

# Natural Disasters, Social Protection, and Risk Perceptions\*

Philip Brown\*, Adam Daigneault\*, Emilia Tjernström\*\*, Wenbo Zou\*\*\*

\*Landcare Research New Zealand

\*\*University of Wisconsin, Madison

\*\*\*University of California, Davis

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## Abstract

Natural disasters give rise to loss and damage and may affect subjective expectations about the prevalence and severity of future disasters. These expectations might then in turn shape individuals' investment behaviors, potentially affecting their incomes in subsequent years. As part of an emerging literature on endogenous preferences, economists have begun studying the consequences that exposure to natural disasters have on risk attitudes, perceptions, and behavior. We add to this field by studying the impact of being struck by the December 2012 Cyclone Evan on Fijian households' risk attitudes and subjective expectations about the likelihood and severity of natural disasters over the next 20 years. The randomness of the cyclone's path allows us to estimate the causal effects of exposure on both risk attitudes and risk perceptions. Our results show that being struck by an extreme event substantially changes individuals' risk perceptions as well as their beliefs about the frequency and magnitude of future shocks. However, we find sharply distinct results for the two ethnicities in our sample, indigenous Fijians and Indo-Fijians, the former of whom are noted for their "collectivist" social organization and the latter of whom are largely self-reliant: the impact of the natural disaster aligns with previous results in the literature on risk attitudes and risk perceptions for Indo-Fijians, whereas they

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have little to no impact on those same measures for indigenous Fijians. Anchored in the institutional context of Fiji, this result is sensible and has implications for how social protection can mitigate some of the negative impacts of natural shocks on households' expectations. To provide welfare implications for our results, we compare households' risk perceptions to climate and hydrological models of future disaster risk, and find that both ethnic groups over-infer the risk of future disasters relative to the model predictions. If such distorted beliefs encourage over-investment in preventative measures at the cost of other productive investments, these biases could have negative welfare impacts. Understanding belief biases and how they vary across social contexts may thus help decision makers design policy instruments to reduce such inefficiencies, particularly in the face of climate change.

## **Introduction**

Natural disasters affected 232 million people, killed over 100,000 people, and caused more than US\$ 100 billion worldwide in damage each year between 2001 and 2010, on average (Guha-Sapir et al., 2012). Strömberg (2007) observes that people in low-income countries are 12 times more likely to die from natural disasters and are similarly more likely to suffer serious economic consequences of disasters, despite the fact that high- and low-income countries do not differ significantly in terms of the number of disasters experienced, nor in terms of the number of people affected.

Moreover, the number of natural disasters recorded per year has increased markedly since 1940 (Munang et al., 2013), and factors such as population pressure and infrastructure development in risk-prone areas have increased the risk of loss and damage from natural disasters (IPCC, 2012; Munang et al., 2013). It is likely that climate change will amplify the number and severity of such disasters over the next century (Preston et al., 2006; Bates and others, 2008).

To reduce the vulnerability of at-risk populations, policy makers are increasingly turning their attention toward climate-change adaptation. Adaptation may involve altering land-use patterns, adjusting crop choices, and building protective infrastructure, and although individuals may have limited say in broader adaptation policy, they may adapt their expect-

tations or risk behaviors in less conspicuous ways, including altering their risk attitudes and risk perceptions.

Economists have recently begun examining the impact of negative shocks on risk attitudes (that is, risk tolerance), perceptions, and behaviors, including natural disasters as well as violent conflicts (Callen et al., 2014; Kim and Lee, 2014; Voors et al., 2012), macroeconomic shocks (Malmendier and Nagel, 2011), and early life traumatic experiences (Bernile et al., 2016). This article belongs to a growing subset of this literature that focuses on the effect of natural shocks on risk attitudes, risk perceptions, and risk-taking behavior. The evidence on risk attitudes is mixed, and the literatures on risk perceptions and behaviors largely focus on developed countries. Our contribution to this literature is fourfold: First, we complement the literature on risk attitudes and perceptions via a natural experiment in the form of a cyclone, the path of which was unpredictable and random. Second, we explicitly measure individuals' subjective expectations of future loss and damage using an experimental method that allows us to explore impacts on both the perceived frequency and perceived magnitudes of natural disasters. Third, our data include two populations affected by the same disaster but who live under distinct institutional arrangements that prompt starkly different responses to the event. Fourth, to provide welfare implications for our results, we compare households' perceptions to predicted future disaster risk from climate and hydrological models, showing that average perceptions greatly exceed baseline predictions, even for households who did not suffer material loss and damage from Cyclone Evan.

Different theoretical models have contrasting predictions concerning the impact of exposure to natural disasters on risk perceptions and risk attitudes. We discuss how predicted effects of shocks vary with different models in more depth in the section entitled Conceptual Model, and introduce the related empirical work here. In the disaster risk literature, perceptions of risk are shown to increase sharply after exposure to flooding in a variety of

settings, including the Netherlands (Botzen et al., 2009), New Zealand (Lawrence et al., 2014), Slovenia (Brilly and Polic, 2005), Switzerland (Siegrist and Gutscher, 2006), Taiwan (Ho et al., 2008; Lin et al., 2008) and post-Katrina New Orleans (Viscusi and Zeckhauser, 2006). For example, Botzen et al. (2009) find that the perceived probability of future flooding is significantly higher for individuals who have previously been evacuated due to flooding.<sup>1</sup> Similar results have been established for avalanches (Leiter, 2011), earthquakes (Kung and Chen, 2012), landslides (Lin et al., 2008) and hurricanes (Peacock et al., 2005).

As for risk attitudes, Cameron and Shah (2015) find that individuals in Indonesia who suffered loss and damage from flooding and/or earthquakes in the previous three years exhibit more risk aversion within the framework of a lab-in-the-field experiment. Similarly, Cassar et al. (2011) find that individuals affected by the 2004 Asian tsunami are substantially more risk-averse four and half years after the disaster. In contrast, Eckel et al. (2009) analyze the risk attitudes of individuals who were displaced by Hurricane Katrina and Page et al. (2014) analyze risk attitudes of home owners who suffered large losses in the Australian floods in 2011. Both studies find that respondents demonstrate high levels of risk-loving immediately after the disaster.

With respect to behavior, Burn (1999) finds that victims of past flooding undertake more preventative measures against future flooding than people who have not experienced flooding but face similar future flooding risks. Lawrence et al. (2014) further find that people with previous exposure to flooding are more willing to make household-level changes and are better prepared against future flooding. Cameron and Shah (2015) find that disaster victims in Indonesia exhibit more risk aversion in real-world behaviors, and Kousky (2010), Atreya et al. (2013), and Bin and Landry (2013) demonstrate that the price premium on

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<sup>1</sup>Botzen et al. (2009) also find that expected damages from future flooding falls with evacuation experience. The authors suggest that most of those who were evacuated did not experience property damage, thus lowering expectations of damage from flooding despite high perceived probabilities of flooding.

housing located outside of flood plains rises significantly after extreme weather events in the United States. Furthermore, Botzen and Van den Bergh (2012) find that survey respondents in the Netherlands over-infer potential loss and damage from hypothetical flooding scenarios in that willingness to pay for low-probability flood insurance exceeds the expected value of losses from flooding. In contrast, Hanaoka et al. (2015) provide evidence that risky behaviors such as smoking and drinking increases with the intensity of exposure to earthquakes among Japanese men. Regardless, it is not clear whether changed behaviors stem from changed attitudes toward risk or changed perceptions of risk.

We investigate the exogenous impact of a natural disaster directly on subjective expectations in a developing-country context. We find that individuals who were struck by Cyclone Evan in Fiji in 2012 and who lack social protection over-infer the probability and severity of future risks; however, individuals whose communities provide social insurance do not change their subjective expectations. We find a similar pattern of the impact of disasters on risk aversion: unprotected individuals who are struck by the cyclone become more risk averse while those with social safety nets do not. The next section describes the research context, including the divergent institutional contexts of the two ethnicities in our sample. We then present a conceptual framework that outlines the various mechanisms through which exposure to a natural disaster can influence people's perceptions of similar risks in the future as well as their risk-taking attitudes toward other independent risks. The following section describes our empirical strategy, followed by a detailed description of the sample and summary statistics. We then turn to the results section, which is followed by a comparison of the resulting inferences to likely loss and damage based on disaster modeling. We find that subjective expectations vastly exceed probable risks even under severe climate-change scenarios, suggesting that the welfare implications of over-inference may be substantial if individuals are adjusting their investment behavior in response to their expectations. The last section concludes.

# Context

## Frequent natural disasters

The World World Bank (1995) reports that natural disasters cause average direct losses of US\$284 million in the Pacific each year. With a combined population of fewer than 10 million people, the Pacific is by population the second-most affected world region by natural disasters (Strömberg, 2007) behind Asia, and its losses are the highest in the world on a per-capita basis (World Bank, 1995).

The Fiji Islands consists of more than 300 remote volcanic islands in the South Pacific, of which approximately 100 are inhabited. Like other small island developing states, the Fiji Islands are highly vulnerable to natural disasters (Weir and Virani, 2011; McGree et al., 2014). Between 1983 and 2012, for example, 106 natural disasters were officially recorded for Fiji, costing an estimated USD 1.2 billion (Holland, 2014).

In 2012, three major natural disasters – one 50-year flood,<sup>2</sup> one 25-year flood, and one Category 4 cyclone – ravaged the northern and western parts of Viti Levu, the largest island of Fiji with 60% of the land mass and an equal share of the population. Flooding in January 2012 resulted in 11 deaths and the temporary displacement of 1,300 people while flooding in March 2012 resulted in four deaths and the temporary displacement of 15,000 people. Tropical Cyclone Evan – the strongest cyclone in Fiji’s written record until Cyclone Winston in 2016 – brought peak winds of 230 km per hour in December 2012, destroyed more than 2,000 homes, and temporarily displaced between 11,000 and 14,000 people.

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<sup>2</sup>The terms “a 25-year flood”, “a 50-year flood”, etc. refer to the flood return period and describe the estimated probability of a flood event happening in a given year. That is, a 100-year flood has a 1/100 probability, or 1 percent, of occurring in any given year. These probabilities are estimated using historical weather and hydrological data.

## Institutions in Fiji

Fiji's population of 837,000 is largely comprised of two ethnic groups (Fiji Bureau of Statistics, 2012). *iTaukei* (57% of the total population of Fiji) arrived in Fiji from elsewhere in Melanesia 3,500 years ago. Like other Melanesian peoples, *iTaukei* have complex social structures that provide membership in multiple groups. For example, they are born members of *bito* or *tokatoka* (family clans). Each *tokatoka* is part of a *mataqali* (clan); each *mataqali* is part of a *yavusa* (tribe); and each *yavusa* is part of a *vanua* (a community of people associated with a specific geographic area).<sup>3</sup> Membership in these concentric groups contributes to a social structure that Belshaw (2013, p. 123) calls "collectivist in organization and spirit". Moreover, Belshaw (2013) argues that this quintessential structure has remained in place through the colonial and post-colonial eras despite significant political change and socioeconomic development.<sup>4</sup>

Dakuidreketi (2012) notes that *iTaukei* culture was until recently exclusively oral, and Bridges and McClatchey (2009) observe that Pacific peoples have survived major, unpredictable, and locally devastating disasters over 100+ generations. As McNamara et al. (2013, p.2) write, "This local knowledge in the Pacific, which is deeply embedded in practice and belief systems, is a crucial resource... While this knowledge has been passed down from one generation to another through songs, dance, and sharing practical know-how, it is rarely formally documented" (see also Salick and Ross, 2009).

In the 1880s, the colonial government instituted a legal land-tenure system nominally based on the customary land-tenure system<sup>5</sup> and deeded 87% of all land in Fiji to *iTaukei*

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<sup>3</sup>Belshaw (2013, p. 35) observes that the *iTaukei* village "is a residential unit, conveniently located with respect to land, with a symbolic and ceremonial significance derived from *yavusa* and *mataqali* which make it up, and linked patrilineally with the *yavusa* and *vanua* of neighboring areas. Marriage connections reinforce these links, but spread them beyond into other territories, increasing the reality of social contact and mobility."

<sup>4</sup>Belshaw (2013, p. 114) writes "Kinship organization is essentially unchanged from that 100 years ago."

<sup>5</sup>The colonial Native Lands Ordinance specified that land may be held by *iTaukei* according to "customs as evidenced by usage and tradition". However, Chappelle (1978) argues that the colonial government fundamentally altered the relationship between *iTaukei* and land.

via inalienable customary title. Since 1940, all land not immediately required for maintenance and support has been surrendered to the *iTaukei* Land Trust Board, which administers and negotiates leases and licenses agreements on behalf of the *iTaukei* landowners. This institution embodies the principle of communal tenure while providing a guaranteed stream of income.<sup>6</sup>

Indo-Fijians (38% of the total population) are largely descended from indentured laborers brought to Fiji to work on colonial sugar cane plantations between 1879 and 1916. With the abolishment of indentured labor, many of these workers remained as independent farmers and/or small business holders (Foley, 2005). Fiji's sugar production continues to be dominated by Indo-Fijians, who often live in scattered settlements close to cane fields that are leased from *iTaukei* owners (Kumar and Prasad, 2004).

In contrast with *iTaukei* social organization, De Vries (2002) and Rao et al. (2011) argue that Indo-Fijian society is individualistic and self-reliant. Reddy (2001) surveys a cross section of Fijian society and finds that business is considered to be “high status” among Indo-Fijians and “moderately low” status among *iTaukei*. As such, wage employment among Indo-Fijians is much higher than among *iTaukei* (Kumar and Prasad, 2004), and World World Bank (1995) reports that the vast majority of entrepreneurs are Indo-Fijian. Indeed, of the 11,000 businesses registered in Fiji in 2001, only 100 were owned by *iTaukei* (Rao, 2004).

Literacy rates in India began to grow exponentially in the early colonial period with increased demand for an educated labor force (Naik and Nurullah, 1995). Thus, many Indian emigrants to Fiji were already literate (Dakuidreketi, 2012). Lacking access to *iTaukei* oral histories and to any written records of natural disasters prior to British colonization,

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<sup>6</sup>Indeed, terms for ordinary land owners have improved considerably in recent years. Prior to 2011, 30% of the net value of leases were reserved for heads of *yavusa* and *mataqali*; since 2011, however, land rents are equally distributed to “all living members of the proprietary unit, in equal proportion” (Native Land Trust (Leases and Licenses) (Amendment) Regulations 2010).

Indo-Fijians have a comparatively short historical record of natural disasters in Fiji. For all of the above reasons, it is not surprising that Gawith et al. (2016) conclude that *iTaukei* communities are more resilient to natural disasters than Indo-Fijian in terms of cohesion, social organization, dynamism, and institutional support.

## Conceptual Framework

In this section, we lay out a conceptual framework to frame the discussion of how the exposure to a negative shock such as a natural disaster can influence (i) individuals' perceptions of similar risks in the future and (ii) their attitudes towards other independent risks. The direction of the impact of disaster exposure on subjective expectations of future disasters is ambiguous; table 1 summarizes several common theories of how disasters influence individuals' risk perceptions and the sign of the predicted effect.

Consider first individuals who observe whether a disaster strikes in a given year, and assume that if a disaster does strike, then they observe its magnitude. Under Bayesian learning, these individuals use these observations to update their expectation of experiencing a future disaster as well as how severe it is likely to be (Gallagher, 2014; Gerrig et al., 2011). If individuals use the full information set (i.e. all historical observations), then the effect of a new observation will become small (and eventually zero) as the stock of information increases.

However, individuals may not consider the complete disaster history or they may assign different weights to different observations. For example, psychological research suggests that individuals employ an "availability heuristic," meaning that they in effect determine the weights by the ease with which they can bring an instance to mind (Tversky and Kahneman, 1974). If recent and salient observations are easier to retrieve from memory, then recent exposure to a severe disaster would dramatically increase the expectation of future risks.

Note, however, that the above discussion assumes that disaster probabilities are constant over a long historical period. If disaster probabilities are changing, for example due to climate change, then this assumption might not hold. Forming expectations based solely on more recent observations may then be a rational response to the changing probabilities rather than a manifestation of the availability heuristic.

Individuals who appear to rely heavily on recent observations when forming their expectations could also be subject to a related but subtly different type of bias. Consider an individual who exaggerates the likelihood that a short sequence of *i.i.d.* signals resembles the true probability distribution from which those signals are drawn, or as Rabin (2002) puts it, who believe in the *law of small numbers*. If such an individual is unaware of the true probability of an event, then she would over-infer from the recent occurrence of a disaster and form unrealistically high expectations of future risk frequencies because she believes that the recent short sequence is representative of the true distribution. Conversely, if the person knows the true probability, then she would instead expect the disaster to be *less* likely to happen in the near future since she believes that the anticipated bad event has already happened. We find it more palatable to assume that individuals consider disaster probabilities to be unknown, but in theory both cases are possible. Regardless, the theoretical prediction of exposure to a disaster on perceived future risk frequency is ambiguous.

Evidence from the psychological literature also suggests that emotions can play a determining role in deciding risk perceptions and attitudes. For example, Lerner et al. (2015) find that experimentally-induced fear causes people to express more pessimistic risk perceptions and more risk-averse choices while experimentally-induced anger causes more optimistic risk estimates and more risk-seeking choices. See Lerner et al. (2015) for a thorough review on the broader topic of emotions and decision making. Disasters can plausibly bring out both fear and anger in the victims.

Disasters can also affect individuals' risk attitudes both through reduced wealth or in-

come and by changing perceptions of background risk, thereby influencing an individual's risk-aversion when she faces other independent risks. We call the first type of effect direct impacts: A reduction in wealth and income can make individuals more (less) risk-averse if said individuals' utility functions exhibit decreasing (increasing) absolute risk aversion (DARA/IARA) (Pratt, 1964). However, if the status quo serves as an individual's reference point as suggested by prospect theory (Kahneman and Tversky, 1979), then she would become risk-seeking following a disaster that caused her to lose wealth or income as the loss would have placed her in the "loss domain."

A change in perceived background risk may also affect risk attitudes. When individuals face multiple sources of risk, the risks interact with each other and conventional wisdom suggests that independent risks are substitutes for each other. Gollier and Pratt (1996) prove (within an expected utility framework) that individuals whose utility functions satisfy "risk vulnerability" will consider individual risks as substitutes,<sup>7</sup> implying that any addition of zero-mean background risk to wealth makes risk-vulnerable agents more risk-averse.

Yet another perspective is offered by psychological theories of diminishing sensitivity, which suggest that if the overall risk level is high, people may be relatively less concerned about the addition of a small independent risk (Kahneman and Tversky, 1979). Formally, by introducing probability weighting and using "generalized expected utility functions," Quiggin (2003) provides proof that independent risks are complements rather than substitutes if the generalized expected utility functions satisfy constant risk aversion. Furthermore, if an individual treats her expectations (as opposed to the status quo) as the prospect theory "reference point," (Koszegi and Rabin, 2006; Ericson and Fuster, 2010) then the decrease in expected future wealth and income resulting from increased perceived future risks of a disaster would place her onto a "gain domain". Over the gain domain, individ-

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<sup>7</sup>A von Neumann-Morgenstern utility function is risk vulnerable, if the indirect utility function,  $v(w) = E(w + \tilde{y})$ , where  $w$  is wealth and  $\tilde{y}$  is a risk with non-positive expectation, is more concave than the original utility function.

uals are expected to be risk-averse, not risk-loving. Overall, as summarized in table 2, the theoretical predictions of how a disaster will influence risk-taking attitudes and behavior towards independent risks are also ambiguous. Nevertheless, the empirical evidence on the relationship between background risk and risk attitudes towards independent risks mostly support that higher (perceived) levels of background risk lead to more risk-averse attitude and behavior (Heaton and Lucas, 2000; Guiso and Paiella, 2008; Lusk and Coble, 2008; Cameron and Shah, 2015).

In sum, the ambiguity of these different theoretical predictions mean that we have few a priori expectations about how natural disasters will affect risk perceptions and attitudes. Furthermore, even after empirically observing the sign of the effect, it is difficult to pin down a precise mechanism because multiple channels and assumptions predict effects of the same direction. However, our results nevertheless allow us to provide some meaningful discussion of the underlying mechanisms (see the Conclusion).

## Empirical strategy

Our basic estimation equation is the following:

$$y_{i,k} = \alpha_0 + \alpha_1 * T_{i,k} + \alpha_2 * E_{i,k} + \alpha_3 * T_{i,k} * E_{i,k} + \mathbf{X}'\eta + \delta_k + \varepsilon_{i,k} \quad (1)$$

where  $y_{i,k}$  denotes the outcome variable for household  $i$  in community  $k$ ,  $T_{i,k}$  is an indicator variable for whether or not the household was struck by Cyclone Evan,  $E_{i,k}$  is a dummy variable for ethnicity that equals one for Indo-Fijians,  $\mathbf{X}$  is a vector of baseline controls, and  $\delta_k$  are community dummy variables.

The indicator variable for whether or not a household was struck by Cyclone Evan is defined by loss and damage: a household is treated as being struck by the cyclone if it

suffered material loss and/or damage in the cyclone, and as not struck otherwise.<sup>8</sup> Apart from marriage, there is very little rural-to-rural migration in Fiji: *iTaukei* are tied to ancestral villages and Indo-Fijian farmers primarily work land that is obtained through leases of 30-90 years. There is thus little or no endogenous sorting in this context<sup>9</sup>, and therefore whether or not a household was struck by the cyclone can be viewed as a random event. We believe that errors for individuals belonging to the same community may be correlated (but that they are uncorrelated across communities), and therefore cluster our standard errors at the community level.

## **Outcome variables**

### **Subjective expectations of future losses from natural disasters**

The main outcome variable of interest is average subjective annual expected losses from all natural disasters. This variable derives from an experimental module in the household survey that elicits a probability distribution over future losses. Directly eliciting probabilities can be difficult in poor countries with lower average levels of education because respondents generally have a weaker understanding of probabilities than do respondents in the developed world (Delavande et al., 2011). We overcome this challenge by using visual aids to elicit probability distributions.

Specifically, respondents were asked to estimate the replacement value of their loss and damage from all natural disasters in the worst year that they can imagine.<sup>10</sup> Respondents

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<sup>8</sup>While acknowledging the literature on “loss and damage” (e.g., Mathew and Akter (2015)) “loss” in this manuscript refers primarily to crop losses and “damage” refers to the replacement value of totally or partially destroyed physical assets and to money spent as a result of the disaster. These definitions are consistent with those developed by the US Economic Commission for Latin America and the Caribbean in 1972 subsequently revised by the World Bank, UNESCO, WHO, and others (see for example World Bank (2003)).

<sup>9</sup>See discussion in the next section for more detail.

<sup>10</sup>The question was worded as follows: “Think of the worst year for natural disasters that you can. How much do you think it would cost to rebuild and replace everything that you would lose to natural disasters during such a year (in Fijian dollars)?”

then forecast the number of years that they would be struck by natural disasters in the next 20 years by sorting shells into two piles, one for being struck and one for not being struck. Enumerators provided a brief explanation of probabilities and emphasized the subjective nature of the question to ensure that respondents reported their beliefs rather than trying to guess the “correct” answer.<sup>11</sup>

Based on the respondent’s worst-case expected loss and damage (henceforth “maximum expected value of loss and damage”), five evenly spaced bins were computed and drawn on a board as shown in figure 1. The respondent was then asked to allocate the shells between the bins according to his or her perceived likelihood of occurrence. Using these probabilities, we calculate the average yearly expected loss and damage for each household. Delavande et al. (2011) review evidence from several developing countries and conclude that people generally understand probabilistic questions and that carefully designed questions yield expectations that are useful predictors of future behavior and economic decisions. Other studies have used this methodology to examine farmers’ beliefs about rainfall (see e.g. Lybbert et al., 2007), and McKenzie et al. (2012) use subjective expectations elicitation to explore potential migrants’ beliefs about earnings abroad.

### **Other outcome variables**

We also want to decompose expectations into their component parts: average expected yearly loss and damage is the product of the perceived probability of loss and damage and the magnitude of loss and damage, and it is not *ex ante* clear which is more likely to be

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<sup>11</sup>The module begins by emphasizing that there are no correct answers to this question: “I will now ask you some hypothetical questions about natural disasters. There are no right or wrong answers; I am just asking for your ideas.” The prompt for the number of years was worded as follows: “Over the next 20 years, how many years do you think you will be affected by natural disasters in some way? For example, if you think that natural disasters will affect you in 10 out of the 20 years, it means that you are just as likely to be affected as not affected in any given year. If you say that natural disasters will affect you in 11 out of the next 20 years, this means that it is slightly more likely to happen than to not happen in any given year. If you say that natural disasters will affect you in 20 out of the 20 years, this means that you are sure it will happen every year.”

affected by a natural disaster. We therefore separately examine respondents' maximum expected value of loss and damage and the expected frequency of disasters, each elicited as described in the previous section.

Since individual risk attitudes are important determinants of economic behavior, we also analyze the effects of being struck by Cyclone Evan on risk aversion. Our measure of individuals' willingness to take risks follows Dohmen et al. (2011), who show that questions about willingness to take risks "in general" correlate with experimental measures of risk aversion as well as real-life risky behaviors. In addition, a recent review and test by Chuang and Schechter (2015) shows that answers to survey-based risk-aversion measures remain quite stable over time while experimental measures are only weakly correlated over time.

## **Causality**

The causal interpretation of our results relies on two main assumptions. First, we assume that the likelihood of being struck by the cyclone is exogenous to unobservable characteristics at the household level, i.e. that households that were struck by the cyclone do not systematically differ from those who were not struck. The path of cyclones is difficult to predict, with 72-hour track errors in the range of 300 km Elsberry (2007). In comparison, Viti Levu – similar in size to the Big Island of Hawaii – is nowhere wider than 150 km. Figure 2 presents the paths of cyclones across Viti Levu between between 1969-2009, revealing no obvious patterns. Furthermore, as the section with summary statistics discusses, the affected and unaffected households appear to be similar on observable characteristics.

Second, in many settings, locational preferences and migration are problematic. Risk-averse individuals may choose to live in areas with lower risk of natural disasters or individuals may selectively relocate after being affected by particularly severe storms. In Fiji,

this concern is mitigated by the fact that migrating to rural areas is unusual.<sup>12</sup> Several additional aspects of our data help to further alleviate potential concerns about endogenous sorting: First, data collection began less than two months after Cyclone Evan struck, so any migration response would have had to have been extremely rapid. Moreover, the sampled households were randomly selected from rosters that were based on information that predated the cyclone, and enumerators located all of the heads of the sampled households in the homes in which they lived prior to the cyclone. In addition, 70 percent of the respondents in our data have lived in their current communities for their entire lives, and less than 14 percent have lived in their current community for less than half of their lives. As such, endogenous sorting is highly unlikely to drive our results. Finally, despite these reassuring facts, our preferred estimates control both for respondent age and for the number of years that the respondent has lived in his or her current community.

## Data

The foundation for this study is an extensive socioeconomic survey designed to assess ecosystem-based adaptation to flooding in the Ba and Penang River catchments on Viti Levu, Fiji. Enumerated just two months after Cyclone Evan struck Viti Levu, it also collected information pertaining to damages caused by the cyclone.

### Location of survey sample

Located in north-western Viti Levu (figure 3), Ba is the second largest province in Fiji by area and the largest by population, with 232,000 residents according to the 2007 census (Fiji Bureau of Statistics, 2012). With a largely rural population, sugar production, tim-

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<sup>12</sup>Rural migration outside of marriage is unusual largely because *iTaukei* households belong to communities and Indo-Fijians farm land on long-term leases. See Chandra (2002) for more detail.

ber harvesting, and fishing are important commercial activities, although Narsey (2008) reports that the province-wide poverty rate is 34%. Just under 46,000 people live within the boundaries of the Ba River catchment, one-third of whom are *iTaukei* and the remaining two-thirds of whom are Indo-Fijian.

Neighboring Ra Province has 29,000 residents, 8,300 of whom lived in the Penang River catchment at the time of the census (Fiji Bureau of Statistics, 2012). Approximately 45% of the population is rural, living in scattered rural settlements and villages. Sugar production is the main economic activity, although tourism and cattle rearing are also locally important industries. Narsey (2008) reports that 53% of the population of Ra Province earns less than the poverty line, making Ra the poorest region in the country. Nearly 42% of the population in the Ba River catchment and over two-thirds of the population in the Penang River catchment are *iTaukei*, and virtually all others are Indo-Fijian.

## **Sampling and survey details**

Respondents were drawn from villages (officially recognized entities that are exclusively *iTaukei*) and settlements (loosely organized clusters of houses that are largely occupied by Indo-Fijians) based on a probability sample with both geographic and ethnic stratification. In this way, 295 households from 14 rural villages (58% of all villages in the catchment) and 14 rural settlements (representing approximately 32% of the Indo-Fijian residences in the catchment) were surveyed in the Ba River catchment. Similarly, 74 households from three villages (60% of all villages in the catchment) and five settlements (representing approximately 50% of the Indo-Fijian residences in the catchment) were surveyed in the Penang River catchment. Maps of the villages and settlements are shown in appendix figures B.1 and B.2.

The household survey consisted of questions on demographics, education, and health;

cropping, livestock, fishing, and forestry; labor income, remittances, durable goods, and housing; time allocation; and risk preferences. The survey also included several elements pertaining to the socioeconomic impacts of natural disasters, including Cyclone Evan. In particular, respondents were asked about crop losses, direct damage to housing and assets, and indirect damage in the form of lost labor, money spent on cleaning supplies, medical costs, and money spent on packaged food during evacuation.

The most recent official data on household income comes from the Household Income and Expenditure Survey (Fiji Bureau of Statistics (2008)) and our households appear to be representative of the province populations. For Fiji's Western Division (which includes the Ba and Ra provinces), average rural household income is FJD 9,960. The average household incomes by community based on our survey results were FJD 7,849 in the Ba River catchment and FJD 10,133 in the Penang River catchment. Given that growth of GDP fluctuated between  $-1\%$  and  $2\%$  between 2009 and 2013, that these households were exposed to three major natural disasters in 2012, and that  $25\%$  of Fiji's poor live in Ba Province (Narsey, 2008), our income figures are consistent with the official figures.

## **Summary statistics**

Table 3 provides summary statistics for the correlates of subjective expectations of future losses and household demographic variables. As noted above,  $41\%$  of the sample is comprised of Indo-Fijians. Average wealth among Indo-Fijian households exceeds that of *iTaukei* households by  $84\%$ , consistent with the characteristics of self-reliance described by Rao (2005) and entrepreneurialism described by Rao (2004). The distribution is positively skewed for both ethnicities, with small numbers of *iTaukei* having significant plantations of *yaqona* (a valuable cash crop) and some Indo-Fijians having accumulated significant assets through of-farm businesses.

The mean household has experienced flooding in 1.5 of the previous 12 years, most commonly in 2009. Nearly 90% of household heads are male, the average age of whom is 51 regardless of ethnicity. The average household consists of 4.5 people, and respondents have lived in their communities for over 40 years, again regardless of ethnicity. Both *iTaukei* and Indo-Fijian household heads have completed eight years of schooling, on average. *iTaukei* respondents suffered an average of FJD 4,703 in loss and damage to Cyclone Evan while Indo-Fijians suffered FJD 3,506 in loss and damage, a difference that is not statistically significant.

Figure 4 depicts the distribution of subjective expectations of future losses by ethnicity and whether the household was struck by Cyclone Evan. In general, Indo-Fijians have higher mean subjective expectations of future loss and damage ( $p=0.0000$ ). Additionally, being struck by Cyclone Evan has little bearing on subjective expectations of future loss and damage among *iTaukei*. Among Indo-Fijians, however, being struck by Cyclone Evan shifts up the mean subjective expectation of future loss and damage.<sup>13</sup> We also compare the households that were struck by Cyclone Evan with those that were not on other baseline characteristics and find that the number of flood events in the past 10 years is both statistically and economically significantly different between the two groups<sup>14</sup>, which we address by controlling for past flooding in our preferred estimates. Flooding is also correlated within communities, so community fixed effects are included to soak up some of these differences. Additional details on the balance between the two groups can be found in table A.2.

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<sup>13</sup>A simple t-test of the equality of the mean subjective expectations for *iTaukei* that were and were not struck by Cyclone Evan has a p-value of 0.8997; for the Indo-Fijians the p-value for the same test is 0.0003.

<sup>14</sup>Households who were struck by Cyclone Evan experienced 0.7 more floods than did those who were not struck by the cyclone.

## Results

### Effects of Cyclone Evan on expected future losses

Tables 4-5 are structured as follows: Column (1) shows the results from a parsimonious regression that controls only for the household's physical assets and ethnicity. Physical assets are a key control variable since asset ownership provides an upper bound on how much a household could foreseeably lose. Column (2) adds community fixed effects while column (3) additionally controls for the number of floods that the household experienced in the past ten years<sup>15</sup>. The number of past flood events proxy for the level of background risk that households face, and as such, are an important control variable when examining subjective expectations. Finally, column (4) adds household demographics and other control variables, including the age and education of household head and land ownership.

As noted in our empirical strategy, the ethnicity dummy variable is very weakly identified once we introduce community fixed effects because all but two of the sample communities are ethnically homogeneous. However, the interaction between the indicator variable and variables that vary within community (i.e. how the impact of these community-varying variables on the outcome variable varies by ethnicity) can be estimated. To make this point, table A-A.1 shows the results from a regression of respondents' expected loss and damage on a dummy variable for whether the household was struck by Cyclone Evan. Once community fixed effects are introduced in column (2), the coefficient on the ethnicity dummy, which is large and significant in column (1), diminishes and becomes statistically indistinguishable from zero. Importantly, the coefficients on Cyclone Evan and physical assets do not change substantially with the inclusion of community fixed effects, nor once past

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<sup>15</sup>The past flooding events were elicited using the following question: "In which of the last 10 years have members of this household been affected by flooding other than the January 2012 flood, the March 2012 flood, and flooding caused by Cyclone Evan?" The questionnaire then asked specific questions about the January and March floods, as the impacts of these floods was the main purpose of the survey. The variable that we use here includes the January and March floods.

flooding is accounted for in column 3, nor when additional covariates are introduced in column (4).

Table 4 shows the impacts of being struck by Cyclone Evan on expected future loss and damage and how this effect varies by ethnicity. Panel A shows the regression coefficients from OLS estimation of equation 1, and Panel B shows the marginal effects of being struck by Cyclone Evan separately for *iTaukei* and Indo-Fijians. Our preferred results are shown in column (4), which includes both community fixed effects and household demographic controls, but it is worth noting that the estimated impact of the cyclone is fairly consistent across specifications. Indo-Fijians who were struck by the cyclone expect to lose about FJD 5,400 more per year from natural disasters over the next 20 years than do Indo-Fijian households who were not struck,<sup>16</sup> an amount equivalent to roughly 14 percent of current Indo-Fijian household assets. Thus, the impact is both statistically and economically significant.

## **Frequency or magnitude?**

These results raise questions about how expectations are formed and which components of subjective expectations are likely to be affected by exposure to natural disasters. This section thus explores the impact of Cyclone Evan on both the frequency with which households expect to experience loss and damage from natural disasters and the maximum expected value of loss and damage in any given year.

In Panel A of table 5, we present results for whether being hit by Cyclone Evan impacts the number of years that respondents expect to incur loss and damage from natural disasters. The differences between the two ethnicities persists: *iTaukei* do not significantly alter their beliefs about how frequently they will be affected while Indo-Fijians who were struck by

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<sup>16</sup>At the time of the survey, FJD 5,400 corresponded to about USD 3,000.

Cyclone Evan believe that they will incur losses roughly two additional years out of the coming twenty. Since the sample average is 11 years out of 20 (9 for *iTaukei* and 13 for Indo-Fijians), the increase for Indo-Fijians is close to 15% of the sample average.

Panel B of table 5 shows how Cyclone Evan affects households' maximum expected value of loss and damage. The effects here are substantial both in statistical and economic terms: being struck by Cyclone Evan increases an Indo-Fijian respondent's maximum expected loss and damage by more than FJD 12,000 while being struck by Cyclone Evan does not significantly change the perceptions of *iTaukei* households. Thus, being struck by Cyclone Evan impacted both components of households expected yearly losses, i.e., both the expected frequency and the expected magnitude of loss and damage.

Another way in which natural disasters may affect individuals is via risk attitudes. As discussed in the introductory section, there is no consensus in the literature on the size or even the direction of this effect. Panel C of table 5 reports the marginal impacts of being struck by Cyclone Evan on respondents' agreement with the statement "In general, I am willing to take risks," a common method of eliciting general risk preferences via survey questions. Given that Chuang and Schechter (2015) report that survey-based measures of risk aversion tend to be very stable over time, we anticipated little impact on this variable, but the effects are large. The question was elicited using a sliding scale from -100 to 100 on which respondents self reported using tablet computers, and the effect for Indo-Fijians is a 30-point difference (a 15 percentage-point change). For *iTaukei* respondents, we detect no statistically significant effect of Cyclone Evan on risk attitudes.

## **Extensions**

*iTaukei* estimate that they will incur \$4,381 in losses and damages to natural disasters in each of the next 20 years, on average; for Indo-Fijians, this figure is \$15,044. The empirical

loss and damage (including crop losses, direct losses, and indirect losses) for the three major natural disasters that impacted residents of the Ba and Penang River catchments in 2012 are shown in table 6.

The mean total loss and damage from Cyclone Evan is FJD 4,703 for *iTaukei*, 7% above the mean subjective expectation of future annual losses. That is, *iTaukei* respondents expect to be affected by a natural disaster of similar magnitude to a category IV cyclone in each of the subsequent 20 years. Among Indo-Fijians, the mean subjective expectation of future annual loss and damage is 430% of the empirical total loss and damage from Cyclone Evan of FJD 3,506.

To evaluate the veracity of these apparently high subjective expectations, we model damages from different flood regimes in the Ba and Penang River catchments; we focus on flooding rather than cyclonic activity because flood regimes are well understood and flood models are better developed. Specifically, we employ the US Army Corps of Engineers Hydrologic Engineering Center's River Analysis System HEC-RAS<sup>17</sup> using the US Army Corps of Engineers' HEC-GeoRAS extension to facilitate the transfer of information between ArcGIS and HEC-RAS. Channel geometry data is developed and cut in to an existing 25m digital elevation model (PacRIS, 2013) to run a steady-flow analysis across each catchment. Manning's N values – surface roughness coefficients used to estimate the amount of friction that must be overcome to enable water to flow over the surface – for each land-use type in the catchment are estimated from Arcement and Schneider (1989), Aldridge and Garrett (1973), Schneider et al. (1977), and Hicks and Mason (1991), and range from 0.04 for marginal floodplains and stream beds to 0.18 for closed upland forests.

The model is calibrated to match the empirical extent of the January 2012 flood (a 1-in-50 year flood) and March 2012 flood (a 1-in-20 year flood). Following calibration, the

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<sup>17</sup>This hydrological model has been used to estimate flood magnitudes and flood control options in the Pacific, including New Caledonia (Terry and Wotling, 2011) and Samoa (Woodruff, 2008).

model is used to estimate flood extent under a range of flood regimes. We use the flood height and damage figures from these two events to construct non-linear flood exceedance probability curves for 1-in-500 (0.2% chance of a flood in any given year), 1-in-200 (0.5%), 1-in-100 (1%), 1-in-50 (2%), and 1-in-20 (5%) year events for each of the villages surveyed. The baseline 1-200 and 1-in-500 events were respectively assumed to cause four and eight times the damage of the 1-in-50 year event.

Catchments are highly idiosyncratic geographic features; therefore, the estimated damages under each type of flood regime is reported by ethnicity and catchment in table 7. Under these estimates, *iTaukei* households in the Ba River catchment would have to experience flooding that is more severe than a 1-in-100 flood every year to meet their subjective expectations of future losses (assuming no other natural disasters strike the household in any given year). *iTaukei* households in the Penang River catchment would have to experience flooding that is more severe than a 1-in-200 flood every year, again assuming that no other natural disasters strike the household in any given year. Analogously, Indo-Fijian households in the Penang River catchment would have to experience flooding nearing the intensity of a 1-in-500 year flood each year to meet their subjective expectations while those in the Ba River catchment would have to experience 1-in-500 year flooding event and a tropical storm akin to Cyclone Evan.

Lata and Nunn (2012) report that awareness of climate change among Fijians in the Rewa River Delta of Viti Levu is very low, although it may be possible that survey respondents in the Ba River and Penang River catchments have internalized climate change projections in their subjective expectations of future loss and damage. That is, Australian Bureau of Meteorology and CSIRO (2014) project that a 1-in-20-year daily rainfall event in Fiji will become, on average, a 1-in-4-year event under Relative Concentration Pathway 8.5 by 2090. However, even if climate change shifts flood return periods by two (i.e., if a 1-in-100 year flood occurs every 20 years), then extreme flooding events would still need

to occur every year to survey respondents' expected losses.<sup>18</sup>

## Conclusion

We hypothesize that objective probabilities and magnitudes of future risks should not differ by exposure to a single idiosyncratic shock. To test whether there are belief-biases that lead to a gap between baseline risks and perceived risks, we use the December 2012 Cyclone Evan as a natural experiment to identify the impact of direct experience on subjective expectations. A unique finding in our study is that the impact of shocks on subjective expectations differs sharply for the two ethnic groups in the sample.

Specifically, the effect of being struck by Cyclone Evan on subjective expectations among Indo-Fijian respondents aligns with previous studies such as Cameron and Shah (2015) in that being struck increases future expectations of loss and damage over the next 20 years. Similar to Cameron and Shah (2015), we find that such pessimistic beliefs are accompanied by a shift in risk attitudes toward risk aversion. Furthermore, we disentangle the subjective expectation of future disasters into perceived frequency and perceived magnitude, finding substantial effects on both margins. In contrast, being struck by Cyclone Evan affects neither *iTaukei* respondents' expectations about future disaster risk nor their risk attitudes.

The conspicuously "collectivist" social structure of *iTaukei* may explain the distinctive results as the concentric circles of relationships provide *iTaukei* with well-functioning risk-sharing networks. On the one hand, *iTaukei* households who did not suffer direct loss and damage may have nevertheless experienced the shock through their risk-sharing networks, and hence, when they are asked to consider future risk, the recent cyclone is as salient

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<sup>18</sup>Moreover, Australian Bureau of Meteorology and CSIRO (2014) report a high level of confidence in models that show 10-40% reductions in the number of cyclones in the south-east basin of the Pacific.

in their memory as it is for those who were struck directly. On the other hand, because risk-sharing networks are strong for *iTaukei* and because the land-tenure system provides an underlying income guarantee for *iTaukei* but not for Indo-Fijians, *iTaukei* society is better placed to absorb idiosyncratic shocks. Thus, we might expect that natural disasters invoke less “fear” in *iTaukei* than in Indo-Fijians, and therefore induces a smaller “treatment effect” on their risk perceptions.

Another possibility is that *iTaukei* are closer to standard Bayesian learners than Indo-Fijians because they have long oral histories regarding natural disasters while Indo-Fijians rely on the much shorter written record (Dakuidreketi, 2012). That is, because *iTaukei* oral history not only records occurrences of natural disasters but also practical knowledge for enduring such hardship (McNamara and Prasad, 2013), exogenous shocks may have lesser influence on the beliefs of *iTaukei* than those of Indo-Fijians.

To provide welfare implications for our results, we use climate and hydrological models to predict future disaster risk, allowing us to determine whether surveyed households over-infer risk based on new information provided by Cyclone Evan. Regardless of whether or not they suffered material loss and damage from Cyclone Evan, we find that both ethnic groups over-infer the risk of future disasters relative to baseline predictions and that over-inference is especially acute among Indo-Fijians. Victims’ distorted beliefs may prevent optimal take-up of insurance and may encourage over-investment in preventative measures and/or under-invest in productive activities. Understanding culture-specific belief biases may thus help decision makers to consider policy instruments that might reduce such inefficiencies, particularly in the face of changing disaster profiles under climate change.

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Table 1: **How Exposure to a Disaster Influences Perceived Future Risks**

<b>Theory</b>	<b>Assumption</b>	<b>Frequency</b>	<b>Magnitude</b>
Bayesian learning	Full information	Approx. 0	Approx. 0
	Availability heuristic	>0	>0 if severe
Law of small numbers	Known probability	<0	N/A
	Unknown probability	>0	N/A
Emotion	Fear	>0	>0
	Anger	<0	<0

Table 2: **How Exposure to a Disaster Influences the Extent of Risk Aversion**

<b>Channel</b>	<b>Theory</b>	<b>Assumption</b>	<b>Prediction</b>
Direct loss	Expected utility theory	Utility function: DARA	>0
	Prospect theory	Reference point: status quo	<0
	Emotion	Fear Anger	<0 >0
Perceived risk	Expected utility theory	Risk vulnerable	>0
	Diminishing sensitivity	N/A	<0
	Prospect theory	Reference point: expectation	>0

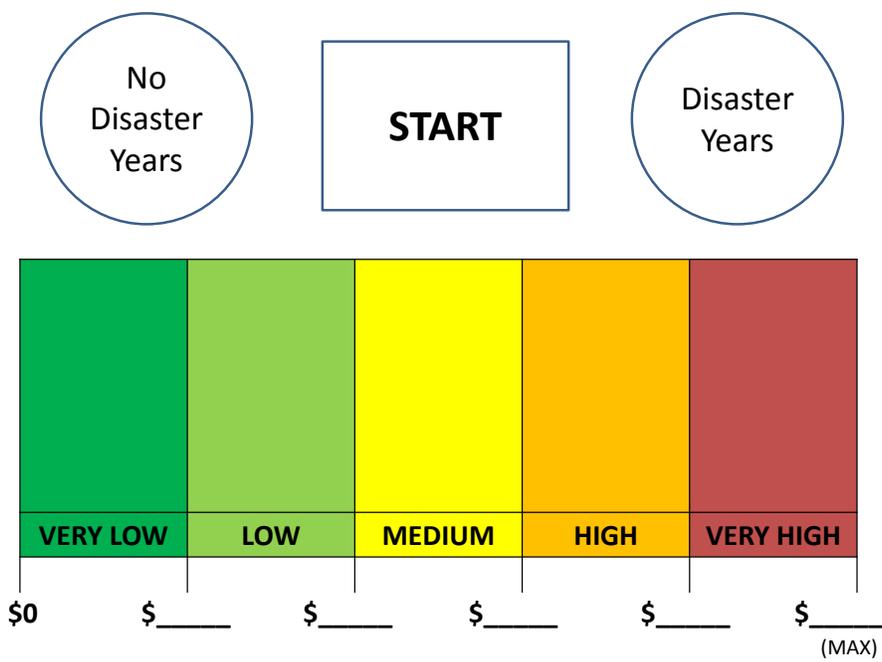
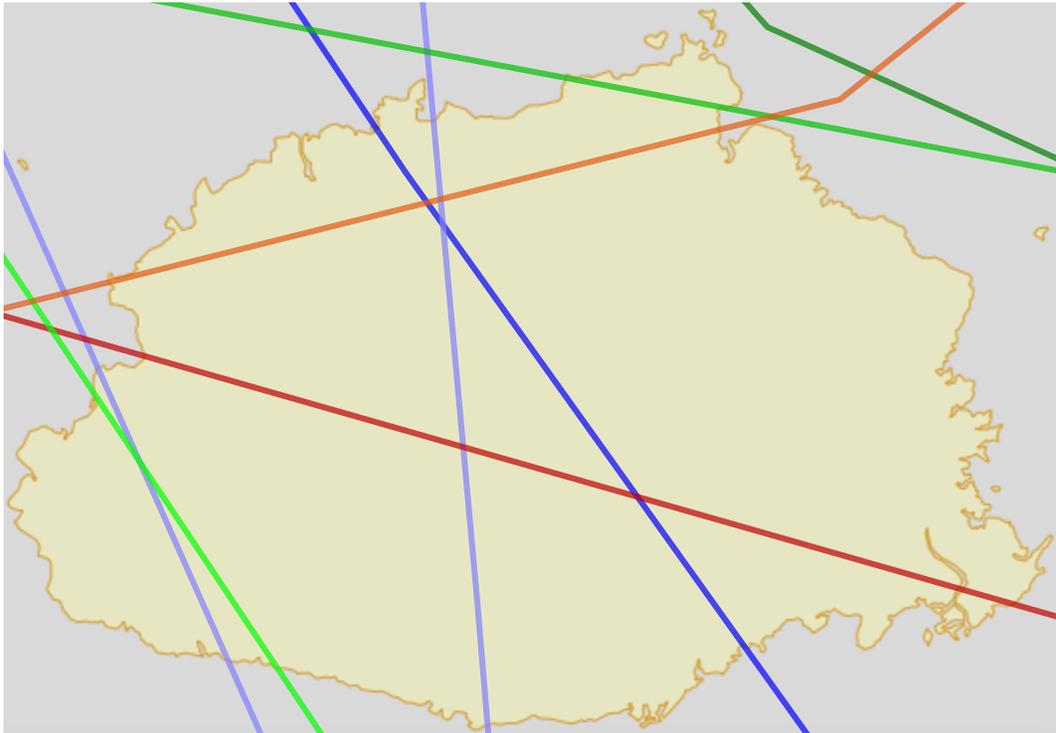


Figure 1: Subjective expectations board



**Figure 2: Cyclone paths crossing Viti Levu, Fiji, 1969-2009**

*Source: Australian Bureau of Meteorology, 2016*

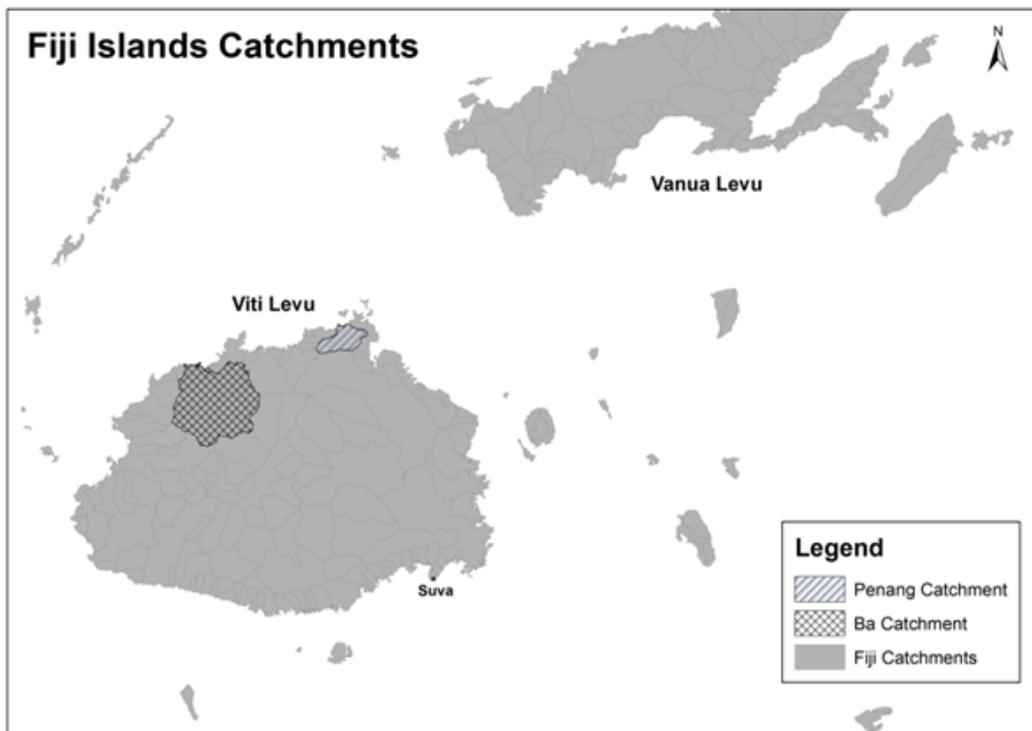


Figure 3: Location of sample catchments

Table 3: **Summary Statistics**

	Overall mean	<i>iTaukei</i>	Indo-Fijians
Is household Indo-Fijian? (0/1)	0.41	0	1
Wealth (FJD)	28248.30	20964.25	38647.25
Nr. of floods that hit household in past 10 years	1.45	1.11	1.94
Age of household head	51.53	51.73	51.24
Household head male? (0/1)	0.89	0.89	0.89
Education of household head	8.27	8.32	8.19
Household size	4.52	4.60	4.40
Nr. of years household head has lived in village	43.34	44.77	41.31
Amount of own land (acres)	2.13	3.52	0.15
Total damages from Cyclone Evan (FJD)	4210.37	4703.47	3506.41

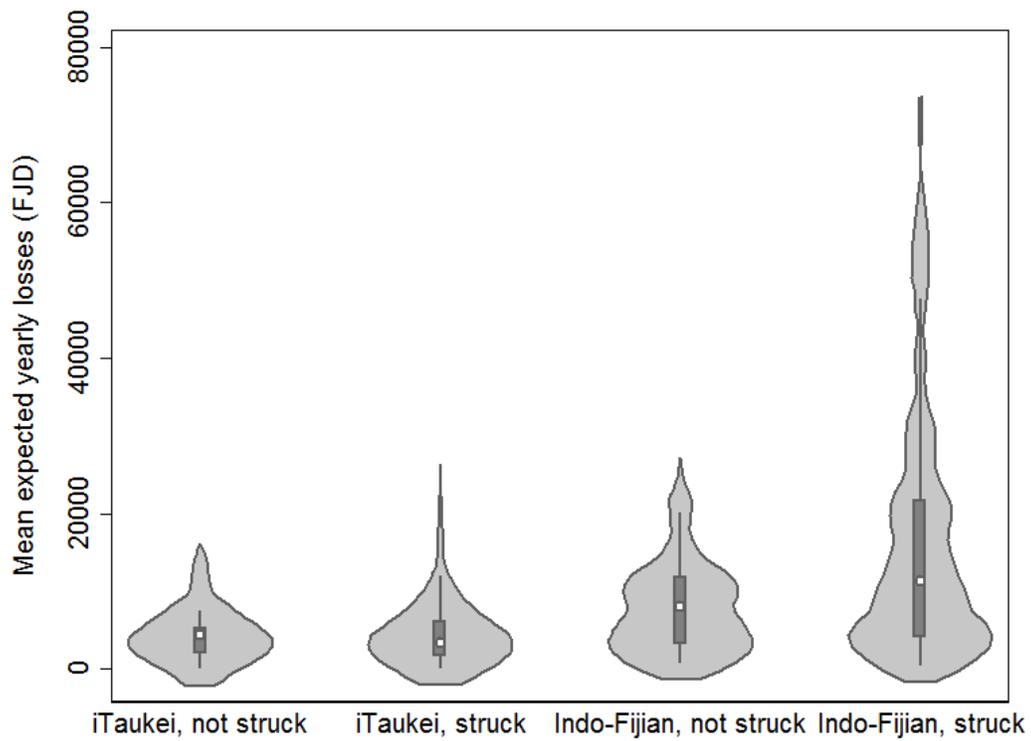


Figure 4: **Distributions of subjective expected losses by Cyclone Evan damage and ethnicity**

**Table 4: Effect of Being Struck by Cyclone Evan on Subjective Expectations of Future Damages, Interacted with Ethnicity**

*Dependent variable: Mean expected damages*

<b>Panel A</b>	(1)	(2)	(3)	(4)
Struck by cyclone (0/1)	-35.01 (838.3)	935.1 (985.0)	609.5 (1014.6)	457.2 (1085.6)
Indo-Fijian (0/1)	3272.3** (1493.5)	-5086.9 (4159.0)	-4258.4 (4323.3)	-5512.9 (4060.9)
(Indo-Fijian) x (Cyclone)	4505.2** (1917.5)	5421.6** (2412.3)	3915.8 (2467.1)	4953.4* (2713.7)
Value of physical assets (FJD)	0.198*** (0.0353)	0.214*** (0.0360)	0.208*** (0.0376)	0.202*** (0.0379)
Number of floods			1096.7** (436.1)	1127.0** (456.7)
Nr. of years lived in community				16.93 (33.40)
Male household head (0/1)				-368.9 (2170.0)
Age of household head				67.27 (53.72)
Household size				216.1 (228.7)
Years of education, hh head				287.9 (176.2)
Land leased (hectares)				94.24 (151.5)
Land owned (hectares)				-80.83 (138.8)
Engaged in cropping activities (0/1)				-2589.3 (3078.6)
Constant	253.5 (1033.8)	7237.7** (3315.7)	5791.0 (3541.5)	1263.6 (4234.6)
Community FE?	NO	YES	YES	YES
<b>Panel B – marginal effects</b>				
Marginal effect of Evan, <i>iTaukei</i>	-35.0 (838.3)	935.1 (985.0)	609.5 (1014.6)	457.2 (1085.6)
Marginal effect of Evan, Indo-Fijian	4470.1** (1705.1)	6356.7*** (2198.5)	4525.3** (2279.0)	5410.6** (2670.9)
<i>N</i>	369	369	369	367
adj. <i>R</i> <sup>2</sup>	0.426	0.462	0.479	0.479

Standard errors in parentheses; standard errors are clustered by community

\* p<.1, \*\* p<.05, \*\*\* p<.01

Panel B reports the F-test for joint significance of Cyclone Evan and its interaction with ethnicity

Table 5: Effect of Cyclone Evan on Alternative Outcome Variables

	(1)	(2)	(3)	(4)
<b>Panel A – Nr. of years out of 20 hh expects to incur losses from disasters</b>				
<i>Marginal effect of Evan, iTaukei</i>	-1.23 (1.71)	-1.70 (1.87)	-1.84 (1.86)	-1.65 (1.84)
<i>Marginal effect of Evan, Indo-Fijian</i>	1.64* (0.97)	2.23** (1.08)	1.44 (1.20)	2.38** (1.22)
<b>Panel B – Value of losses from all natural disasters in worst possible year</b>				
<i>Marginal effect of Evan, iTaukei</i>	-290.7 (2731.8)	4762.0* (2508.9)	4215.7 (2571.2)	3043.1 (2885.9)
<i>Marginal effect of Evan, Indo-Fijian</i>	10448.4*** (2860.5)	14141.2*** (4563.7)	11068** (4453.0)	12267.7** (4639.5)
<b>Panel C – Extent of agreement with the statement “In general, I am willing to take risks.” Scale: -100 to 100</b>				
<i>Marginal effect of Evan, iTaukei</i>	8.09 (6.25)	4.0 (8.2)	5.0 (8.1)	2.1 (9.4)
<i>Marginal effect of Evan, Indo-Fijian</i>	-24.5*** (9.0)	-37.3*** (4.8)	-31.8*** (7.4)	-30.7** (12.6)

Standard errors in parentheses; standard errors are clustered by community

\* p<.1, \*\* p<.05, \*\*\* p<.01

Column (2) controls for community FE; column (3) adds number of past floods;  
column (4) includes full set of covariates

**Table 6: Mean Empirical Damage from Three Natural Disasters in 2012, in FJD**

	<b>Jan 2012 flood</b>	<b>March 2012 flood</b>	<b>Cyclone Evan</b>	<b>Expected annual loss</b>
<i>iTaukei</i>	1,446	526	4,703	4,381
Indo-Fijian	1,594	1,183	3,506	15,044

**Table 7: Projected Loss and Damage under Different Flood Regimes, by Ethnicity and Catchment, in FJD**

	<b>1-in-20 year flood</b>	<b>1-in-50 year flood</b>	<b>1-in-100 year flood</b>	<b>1-in-200 year flood</b>	<b>1-in-500 year flood</b>
<b>Ba River catchment</b>					
Avg. <i>iTaukei</i> hh	519	1,636	3,272	6,544	13,089
Avg. Indo-Fijian hh	866	1,403	2,805	5,610	11,221
<b>Penang River catchment</b>					
Avg. <i>iTaukei</i> hh	678	986	1,972	3,943	7,887
Avg. Indo-Fijian hh	1,250	2,178	4,355	8,710	17,421

**Table A.1: Effect of Being Struck by Cyclone Evan on Subjective Expectations of Future Damages**

*Dependent variable: Mean expected damages*

	(1)	(2)	(3)	(4)
Struck by cyclone (0/1)	1970.7*	3255.4**	2229.7*	2334.6*
	(980.2)	(1314.3)	(1219.0)	(1337.7)
Indo-Fijian (0/1)	7145.0***	32.00	-595.2	-660.1
	(1180.1)	(3766.5)	(3913.0)	(3173.0)
Value of physical assets (USD)	0.202***	0.218***	0.210***	0.205***
	(0.0351)	(0.0358)	(0.0375)	(0.0377)
Number of floods			1159.7***	1173.9**
			(414.8)	(436.1)
Nr. of years lived in community				15.96
				(34.09)
Male household head (0/1)				-286.4
				(2165.3)
Age of household head				65.75
				(55.16)
Household size				204.5
				(230.5)
Years of education, hh head				287.6
				(175.0)
Land leased (hectares)				107.2
				(148.7)
Land owned (hectares)				-66.31
				(146.7)
Engaged in cropping activities (0/1)				-1896.1
				(3087.8)
Constant	-1587.7	5010.9	4135.1	-1219.2
	(1289.5)	(3595.3)	(3682.9)	(4365.3)
Community FE?	NO	YES	YES	YES
<i>N</i>	369	369	369	367
adj. <i>R</i> <sup>2</sup>	0.423	0.458	0.478	0.476

Standard errors in parentheses; standard errors are clustered by community

\*  $p < .1$ , \*\*  $p < .05$ , \*\*\*  $p < .01$

Table A.2: **Balance Test**

	<b>Mean, not struck</b>	<b>Mean, struck</b>	<b>Difference</b>	
Is household Indo-Fijian? (0/1)	0.46	0.41	0.0509	(0.64)
Wealth (FJD)	23077.21	28984.74	-5907.5	(-1.54)
Nr. of floods that hit household in past 10 years	0.78	1.54	-0.762***	(-5.03)
Age of household head	52.13	51.44	0.688	(0.41)
Household head male? (0/1)	0.76	0.91	-0.146**	(-2.23)
Education of household head	7.93	8.31	-0.381	(-0.76)
Household size	4.04	4.59	-0.542*	(-1.79)
Nr. of years household head has lived in village	38.85	43.98	-5.138	(-1.52)
Amount of own land (acres)	2.47	2.08	0.387	(0.58)

*t* statistics in parentheses

\*  $p < .1$ , \*\*  $p < .05$ , \*\*\*  $p < .01$

**Table A.3: Effect of Cyclone Evan on Expected Frequency of Future Damages**  
*Dependent variable: Number of years household expects to experience losses from natural disasters*

<b>Panel A</b>	(1)	(2)	(3)	(4)
Struck by cyclone (0/1)	-1.229 (1.709)	-1.703 (1.870)	-1.843 (1.864)	-1.648 (1.802)
Indo-Fijian (0/1)	0.615 (1.893)	-5.907*** (1.950)	-5.549*** (1.977)	-5.985*** (1.990)
(Indo-Fijian) x (Cyclone)	2.868 (1.987)	3.937* (2.158)	3.287 (2.234)	4.026* (2.227)
Value of physical assets (USD)	0.00000106 (0.0000100)	0.00000484 (0.0000104)	0.00000221 (0.00000962)	0.00000364 (0.00000893)
Number of floods			0.474** (0.229)	0.515** (0.250)
Nr. of years lived in community				-0.0114 (0.0256)
Male household head (0/1)				1.516 (0.992)
Age of household head				0.0219 (0.0439)
Household size				-0.0280 (0.174)
Years of education, hh head				-0.0518 (0.136)
Land leased (hectares)				0.0512 (0.0700)
Land owned (hectares)				-0.0725 (0.153)
Engaged in cropping activities (0/1)				-2.518** (1.231)
Constant	10.98*** (1.671)	17.36*** (1.687)	16.73*** (1.735)	16.62*** (3.361)
Community FE?	NO	YES	YES	YES
<i>N</i>	369	369	369	367
adj. <i>R</i> <sup>2</sup>	0.084	0.116	0.129	0.134

Standard errors in parentheses; standard errors are clustered by community

\* p<.1, \*\* p<.05, \*\*\* p<.01

Panel B reports the F-test for joint significance of Cyclone Evan and its interaction with ethnicity

**Table A.4: Effect of Cyclone Evan on Maximum Losses from Natural Disasters**  
*Dependent variable: Value of losses from natural disasters in worst possible year*

<b>Panel A</b>	(1)	(2)	(3)	(4)
Struck by cyclone (0/1)	-290.7 (2731.8)	4762.0* (2508.9)	4215.6 (2571.2)	3043.1 (2885.9)
Indo-Fijian (0/1)	8869.3** (3970.8)	6542.1 (5799.1)	7932.5 (5700.4)	3232.4 (6197.3)
(Indo-Fijian) x (Cyclone)	10739.1*** (3820.6)	9379.1* (5164.1)	6852.4 (5031.0)	9224.5* (5066.1)
Value of physical assets (USD)	0.773*** (0.136)	0.828*** (0.135)	0.817*** (0.141)	0.808*** (0.142)
Number of floods			1840.4* (938.7)	1896.1** (898.9)
Nr. of years lived in community				115.2 (75.81)
Male household head (0/1)				-5167.8 (4702.2)
Age of household head				63.16 (125.1)
Household size				630.4 (714.4)
Years of education, hh head				428.6 (501.1)
Land leased (hectares)				156.1 (365.6)
Land owned (hectares)				-564.0 (363.0)
Engaged in cropping activities (0/1)				-3667.7 (4285.3)
Constant	232.2 (3647.5)	-9392.1** (3770.5)	-11819.8*** (3499.3)	-15333.7** (7037.3)
Community FE?	NO	YES	YES	YES
<i>N</i>	369	369	369	367
adj. <i>R</i> <sup>2</sup>	0.576	0.620	0.625	0.626

Standard errors in parentheses; standard errors are clustered by community

\* p<.1, \*\* p<.05, \*\*\* p<.01

Panel B reports the F-test for joint significance of Cyclone Evan and its interaction with ethnicity

**Table A.5: Effect of Cyclone Evan on Risk Aversion**

*Dependent variable: How strongly does the respondent agree with the statement “In general, I am willing to take risks.”*

<b>Panel A</b>	(1)	(2)	(3)	(4)
Struck by cyclone (0/1)	8.090 (6.248)	4.040 (8.187)	5.019 (8.133)	2.111 (9.396)
Indo-Fijian (0/1)	14.12 (10.94)	32.37 (22.34)	29.88 (22.63)	20.27 (22.56)
(Indo-Fijian) x (Cyclone)	-32.57*** (11.07)	-41.32*** (9.779)	-36.79*** (11.27)	-32.85* (16.21)
Value of physical assets (USD)	0.0000980 (0.000107)	0.0000498 (0.000134)	0.0000681 (0.000124)	0.0000703 (0.000122)
Number of floods			-3.298 (2.790)	-2.911 (2.933)
Nr. of years lived in community				-0.325* (0.183)
Male household head (0/1)				-5.639 (6.488)
Age of household head				0.593 (0.358)
Household size				0.818 (1.584)
Years of education, hh head				-1.523 (1.506)
Land leased (hectares)				-0.241 (0.723)
Land owned (hectares)				-2.314* (1.290)
Engaged in cropping activities (0/1)				7.430 (12.67)
Constant	63.60*** (5.635)	58.36*** (20.97)	62.71*** (21.01)	62.93** (24.82)
Community FE?	NO	YES	YES	YES
<i>N</i>	369	369	369	367
adj. <i>R</i> <sup>2</sup>	0.017	-0.028	-0.023	-0.008

Standard errors in parentheses; standard errors are clustered by community

\* p<.1, \*\* p<.05, \*\*\* p<.01

Panel B reports the F-test for joint significance of Cyclone Evan and its interaction with ethnicity

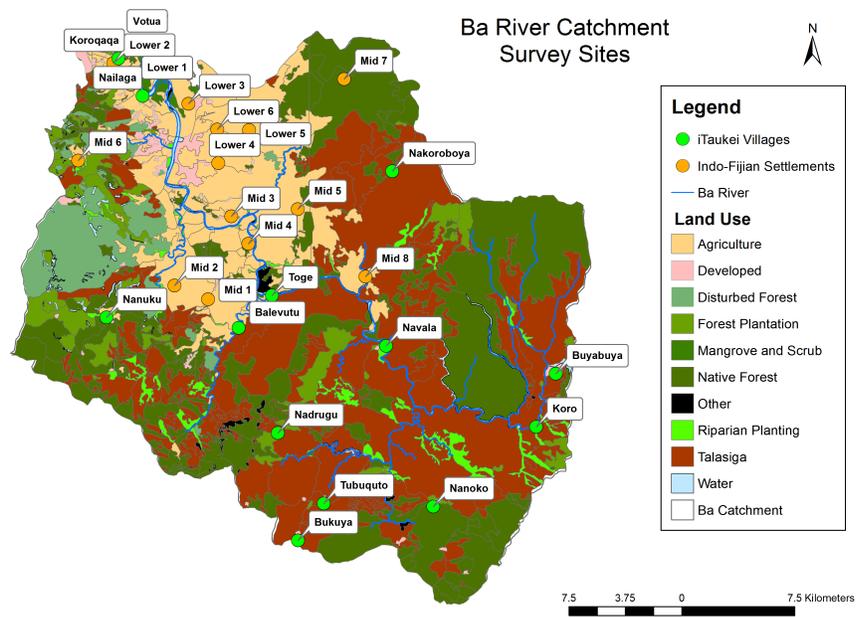


Figure B.1: Map of survey sites, Ba River Catchment

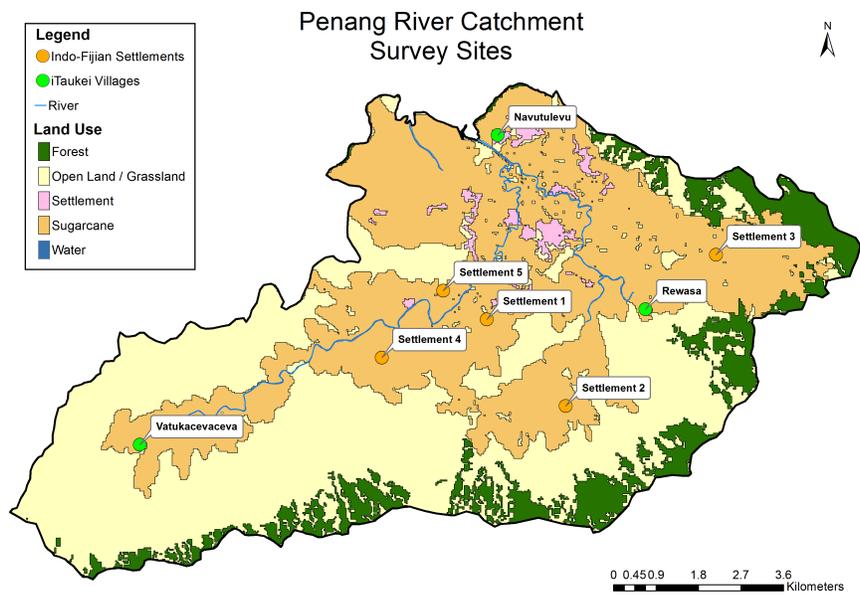


Figure B.2: Map of survey sites, Penang River Catchment