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**Article**

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## A HURRICANE HITS HAWAII: A TALE OF VULNERABILITY TO NATURAL DISASTERS

MAKENA COFFMAN AND  
ILAN NOY\*

### Introduction

Hurricane Iniki, which hit the island of Kauai on 11 September 1992, was the strongest hurricane that hit the Hawaiian Islands in recorded history, and the one that wrought the most damage, estimated at USD 7.4 billion (in 2008 USD) though fortunately mortality was low. Today, with the evident warming of the planet and the changes in the patterns of climatic events that are predicted to accompany such warming, the importance of understanding the long-term economic impact of natural disasters cannot be overstated.

Research in both the social and natural sciences has been devoted to increasing our ability to predict disasters and prepare for them; but curiously, there are few analyses of their *ex-post* economic impact. We were surprised to realize at the onset of this project, for example, that no comprehensive or even cursory attempt has been made to account for the long-term impact of hurricane Iniki on the economy of the island of Kauai; nor, as far as we know for any other natural disaster that has previously impacted the Hawaiian islands.

Here, we would like to focus on Iniki's impact on the economy of Kauai. Observing Iniki's impact is easier both because of the availability of *ex post*, long-term data and because of the existence of an obvious control group (the island of Maui). Because Hawaii's experience with disasters is not in any way unique, we first describe the current state of the literature that examines the economics of disasters in small island (mostly nation-) states, and discuss a recent attempt by the United Nations to assess vulnerabili-

ties to these disasters. We then assess the impact of Iniki on the island of Kauai, and finish by describing the current state of knowledge on the connection between climate change and storms.

### The economics of natural disasters

The economy of the State of Hawaii, with its unique set of vulnerabilities, will most likely be impacted differently by large disaster events than significantly bigger countries. Storms, unlike geo-physical disasters such as earthquakes and volcanic eruptions, are fairly expected events with some advance warning, even if their ferocity can be unpredictable. This level of certainty, together with the resources that can be mobilized both before and after a storm hits, also differentiate Hawaii's likely experience with that of, for example, Japan's experience with the surprise of the Kobe earthquake or hurricane Nargis' impact on Myanmar where little *ex ante* preparation occurred. (Several papers identify the importance of institutional characteristics and the type of disaster in determining the post-disaster outcomes in terms of mortality, direct damages, and long-term economic cost – see e.g. Skidmore and Toya 2002; Kahn 2004; Anbarci *et al.* 2005; Noy and Nualsri 2007; Noy 2009; Cavallo, Galiani, Noy and Pantano 2010.)

Two research projects have investigated the impact of hurricanes on economies in the Caribbean. Given similarities between island economies, these studies are likely to provide more insight into the case of Hawaii. Rasmussen (2004) conducts a tabulation of the data for the island members of the Eastern Caribbean Currency Union (ECCU). He finds that: “among these [...] the median number of affected persons amounted to 9 percent of the country's population and the median value of damage was equivalent to 14 percent of the country's annual GDP” (Rasmussen 2004, 7).<sup>1</sup>

<sup>1</sup> Though, as Rasmussen (2004) points out, some events can be significantly worse. “For example, in 1979 hurricane David hit Dominica killing 42 people, damaging 95 percent [of GDP] and completely destroying 12 percent of buildings, damaging or destroying the entire banana crop and 75 percent of the country's forests, rendering virtually the entire population homeless, and leading to the temporary exodus of about a quarter of the population” (Rasmussen 2004, 7).

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Heger *et al.* (2008) also focus on Caribbean islands (not limiting themselves to ECCU countries only). Their results also do not agree with the earlier largely optimistic research which concluded that disasters are typically followed by a period of higher growth. They find that as growth collapses, the fiscal and trade deficits both deteriorate and the island economies of the region find it difficult to rebound from the short-run impact of the disaster. They relate this deepening recession to the reliance of island economies in the region on very few sectors.

### Vulnerabilities to disasters

Regions are vulnerable to disasters for many reasons. Besides traditionally conceived geographical characteristics such as proximity to coastal areas, volcanoes or tectonic fault lines, there is a growing understanding of economic conditions that make regions vulnerable as well. Economic circumstances may lead to resiliency in the aftermath of a disaster or, alternatively, exacerbate its impacts. Vulnerability has been defined in many ways. The United Nations International Strategy for Disaster Reduction describes it as the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impacts of hazards. Resiliency, the antonym of vulnerability, is described as the capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure (United Nations 2010).

Vulnerability (or conversely resiliency) to hazards can be categorized both *ex-ante* and *ex-post*. *Ex-ante* vulnerability is described by indicators such as frequency and magnitude of disaster events, susceptibility of the economy to be impacted by external shocks, and existence of disaster management plans such as adequate shelters. *Ex-post* vulnerability is characterized by the ability to recover from the aftermath of a disaster. Relevant factors include success in the deployment of disaster management plans, access to inflows of outside aid, and the ability of different economic sectors to rebound. For the purposes of this note, and as a useful example, we briefly discuss the economic characteristics of vulnerability in Hawaii.

Baritto (2008) assesses which factors can make an economy sensitive to the impact of external shocks.

Because Hawaii is a State and not a country, Baritto's set of indicators do not necessarily translate to the case of Hawaii. Nonetheless, the general themes of his vulnerability assessment remain: (1) diversification of export products and destinations, (2) levels of wealth, (3) net food import ratio, (4) manufacturing and services value-added proportion, and (5) characteristics of imports. We briefly discuss each in turn.

Regions with a large export sector will generally be less vulnerable to disasters because the demand markets for products will presumably be unaffected. At the same time, an economy with a less diversified set of export products is generally more vulnerable to external shocks. Hawaii has a very small manufacturing export base, with 2.4 percent of the value of Hawaii's USD 90.2 billion economy, roughly 2.2 billion US dollars. By far the largest export sector in the state is tourism. Although tourism activities take place within the State, goods and services are 'exported' to out-of-State consumers. Tourism, with its heavy reliance on domestic infrastructure and public perceptions, is different than other export sectors in terms of its vulnerability to disasters. Tourism activity typically decreases significantly following disasters, as was the case after hurricane Iniki (see next section). Hawaii's tourism sector accounts for 22 percent of Hawaii's state gross product or seven times the value of all other exported goods. As is often the case, this sector is not even diversified in terms of destinations. Nearly 70 percent of visitor expenditures are from the continental United States. Japanese visitors comprise 15.5 percent of spending and Canadian visitors only 5 percent.

Per capita income in Hawaii in 2007 was 39,239 US dollars, which is relatively high for an island economy. High income better enables reconstruction activity. Nonetheless, in terms of distribution, nearly 11 percent of the population is considered to be living under the poverty line. The poor are generally much more vulnerable during disasters, as the events following hurricane Katrina amply and painfully demonstrate.

Baritto (2008) also suggests that regions with high levels of food imports are more vulnerable to disasters, particularly depending on the infrastructure required to bring in food. Over 85 percent of the food consumed in Hawaii is imported through one primary port (Leung and Loke 2008). This suggests

that Hawaii's food 'infrastructure' may be quite vulnerable in the case of disaster.

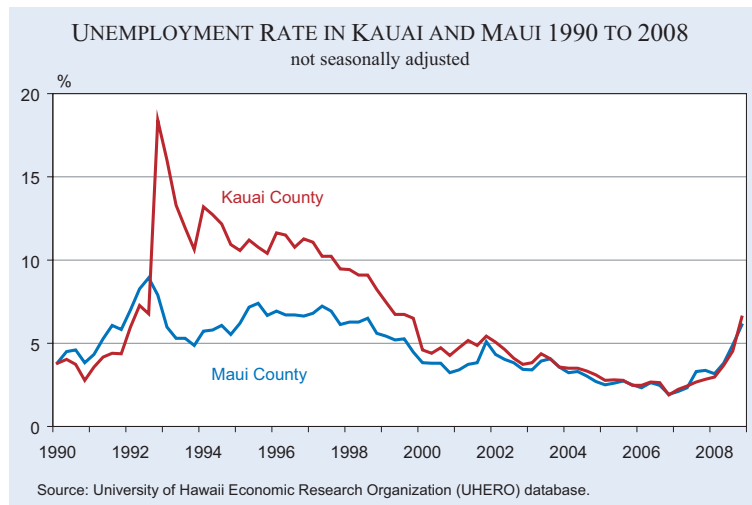
### Kauai's hurricane Iniki

Hurricane Iniki hit land on the south shore of Kauai on the afternoon hours of 11 September 1992: for a more detailed description of Iniki's trajectory and consequences, see Coffman and Noy (2009). CRED-EMDAT, the most comprehensive and readily available international data source on natural disasters, estimates that 4 people were killed, 25,000 were affected, and there was USD 7.4 billion (2008 USD) destruction of infrastructure and property. According to the National Oceanic and Atmospheric Administration (NOAA), 14,350 homes were damaged or destroyed on Kauai, and electric power and telephone service were lost throughout the island and only 20 percent of the power had been restored four weeks later. Crop damage was likewise extensive.

Iniki was not the only hurricane to hit Kauai in the past 50 years but the direct destruction that Iniki wrought was unprecedented. These direct impacts, however, do not necessarily represent the longer-run indirect economic effects of the hurricane. Distinguishing these long-term economic effects is, however, not easy since Kauai, like the other Hawaiian Islands, was hit at about the same time by a prolonged and painful recession in Japan. The similarities between Kauai and Maui (another Hawaiian island that was not hit by the hurricane), enable us to identify more definitively the hurricane's economic effects.

The massive destruction of property and infrastructure resulted in a dramatic rise in unemployment as is shown in Figure 1. Unemployment was already inching up from a low of around 3 percent in 1990 to 7 percent just before the hurricane as the

**Figure 1**



Japanese economy was suffering from the aftermath of its real estate and stock market bubbles. However, immediately after the hurricane, unemployment on Kauai shot up to 17 percent. Maui, our control group, also experiences a rise in unemployment as a result of the Japanese financial crisis, but on Maui unemployment peaked at only 9 percent. Clearly, the drastic rise in unemployment was primarily due to Iniki.

Maybe more striking is that it took Kauai seven years for its labor market to recover to its previous pre-Iniki unemployment rate of 7 percent (by that time, Maui's unemployment was less than 5 percent). This pattern of a recovery that takes seven to eight years, while evident in several other statistics, is also misleading because there was a striking influx of resident out-migration. Figure 2 presents population figures for Kauai and Maui.

**Figure 2**

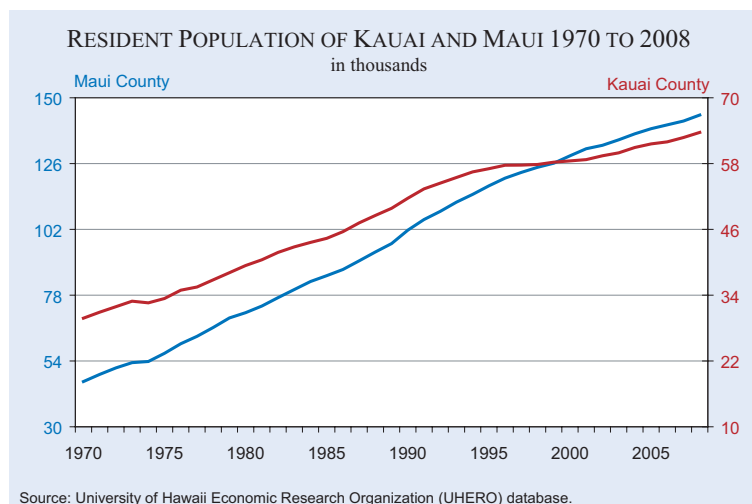
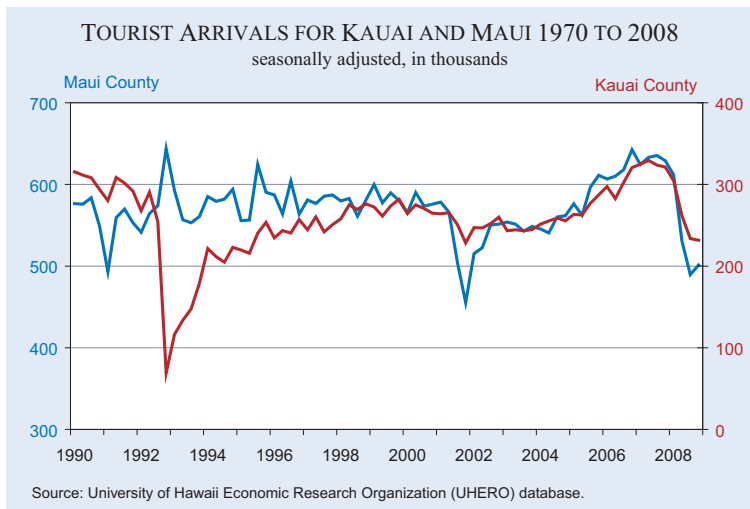


Figure 3



Both islands seem to follow a similar population trajectory starting in 1970, with both experiencing a very constant rate of population increase. However, Kauai's population trajectory shifts in 1992. For several years after that (about seven to eight) the population is constant, but the rate of population increase after that is slower than before. Not only does Kauai not recover the population it 'lost' as a result of the hurricane, it has yet to return to its previous growth rate. In that sense, Kauai seems to have permanently 'lost' about 10 percent of its population. By comparing Kauai and Maui's population trajectories, it again becomes apparent that the changes in Kauai were the result of Iniki since both were exposed to the same external economic conditions befalling the islands during the 1990s.

Figure 3 examines the tourism sector in both islands by looking at tourist arrival data for the years surrounding the hurricane. The tourism cycle seems to be highly correlated between the two islands, except for the seven to eight years following Iniki. Immediately after the hurricane, tourist arrivals drop by 70 percent, with a temporary spike up in tourist arrivals in Maui when previously booked trips were re-directed to Maui facilities. Kauai's tourism based economy only recovered almost a decade later when tourist arrivals climbed back up to pre-Iniki numbers in 2000. This number remained fairly cons-

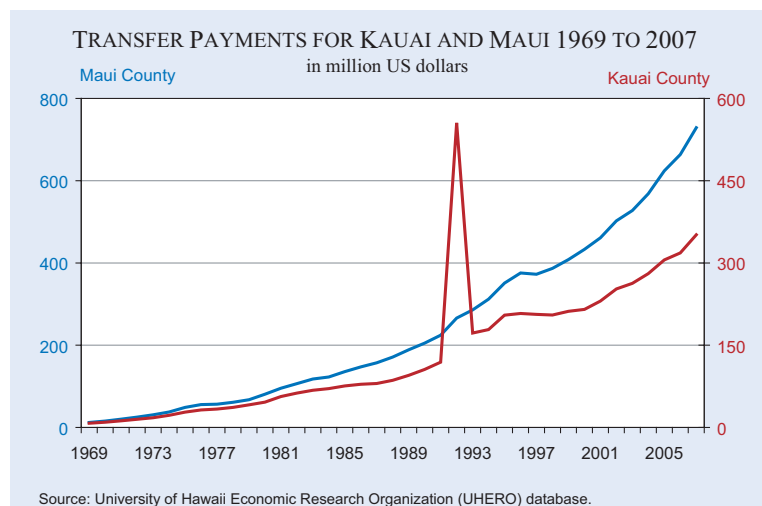
tant in spite of the events of 11 September 2001, and visitor arrival numbers only reached the pre-Japanese bubble numbers of 1990 in 2006.

A reason why Kauai's experience with Iniki could have been much worse is evident once one examines the amount of funds the county received from state and federal sources (see Figure 4). Clearly, the spike in funds associated with Iniki enabled a quicker recovery than otherwise would have been the case. However, even with this massive increase in transfers to the state government (about 450 million US dollars), the economy of Kauai only recovered after nearly a decade, and by some measures it had never recovered.

#### Climate change and natural disasters

The Intergovernmental Panel on Climate Change (IPCC 2007) states that: 'warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level'. Average global surface warming is projected to increase by between 1.8 and 4 degrees Celsius depending on the success of emissions mitigation strategies by 2100 (IPCC 2007). The 2007 IPCC report predicts sea levels to

Figure 4





rise between 0.18 and 0.59 meters by 2100. Current predictions of global sea level rise are considerably more drastic, however, as increased information on glacial melting has become available since 2005. In addition, the absorption of carbon in the ocean has led to increased acidity and has resulted in calcification of coral reefs. Coral bleaching leads to destruction of surrounding ecosystems, both harming fisheries and deteriorating reef systems that protect coastal areas from storm surges.

There is limited understanding on how global warming will affect hurricanes (or cyclones). There are five necessary conditions for hurricane formation: (1) ocean water temperature greater than 26 degrees Celsius (80 degrees Fahrenheit) to a depth of about fifty meters, (2) an unstable atmosphere (i.e. thunderstorm activity), (3) high relative humidity in the middle troposphere, (4) a pre-existing disturbance with cyclonic circulation, and (5) little to no change in the wind speed or direction so that warm air is concentrated over one area (Businger 2009). Several studies posit that, as global sea surface temperatures rise, there will either be more or more intense hurricanes (see e.g. Webster *et al.* 2005).

The science, however, is not entirely conclusive. IPCC (2007) states that: 'there is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones. It is difficult to ascertain longer-term trends in cyclone activity, particularly prior to 1970' (IPCC 2007). Elsner *et al.* (2008) suggested that warming temperatures allowed for already strong storms to get even stronger; while there may not necessarily be an increased occurrence of storms, there will be an increased occurrence of strong storms. Islands are extremely vulnerable to the expected (and often already occurring) effects of climate change. Sea level rise will exacerbate inundation, storm surge, erosion and other coastal hazards (IPCC Working Group II 2007).

## Conclusion

Islands are vulnerable to effects of climate change with very high confidence (IPCC Working Group II 2007). This assessment is based not, however, only on the physical implications of climate change on island ecosystems (proportionately larger coastal areas,

dependence on ocean ecosystems, and limited fresh water availability), but also on the economic conditions of islands (tourism dependence, narrow export markets, large import base and limited agricultural production). As the case of Iniki shows, high dependence on tourism made Kauai particularly vulnerable in the aftermath of the storm. It was difficult for Kauai's economy to rebound quickly as it immediately lost its primary export and income generator: visitors. Kauai did not regain its previous levels of visitor arrivals until 2000, eight years after Iniki hit. That resulted in out-migration of Kauai residents from which the island has never fully recovered.

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