques and materials.

Several public policies result in unnecessarily risky and inefficient coastal development, and this increases hurricane damage without sufficient offsetting benefits. Insurance regulation, government-subsidized flood insurance, mitigation, and building code enforcement significantly affect the amount and quality of building along the coast.

#### *State-Level Subsidized Insurance: Wind Pools*

Insurance provides the primary market mechanism to support risky activities like operating an offshore oil drilling platform in the Gulf of Mexico or building a resort on the coast. Insurance subsidies shift some of the costs of hurricanes for high-risk areas to third parties—who are often unwilling—thereby creating an externality. Insurance provides third-party payment when policy holders suffer a loss. The externality does not arise from the payment itself. Rather, it hinges on whether premiums reflect the losses that can be expected each year—that is, whether high-risk property owners pay actuarially adequate rates. If owners of high-risk properties pay adequate premiums each year for coverage, insurance does not involve a subsidy, even if a particular homeowner files a claim greater than all the premiums he or she has paid to date. In a free insurance market, a company would not cover a high-risk property if the premium is inadequate, because over time, as hurricanes incurred accumulating damages, the company would lose money.

*Some people who would not otherwise move into these high-risk areas choose do so due to insurance subsidies, thus increasing losses from future hurricanes.*

Insurance, however, is a highly regulated industry, with rates, terms of coverage, and company investments subject to state approval. State regulators can and do force insurance companies to offer coverage for high-risk properties at artificially low rates, to be paid for by higher rates on other policy holders in what economists call cross-subsidization. In the most hurricane-prone coastal states, the insurance subsidies for high-risk properties have been institutionalized through mechanisms known as wind or beach insurance "pools." The state-run pools offer coverage for at least wind damage to properties in eligible coastal areas.  They are euphemistically called residual markets, allegedly to cover only properties owners who are unable to find coverage on the market at prevailing rates.[14] But wind pool rates are actuarially inadequate, and private insurance companies know better than to write coverage at these rates. Almost 2 million policies are now serviced by the various state wind pools. When a pool suffers losses in excess of accumulated reserves, it can impose assessments on policies written by all "member" companies, but all insurance companies must be members of the pool as a condition of their license to operate in the state. Assessments are effectively equivalent to an excise tax on insurance policies.[15]

Insurance subsidies lower the cost to residents of living, working, and vacationing in coastal areas vulnerable to hurricanes. Some people who would not otherwise move into these high-risk areas choose do so due to insurance subsidies, thus increasing losses from future hurricanes. Below-market insurance is one of many factors in decisions to live along the coast, and many people would still choose to live in high-risk areas even if they had to pay full price for hurricane insurance. But the effect of subsidies institutionalized through wind pools may be significant. Consider for example the simple before-and-after comparison of population growth in the coastal counties of the seven states—Alabama, Florida, Louisiana, Mississippi, North Carolina, South Carolina, and Texas—that have wind or beach pools. In the decade before the establishment of the wind pools, the 77 coastal counties in these seven states experienced on average annual population growth of 26 percent, while population growth in the decade after establishment of the wind pools averaged 42 percent.

*For-profit insurers would be reluctant to assume new risks which might escalate in the future, like new development too close to the shore. But the NFIP as a government program can offer coverage now, with potential losses to be paid for by future tax payers.*

***Federal Subsidized Insurance: The National Flood Insurance Program***

Flooding accounts for a considerable portion of hurricane losses, and the National Flood Insurance Program covers flood losses. NFIP has existed in its current form since 1973. By the end of that year, a majority of America's seriously flood-prone communities had joined NFIP and the program's supposed veil of protection covered an increasing number of homes. The program subsidizes insurance for high-risk properties, particularly those vulnerable to storm-surge flooding.

NFIP subsidizes flood insurance in two ways. First, intentionally low rates were offered for structures existing prior to enactment of the NFIP in 1968, although these have dwindled over time. Second, the rates charged by the NFIP are only expected to cover losses in a normal year, and thus the NFIP did not charge rates sufficient to build up reserves to cover catastrophic losses. Hurricane Katrina resulted in losses of $18 billion for the NFIP in 2005; today the program still owes the Treasury over $17 billion.[16] Thus, the National Flood Insurance Program shifts hurricane costs to taxpayers across the nation, exacerbating the wind-pool property insurance subsidy.

The subsidy from flood insurance could be even greater in some instances, since after a hurricane, insurance companies and the NFIP must determine if losses resulted from wind or flooding, and wind damage could be labeled flood damage and shifted to the NFIP, and thus federal taxpayers.

The NFIP also encourages excessive coastal development. For-profit insurers would be reluctant to assume new risks which might escalate in the future, like new development too close to the shore. But the NFIP as a government program can offer coverage now, with potential losses to be paid for by future taxpayers. As of 2006, the Government Accountability Office had identified over 125,000 NFIP policies as covering repetitive loss properties, with nearly $8 billion in losses.[17]

***Mitigation***

Improved construction cannot eliminate losses, but it can substantially reduce them. Engineers have learned much about how to build homes, condominiums, and commercial buildings that are more resistant to hurricane force winds and to storm surge. Some types of mitigation are obvious—like installing hurricane blinds or shutters to prevent the breaking of windows—while others are less so—such as the shape of a home's roof or the direction of nailing in construction. In most cases, mitigation involves an extra construction or retrofitting expenditure, with the return realized in the future—the next time a hurricane strikes. Public policy creates disincentives for mitigation. The greatest disincentive is the availability of below-market property insurance. If homeowners can shift hurricane losses to third parties, they have less of an incentive to invest in mitigation to reduce these losses. Also, because regulation limits the premiums insurers can charge to high-risk properties, private insurers are reluctant to offer additional premium reductions for mitigation. Moreover, state regulators and lawmakers sometimes directly inhibit mitigation, as occurred in Connecticut in 2006, when some insurers wanted to make the installation of hurricane shutters a condition for coverage or renewal of insurance.[18]

***Building Codes***

Government building codes regulate many elements of quality and mitigation in construction. Most states have adopted building codes, which local governments must enforce. Overall, building codes can substantially reduce damage from hurricanes, by possibly 40 percent or more.[19] However, local governments have done a poor job of enforcing building codes, as was illustrated after Hurricane Andrew in 1992. Local governments hired too few inspectors, and approved the use of building materials and construction techniques that could not meet the South Florida Building Code. Homes built after 1980 suffered significantly more damage than did older structures, and 25 percent of the damage from Andrew was attributed to poor building code enforcement.[20]

Poor code enforcement by government has an especially pernicious effect on hurricane losses; the existence of building codes can lull homeowners and insurers into a false sense of security because they assume homes are being built to code. Neither Louisiana nor Mississippi had a state building code in 2005, so poor construction likely affected damage from Hurricane Katrina as well. The nation will need to devise ways to better assure the quality of construction in hurricane-prone areas.[21] Market forces can likely supplement building codes. One example of market-based quality assurance for disaster resistant construction is the *Fortified ... for Safer Living* program of the Institute for Business and Home Safety (IBHS).[22] The program includes design provisions to mitigate against wind, flooding, and other hazards. Home builders who

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want to build a *Fortified*-compliant home must submit plans for approval with multiple inspections during construction to assure that the home meets the design criteria. In addition, the performance of homes built by various home builders as revealed in post-hurricane damage assessments could be publicized by FEMA or IBHS, analogous to automobile crash test safety ratings.

*Hurricanes will continue to occur regardless of any trends in the global climate. Eliminating insurance subsidies and creating incentives for mitigation and strengthened construction will yield billions of dollars of benefits to the nation in the years to come.*

Inefficient coastal development—that is, economic or recreational uses of coastal property that do not generate sufficient benefits to cover the added cost due to hurricanes—increases the nation's vulnerability to hurricanes. Sound policy reforms should eliminate incentives for inefficient coastal development. And the return to these reforms will increase if climate change were to lead to an increase in the destructiveness of land-falling hurricanes. Suppose for example, that the policy reforms discussed here—elimination of property-casualty and flood insurance subsidies, and improved enforcement of building codes and incentives for mitigation—together could reduce hurricane damage in the long run by 50 percent. Losses due to hurricanes since 1970 have averaged about $7 billion per year adjusted for inflation. Thus, the return to insurance and mitigation policy reforms in the long run would be $3.5 billion annually. If global warming does occur and hurricane losses increase, the benefits of these policy reforms increase automatically. If for instance, as William Nordhaus suggests, global warming doubles hurricane damages, insurance reform and mitigation incentives could keep damages at their current level, even as hurricanes become more intense.

Insurance subsidies and building codes may not be the first policies that spring to mind for addressing possible climate change, but these policies affect our vulnerability to hurricanes, regardless of how hurricanes may be affected by global warming. Substantial uncertainty surrounds climate science and the possible impacts of anthropogenic climate change. Consequently, insurance reform and mitigation represent particularly appropriate policy measures to prepare for possible climate change. Hurricanes will continue to occur regardless of any trends in the global climate. Eliminating insurance subsidies and creating incentives for mitigation and strengthened construction will yield billions of dollars of benefits to the nation in the years to come. If hurricanes do become stronger due to global warming, the return on these policies will be even greater, and future generations will credit our resolve to stop subsidizing risky activities today.

## Conclusion

This paper has critiqued the assumptions and methods of alarmist projections for hurricanes and global warming, particularly those of a recent National Resources Defense Council study. The NRDC study inflates the projected costs of hurricanes due to global warming by the choice of an unrepresentative period for base damages, a hurricane intensity adjustment that likely overstates damages from an increase in wind speed, and a dubious sea level rise adjustment. In today's dollars and economy, the NRDC projection translates to about a $54-billion annual increase in hurricane damages due to global warming. In fact, any potential increase in damages is unlikely to exceed William Nordhaus's estimate of $8 billion per year, or about double the annual damages from 1970 to 2005. There is no reason to expect an increase in fatalities, given that our ability to forecast and warn for hurricanes is likely to improve.

What should policy makers do about this threat now? The NRDC study recommends that the U.S. reduce its emissions of greenhouse gases by 80 percent by 2050. Increased hurricane losses are only a portion of the costs of global warming on which this recommendation is based, but the economic costs of such a drastic reduction in greenhouse gases would be not only immense, but counterproductive, as reduced wealth creation leads to there being fewer resources available for coping with hurricanes.[23] Moreover, such drastic action would yield few benefits if the emission of greenhouse gasses by humans does not drive global climate change, or if the effects of climate change are not adverse.

A better approach for addressing hurricane-related damages would be to focus on incentives for mitigation, the elimination of subsidies for property and flood insurance, and the devising of better ways to enforce building standards. Poor policies lead to excessive vulnerability to hurricanes and increase the cost to the nation's taxpayers and low-risk insurance policy holders. Policies that lead to excessive coastal development amount to a check drawn on the taxpayers. Finding the political courage to eliminate insurance subsidies will be challenging, as vested interests that benefit from current policies will fight hard to defend the status quo. There may not be a scientific consensus that human-caused climate change is adversely affecting society, but there is always the potential for it. Insurance subsidies and mitigation may not be normally considered part of the climate change debate, but they should be. These policy reforms are justified on a "no regrets" basis—that is, they can only

*A better approach for addressing hurricane-related damages would be to focus on incentives for mitigation, the elimination of subsidies for property and flood insurance, and the devising of better ways to enforce building standards.*

yield benefits. Insurance reform and mitigation incentives represent true no-regrets policies to address climate change, since they are sure to benefit society regardless of climate change.

## Notes

1 Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, *Synthesis Report*, November 2007, p. 46, http://www.ipcc.ch. A more controversial question is whether global warming is already making hurricanes stronger, a question raised during the record 2005 Atlantic hurricane season. The relevant scientific papers include Kerry Emanuel, "Increasing Destructiveness of Tropical Cyclones over the Past 30 Years," *Nature*, August 4, 2005, pp. 686-88; P. J Webster, G. J. Holland, J. A. Curry, and H. R. Change, "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science*, Volume 309, September 16, 2005, pp. 1844-46; Christopher W. Landsea, Bruce A. Harper, Karl Hoarau, and John A. Knaff, "Can We Detect Trends in Extreme Tropical Cyclones," *Science*, Volume 313, July 28, 2006, pp. 452-54; R. A. Pielke Jr., C. Landsea, M. Mayfield, J. Laver, R. Pasch, "Hurricanes and Global Warming," *Bulletin of American Meteorological Society*, November 2005, pp. 571-75; Philip J. Klotzbach, "Trends in Global Tropical Cyclone Activity over the Past Twenty Years (1986-2005)," *Geophysical Research Letters*, Volume 33, L10805-808, 2006, Philip J. Klotzbach and William M. Gray, "Causes of the Unusually Destructive 2004 Atlantic Basin Hurricane Season," *Bulletin of the American Meteorological Society*, October 2006; and Kerry Emanuel, "The Hurricane-Climate Connection," *Bulletin of the American Meteorological Society*, May 2008, pp. ES10-ES20.

2 Frank Ackerman and Elizabeth A. Stanton with Chris Hope, Stephan Alberth, Jeremy Fisher, and Bruce Biewald, *The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked*, May 2008, Natural Resources Defense Council, Washington, DC, http://www.nrdc.org/globalWarming/cost/cost.pdf.

3 IPCC, *Synthesis Report*, p. 46, states: "[I]t is *likely* that future tropical cyclones will become more intense," while "there is less confidence in projections of a global decrease in the number of tropical cyclones." William Nordhaus adopts this projection in his analysis of global warming and hurricane damages as well. Experts in atmospheric science disagree over many of the projections employed in the NRDC study. As an economist, it is beyond the range of my expertise to contribute to this debate. Consequently, I will not challenge the NRDC study's climate change predictions and focus on the questionable damage projections. However, I will note that dissenting studies offer different estimates of hurricane-relevant climate change.

4 Roger A. Pielke, Jr., and Christopher W. Landsea, "Normalized Hurricane Damages in the United States: 1925-1995," *Weather and Forecasting*, 2005, 13(3), pp. 621-31; and Roger A. Pielke Jr., Joel Gratz, Christopher W. Landsea, Douglas Collins, Mark Saunders, and Rade Musulin, "Normalized Hurricane Damage in the United States: 1900-2005," *Natural Hazards Review*, February 2008, pp. 29-42.

5 Thomas Knutson and colleagues, by contrast, project only a 1.7-percent increase in wind speed due to a warming climate. They also project an 18-percent *decrease* in the total number of hurricanes, in contrast to the NRDC assumption of no change in the number of hurricanes. See Thomas R. Knutson, Joseph J. Sirutis, Stephen T. Garner, Gabriel A. Vecchi, and Isaac M. Held, "Simulated Reduction in Atlantic Hurricane Frequency Under Twenty-First-Century Warming Conditions," *Nature Geoscience*, 2008, volume 1, pp. 359-364.

6 In logarithms, Nordhaus's relationship is LN(Damage) = 8*LN(Wind Speed), where LN is the natural logarith. William D. Nordhaus, "The Economics of Hurricanes in the United States," Working Paper 12813, National Bureau of Economic Research, 2006.

7 Pielke et al., "Normalized Hurricane Damage in the United States: 1900-2005."

8 Nordhaus, "The Economics of Hurricanes."

9 Other hurricanes like Katrina, Rita and Wilma in 2005 attained category 5 status but weakened before landfall.

10 To appreciate the magnitude of reconstruction over time, the median year of housing units built in the U.S. in 2000 was 1971, and only 15 percent of housing units in 2000 were built before 1940 (the earliest year reported by the Census). Alternatively, about 47 percent of housing units in 1940 were still in use in 2000. A report by Architecture 2030, an environmental advocacy group, estimates that by 2035, 75 percent of the U.S. building stock will be new or renovated; see 2030 Research Center, *Nation Under Siege: Sea Level Rise at Our Doorstep*, September 2007, p. 10, http://www.architecture2030.org/pdfs/nation_under_siege_lr.pdf.

11 The NRDC study implicitly assumes this. One of the other costs which the report considers is inundation of coastal property due to sea level rise. By 2100, an estimated $360 billion worth of coastal property will be lost annually. If property is inundated, presumably the new construction will occur beyond the new coast line.

12 IPCC *Summary Assessment*, Table 3-1. The probability that sea level rise will exceed the upper bound of the likely range is estimated to be .33.

13 The NRDC report assumes the following distribution of hurricanes per year prior to global warming, with damage per storm:

- Category 1: 0.71 per year, $.56 billion
- Category 2: 0.46 per year, $4.0 billion
- Category 3: 0.49 per year, $15.7 billion
- Category 4: 0.12 per year, $17.2 billion
- Category 5: 0.02 per year, $64.5 billion

I assume a uniform distribution of storms within the wind speed ranges of each category of storm.

14 States address high-wind risk properties in different ways. In addition to the seven states with wind pools, nine other coastal states (Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, Delaware, Virginia, and Georgia) have general residual market mechanisms or Fair Access to Insurance Requirement plans, which address in part wind-risk properties. The wind pools also differ in their size and on whether they offer only wind coverage or multi-hazard homeowners' insurance.

15 For a description of the operation of wind pools see Daniel Sutter, "Ensuring Disaster: State Insurance Regulation, Coastal Development, and Hurricanes," Mercatus Center Policy Comment #14, September 2007, http://www.mercatus.org/PublicationDetails.aspx?id=16176. As of July 2008, state wind pools covered more than 1.8 million policies with a total value of more than $600 billion.

16 Government Accountability Office, "National Flood Insurance Program: Financial Challenges Underscore Need for Improved Oversight of Mitigation Programs and Key Contracts," June 2008, GAO-08-437, http://www.gao.gov/new.items/d08437.pdf.

17 GAO, "National Flood Insurance Program."

18 For more on the policy disincentives for mitigation see Daniel Sutter, Building a Safe Port in the Storm: Private versus Public Choices in Hurricane Mitigation," Mercatus Policy Comment #21, July 2008.

19 See the Building Codes section of the Institute for Business and Home Safety's webpage at www.disastersafety.org. For engineering studies of the potential damage reduction from wind loads see Shimberg Center for Affordable Housing and Applied Research Associates, *Florida Building Code Cost and Lost Reduction Benefit Comparison Study*, 2002, Tallahassee Florida: Florida Department of Community Affairs and Marc L. Levitan, Carol Hill Friedland, and T. Eric Stafford, *Residential Wind Damage in Mississippi: Potential Hurricane Damage Reduction through Improved Building Codes and Building Practices*, 2006, LSU Hurricane Center and T. Eric Stafford & Associates.

20 See Dennis Mileti, *Disasters by Design*, 1999 (Washington: Joseph Henry Press); and Paul Fronstin and Alphonse Holtman, "The Determinants of Residential Property Damage Caused by Hurricane Andrew," *Southern Economic Journal*, Volume 61, 1994, pp. 387-97.

21 On why the public sector performs worse than market forces in quality assurance, see Randall Holcombe, *Public Policy and the Quality of Life*, Westport, Connecticut: Greenwood Publishers, 1995, pp. 93-106.

22 For a description of the program and design standards see Institute for Business and Home Safety, *Fortified ... for Safer Living Builder's Guide*, Version 2.2, December 2007, http://disastersafety.org/resource/resmger/PDFs/builders_guide.pdf.

23 The NRDC study does not offer any cost estimates, but the cost of the Waxman-Markey climate change bill in the current Congress has been estimated at $7.4 trillion of lost GDP by 2035. See William W. Beach, David W. Kreutzer, Karen Campbell, and Ben Lieberman, "The Economic Impact of Waxman-Markety," The Heritage Foundation, http://www.heritage.org/Research/EnergyandEnvironment/wm2438.cfm.

24 See Pielke and Landsea, "Normalized Hurricane Damage in the U.S.," 1998, Richard W. Katz, "Stochastic Modeling of Hurricane Damage," *Journal of Applied Meteorology*, Volume 41, 2002, pp. 754-62, Nicole Cornell Sadowski and Daniel Sutter, "Hurricane Fatalities and Hurricane Damages: Are Safer Hurricanes More Damaging?" *Southern Economic Journal*, Volume 72, 2005, pp. 422-32.

25 See Nejit Anbarci, Monica Escaleras, and Charles A. Register, "Earthquake Fatalities: The Interaction of Nature and Political Economy," *Journal of Public Economics*, Volume 89, 2005, pp. 1907-33; Matthew E. Kahn, "The Death Toll From Natural Disasters: The Role of Income, Geography, and Institutions," *Review of Economics and Statistics*, Volume 87, 2005, pp. 271-84; Monica Escaleres and Charles A. Register, "Mitigating Natural Disasters through Collective Action: The Effectiveness of Tsunami Early Warnings," *Southern Economic Journal*, 74(4), 2008, pp. 971-996.

26 The National Hurricane Center reports two tallies of hurricane fatalities: direct deaths and indirect deaths. Indirect deaths include, for example, deaths during a cleanup after the hurricane. Researchers typically use the direct fatality total in analyses, as this is consistent with the fatality totals reported by the National Weather Service for other weather events. The NRDC study appears to use indirect deaths, because it reports 31 deaths for Charley and 76 for Andrew; thus their base level of 121 fatalities per year for 1990 to 2006 is excessive, as well.

## About the Author

Daniel Sutter is Associate Professor of Economics at the University of Texas, Pan American. Previously, he was at the University of Oklahoma (1995-2006). He has a Ph.D. in economics from George Mason University (1993) and a B.S. from Rensselaer Polytechnic Institute (1987).

Dr. Sutter has published over seventy academic journal articles, in journals including *Economic Inquiry, Southern Economic Journal, Public Choice, Weather and Forecasting, Natural Hazards Review,* and *Risk Analysis*. His research interests include the impact of weather hazards, the value of weather forecasts, the economics of the news media and news bias, and constitutional economics. He is a Senior Affiliated Scholar of the Mercatus Center at George Mason University, where he has worked on their Hurricane Katrina project and has co-edited symposia on Hurricane Katrina for the *Southern Economic Journal* and the *Journal of Business Valuation and Economic Loss Analysis*. His research on weather hazards has examined tornado casualties, the value of tornado shelters, hazards mitigation and the housing market, the determinants of societal vulnerability to hurricanes, and the value of hurricane forecasts.

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