AUSTRALIAN AGRICULTURAL & RESOURCE ECONOMICS SOCIETY

Does community resilience mitigate disaster damages? Evidence based on survey data

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Contributed paper prepared for presentation at the 59th AARES Annual Conference, Rotorua, New Zealand, February 10-13, 2015

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Abstract

Policy makers view community resilience as a critical component of adaptation to climate change, and considerable energy has been devoted to defining resilience at a conceptual level. Less energy has been spent to empirically analyse the effect of community resilience on the financial impacts of disasters on individuals. In this paper, we use detailed surveys of households in Fiji to develop a composite index of community resilience and then to evaluate the extent to which community resilience mitigates losses and damages caused by disasters. We find that resilience is negatively correlated with damages to housing and assets and with indirect damages (over which human intervention may reduce damages), but not with crop losses (over which intervention is less effective), suggesting that resilience may be operationalised to efficiently limit impacts. We further find that this result holds for a cyclone (about which communities had plenty of advance warning) but not for river flooding (for which respondents had little advanced warning), suggesting that early warning is a necessary condition for community resilience to become responsive.

Keywords

Resilience; Natural Disasters; Early Warning; Fiji

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1. Introduction

Natural disasters affected 232 million people, killed over 100,000 people, and caused more than US$ 100 billion worldwide in damages each year between 2001 and 2010, on average (Guha-Sapir *et al*., 2011). The number of natural disasters recorded per year has increased markedly since 1940 (Munang *et al*., 2013), and it is likely that anthropogenic climate change will contribute to further increases in the number of natural disasters over the coming century (Preston *et al*., 2006; Bates *et al*., 2008). Increasing communities' resilience has been touted as a key strategy for managing increased disaster risk under climate change (e.g., Tompkins and Adger, 2004; Tompkins 2005; Boyd *et al*. 2008; Tompkins *et al*. 2010; Leichenko; Nelson, 2011; Wise *et al*. 2014).

The term 'resilience' originated in the physical sciences, where it is used to describe a material's ability to "store strain energy and deflect elastically under a load without breaking or being deformed" (Gordon, 1979).[1] The term was first adapted for ecology by Holling (1973) to describe the capacity of species and ecosystems to endure stress (Klein *et al.*, 2003; Norris *et al.*, 2008; Nelson, 2011). It is now also commonly used to describe the capacity of social systems to rebound from stressors (Brooks *et al.*, 2005) as well.

Resilience may be conceptualised with reference to 'basins of attraction' that describe the tendency of systems to settle toward equilibria. Most systems have multiple equilibria, meaning that there exist numerous configurations to which the social system may converge depending on the nature and magnitude of a given perturbation. Walker *et al.* (2004) define resilience as the capacity of a system to maintain the current equilibrium, i.e., to withstand perturbations. In contrast, Adger *et al.* (2005), Folke (2006), and Gallopín (2006) emphasise the potential for systems to re-organise and to change their structures in response to disturbances, i.e., to shift to other equilibria.[2] Similarly, Chapin *et al.* (2009, p. 24) define resilience as the capacity of a social system "to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity, and feedbacks through either recovery or reorganization in a new context". These conceptual differences notwithstanding, resilient social systems are those that are robust to disturbances of different types and magnitudes.

While a great deal of scientific attention has been devoted to conceptualising social resilience, only a handful of studies have focussed on measuring resilience using indicators or indices. For example, Kaly *et al*. (2004) and Aalbersberg (2011) each propose indicators of community resilience, but neither applies those indices to evaluate the resilience of study communities. In contrast, Cutter *et al.* (2014) develop a resilience indicator and subsequently measure the relative resilience of US counties. This investigation takes an additional step by assessing whether resilience affects the impacts of natural disasters on vulnerable communities, and if so, by how much.

Specifically, our approach is to use survey microdata to construct indicators of resilience in 36 Fijian communities that were exposed to multiple severe natural disasters in 2012. We then compare average damages incurred in more and less resilient communities to calculate the role of resilience in mitigating losses and damages. Because some forms of losses and damages are virtually unavoidable in hydro-meteorological natural disasters (e.g., crop losses), we evaluate several categories of losses and damages, including crop losses, direct damages (e.g., damages to housing

[1] This definition reflects its Latin origin – *resiliere*, meaning 'to jump back'.
[2] Indeed, Gallopín (2006) notes that the existence of multiple equilibria distinguishes the concept of resilience from that of vulnerability.

and assets), and indirect damages (e.g., lost wages and purchased clean-up supplies). Moreover, because resilience matters most when communities have time to take concerted action (Barnett, 2001; Ganor and Ben-Lavy, 2003; Comfort, 2005; Longstaff, 2005),[3] we compare the effectiveness of resilience in reducing the losses and damages associated with flooding (which came virtually without warning) to that in reducing the losses and damages associated with a tropical cyclone (about which residents were notified several days in advance). If resilience is an important mitigant of losses and damages, then more resilient communities should incur fewer losses and less damage from cyclones than from flooding.

In this paper, we first introduce the physical, social, and economic characteristics of the study sites on Viti Levu, Fiji. The impacts of a large flood in January 2012 and Cyclone Evan in December 2012 are then described. Details of the household surveys are provided in the third section, along with the calculation of event losses and damages, the construction of the community resilience index, and the structure of the regression analysis. Results of the study are then presented, followed by discussion and conclusions.

2. Study Sites

The Fiji Islands are remote and prone to climate-related disasters. According to Neumayer *et al*. (2014), the frequency of natural disasters in places such as Fiji is likely to encourage private and public investment in disaster reduction and damage mitigation, implying that such communities may be more resilient than similar communities elsewhere. In contrast, Maru *et al*. (2014) observe that remote, disaster-prone communities are chr onically disadvantaged and may in fact be less resilient than other communities. In the case of Fiji, Barnet and Campbell (2010) and McMillen *et al*. (2014, p. 1) side with Neumayer *et al*. (2014), noting the Pacific's "long history of resilience to environmental variability".

Our study sites are the Ba and Penang river catchments located on Fiji's largest island, Viti Levu (Figure 1). The Ba River runs north from its headwaters in the central, mountainous parts of Viti Levu, spilling into the Pacific near the village of Nailaga. 'Ba' is also the name given to the province, a tikina (an administrative area comprising several towns and/or villages), and a prominent town. The population of the Ba district is predominantly rural and generally poor, with 34% of residents below the poverty line (Narsey, 2008). Some 45,879 people live within the boundaries of the Ba River catchment, most of them in Ba Town and downstream, where flooding is a particular risk. Flooding was recorded on the Ba River in 1871, 1892, 1918, 1931, 1938, 1939, 1956, 1964, 1965, 1972, 1986, 1993, 1997, 1999, 2009, and 2012 (McGree et al. 2010). Tropical cyclones have also caused substantial losses of crops, property, and life in the province.

Bordering Ba Province on the east, Ra Province is comparatively small, with just 29,464 residents at the time of the 2007 census. Approximately 15% of the population lives in Rakiraki Town, its only urban settlement, with the remaining 85% living in scattered rural settlements and villages. Overall, 53% of the population of Ra Province live below the poverty line (Narsey, 2008), suggesting that this population may be especially vulnerable to disasters (Maru et al., 2014). The Penang River is the district's main waterway and flows approximately 1 kilometre outside Rakiraki Town. While the Penang River is considerably smaller than the Ba River, flooding and forced

[3] Norris *et al.* (2008, p. 140) observe that during natural disasters, "People need accurate information about the danger and behavioural options, and they need it quickly".

evacuations in recent years have prompted the Rakiraki provincial administrator to call for proposals to divert the river and/or to relocate Rakiraki Town (Fiji Ministry of Information, 2012).

Two thirds of the population in Ba province are of Indo-Fijian ethnicity, largely descended from indentured labourers brought to Fiji to work on colonial sugar plantations. The remaining one-third are iTaukei , i.e., indigenous Fijians. In the Penang catchment, nearly 70% of the population is ethnically iTaukei while just over 30% are Indo-Fijian (Fiji Bureau of Statistics, 2012b). iTaukei hold 87% of the land in Fiji via inalienable customary title; in contrast, Indo-Fijians lease the right to farm land from iTaukei owners, generally working for wages or growing cash crops on land leased from iTaukei owners (Kumar and Prasad, 2004).

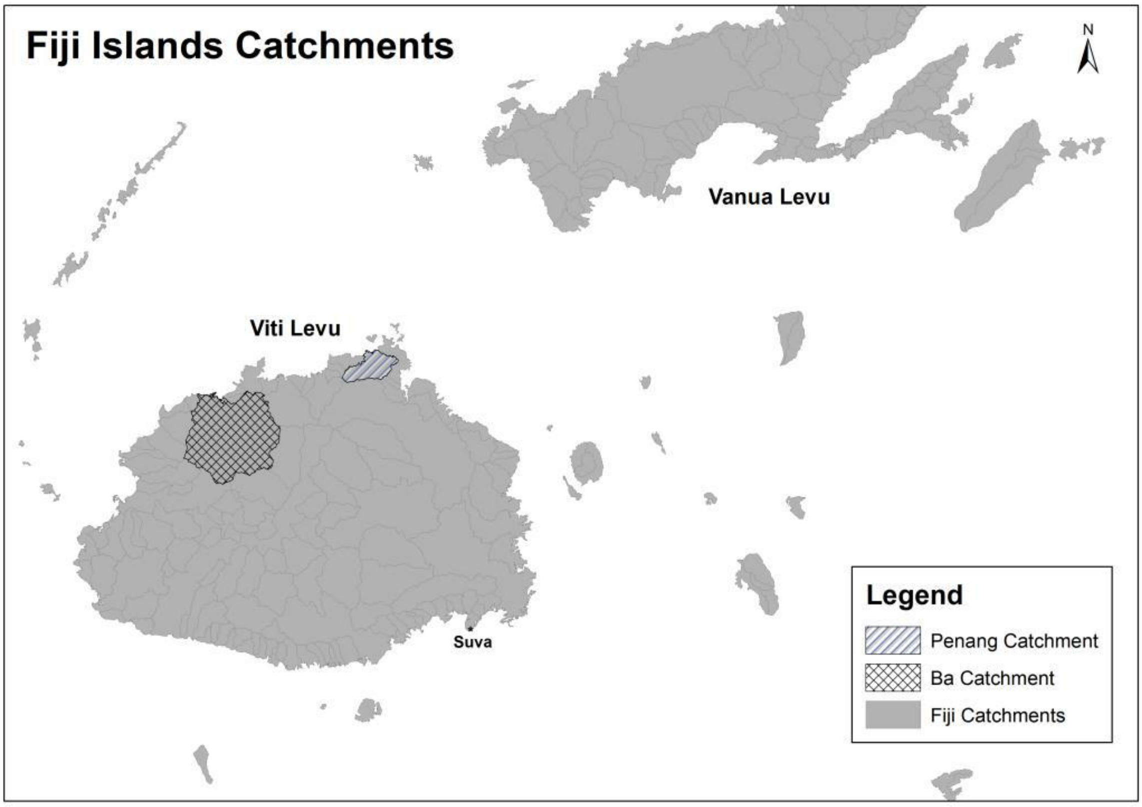

Figure 1: Locations of the Ba and Penang River catchments in the Fiji Islands

Weather-related disasters caused considerable losses and damages in Fiji in 2012. Between 21 January and 12 February, 2012 the districts of Nadi, Ba, and Ra recorded flooding that killed 11 people, temporarily displaced 1,300 people, and caused FJ$36.4 million and FJ$12.2 million in losses and damages for the Ba and Penang River catchments, respectively (Brown *et al*., 2014). Difficulties in flood forecasting compounded by sparse monitoring and poor topological information meant that the average community was alerted only five hours prior to the arrival of the January 2012 flood (Figure 2). Poor early warning systems are reflected in the method of warning: 37% of communities in our study were first alerted to the pending flooding by storm clouds, high humidity, and rising waters; in contrast, 54% of respondents were alerted via television, radio, and/or internet sources (Brown *et al*., 2014). With such short notice, preparations for flooding were generally limited to evacuating.

In December 2012, Tropical Cyclone Evan destroyed more than 2,000 homes, temporarily displaced between 11,000 and 14,000 people, and caused an estimated FJ$194.9 million in losses and damages (Simmons and Mele, 2013; SPC and SOPAC, 2013). Many of the phenomena that lead to tropical cyclones are well understood, and recent developments in forecasting allow meteorologists to predict the movement and speed of cyclones with increasing levels of precision. In contrast to the January flooding, more than 90% of respondents received warnings via radio, television, and/or internet sources (Brown *et al*., 2014). As a result, communities were aware of the trajectory of Cyclone Evan more than 45 hours before its arrival, on average (Figure 2). With such lengthy warnings, households were able to move or secure household goods, to cut branches and/or trees that may cause damage, to reinforce roofing, to shutter windows and doors, to buy provisions, to evacuate, and – importantly – to help their neighbours to do the same.

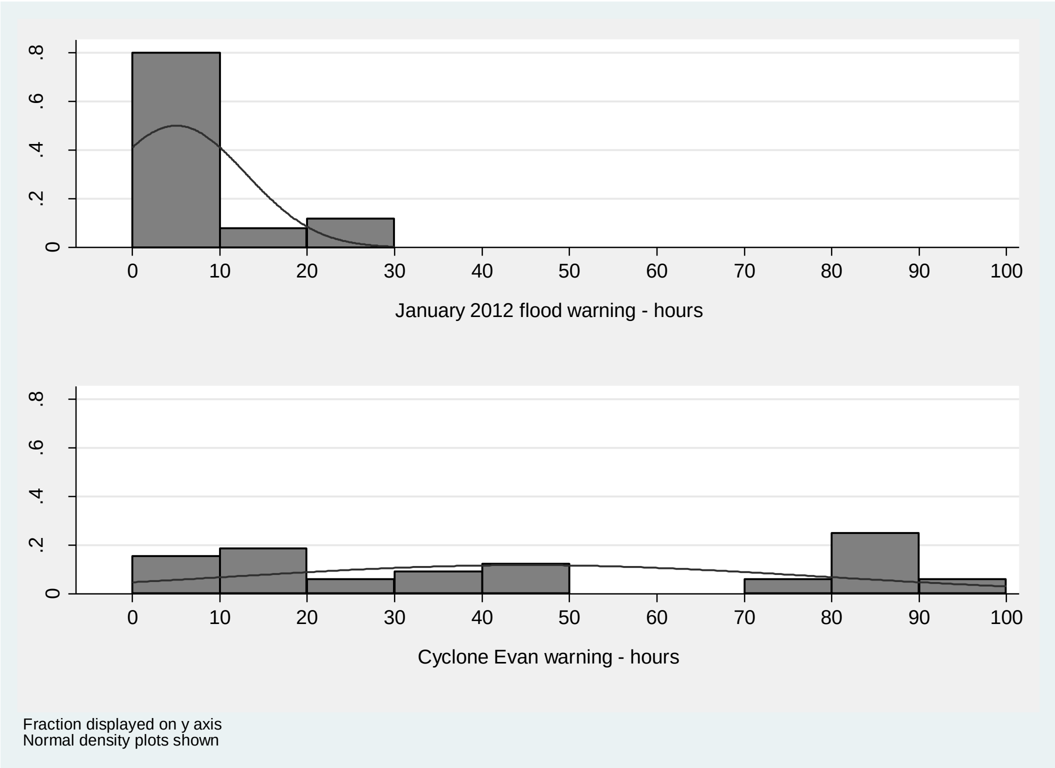

Figure 2: Early warning for each disaster by community

3. Methods

The backbone of this study is an extensive socioeconomic survey that quantifies the direct and indirect impacts of the January 2012 floods and Cyclone Evan in the Ba and Penang river catchments. Respondents were drawn from villages (officially recognised entities that are exclusively *iTaukei*) and settlements (loosely organised clusters of houses that are largely Indo-Fijian) based on a probability sample. In this way, 295 households from 14 villages (58% of those registered in the catchment) and 14 settlements (representing approximately 32% of the Indo-Fijian population) were surveyed in the Ba catchment. Similarly, 74 households from three villages (60% of those in the catchment) and five settlements (50% of those in the catchment) were surveyed in the Penang catchment.

The household surveys were administered on tablet devices and consisted of questions on demographics, education, and health; cropping, livestock, fishing, and forestry; labour income, remittances, durable goods, and housing; and time allocation. The surveys also contained a section on community resilience in which respondents were asked the extent to which they agreed with statements such as “The community has the skills and knowledge to limit the damage from natural disasters”. Answers to these questions were entered by respondents themselves, reducing the risk of responses based on social desirability. Responses were entered on a Likert scales with ‘strongly disagree’ on one end of the scale, ‘strongly agree’ on the other, and 199 gradients in between, allowing for greater flexibility and nuance than the usual 5-point Likert scale (Lozano, *et al*. 2008). Scores above (below) zero indicate agreement (disagreement), with higher scores indicating stronger agreement and lower scores indicating stronger disagreement. Responses to these questions were then used to construct a composite index of community resilience per Adger (2000).

Composite indices use mathematical formulae to produce a single metric based on a combination of theory, pragmatism, intuitive appeal, data availability, empirical analysis, simplicity, reliability, validity, and comparability (Booysen, 2002). They are useful for understanding resilience insofar as they integrate a number of individual indicators[4] into a single metric (Booysen, 2002; Sullivan *et al.*, 2003; Sullivan and Meigh, 2005). As such, composite indices are politically appealing, are commonly used to bridge gaps between social-scientific understanding and policy (Jing and Leduc, 2010), and have been used to measure vulnerability, adaptability, and resilience to natural disasters (Mayunga, 2007; Cutter *et al.*, 2014).

Cutter *et al*. (2014) argue that community resilience to natural disasters is derived from six forms of capital[5], although Aalbersberg (2011) has concluded that social and human capital are the primary determinants of resilience in the Pacific.[6] Hence, we focus on these two forms of capital. Specifically, the composite index of resilience used in this study comprises six general ‘domains’, four for social capital and two for human capital. Social capital is measured by ‘cohesion’, ‘cooperation’, ‘social organisation’, and ‘institutional support’. Cohesion enhances resilience by enabling communities to draw together during times of stress (Aalbersberg, 2011). Similarly, social organisation describes the extent to which community members already work together on group decision making (Aalbersberg, 2011). Cooperation is important insofar as communities that are more inclined to work together to achieve objectives are generally more resilient (Davidson, 2006). Institutional support provides a further indicator of resilience as it describes the presence of inter-organisational networks and support structures that can assist in developing the functional workings of communities and offer support during recovery from disasters (Norris *et al.*, 2008).

Human capital is represented by the domains of ‘capability’ and ‘dynamism’ in the community resilience index. Capability was assessed through respondents’ views about the ability of their communities to navigate challenges and to draw on traditional knowledge (Folke *et al.*, 2006; Mayunga, 2007). The ability to learn, change systems, and adapt – referred to as ‘dynamism’ – is an additional aspect of capability (Barnett, 2001) and is evaluated through respondents’ attitudes toward risk and views about the community’s attitude toward new ways of solving problems. Table 1 lists the survey questions that are reflected in each domain.

Empirical values from the survey questions were combined to form composite index values. To ensure that composite indices reflect the relative importance of individual indicators, weightings

[4] Individual indicators of resilience are often highly interdependent (Aalbersberg, 2011), and thus of little use in inferential analysis. As such, Mayunga (2007) argues that resilience measures must move beyond focusing on particular indicators or dimensions.
[5] Specifically: social capital; economic capital; housing and infrastructure capital; institutional capital; community capital; and environmental capital.
[6] Aalbersberg (2011) suggest that social and human capital are the most important determinants of adaptive capacity (used synonymously with resilience in this context) in the Pacific.

are often assigned to individual measures during aggregation. However, there is considerable debate as to whether indicators should be weighted. For example, Booysen (2002) observes that any attempt at weighting indicators can be criticised, and Babbie (1995) and Atkinson *et al.* (2003) argue that not applying weightings should be the standard approach.

Table 1. Domains, survey questions and implicit weightings that make up the community resilience index

Domain	Survey Questions	Unweighted Domains	Weighted Domains
Capability	Traditional practices and knowledge are important for solving current problems.	0.056	0.056
	The village/community does have the skills and knowledge to limit the damage from natural disasters such as flooding and drought.	0.056	0.056
	The people of this village/community have control over our future.	0.056	0.056
Cohesion	The village/community holds meetings to deal with issues in the village/community.	0.056	0.167
Cooperation	People in this village/community work together to solve problems.	0.056	0.042
	There are conflicts among people of this community.	0.056	0.042
	I can depend on individuals in this village/community to help me during difficult times.	0.056	0.042
	I can rely on groups in this village/community for assistance when times are difficult.	0.056	0.042
Social Organisation	Village/community members are involved in decision-making about the future of the village/community.	0.056	0.042
	Women are involved in making important decisions in the village/community.	0.056	0.042
	Young people are involved in making important decisions in the village/community.	0.056	0.042
	The leadership of this village is effective.	0.056	0.042
Dynamism	The village/community looks for new ways to solve problems.	0.056	0.042
	The village/community is able to identify new ways to solve problems.	0.056	0.042
	The village/community has used new ways to limit the damage from natural disasters such as flooding and drought.	0.056	0.042
	In general, I am willing to take risks.	0.056	0.042
Institutional Support	I can depend on the government for help during difficult times.	0.056	0.083
	Organizations (other than government) outside this village/community can be relied upon for help when I have problems.	0.056	0.083

Note: All questions are written in the positive for simplicity, although approximately one-third appeared in the negative form in the survey to reduce concerns of yea-saying.

In order to test sensitivity to different weightings, we constructed two composite indices – one with equal weightings applied to the individual indicators (which we term 'unweighted') and one with equal weightings applied to each domain (which we term 'weighted'). In the first approach, differing distributions of responses for each question means that indicators will have different impacts on the overall index score (Mayunga, 2007). The second approach produces weights for each indicator depending on the number of indicators in each domain. These implicit weights are likely to have minor effects relative to the explicit weighting of variables. Therefore, depending on whether the individual indicators or the domains in which they are placed are considered to better represent resilience, either approach could be seen to align with the suggestions of Babbie (1995) and Atkinson *et al.* (2003).

Despite the advantages of using indices described above, composite indices have come under wide criticism. Uncertainty stems from imperfect or incomplete data collection, subjective weighting, simplification of complex dimensions, and site specificity (Booysen, 2002). In a broader sense, the selection of indicators remains arbitrary as our understanding of the dimensions of resilience is incomplete (Alkire and Foster, 2011). Indeed, Klein *et al.* (2003, P. 41) suggest that converting resilience from a concept to an operational tool is "a challenge that thirty years of academic debate does not seem to have resolved". Given these limitations, we employ indices simply to provide an understanding of the relative resilience of communities in the Ba and Penang river catchments; we make no claim to measure resilience in absolute terms.

We use the survey data in a multiple regression framework to understand the relationship between resilience and disaster impacts. Specifically, we regress losses and damages from natural disasters on the composite index of resilience. Because personal assets are highly correlated with potential losses, losses are measured as a share of household wealth (for robustness, we also regress losses in levels on the composite index of resilience).

Resilience is measured as the average resilience score across all households in the community, commensurate with the recommendations of Adger (2000). Because community resilience is influenced by economic resources (Mayunga, 2007), we control for community wealth in our analysis. In addition, our empirical approach controls for the highest level of education attained by any household member (because more educated households may have access to better information for mitigating the adverse effects of natural disasters), the length of time that the household has been part of the community (because more established households may receive differential treatment from neighbours during emergencies), and the gender and age of the respondent (because different household members may have different access to information about damages caused by disasters).

Our multiple regression approach also controls for ethnicity because the structure of *iTaukei* and Indo-Fijian communities – and thus their ability to endure hardship caused by natural disasters – are highly distinct. For example, *iTaukei* Fijians are born members of *tokatoka* (family clans). Each *totaktoka* is part of a *mataqali* (clans); each *mataqali* is part of a *yavusa* (tribe); and each *yavusa* is part of a *vanua* (a community of people associated with a specific land area). Individual *iTaukei* typically identify with each of these larger entities: for example, it is common for *iTaukei* to introduce themselves by identifying their *yavusa*, *mataqali*, and *tokatoka*. In contrast, Indo-Fijian communities lack such inclusive community structures.[7]

Models are estimated using tobit estimators to account for lower bounds equal to zero (both for losses and damages as a share of wealth and for total losses and damages) with heteroskedasticity-robust standard errors. Next, to further isolate the potential endogeneity of wealth to community resilience, we estimate separate models for crop losses, direct damages to housing stock and assets, and indirect damages under the hypothesis that resilience affects damages that may be influenced by human intervention (i.e., direct and indirect damages) better than losses where human intervention is ineffectual (i.e., crop losses). To further test this hypothesis, we compare the magnitudes of the different types of damage caused by Cyclone Evan (for which there was nearly two days' warning, on average) and to those caused by the January flooding (for which little warning was available).

[7] In addition, *iTaukei* own most land while Indo-Fijians lease farm land from *iTaukei* owners. Finally, assets are largely considered to belong to individual households in the Indo-Fijian community and to the community as a whole among *iTaukei*. Belshaw (1964) and Kumar and Prasad (2004) provide additional detail on the organisational structures of different Fijian communities.

4. Results

Table 2 shows descriptive statistics for potential correlates of reported damage incurred by natural disasters, including community wealth, household education, the length of time that household members have resided in the community, and the gender and age of the survey respondent. The mean household owns FJ$ 27,532 in housing, durables, and liquid assets. Its highest educated members have 11.4 years of schooling and its longest-residing members have spent 46.1 years in the community. Nearly two-thirds of respondents are male, and the average age is 45.2.

Table 2: Covariates of damage by ethnicity

	All Households		***iTaukei***		**Indo-Fijian**		
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Difference**
Average community wealth (FJ$)	27,532.60	(15,669.59)	17,022.93	(6,089.98)	42,536.53	(12,649.10)	***
Highest education in household (years)	11.38	(2.28)	11.16	(1.99)	11.69	(2.62)	**
Length of time in this community (years)	46.13	(17.82)	47.73	(16.40)	43.86	(19.51)	**
Male respondent (dummy)	0.64	(0.48)	0.66	(0.48)	0.63	(0.49)	
Respondent age (years)	45.20	(13.67)	45.54	(13.72)	44.71	(13.62)	

Notes: Differences are tested using two-sided t-tests. * $p<0.10$, ** $p<0.05$, and *** $p<0.01$

Indo-Fijian households hold over 50% more wealth than *iTaukei* households, on average, statistically significant at the 1% level. This difference is consistent with the contrasting systems of social support available to each group, i.e., Indo-Fijians are not born into the complex, overlapping social support groups to which *iTaukei* automatically belong and are thus individually responsible for insuring against risk. Indo-Fijian households are slightly more educated, with the mean highest household education 0.53 years higher than for *iTaukei* households, a difference that is statistically significant at the 5% level. The mean length of time that *iTaukei* households have spent in their communities is 3.87 years longer than Indo-Fijian households, a difference that is statistically significant at the 5% level. The sex and age of respondents is statistically indistinguishable between ethnicities in the survey.

Summary statistics for flood and cyclone damages are shown in Table 3. Damages were greater during Cyclone Evan than during the January floods for both *iTaukei* and Indo-Fijian households. For both ethnicities during both events, crop losses made up more than 90% of total losses and damages, followed by direct damage; indirect damages were small. Crop losses for Indo-Fijian households are statistically indistinguishable from those for *iTaukei* households for the January flooding. However, the mean crop losses associated with Cyclone Evan are nearly FJ$ 2000 lower for Indo-Fijian households, a difference that is statistically significant at the 5% level and a result that is consistent with the land tenure system described above. Direct damages were more than FJ$ 100 higher in Indo-Fijian households than in *iTaukei* households during the January floods and more than FJ$ 450 higher in Indo-Fijian households during Cyclone Evan, differences that are statistically significant at the 10% and 1% levels, respectively. Indirect damages were higher among Indo-Fijian households than *iTaukei* households by more than FJ$ 40 during the January floods and more than FJ$ 70 during Cyclone Evan, differences that are both statistically significant at the 1% level.

Table 3: Crop losses, direct losses, and indirect losses by ethnicity

		All Households		*iTaukei*		Indo-Fijian		
	Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Difference**
January 2012 Flood	crop losses (FJ$)	1366.61	(4353.60)	1431.12	(5215.84)	1274.52	(2694.77)	
	direct losses (FJ$)	51.10	(542.59)	8.29	(65.44)	112.20	(839.62)	*
	indirect losses (FJ$)	22.82	(105.54)	5.97	(45.06)	46.88	(152.49)	***
Cyclone Evan	crop losses (FJ$)	3847.05	(9295.13)	4640.71	(11481.22)	2713.99	(4450.18)	**
	direct losses (FJ$)	244.47	(930.27)	56.08	(404.42)	513.42	(1323.37)	***
	indirect losses (FJ$)	36.25	(99.75)	6.54	(26.35)	78.66	(142.04)	***

Notes: Differences are tested using two-sided t-tests. * p<0.10, ** p<0.05, and *** p<0.01

Components of the community resilience index are described in Table 4, Figure 3, and Figure 4. Specifically, Table 4 shows the mean and standard deviation for each of the six domains by ethnicity; it also indicates both the unweighted composite index score and the weighted composite index score. The full distribution for each measure of resilience is shown via histograms in Figure 3. These distributions are summarised in Figure 4, which captures differences in mean scores across the six domains of resilience by ethnicity using an amoeba diagram. Overall, survey respondents report high levels of cohesion and dynamism, with mean scores of 54.4 and 49.6, respectively, on the -100 to +100 scale. Capability shows the lowest overall mean at 6.4.[8] The mean unweighted resilience index score is 31.5 while the mean weighted resilience index score is 33.4.

Table 4: Six domains comprising the community resilience index by ethnicity

	All Households		*iTaukei*		Indo-Fijian		
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Difference**
Capability	6.36	(38.61)	-0.08	(33.87)	15.56	(42.98)	***
Cohesion	54.41	(61.14)	73.49	(37.68)	27.16	(76.20)	***
cooperation	27.22	(35.14)	26.15	(30.24)	28.76	(41.18)	
social organisation	28.72	(46.41)	47.43	(34.28)	2.01	(48.44)	***
Dynamism	49.57	(39.26)	58.45	(34.24)	36.89	(42.47)	***
institutional support	34.09	(51.02)	44.25	(43.63)	19.58	(57.10)	***
resilience indicator, unweighted	31.47	(24.78)	37.79	(19.70)	22.45	(28.32)	***
resilience indicator, weighted	33.40	(26.67)	41.62	(20.12)	21.66	(30.32)	***

Notes: Differences are tested using two-sided t-tests. * p<0.10, ** p<0.05, and *** p<0.01

iTaukei communities score higher than Indo-Fijian communities in terms of cohesion, social organisation, dynamism, and institutional support. For example, the mean score for cohesion among *iTaukei* communities is 73.49, some 46 points higher than the mean score in Indo-Fijian communities, a difference that is statically significant at the 1% level. The mean score for social organisation is similarly high in *iTaukei* communities vis-à-vis Indo-Fijian communities, also significant at the 1% level. Indeed, *iTaukei* communities report statistically higher levels of dynamism and institutional support as well as overall resilience, whether unweighted or weighted. In contrast, the mean score for capability in Indo-Fijian communities exceeded that in *iTaukei* communities by

[8] Capability was assessed using respondents' perceptions on their community's ability to control future outcomes and to limit damages; the low scores may reflect the occurrence of multiple weather-related disasters in the recent past coupled with high levels of poverty in each catchment.

15.6 points, also significant at the 1% level. Scores for cooperation are statistically indistinguishable across ethnicities.

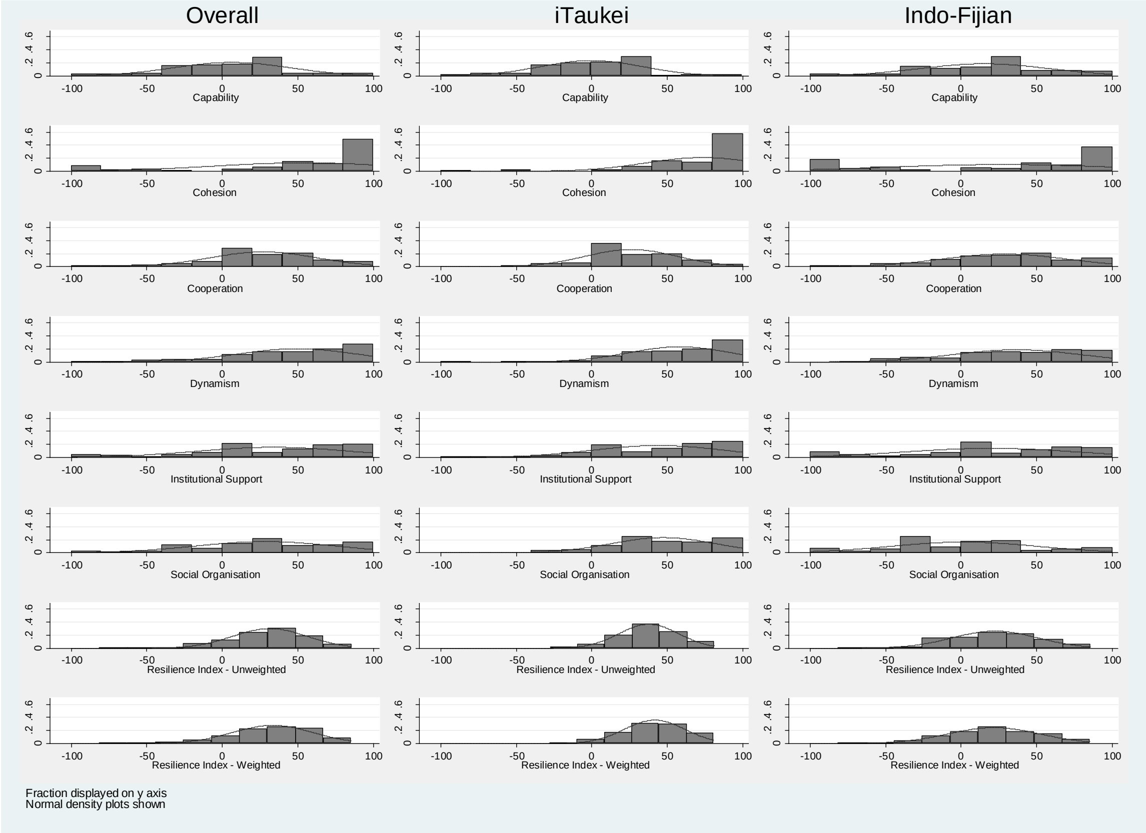

Figure 3: Empirical distribution of scores across domains of resilience by ethnicity

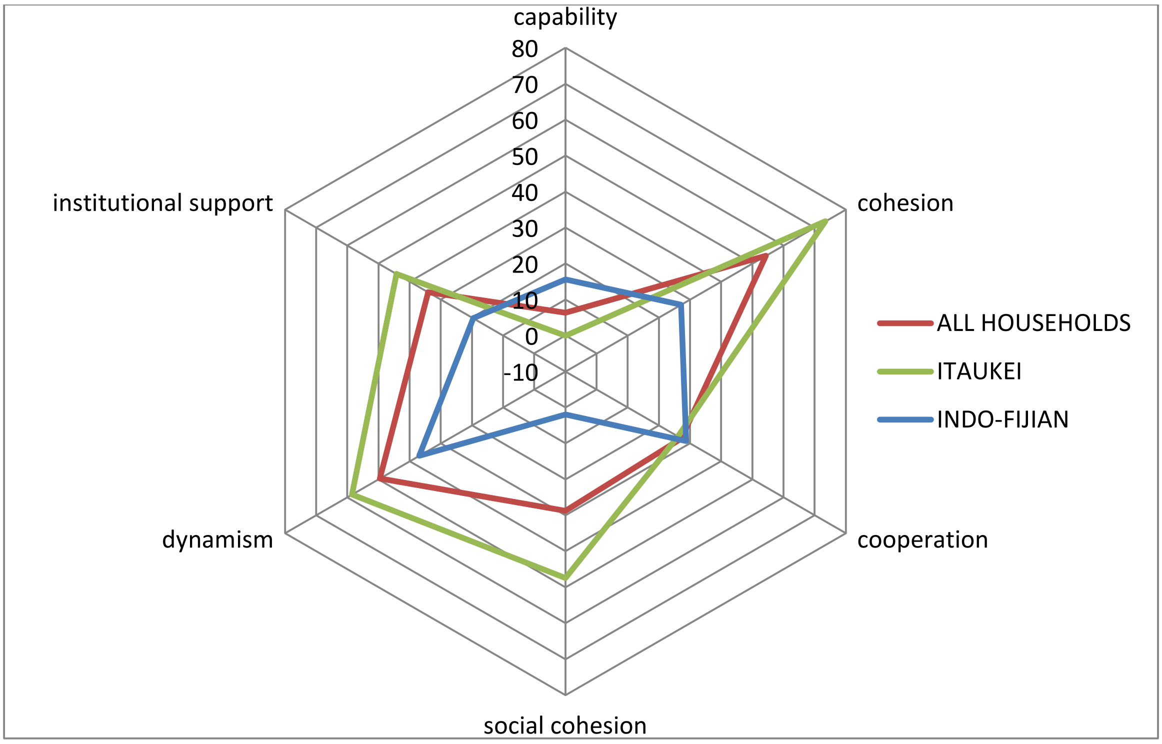

Figure 4: Amoeba diagram showing index scores for each domain comprising the community resilience index

Table 5 shows the relationship between resilience (measured as the community mean of the unweighted composite index) and losses and damages from natural disasters during 2012, each measured as a share of household wealth. Columns (1), (2), and (3) report crop losses, direct damages, and indirect damages, respectively, caused by the January flooding; columns (4), (5), and (6) report analogous losses and damages caused by Cyclone Evan. As noted above, the models are estimated as tobits to account for censoring at zero. To minimize concerns of omitted variable bias, we control for ethnicity, community wealth, education, time in the community, and the gender and age of the respondent. Hetroskedasticity-robust standard errors are reported in parentheses.[9] Community resilience has no bearing on crop losses, direct damage, or indirect damage stemming from the January flooding, i.e., all three point estimates are statistically indistinguishable from zero. Other explanatory variables also fail to explain losses from the January flooding, although older respondents report significantly lower indirect damages from the flood. In contrast, community resilience does mitigate some damages caused by Cyclone Evan. Specifically, each point on the 201-point scale is associated with 0.28% lower direct damages as a share of wealth (statistically significant at the 5% level) and 0.03% lower indirect damages as a share of wealth (significant at the 1% level). Community resilience does not impact crop losses. Recalling that communities had five hours advance warning of the flood and nearly two days advance warning of the cyclone, on average, these findings suggest that resilient communities may mobilise to mitigate the impacts of disasters when they have sufficient time to do so. Moreover, resilience mitigates impacts against which communities may intercede (e.g., by working together to reinforce buildings in the case of direct damages or by sharing food in the case of indirect damages), but not impacts against which intervention has little impact (i.e., crops that are not ready to be harvested are unlikely to be saved). *iTaukei* households experience significantly lower crop losses as a share of wealth than Indo-Fijians; likewise, average community wealth is negatively associated with crop losses as a share of wealth. Other variables fail to explain losses associated with Cyclone Evan.

[9] Sample sizes vary by specification. For both the January flooding and Cyclone Evan, the sample was restricted to communities in which at least one household was adversely affected by the disaster, i.e., to vulnerable communities. For crop damage, the sample was further restricted to households that grow crops.

Table 5: Losses and damage as a share of wealth, unweighted

	January flooding			Cyclone Evan		
VARIABLES	**crop losses**	**direct damage**	**indirect damage**	**crop losses**	**direct damage**	**indirect damage**
Ethnicity (*iTaukei*)	0.0119	0.0205	-0.00211	-0.916***	-0.0876	-0.00626
	(0.174)	(0.0646)	(0.00422)	(0.345)	(0.0603)	(0.00502)
Community resilience (mean score)	0.000641	-0.00133	0.0000146	0.0307*	-0.00278**	-0.000290***
	(0.00462)	(0.00184)	(0.000117)	(0.0182)	(0.00142)	(0.000124)
Average Wealth in Community (log FJ$)	-0.0707	0.0703	0.00598	-0.894***	0.0673	0.00643
	(0.148)	(0.0580)	(0.00366)	(0.267)	(0.0477)	(0.00397)
Maximum education in household (years)	0.00665	0.00488	0.000693	-0.0283	0.000486	-0.000221
	(0.0213)	(0.00826)	(0.000547)	(0.0398)	(0.00645)	(0.000545)
Length of time in the community (years)	0.000748	0.000114	0.0000806	-0.000205	-0.000675	-0.000774
	(0.00298)	(0.000993)	-0.0000655	(0.00541)	(0.000892)	-0.0000736
Gender (male)	-0.00989	-0.0400	-0.00163	0.229	0.0135	0.00396
	(0.0932)	(0.0347)	(0.00227)	(0.180)	(0.0319)	(0.00271)
Respondent age (years)	-0.00269	-0.000722	-0.000252***	0.00364	-0.000590	-0.0000980
	(0.00353)	(0.00146)	(0.0000933)	(0.00668)	(0.00124)	(0.000104)
Constant	0.678	-0.907	-0.0710*	8.868***	-0.683	-0.0583
	(1.553)	(0.612)	(0.0387)	(2.775)	(0.496)	(0.0413)
Observations	185	232	232	285	333	333

Heteroskedasticity-robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6 replicates the above analysis with the weighted composite index of community resilience. Consistent with the results for the unweighted index, resilience does not mitigate crop losses, direct damages, or indirect damages caused by the January flooding or crop losses caused by Cyclone Evan, but it does ameliorate direct damage and indirect damage caused by Cyclone Evan. To wit, one additional point of resilience is associated with 0.28% lower direct damages as a share of wealth and 0.02% lower indirect damages as a share of wealth, each significant at the 5% level.

Table 6: Losses and damage as a share of wealth, weighted

	January flooding			Cyclone Evan		
VARIABLES	**crop losses**	**direct damage**	**indirect damage**	**crop losses**	**direct damage**	**indirect damage**
Ethnicity (*iTaukei*)	-0.00745	0.0214	-0.00231	-0.933***	-0.0980	-0.00671
	(0.177)	(0.0654)	(0.00430)	(0.353)	(0.0618)	(0.00516)
Community resilience (mean score)	0.00150	-0.00119	0.0000231	0.0276	-0.00284**	-0.000235**
	(0.00440)	(0.00176)	(0.000112)	(0.0184)	(0.00144)	(0.000119)
Average Wealth in Community (log FJ$)	-0.0738	0.0665	0.00600	-0.832***	0.0594	0.00564
	(0.146)	(0.0573)	(0.00364)	(0.266)	(0.0474)	(0.00393)
Maximum education in household (years)	0.00679	0.00493	0.000694	-0.0261	0.000623	-0.000215
	(0.0212)	(0.00820)	(0.000547)	(0.0399)	(0.00648)	(0.000548)
Length of time in the community (years)	0.000663	0.000142	(0.0000799)	-0.000291	-0.000671	-0.000752
	(0.00299)	(0.000993)	0.0000657	(0.00543)	(0.000897)	0.0000741
Gender (male)	-0.0140	-0.0394	-0.00168	0.235	0.0116	0.00391
	(0.0932)	(0.0347)	(0.00228)	(0.180)	(0.0321)	(0.00273)
Respondent age (years)	-0.00264	-0.000696	-0.000253***	0.00343	-0.000535	-0.0000951
	(0.00353)	(0.00145)	0.0000953	(0.00670)	(0.00124)	(0.000104)
Constant	0.698	-0.873	-0.0713*	8.280***	-0.623	-0.0516
	(1.536)	(0.608)	(0.0386)	(2.775)	(0.496)	(0.0412)
Observations	185	232	232	285	333	333

Heteroskedasticity-robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

For robustness, Tables 7 and 8 show the effect of resilience on losses and damages reported in levels (as opposed to shares of wealth) for the unweighted and weighted composited indices, respectively. As above, community resilience does not affect crop losses caused by either disaster or direct or indirect damages caused by the January flooding, but it does reduce direct and indirect damages caused by Cyclone Evan. Each additional point on the 201-point scale is associated with FJ$14-21 lower direct damages and FJ$1.7-2.1 lower indirect damages, depending on weighting (although we note that reductions in direct damage fall shy of statistical significance with the unweighted measure of resilience). Again, these results indicate that more resilient communities work together to reduce the adverse effects of natural disasters given the time and ability to do so; without sufficient preparatory time (as in the case of the January flooding) or ability to effectively intervene (as in the case with crops), community resilience has no discernible effect.

Table 7: Losses and damage in FJ$, unweighted

	January flooding			**Cyclone Evan**		
VARIABLES	**crop losses**	**direct damage**	**indirect damage**	**crop losses**	**direct damage**	**indirect damage**
Ethnicity (*iTaukei*)	-1,286	412.0	-72.43	-5,126**	-879.7	-89.66
	(978.9)	(1,654)	(121.1)	(2,569)	(605.5)	(59.10)
Community resilience (mean score)	7.414	-30.27	1.117	287.3	-20.79*	-2.072*
	(26.07)	(47.25)	(3.374)	(184.92)	(12.47)	(1.236)
Average Wealth in Community (log FJ$)	-428.1	1,798	214.0**	-2,296	1,121**	134.7***
	(834.1)	(1,486)	(105.7)	(1,993)	(481.1)	(46.92)
Maximum education in household (years)	66.51	134.4	32.03**	358.9	19.90	7.023
	(119.6)	(211.7)	(16.16)	(297.5)	(65.34)	(6.508)
Length of time in the community (years)	-15.60	1.505	1.405	-17.18	-5.321	-0.409
	(16.64)	(25.36)	(1.868)	(40.42)	(8.986)	(0.872)
Gender (male)	987.9*	-1,068	-81.28	2,056	264.5	67.33**
	(526.2)	(888.7)	(65.45)	(1,344)	(322.9)	(32.18)
Respondent age (years)	4.394	-15.34	-5.362**	69.49	-15.02	-1.246
	(19.80)	(37.29)	(2.667)	(49.95)	(12.51)	(1.225)
Constant	4,631	-23,408	-2,656**	13,200	-11,349**	-1,441***
	(8,746)	(15,692)	(1,119)	(20,687)	(5,010)	(488.9)
Observations	185	232	232	285	333	333

Heteroskedasticity-robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Losses and damage in FJ$, weighted

VARIABLES	January flooding crop losses	January flooding direct damage	January flooding indirect damage	Cyclone Evan crop losses	Cyclone Evan direct damage	Cyclone Evan indirect damage
Ethnicity (*iTaukei*)	-1,518	446.7	-69.36	-5,494**	-966.7	-94.90
	(994.1)	(1,674)	(123.5)	(2,628)	(619.0)	(60.37)
Community resilience (mean score)	17.69	-28.15	0.832	268.2	-13.96	-1.678*
	(24.73)	(45.00)	(3.236)	(182.49)	(10.66)	(1.015)
Average Wealth in Community (log FJ$)	-467.4	1,712	217.3**	-1,742	1,057**	128.4***
	(819.1)	(1,468)	(105.1)	(1,983)	(477.0)	(46.38)
Maximum education in household (years)	68.08	135.3	32.08**	381.7	21.03	7.080
	(119.2)	(210.0)	(16.19)	(298.2)	(65.49)	(6.516)
Length of time in the community (years)	-16.61	2.227	1.396	-18.46	-5.291	-0.397
	(16.63)	(25.36)	(1.874)	(40.50)	(9.020)	(0.874)
Gender (male)	939.2*	-1,050	-80.66	2,085	247.8	66.49**
	(524.4)	(888.5)	(65.88)	(1,346)	(324.1)	(32.30)
Respondent age (years)	4.999	-14.77	-5.382**	68.29	-14.56	-1.218
	(19.73)	(37.01)	(2.669)	(50.01)	(12.52)	(1.225)
Constant	4,878	-22,615	-2,684**	7,722	-10,857**	-1,389***
	(8,627)	(15,566)	(1,117)	(20,676)	(4,997)	(486.2)
Observations	185	232	232	285	333	333

Heteroskedasticity-robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Discussion

While Neumayer *et al*. (2014) demonstrate that the impacts of individual disasters are lower in communities with higher disaster propensity, we demonstrate that community resilience affects impacts over the event timescale. Specifically, we show that while early warning and community resilience are both necessary conditions for reducing losses and damages, neither is sufficient: resilient communities are able to reduce losses and damages from climate-related natural disasters only when they have sufficient time to react.

The importance of resilience in operationalising early warnings has been noted in the literature. For example, the loss of life during Hurricane Katrina is a prime example of early warnings being ineffectively exploited (Basher, 2006). Our findings provide quantitative evidence of the importance of resilience in reducing losses and damages through early warnings. Furthermore, our findings extend the definition of resilience beyond a characteristic that is static to one that can be operationalised. As such, resilience is more than a conceptual description of systems that are able to absorb shocks and perturbations. Rather, resilient social systems are able to act pre-emptively to reduce the impacts of perturbations.

We consider this responsive form of resilience to be purposive, and we believe that it is likely to characterise resilience in many sentient systems. If so, then New Orleans neighbourhoods with high community resilience would have suffered significantly lower impacts than neighbourhoods with low community resilience during Hurricane Katrina due to the ability of resilient communities to act purposefully when presented with warnings of the impending hurricane. Importantly, we would not expect community resilience to be a significant mitigator of damages and losses if New Orleans were instead struck by a disaster with little warning (e.g., an unanticipated earthquake) because more resilient communities would lack sufficient time to operationalise that resilience.

6. Conclusion

The frequency and severity of natural experiences will increase under most climate-change projections, and resilience is increasingly viewed as a critical component of adaptation to climate change. Considerable work has been undertaken to define resilience as it relates to human communities, and a number of attempts have been made to quantify resilience by identifying its social and economic traits determinants. However, converting resilience from a concept into an operational tool has proven difficult.

We construct a community resilience index based on extensive survey data from 36 communities in Fiji. We then move beyond the quantification of resilience to test whether it affects losses and damages incurred during disasters. Specifically, we regress losses and damages on community resilience for disastrous flooding and a cyclone that struck Fiji in 2012. To address possible endogeneity in assessing the impact of resilience on damages, we exploit the fact that communities received warning only five hours in advance of the flooding while they received warnings over 45 hours in advance of the cyclone, on average. We separate losses and damages in order to isolate losses that were effectively unavoidable (i.e., crop losses) from direct and indirect damages that may be ameliorated by communities working together given sufficient warning.

We find that resilience had no effect on crop losses during the flooding or cyclone due to the fact that these losses were effectively unavoidable. Similarly, community resilience had no effect on direct and indirect damages incurred during the January flooding, which we interpret to be a consequence of little advanced warning. Resilience did, however, influence direct and indirect damages incurred during the cyclone. Specifically, each point of resilience (measured on a 201-point scale) is associated with 0.28% lower direct damages as a share of wealth and 0.03% lower indirect damages as a share of wealth. These findings are robust to different measures of damage and to different weightings being applied to the composite index of resilience.

Our results demonstrate that advanced warning and community resilience are both necessary conditions for reducing losses and damages, although neither is sufficient. This finding highlights the importance of robust early warning systems and demonstrates the influence that resilience has on losses and damages. Furthermore, our findings demonstrate that resilience in Fijian communities is dynamic and responsive: indeed, community resilience is only an effective mitigator of climate-induced disaster damage when community have sufficient time and ability to respond to pending threats.

Acknowledgements

The authors gratefully acknowledge the Climate and Development Knowledge Network (grant number RSGL-0024F) for underwriting this research.

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