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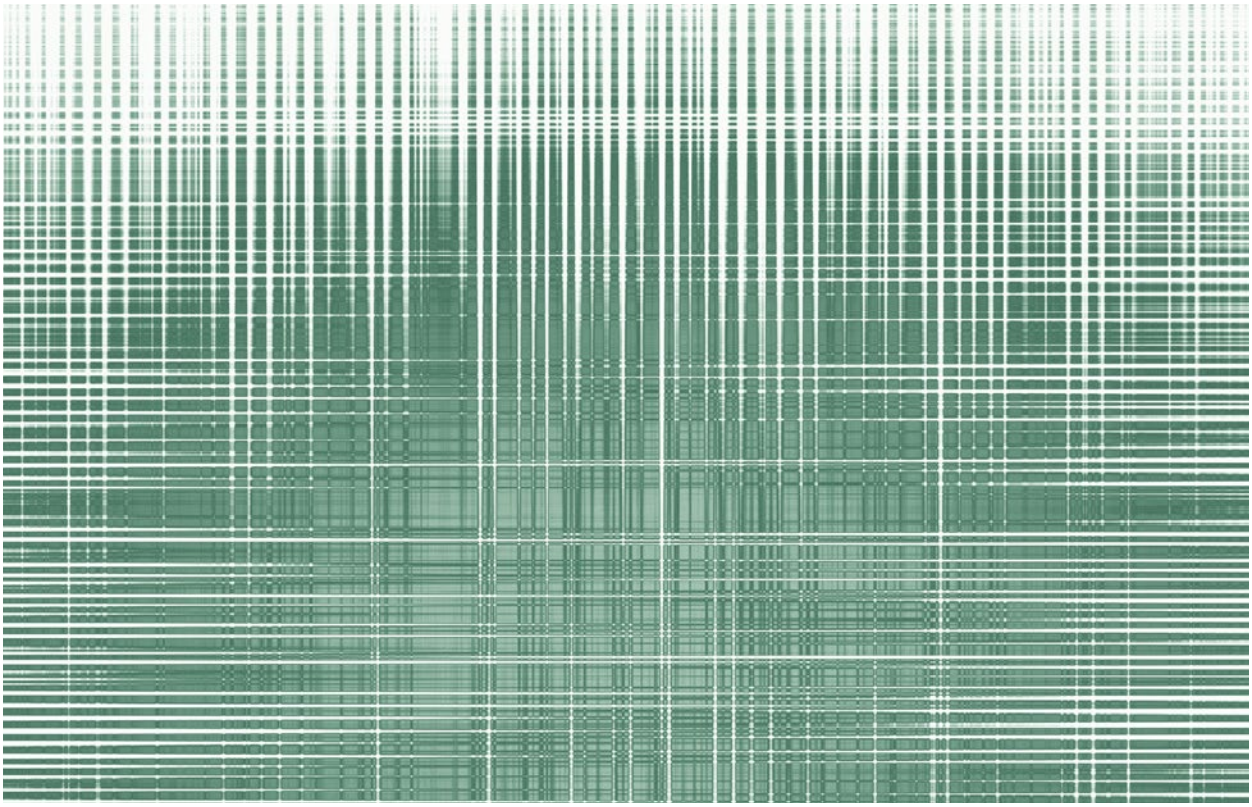

Measuring natural disasters through self-report: the case of a national child cohort study

B Edwards, M Gray and JB Borja

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Professor Matthew Gray
Director, ANU Centre for Social Research & Methods
Research School of Social Sciences
College of Arts & Social Sciences
The Australian National University
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ANU Centre for Social Research & Methods
Research School of Social Sciences
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Measuring natural disasters in a national child cohort study

B Edwards, M Gray and JB Borja

Ben Edwards is an Associate Professor at the ANU Centre for Social Research & Methods.

Matthew Gray is Director of the ANU Centre for Social Research & Methods and a Professor of Public Policy at the Australian National University.

Judith B Borja is Professor at the University of San Carlos, Philippines, and former Director of the University of San Carlos (USC) – Office of Population Studies Foundation.

Abstract

Children are considered to be disproportionately affected by natural disasters related to climate change. The impacts on the development of children of being exposed to multiple natural disasters are not well understood. This paper reports on the development and validation of a cumulative measure of exposure to natural disasters (2013–17) at the area level, as well as an individual-level measure of the impact of these natural disasters using data from the Longitudinal Cohort Study on the Filipino Child and linked data from the International Disaster Database (EM-DAT). First, we show that a caregiver-reported measure of cumulative exposure to natural disasters had statistically significant associations with disasters reported by officials responsible for the geographic area and with disasters in EM-DAT. A substantial proportion of the variation in individual reports of exposure to natural disasters occurred at the area level (25%), supporting the idea that taking community averages reflects a consensus of the exposure to natural disasters. We then generated a community average measure of exposure to natural disasters, based on neighbours' reports but not individual self-reports – therefore providing an exogenous measure of disaster exposure in the local area for each household. Second, we show that this community measure was more strongly related to EM-DAT and barangay (small administrative unit) official reports than individual household reports. Third, many household factors (e.g. quality of housing) will mitigate the impact of a natural disaster. Even though exposure to a natural disaster may be a shared experience, we develop an individual-level measure of disaster impacts. Importantly, this measure of disaster impact was associated with measures of exposure (individual and community average), community ratings by officials and EM-DAT. However, the impact measure was only moderately associated with the community average exposure. Both the community average and disaster impacts measures were consistently related to household income and the adequacy of income in households. We discuss the implications of our study for more nuanced measures of disaster exposure and monitoring.

Acknowledgments

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Any views expressed in this paper are those of the authors and not those of the Australian or Philippines governments.

Acronyms

ANU	Australian National University
CSRM	Centre for Social Research & Methods
EM-DAT	International Disaster Database
LCSFC	Longitudinal Cohort Study on the Filipino Child
UNFPA	United Nations Population Fund
USC	University of San Carlos

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Tables and figures

1 Introduction

Climate change is leading to an increased number of natural disasters in many countries (Oppenheimer & Anttila-Hughes 2016). Natural disasters have significant negative impacts on affected populations. Although all members of a community can be negatively affected, children are often disproportionately affected. Save the Children estimated that, during the decade beginning 2007, up to 175 million children every year would be likely to be affected by natural disasters related to climate change (McDiarmid 2008).

To date, research on the impacts of natural disasters on children has focused on physical and mental health, and schooling (Kousky 2016). Although a number of studies have found the impact of natural disasters on children's wellbeing to be small, some studies have found significant long-lasting impacts. For example, a study of the long-term impacts of the Australian 'Black Saturday' bushfires in 2009, which resulted in the loss of 180 lives, found that children in primary school who had been in bushfire-exposed areas performed substantially worse on numeracy and literacy tests, and this effect continued 4 years after the fires (Gibbs et al. 2019). There is also some evidence of impacts in utero. For example, a month after Super Typhoon Haiyan hit the Philippines in 2013, a qualitative study revealed that pregnant and lactating women were among the most vulnerable health-wise in the aftermath (USC-OPS 2014), indicating an impact that is likely to extend to offspring in their formative stages.

Most studies of the impact of natural disasters on children have focused on particular areas and on a particular disaster. Kousky (2016) noted that there is a need for research to examine the cumulative effects of experiencing multiple natural disasters on children living in high-risk disaster areas.

Although there are well-established scientific methods for quantifying the occurrence and impact of a number of types of natural disasters, methods for quantifying other natural disasters, such as drought, are not well established. Moreover, we are not aware of a standard technique for quantifying exposure to multiple natural disasters over time. A related issue to assessing disaster exposure is quantifying the impact of natural disasters on human populations. Developing measures of disaster impact is important because the measures can potentially be used to inform the development and implementation of disaster mitigation strategies that could reduce the impact of exposure to natural disasters (World Bank & UN 2010).

In this paper, we report on the development and validation of a measure of natural disasters based on self-reports of exposure to disasters collected as part of a national cohort survey of children in the Philippines (USC-OPS 2018). The self-report of exposure to natural disasters is obtained from the primary caregiver of the study children.

This approach draws heavily on that pioneered to measure exposure to drought in Australia (Hunter et al. 2012; Edwards et al. 2014, 2019). It uses self-reports of experience of natural disaster collected using survey data and then aggregates these self-reports to the geographic area level. Aggregation of area ratings by self-report to neighbourhoods is not new. It has been routinely used in studies examining the physical and social environments of neighbourhoods since the late 1990s (e.g. Sampson et al. 1997, Mair et al. 2010). The approach is well respected: a paper published in *Science* describing the technique has been cited by other papers more than 10 600 times, suggesting that the method has been acknowledged by the research community as legitimate for construction of area measures (Sampson et al. 1997).

The Philippines is an ideal country in which to study the impact of natural disasters on human development because it has a large number of such disasters; in 2018, the Philippines had the second highest number of people affected by natural disasters, after India (6.5 million,

according to the International Disaster Database – EM-DAT). Moreover, recent research in the Philippines reported that rainfall shocks are associated with chronic total poverty and food poverty (Bayudan-Dacuycuy & Baje 2019). The Longitudinal Cohort Study on the Filipino Child (LCSFC) has unusually rich data collected on natural disaster exposure and impact reported by caregivers and barangay (small administrative unit) officials. In addition to these measures, we link information compiled in EM-DAT (CRED 2017) to validate our measures of natural disasters constructed from individual-level self-report.

There are several reasons for wanting to construct a measure of exposure to disaster based on individual self-report. If the aim of a study is to estimate the impact of experiencing a natural disaster on individual (or household)-level outcomes, individual self-report is likely to better reflect the individual's (or their household's) exposure to disasters than measures derived from national or international monitoring systems, or reported at the community level by someone in a position of authority. The main reason is that impacts of some disasters can be very localised. For example, data on the occurrence of a natural disaster in a particular geographic region from a national or international monitoring system may not reflect an individual's own direct experience. Flooding is a good example of this type of disaster – there could be extensive damage to houses in low-lying areas but not houses that were built on higher ground in the same village.

One limitation of self-reported measures of natural disasters is that they can be coloured by individual circumstances, such as exposure to poverty or mental health issues. In this study, we overcome this limitation by creating an individual-specific average rating of natural disaster exposure in the local area that uses neighbours' reports and excludes caregivers' own reports in constructing the measure for caregivers' households. The paper also develops a measure of the impact of natural disasters in which impact is conceptualised in terms of economic or health effects. The disaster impacts measure is only for the household level, since many household-specific factors can mitigate severe impacts of natural disasters – for example, precise location of housing, quality of housing and economic reserves held by a household. The measure of disaster impacts is nevertheless based on reports on objective characteristics such as damage to houses or property, loss of livelihood or injuries to household members.

The validity of the disaster measure based on household self-report is established using other objective measures of disasters and showing that these disaster measures are related to the economic wellbeing of households (predictive validity). This research is foundational to understanding the full range of potential impacts of natural disasters on children and families.

2 Methods

This section provides an overview of the data sources used in this paper.

2.1 Longitudinal Cohort Study on the Filipino Child

The LCSFC is the Philippines' first nationally representative longitudinal study of child development. It is planned as a 15-year study, starting in 2016, and is designed to examine how the lives of young Filipinos change as the United Nations Sustainable Development Goals are implemented. The study recruited 4952 10-year old children at baseline (2016–17), and this cohort will be observed through to age 25. The study sample was selected to be nationally representative of 10-year old Filipinos, from the country's three main island groups of Luzon, Visayas and Mindanao. The sampling design included marginalised children through implicit stratification (specifically from Indigenous peoples, and households with children with disabilities) (Lynn 2018). The goal is to retain about 2000 of the original cohort by the final survey (2030–31). At each wave, the study collects community-level data from the barangays (the smallest administrative units in the country) where the study children live.

2.2 Measures of natural disasters in the LCSFC

In the LCSFC, information about exposure to natural disasters is collected from two sources: a barangay official (generally the barangay captain or secretary) and the primary caregiver (83% mothers) of the study child (household self-report).

Table 1 summarises the information on the experience of natural disasters collected from the barangay official and the primary caregiver. Barangay officials were asked to provide detailed information about the number and types of disasters experienced in the barangay in the previous 3 years. For each disaster, we obtained information on the number of deaths and the number of households affected. The primary caregiver of the study child was asked to report on disasters experienced by their household since 2013. Depending on the timing of the interview, this was during either the previous 3 years or the previous 4 years. The primary caregiver was also asked about the types of damage inflicted by each disaster (e.g. deaths, injuries, damage to the house, loss of property, loss of livelihood or crops). However, the primary caregiver was not asked to quantify the extent of damage experienced by their household.

In this paper, the primary caregivers' survey responses were used to construct a measure of the number of types of natural disasters the household had experienced since 2013.

The community-level measure of experience of natural disasters is the number of natural disasters that the barangay official reported the community having experienced during the previous 3 years.

2.3 International Disaster Database

A third source of data on the experience of natural disaster is EM-DAT. This provides data on the occurrence and effects of more than 23 000 natural and technological disasters from 1900 to the present. It is compiled from information provided by United Nations agencies, the United States Office of Foreign Disaster Assistance, national governments, the International Federation of Red Cross and Red Crescent Societies, other nongovernment organisations, insurance companies, research institutes and the media.

Table 1 Disaster variables collected in the Longitudinal Cohort Study on the Filipino Child, wave 1

Respondent	Variable	Response format
Barangay official	Type of disaster experienced in the barangay	Tropical cyclone (tropical depression, storm, typhoon, supertyphoon), extreme rainfall, drought, volcanic eruption/lava flow, storm surge, sea level rise, flooding/flash flood, tsunami, earthquake-induced landslide, rainfall-induced landslide, fire, armed conflict/strife/war, wildfire, epidemic, marine pollution (oil spill, fish kill, red tide, etc.)
	Experienced in the past 3 years	Yes, No
	Year(s) happened	Year(s)
	Number of households affected by last occurrence of the disaster	Number
	Number of deaths in the last occurrence	Number
Primary caregiver	Type of disaster experienced since 2013 by the household	Tropical cyclone (tropical depression, storm, typhoon, supertyphoon), extreme rainfall, drought, volcanic eruption/lava flow, storm surge, sea level rise, flooding/flash flood, tsunami, earthquake-induced landslide, rainfall-induced landslide, fire, armed conflict/strife/war, wildfire, epidemic, marine pollution (oil spill, fish kill, red tide, etc.)
	Loss of lives	Yes, No
	Injury	Yes, No
	House damage	Yes, No
	Loss of property	Yes, No
	Loss of livelihood/crops	Yes, No
	Others, specify	Open text

Source: LSCFC wave 1 – barangay official and primary caregiver questionnaires

The Centre for Research into the Epidemiology of Disasters defines a disaster as 'a situation or event that overwhelms local capacity, necessitating a request at the national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering' (CRED 2017).

For a disaster to be entered into EM-DAT, one or more of the following criteria must be met:

- 10 or more people reported killed
- 100 or more people reported affected
- a declaration of a state of emergency
- a call for international assistance.

For this study, we have linked disasters collected in EM-DAT to the barangay level. The types of disaster in EM-DAT that we use in this paper are described in Table 2. Disasters are classified according to a standardised classification system adapted from the Integrated Research on Disaster Risk peril classification and hazard glossary (IRDR 2014).

The EM-DAT database includes information on other aspects of disasters.[1] Although this information could potentially be used for generating economic and social costs of disaster, there is no accepted protocol for summarising these other varied measures of disaster impact at the small area level. There is also variation

Table 2 Types of disasters and definitions in EM-DAT

Type of disaster	Description
Drought	An extended period of unusually low precipitation that produces a shortage of water for people, animals and plants. Drought is different from most other hazards in that it develops slowly, sometimes even over years, and its onset is generally diffcult to detect. Drought is not solely a physical phenomenon because its impacts can be exacerbated by human activities and water supply demands. Drought is therefore often defined both conceptually and operationally. Operational definitions of drought, meaning the degree of precipitation reduction that constitutes a drought, vary by locality, climate and environmental sector
Earthquake	Sudden movement of a block of Earth's crust along a geological fault and associated ground shaking
Epidemic	Either an unusual increase in the number of cases of an infectious disease that already exists in the region or population concerned, or the appearance of an infection previously absent from a region
Flood	A general term for the overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than-normal levels along the coast and in lakes or reservoirs (coastal flooding), or ponding of water at or near the point where the rain fell (flash floods)
Landslide (rainfall induced)	Any kind of moderate to rapid soil movement, including lahar, mudslide and debris flow. A landslide is the movement of soil or rock by gravity; the speed of the movement usually ranges between slow and rapid, but not very slow. It can be superficial or deep, but the materials have to make up a mass that is a portion of the slope or the slope itself. The movement has to be downward and outward with a free face
Tropical storm	A tropical storm originates over tropical or subtropical waters. It is characterised by a warm-core, nonfrontal synoptic-scale cyclone with a low pressure centre, spiral rain bands and strong winds. Depending on their location, tropical cyclones are referred to as hurricanes (Atlantic, northeast Pacific), typhoons (northwest Pacific) or cyclones (south Pacific and Indian Ocean)
Volcanic activity	A type of volcanic event near an opening/vent in Earth's surface, including volcanic eruptions of lava, ash, hot vapour, gas and pyroclastic material

Source: EM-DAT glossary (www.emdat.be/Glossary#letter_s)

between variables and countries in what is captured and the reliability of the measures. Given these uncertainties and the exploratory nature of the study, we only include a cumulative measure of disaster exposure from 2006 to 2017.

On initial examination, it appears as though the reports from the LCSFC capture more detailed information than EM-DAT. However, this is a result of the way disasters are captured in EM-DAT.[2] Many of the disasters captured in the LCSFC questionnaire would be categorised in EM-DAT as disaster subtypes or associated disasters. For example, tropical cyclone is a subtype of storm in EM-DAT. Another example is a storm surge, which would also be categorised as a disaster subtype. In this study, we count disaster subtypes and associated disasters in the same manner as disasters to align with how data are collected in the LCSFC.

3 Results

3.1 Validating household self-reported experience of natural disasters

This section reports on the results of validating self-reported caregiver household experience of the number of disasters that their household experienced during the period 2013–17. The individual household self-report is validated by estimating its relationship to two other independent measures of the occurrence of disasters: the barangay official report and a measure derived from EM-DAT. If the barangay official report and the EM-DAT measure are strongly associated with the household self-report, there is evidence of convergent validity – that is, the self-report is a valid measure of the experience of natural disaster. We would not expect either the barangay official report or the EM-DAT measure to be perfectly correlated with the individual household report because the experience of disaster, for at least some types of disaster, can be highly localised and because of geographic mobility of households.

The relationship between the household self-report of the number of disasters experienced by the household and either the barangay official report or the EM-DAT measure of the number of disasters experienced by the barangay is estimated using a random effects linear regression model (Table 3). In addition to the barangay official report and the EM-DAT measure of the incidence of disaster, a range of household demographic characteristics, year of interview and geographic location were also included. None of the included demographic variables were significantly associated with disaster ratings at the household level (see Appendix).

There was significant regional variation: households in Visayas had the highest ratings of disasters, followed by Luzon and then Mindanao. The barangay official report and the EM-DAT measures of the number of natural disasters experienced by the barangay were statistically significantly related ($P < 0.001$) to the household self-report of the number of disasters experienced by the household.

The random effects model also showed that 25% of variation in ratings occurred at the barangay level. This supports the idea of taking average ratings of other residents at the barangay level as an independent rating of the area.

3.2 Number of disasters experienced

This section describes the measure of the average number of disasters experienced by households in a barangay.

Figure 1 show the distribution of the number of disasters reported by individual households. Figure 2 shows the average number of disasters reported by households in each barangay. If the barangay-level measure of the number of disasters experienced is used to estimate the impact of disasters on individual or household outcomes, households' own responses should be excluded from this measure to ensure that the measure of disaster is exogenous to other outcomes of interest in the survey (e.g. caregiver ratings of exposure to violence, stress and depression; child ratings of violence and abuse). This approach follows Hunter et al. (2012).

Table 3 Correlates of individual household self-reported experience of disaster (number of disasters 2013–17), random effects linear regression models

Characteristic	Model 1	Model 2	Model 3
Domain (reference: Luzon)			
Visayas	0.53 (0.0988)***	0.50 (0.10)***	0.52 (0.09)
Mindanao	−0.59 (0.10)	−0.71 (0.10)	−0.40 (0.12)
Year of interview (reference: 2016)			
2017	0.09 (0.14)	0.11 (0.13)	0.10 (0.14)
Internet access (reference: No)			
Yes	−0.07 (0.0423)	−0.08 (0.04)	−0.07 (0.04)
Barangay official report		0.09 (0.02)***	
EM-DAT			0.03 (0.01)**
Intercept	2.83 (0.09)***	2.60 (0.10)***	2.12 (0.27)***
Number of households	4932	4932	4932
Number of barangays	345	345	345
ICC	0.25	0.23	0.25
R^2 – within	0.003	0.003	0.003
R^2 – between	0.304	0.358	0.319
Overall R2	0.122	0.142	0.128

* = statistically significant at the 5% level; ** = statistically significant at the 1% level; *** = statistically significant at the 0.1% level; EM-DAT = International Disaster Database; ICC = intraclass correlation coefficient

Notes:

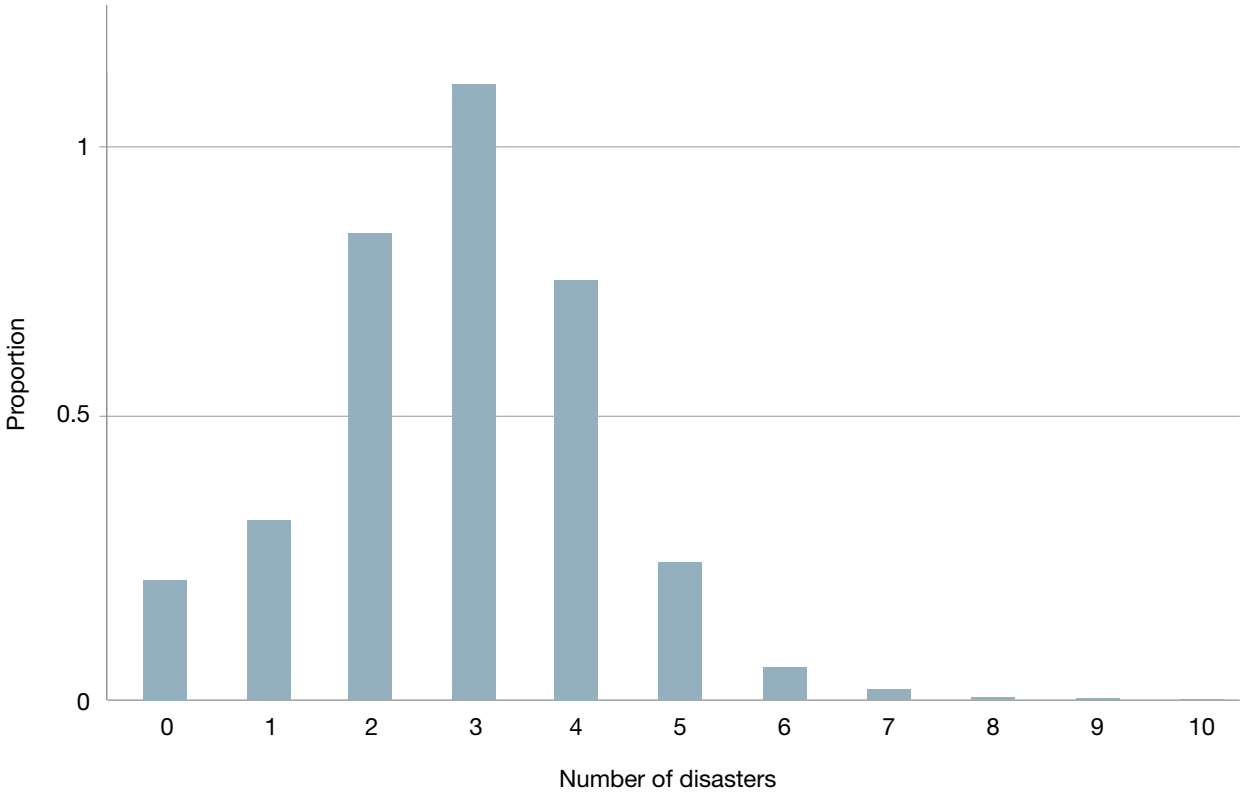
1. Standard errors are in parentheses.
2. Models also included the following demographic variables: household type, number of people in the household, number of rooms used for sleeping and mean household income ('000 pesos).

In addition to being an individual-specific mean of neighbours' reports of disaster exposure, the ratings at the barangay level have fewer extreme values at either end of the distribution.

Figure 3 shows the relationship between the individual household report of the number of disasters experienced since 2013 and the average community report of the number of disasters experienced since 2013. The relationship between the disaster measures is illustrated using a nonlinear lowess curve. As expected, there is a strong relationship between the two variables. The correlation of 0.55 (Table 4) also shows that, although a strong relationship exists, the variables are not identical.

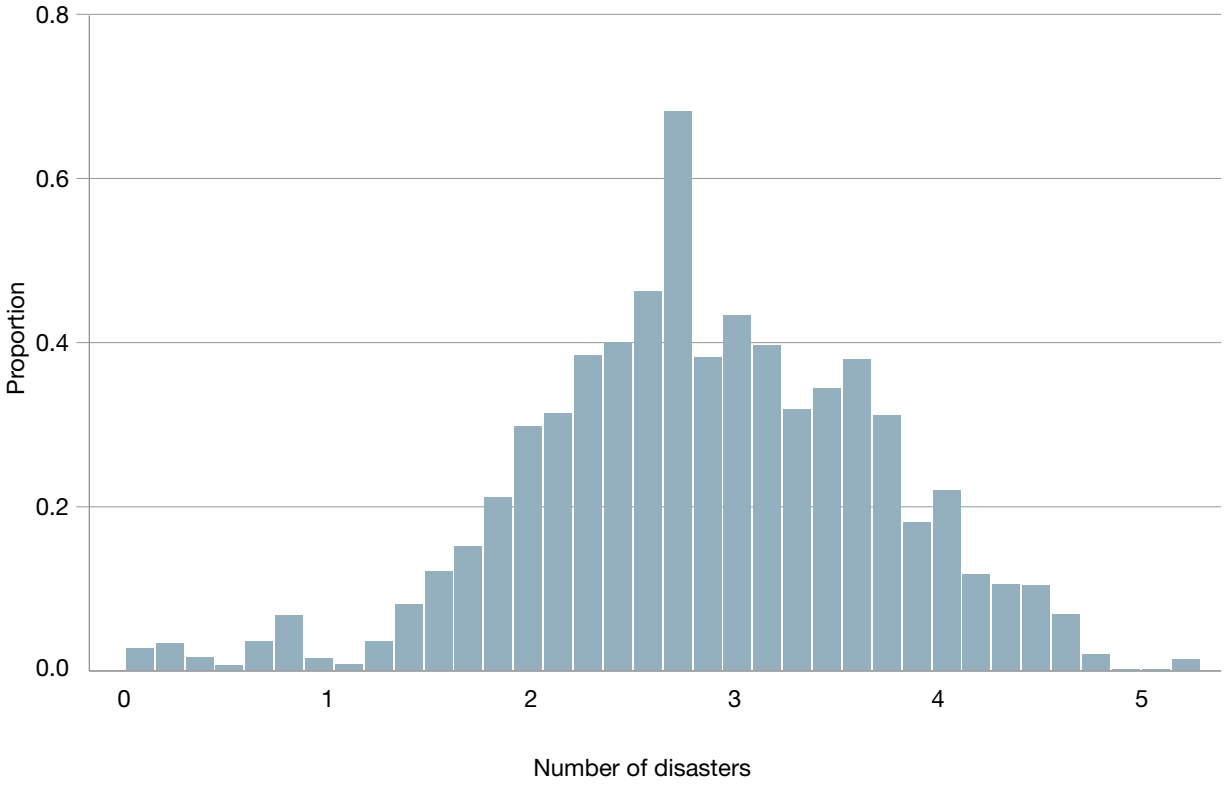
A strong relationship also exists between the average community report and EM-DAT (Figure 4). Interestingly, Table 4 shows a stronger correlation between the average community report and EM-DAT (r = 0.42) than between the individual ratings and EM-DAT (r = 0.26). Moreover, barangay official reports of disaster were only weakly correlated with individual household self-reports (r = 0.07) and average community reports (r = 0.12), and there was a negative correlation with the disaster variable from EM-DAT (r = −0.10).

Figure 1 **Number of disasters experienced by households, individual household self-report**



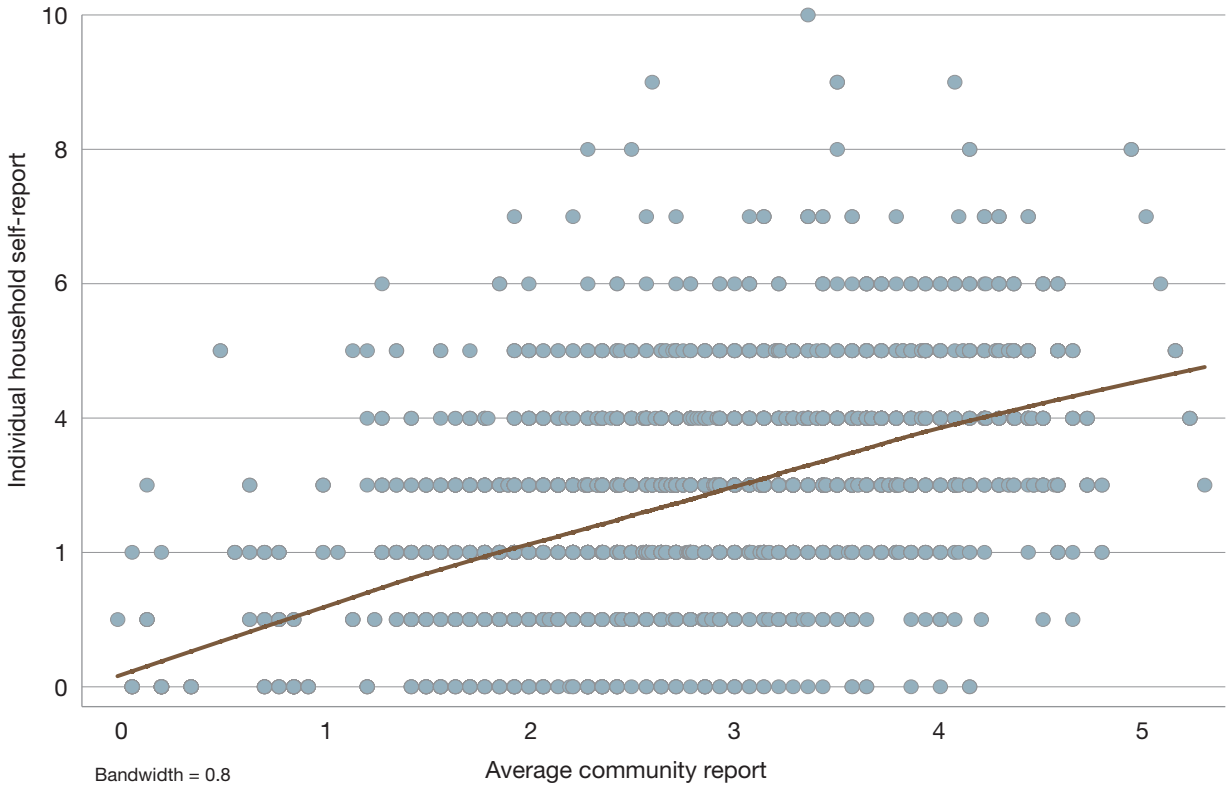
Source: Longitudinal Cohort Study on the Filipino Child, 2017

Figure 2 **Number of disasters experienced by households, average community report**



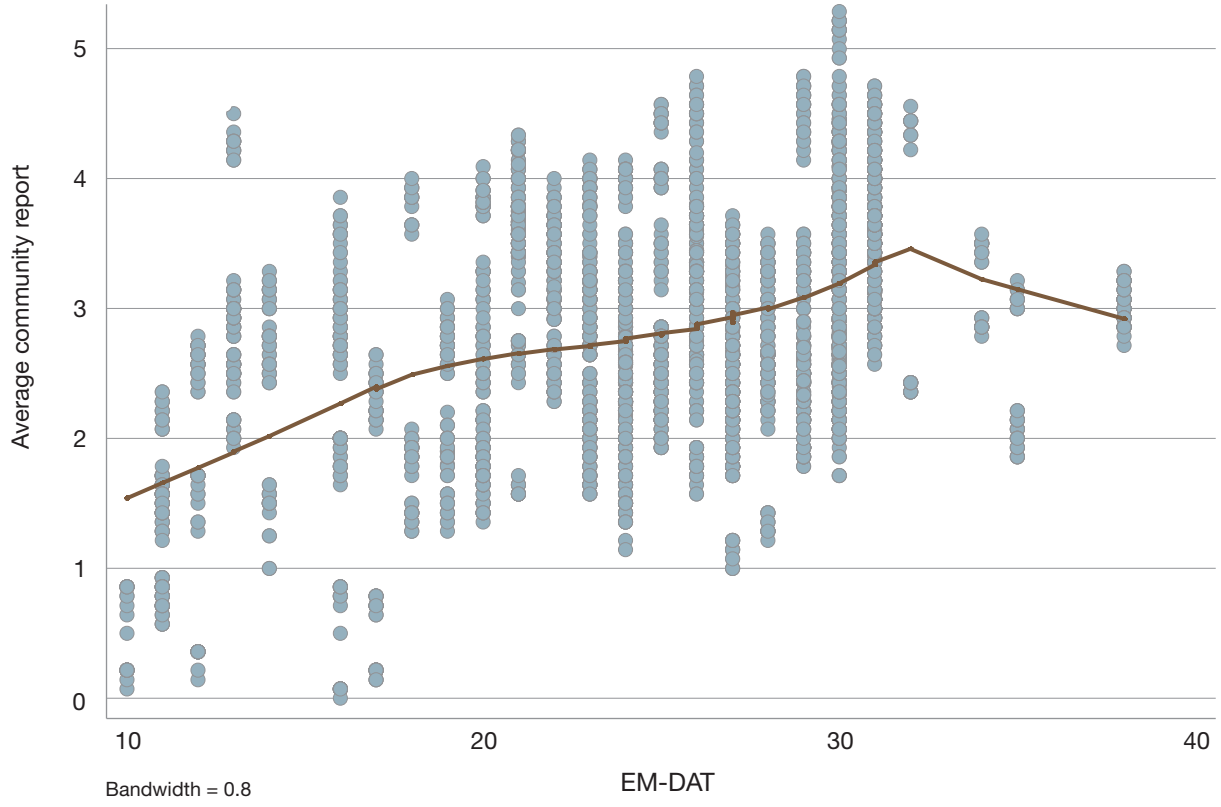
Source: Longitudinal Cohort Study on the Filipino Child, 2017

Figure 3 **Relationship between individual household self-report and average community report, lowess curve**



Source: Longitudinal Cohort Study on the Filipino Child, 2017

Figure 4 **Relationship between average community report and number of disasters experienced by barangay as measured in EM-DAT, lowess curve**



Source: Longitudinal Cohort Study on the Filipino Child, 2017

3.3 Development of a disaster impacts variable

Exposure to a natural disaster does not necessarily mean that there will be substantial impacts on the physical and psychological wellbeing of individuals, nor does it necessarily affect the livelihood of those exposed. Given the frequency of natural disasters in the Philippines, another important question is the impact of natural disasters on children and their families. Therefore, we developed a measure of disaster impact based on self-report of participants exposed to natural disasters in the Philippines. This measure was operationalised at the individual level because we were concerned with the direct impacts of natural disasters on individual households rather than community impacts.

For each natural disaster experienced since 2013, survey participants were asked whether any member of the household was injured, and whether there was any damage to the house, loss of property, or loss of livelihood or crops. Participants were asked to respond 'Yes' or 'No' for each disaster experienced (see Table 1). For each respondent, responses to these four types of impacts were summed to generate an indicator of injuries, damage to the house, loss of property and loss of livelihood or crops. The descriptive statistics are provided in Table 5.

A summary score for impact was generated based on exploratory factor analysis. The death of a family member infrequently occurred and is a highly significant event. Our initial exploratory factor analysis using maximum likelihood estimation and a quartimax rotation indicated that deaths due to natural disasters did not correlate highly with the other indicators. Therefore, we removed this indicator. The second exploratory factor analysis using maximum likelihood estimation and a quartimax rotation suggested that there was only one factor, with an eigenvalue of 1.53. The factor loadings can be seen in Table 6.[3] Factor loadings suggest that property loss and damage to the house were the highest loading items. We created a factor score on the basis of these factor loadings.

Figure 5 shows the highly skewed distribution of the disaster impacts factor score. There are two main points to note from this figure. First, 50% of respondents did not report any impact from any natural disasters. Second, 25% scored between 0.4 and 1.1, and a further 15% scored between 1.2 and 1.99. The remaining 10% scored between 2.0 and 11.86, with around 2.5% of cases scoring 4.01 to 11.86.

Table 7 shows that correlations between the disaster impacts and disaster deaths variables and the four other disaster variables were statistically significant but not high, suggesting that the two sets of variables were measuring substantively different constructs. As expected, the number of disasters reported at the household level was most closely related to disaster impacts, followed by disasters at the barangay level and deaths. EM-DAT was also significantly associated with disaster impacts, as was the barangay official community-level report, but the correlations were much smaller. For disaster-related deaths, the number of disasters reported at household level and the average number at the barangay level had the same but small associations. Barangay official community-level reports and EM-DAT also had significant associations with disaster-related deaths, although these were quite small.

Table 4 Pearson correlations between disaster reports

Information source	Individual household self-report	Average community report	Barangay official's report
Average community report	0.55***		
Barangay official's report	0.07***	0.12***	
EM-DAT	0.26***	0.42***	–0.10***

* = statistically significant at the 5% level; ** = statistically significant at the 1% level; *** = statistically significant at the 0.1% level; EM-DAT = International Disaster Database

Sources: Longitudinal Cohort Study on the Filipino Child, 2017; EM-DAT

Table 5 Descriptive statistics for impact of disasters indicators, individual household self-report

Variable	Mean (standard deviation)	Minimum	Maximum
Injuries	0.05 (0.29)	0	5
Property loss	0.21 (0.59)	0	5
Damage to house	0.51 (0.77)	0	5
Loss of livelihood or crops	0.54 (1.04)	0	6
Deaths	0.03 (0.19)	0	4

N = 4952

Source: Longitudinal Cohort Study on the Filipino Child, 2017

Table 6 Factor loadings and uniqueness for impact of disasters indicators

Variable	Factor loading	Uniqueness
Injuries	0.45	0.80
Property loss	0.80	0.36
Damage to house	0.73	0.47
Loss of livelihood or crops	0.39	0.85
Deaths	0.03 (0.19)	0

Source: Longitudinal Cohort Study on the Filipino Child, 2017

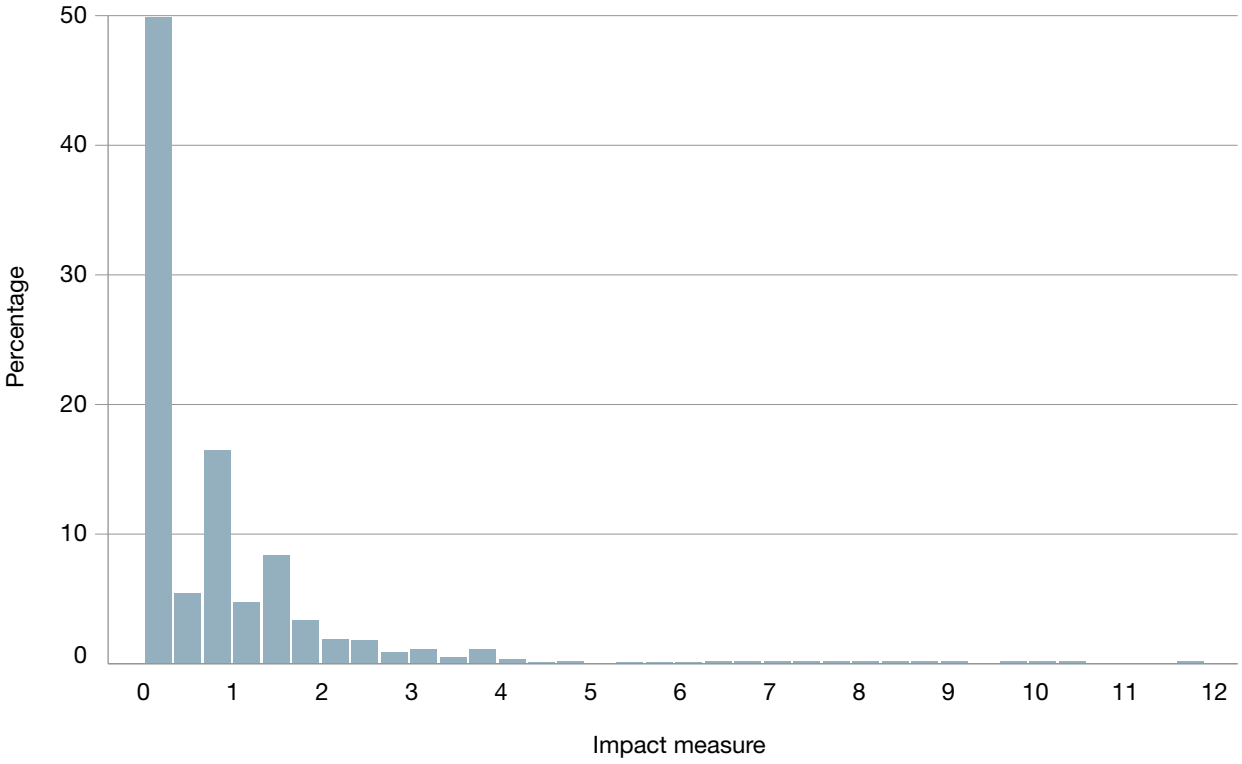
Table 7 Pearson correlations between disaster impacts/disaster deaths and incidence of disaster measures

Variable	Disaster impacts	Disaster deaths
Disaster deaths	0.25***	–
Average community report	0.28***	0.13***
Individual household self-report	0.37***	0.13***
Barangay official report	0.08***	0.04**
EM-DAT	0.13***	0.05***

* = statistically significant at the 5% level; ** = statistically significant at the 1% level; *** = statistically significant at the 0.1% level; EM-DAT = International Disaster Database

Sources: Longitudinal Cohort Study on the Filipino Child, 2017; EM-DAT

Figure 5 **Index of the impact of disasters experienced by the household, individual household self-report**



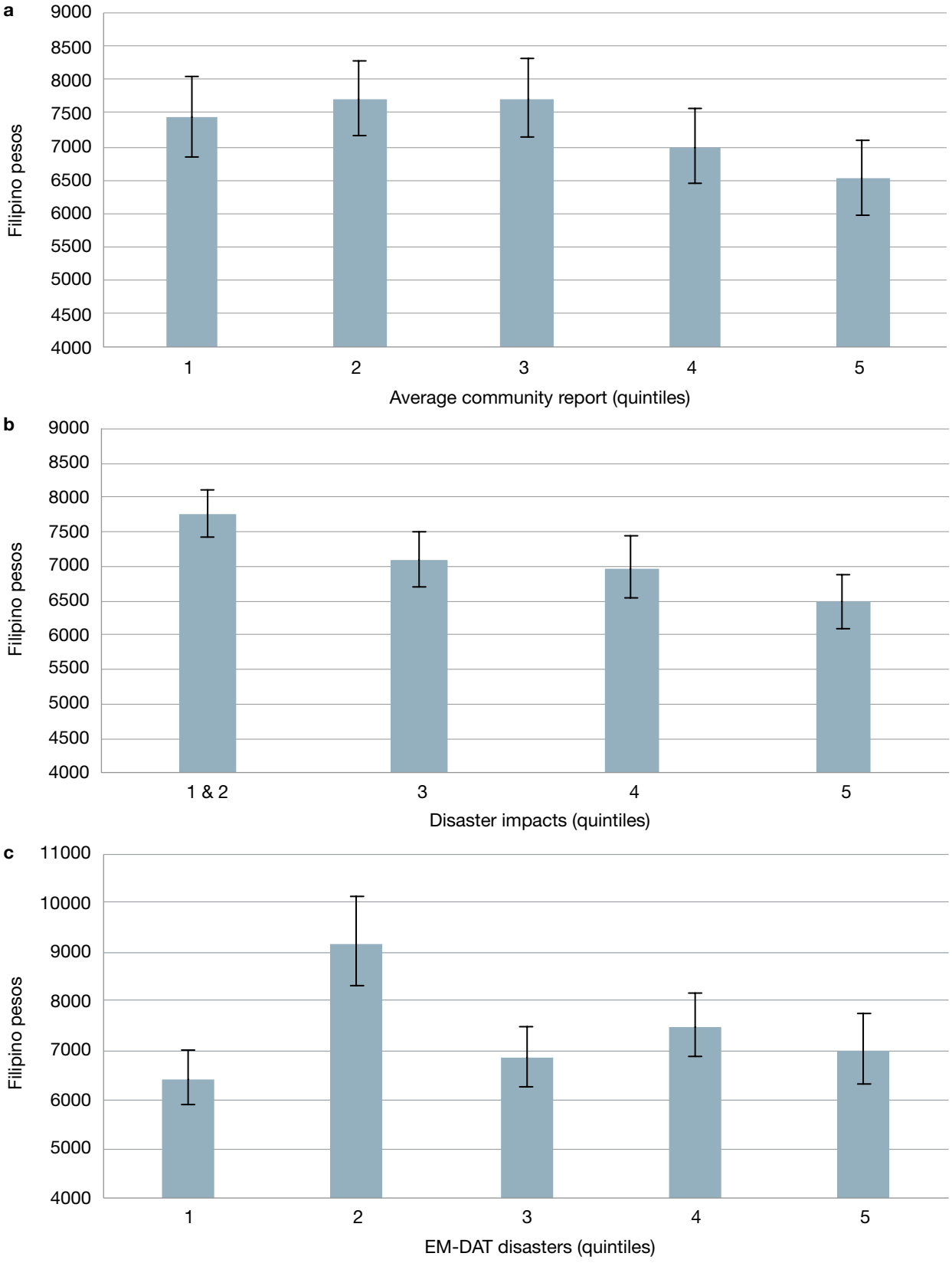
Source: Longitudinal Cohort Study on the Filipino Child, 2017

3.4 Relationship between disaster measures and household economic outcomes

Other research has shown that self-report of disasters translates into financial impacts at the household level, providing further evidence of the validity of the measure (Edwards et al. 2019). In our study, we estimated the association between our disaster variables and measures of monthly household income and income adequacy. The average community report and EM-DAT disasters measures were categorised into quintiles to include in a regression model predicting monthly household income. We also attempted to create a quintile for disaster impacts; however, because of the distribution of the variable, the bottom 40% of the distribution could not be disaggregated (as a result of a lack of any impact). Therefore our 'quintile 1' in this instance is the bottom 40% (including those who scored zero); quintiles 3, 4 and 5 followed the conventional categorisation. For consistency of comparison across disaster measures, we decided to keep this categorisation rather than creating quartiles.

Figure 6 shows the predicted mean monthly household income by disasters variable. The predicted incomes are derived from the regression model. As would be expected, the community average exposure to the disasters variables shows that only households in areas exposed to the most disasters (quintile 5) had significantly lower levels of household income. In contrast, the impact of disasters was evident from the third quintile. Despite the consistent pattern of results for disaster exposure at the barangay level and for disaster impacts, there was little meaningful pattern in the association between the EM-DAT measure and monthly household income (see Figure 6c). In this instance, household income was highest for those in the second quintile, and there were no statistically significant differences in household income for the other four EM-DAT disaster quintiles.

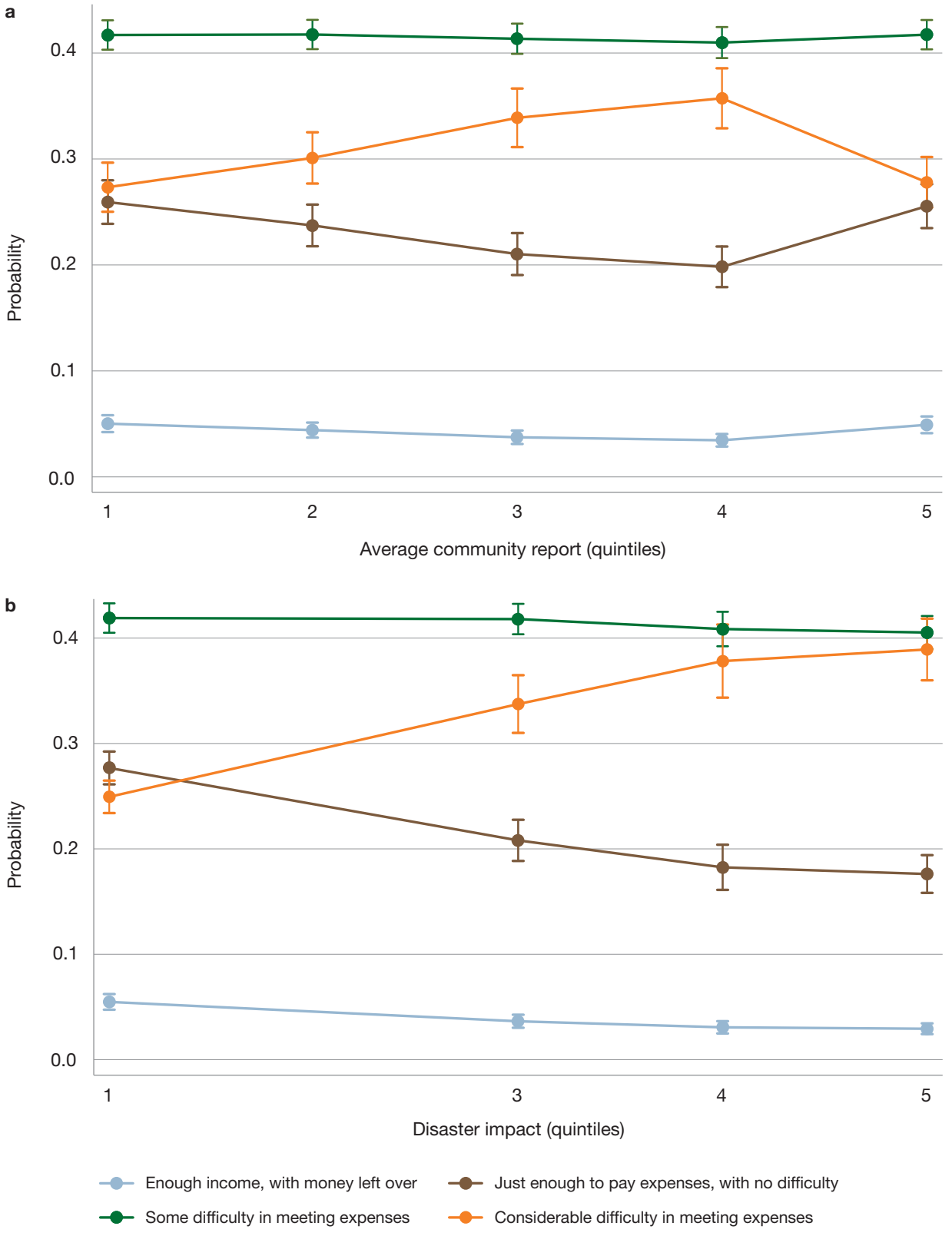
Figure 6 **Predicted average household monthly income by (a) average community report of disasters, (b) household self-reported impact of disasters and (c) number of disasters from EM-DAT**



EM-DAT = International Disaster Database

Sources: Longitudinal Cohort Study on the Filipino Child, 2017; EM-DAT

Figure 7 **Predicted probability of level of income adequacy by disaster, (a) average community report and (b) disaster impact at the household level**



Source: Longitudinal Cohort Study on the Filipino Child, 2017

In addition to reporting on monthly household income, caregivers were also asked to rate adequacy of income to meet expenses. The categories were:

1. There is enough (income), with money left over.
2. Just enough to pay expenses, with no difficulty.
3. Some difficulty in meeting expenses.
4. Considerable difficulty in meeting expenses.

We also tested whether average community reports and impact at the household level were associated with adequacy of income. Figure 7 shows predicted probabilities for each of the four categories of income adequacy. It shows that categories 1 and 2 were relatively stable over the average community reports but that there was a linear increase in category 4 and a decrease in category 3 from quintile 1 to quintile 4.

For an unknown reason, quintiles 1 and 5 had very similar patterns. For disaster impact, the results were more clear-cut, with categories 1 and 2 relatively stable but a consistent linear increase in households experiencing considerable difficulty in meeting expenses as disaster impact increased and a decrease in households who reported that they had just enough to pay expenses.

These results provide fairly strong and consistent evidence of the predictive validity of the disaster average at the barangay level and the disaster impacts variable.

4 Discussion

This paper reports on the development and validation of cumulative measures of exposure to natural disasters, in the period 2013–17, at the individual household and community levels. It also reports on the development of an individual household–level measure of the impact of natural disasters. First, we showed that the individually reported household cumulative exposure to natural disasters had statistically significant associations with disasters reported by officials responsible for the geographic area and with disasters collected in EM-DAT. Also noteworthy was that 25% of variation in individual reports of exposure to natural disasters occurred at the community level, supporting the idea that taking average ratings from other residents reflects a consensus of the exposure to natural disasters. We then generated a community-level measure of exposure to natural disasters based on neighbours' reports, but not individual self-reports, thereby providing an exogenous measure of disaster exposure in the local area for each household.

Second, we showed that these community-level scores are more strongly related to EM-DAT and reports from barangay officials than individual reports.

Third, we developed a summary score of disaster impacts at the individual level that has adequate internal consistency. The rationale for an individual-level report of disaster impacts was that, whereas exposure is likely to be a shared experience, many household factors will mitigate the impact of exposure to a natural disaster (e.g. quality housing, sources of livelihood). Importantly, this individual-level measure of disaster impact was associated with measures of exposure (individual and area level), barangay official community-level reports and EM-DAT (CRED 2017). However, the impact measure was only moderately associated with the community average, indicating that it was an independent measure of disaster impact.

One key outcome of a natural disaster is the economic impact on households and communities (World Bank & UN 2010). We showed that our preferred measure of disaster exposure, the average community report and disaster impact show evidence of predictive validity in that they are consistently related to household income and the adequacy of income in households.

Previous research in this area is limited, but our findings do align with the existing research. For example, Hunter and colleagues (2012) showed that a self-reported measure of drought was related to objective measures of rainfall, that there was substantial agreement within geographic areas on whether there is a drought, that the heterogeneity of farmers' reports of drought was due to access to other ways of sourcing water through irrigation, and that self-report measures of drought were correlated with financial hardship and worsening financial position. In subsequent work, the same research group showed that self-reported drought, aggregated at the area level in the same way as in our study, was associated with mental health problems, financial stress, decreases in household income and loss of services (with those engaged in agriculture experiencing greater impacts on mental health, financial stress and household income) (Edwards et al. 2019).

One of the limitations of the current study was that the measures of disasters varied in the time period that was captured. Whereas household ratings reported on the past 3–4 years and barangay official community-level reports covered the past 3 years, the cumulative data captured in EM-DAT were for the past 11 years. Therefore, it is not surprising that the relationship between the variables was not higher. Coding of the EM-DAT data is under way to establish a temporally consistent variable. Another limitation of self-reported measures of natural

disasters is that they can be endogenous, or coloured by individual circumstances such as exposure to poverty or mental health issues. In this study, we overcame this limitation by creating an individual-specific average rating of natural disaster exposure in the barangay that uses neighbours' reports but not caregivers' reports. The fact that the two other 'objective' measures of natural disasters – reports by barangay officials and EM-DAT – were more highly correlated with community average reports reinforces the strength of this methodological approach. We chose to develop an individual measure of disaster impact, but EM-DAT also has estimates of the economic impacts of each natural disaster. A limitation of EM-DAT data is that these economic impacts are estimated for the whole disaster and not disaggregated to small neighbourhood areas. Although we did have another source for impacts of natural disasters – reports from barangay officials – these reports were subject to substantial missing information (40% or more barangays). Therefore, although there are attractions in using another rater of disaster impact or another source of information on disaster impact, the significant data limitations precluded such an approach in this study.

This research has several implications. The study further demonstrates that individual self-reports, when aggregated at the area level, can be a valid and reliable measure of disaster exposure (Hunter et al. 2012). This has direct implications for researchers. In the same way that 'ecometric' measures of neighbourhood social capital and disorder (Sampson et al. 1997, Raudenbush & Sampson 1999) heralded an explosion of research into neighbourhood-level measures of social capital and physical disorder, there is potential for our methodology to be adopted by other research groups to generate more nuanced measures of people's disaster exposure than are currently available from objective measures such as EM-DAT. Our technique could also be applied beyond surveys to 'crowd sourced' information through social media or other online platforms – with further development and refinement, these could be used as 'social barometers' of the impact of weather events on populations. They could potentially be used to monitor the implications of climate change, and lead to better and more nuanced supports and mitigation strategies.

Appendix

Table A1 Correlates of individual household self-reported experience of disaster r (number of disasters 2013–17), random effects linear regression models

Characteristic	Model 1	Model 2	Model 3
Indigenous status	−0.0984 (0.0748)	−0.0971 (0.0741)	−0.0678 (0.0755)
Household type (reference: nuclear family)			
Horizontally extended nuclear family	0.0546 (0.0968)	0.0541 (0.0967)	0.0541 (0.0967)
Vertically extended nuclear family	0.0406 (0.0471)	0.0385 (0.0471)	0.0401 (0.0471)
Horizontally and vertically extended nuclear family	0.156 (0.160)	0.152 (0.160)	0.158 (0.160)
Multinuclear family	0.0699 (0.0548)	0.0693 (0.0547)	0.0711 (0.0547)
Number of people in household	0.0117 (0.00846)	0.0112 (0.00845)	0.0120 (0.00846)
Number of rooms used for sleeping	−0.00622 (0.0123)	−0.00550 (0.0123)	−0.00698 (0.0123)
Mean household income ('000 pesos)	−0.00328 (0.00200)	−0.00324 (0.00199)	−0.00333 (0.00200)
Domain (reference: Luzon)			
Visayas	0.530 (0.0988)***	0.495 (0.0956)***	0.521 (0.0981)***
Mindanao	−0.589 (0.0976)***	−0.708 (0.0973)***	−0.400 (0.118)***
Year of interview (reference: 2016)			
2017	0.0937 (0.136)	0.105 (0.132)	0.101 (0.135)
Internet access (reference: No)			
Yes	−0.0741 (0.0423)	−0.0758 (0.0423)	−0.0722 (0.0423)
Barangay official's report		0.0897 (0.0177)***	
EM-DAT disasters			0.0254 (0.00902)**
Intercept	2.830 (0.0916)***	2.596 (0.101)***	2.122 (0.267)***
Number of households	4932	4932	4932
Number of barangays	345	345	345
ICC	0.2533	0.2346	0.2501
R^2 – within	0.0026	0.0026	0.0027
R^2 – between	0.3041	0.3579	0.3193
Overall R^2	0.1219	0.1423	0.1278

* = statistically significant at the 5% level; ** = statistically significant at the 1% level; *** = statistically significant at the 0.1% level; EM-DAT = International Disaster Database; ICC = intraclass correlation coefficient

Note: Standard errors are in parentheses.

Notes

1. EM-DAT includes the the event name; geographical information (standard geography, latitude and longitude); disaster magnitude scale and value (e.g. Richter scale for earthquake, area for flood and drought); date of the disaster; group, subgroup, type and subtype of the disaster; secondary or associated effects or consequences of a primary event (e.g. landslide for a flood, explosion after an earthquake); and the human impact (e.g. number of deaths, people affected, total estimated damages, insured losses). See https://www.emdat.be/guidelines.
2. See www.emdat.be/classification.
3. Cronbach's alpha for the unweighted impacts of disaster variable was 0.61.

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CENTRE FOR SOCIAL
RESEARCH & METHODS

+61 2 6125 1279
csrm.comms@anu.edu.au

The Australian National University
Canberra ACT 2601 Australia

www.anu.edu.au