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Analysis

Projected Increases in Hurricane Damage in the United States: The Role of Climate Change and Coastal Development

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ABSTRACT

The combined forces of climate change and coastal development are anticipated to increase hurricane damage around the globe. Estimating the magnitude of those increases is challenging due to substantial uncertainties about the amount by which climate change will alter the formation of hurricanes and increase sea levels in various locations; and the fact that future increases in property exposure are uncertain, reflecting local, regional and national trends as well as unforeseen circumstances. This paper assesses the potential increase in wind and storm surge damage caused by hurricanes making landfall in the U.S. between now and 2075 using a framework that addresses those challenges. We find that, in combination, climate change and coastal development will cause hurricane damage to increase faster than the U.S. economy is expected to grow. In addition, we find that the number of people facing substantial expected damage will, on average, increase more than eight-fold over the next 60 years. Understanding the concentration of damage may be particularly important in countries that lack policies or programs to provide federal support to hard-hit localities.

1. Introduction

Climate change is likely to increase the frequency of the most intense categories of hurricanes in some parts of the world, including the North Atlantic Basin, and is expected to increase sea levels, leading to more destructive storm surges when hurricanes occur (see IPCC, 2013). Moreover, growing populations and rising incomes are expected to place more people and property in harm's way. This paper estimates the increase in U.S. hurricane damage between now and 2075 using a Monte Carlo framework. We simulate damage 5,000 times, with each simulation providing an estimate of expected damage based on a unique set of draws from the projected distributions of four factors that determine damage: hurricane frequencies, location-specific sea levels, and changes in population and per capita income in coastal counties (which serve as proxies for increases in property exposure). We compare the distribution of expected damage in 2075 to an estimate of expected hurricane damage based on current conditions.

The importance of accounting for the effects of both climate change and increases in exposure in estimating the damage from extreme events was highlighted in a special report by the Intergovernmental Panel on Climate Change (IPCC, 2012) and in the most recent National Climate Assessment (Melillo et al., 2014).[1] Moreover, Nicholls et al. (2008) estimates that the total value of global assets exposed to damage from coastal flooding from storm surge and damage due to high winds (in 135 port cities) was around 5% of global GDP in 2005 (measured in international USD). In the case of hurricanes, climate change will exacerbate damage on both existing and newly constructed properties and increases in property exposure will aggravate the escalation of hurricane damage that climate change would otherwise bring about.

Our analysis builds on previous studies that have examined the effects of climate change on coastal communities in the United States. For example, Yohe (1990) develops a method of estimating nationwide damage from sea level rise (SLR) and Neumann et al. (2015) examines the joint effects of storm surge and sea level rise. Houser et al. (2015), uses estimates of future hurricane frequencies and location-specific

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[1] Much of the early literature on sea level rise addressed its direct effects such as inundation and erosion rather than its effect on damage from storm surges. Besello and Cian (2014) describe the types of models used to measure effects and group them into "bottom up" and "top down" approaches, with the former providing much greater special resolution and the latter assessing economy-wide impacts. Our analysis would be classified as a bottom up approach.

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estimates of increases in sea levels to project how climate change will increase both wind and storm surge damage due to hurricanes; however they do not account for the effects of coastal development. (For a discussion of variation in sea level rise, see Sallenger et al., 2012). Pielke et al. (2008) demonstrates the importance of accounting for changes in property exposure in explaining historic trends in hurricane damage; however, given the infrequency of hurricanes and the importance of the point of landfall in determining damage, historic records may not be long enough to detect the effects of climate change (Hallegatte, 2007). Nordhaus (2010) uses historic data to construct a damage function that relates wind speed to damage and estimates future increases in U.S. hurricane damage due to the changes in the frequency and intensity of hurricanes that would be associated with an equilibrium doubling of CO_2-equivalent atmospheric concentrations. Mendelsohn et al. (2011) also constructs a damage function based on historic data (using barometric pressure as well as wind speed) and estimates increases in U.S. hurricane damage due to changes in hurricane frequencies. They estimate the effects of coastal development using county level estimates of changes in population and per capita income. Neumann et al. (2015) estimate U.S. damage resulting from the joint effect of SLR and storm surges through 2100. Their analysis primarily focusses on the potential effects of mitigation and adaptation (see the discussion section below).

Our work most directly expands on the work of Hauser et al. (2015) and Mendelsohn et al. (2011). Like Hauser et al., we compare expected damage under current conditions and under future conditions (reflecting climate-induced changes in hurricane frequencies and sea levels). We expand on that work by using a much wider range of predictions about changes in U.S. hurricane frequencies (reflecting the significant underlying uncertainties about the effects of climate change on hurricane formation) and by accounting for the interaction between climate change and coastal development. Like, Mendelsohn et al., we use county-level changes in population and per capita income in estimating exposure. We expand on their work by weighting county-level estimates based on each county's relative vulnerability to damage from wind and storm surges, by accounting for the location-specific effects of sea level rise on damage, and by constructing estimates of future damage that explicitly account for uncertainty in the underlying drivers of damage (changes in hurricane frequencies, sea levels, and location-specific populations and per capita incomes).

While our damage estimates are specific to the United States, our approach can be applied in other countries. That approach, however,

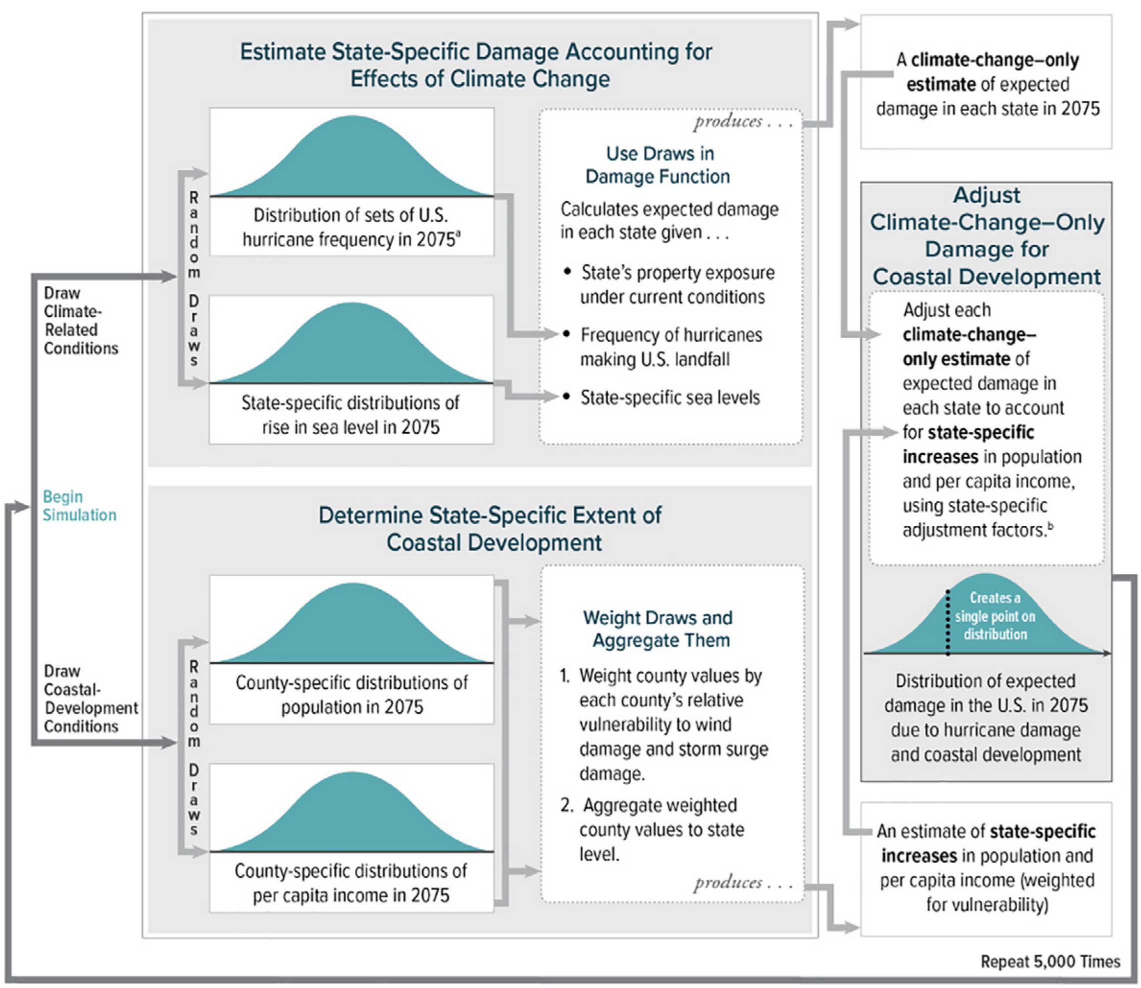

Fig. 1. Flow of the model for estimating the effects of climate change and coastal development on hurricane damage in 2075. a. Each set consists of a projection of frequency for hurricanes in each of five categories. (The five categories of hurricanes are based on peak wind speed. Category 5 storms are the most intense.) b. Each state's increase in expected damage due to an increase in its population and per capita income is uniquely determined based on the share of the state's expected damage (measured under current conditions) that comes from wind versus storm surge damage. That unique determination incorporates different responses of wind and storm surge damage to a given increase in population and per capita income.