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Short and medium-run effects of the Indian Ocean tsunami on health costs in Indonesia

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ABSTRACT

This paper looks at the direct and indirect health-related monetary costs that households incurred in the short and medium terms because of the 2004 Indian Ocean Tsunami. The paper uses three rounds of a longitudinal household survey of Aceh and North Sumatra where data were collected 5–17, 18–30, and 31–40 months after the event. The results show that direct costs, measured by out-of-pocket health expenses, increased significantly by a third (35%) compared to pre-tsunami spending, for households living in heavily damaged areas. This effect, however, was seen only in the short-term, 5–17 months after the tsunami struck, and did not persist to the later years. The tsunami had significant effects on mental wellbeing as measured using the post-traumatic stress reaction score (PTSR). Among men, these changes to mental wellbeing were associated with a 4% fall in wage earnings two years after the tsunami. Physical health also worsened according to self-reported measures, and this was associated with a 34% fall in men's earnings three years after the tsunami. Thus, although the direct costs of the tsunami in terms of increasing household out-of-pocket health spending were seen only in the short term, the indirect costs via effects on mental and physical health were apparent two to three years after the event.

1. Introduction

The December 26, 2004, Indian Ocean Tsunami was one of the most destructive natural hazards in modern times directly affecting more than 10 countries in Asia and Africa. In Indonesia alone, around 168,000 people were recorded as having perished or missing with over 500,000 displaced. In spite of the high fatalities, the number of serious injuries following flooding events such as the 2004 tsunami, is argued to be lower than what medical teams expect (Brown, 2005, Morgan and Cairncross, 2005, Sondorp and Bornemisza, 2005). This is thought to be due to those seriously injured facing a higher risk of drowning. However, information is sparse regarding the severity and type of injuries among survivors, consequent infections, mental health impacts, and cascading effects due to public health concerns such as a rise in water or vector-borne diseases. Still more sparse are data regarding monetary costs to households of such effects on health (Guha-Sapir and van Panhuis, 2009). Thus, little empirical work is available about the physical and mental health impacts of the tsunami.

This paper looks at the short and medium-term effects of a tsunami on household-level direct and indirect health costs. It uses the case of Indonesia following the 2004 Indian Ocean tsunami. Direct costs are measured using an estimate of out-of-pocket health expenditure. Indirect costs through earnings lost due to the effect on mental wellbeing. The specific objectives of the paper are as follows (i) identify how out-of-pocket health expenses in a household changed 11, 22, and 36 months after the tsunami compared to pre-tsunami expenses. (ii) identify if there were persistent indirect costs borne by households in terms of income loss associated with poor mental wellbeing. The paper uses three rounds of longitudinal data collected from Aceh and North Sumatra from 5,495 households 5–17 months, 18–30 months, and 31–40 months after the tsunami. These two provinces were severely affected due to their proximity to the earthquake epicentre.

The paper makes several contributions to the literature on disasters and health impacts. First, it is one of the handful of empirical micro-economic papers that evidence the impacts of a disaster on household-level health costs. Although there is a large literature on disasters and health, it is based mainly on qualitative assessments or outcomes at the macroeconomic level, there is very little empirical literature that looks at the household or individual level. Most of the empirical microeconomic literature that does look at disaster impacts focuses on

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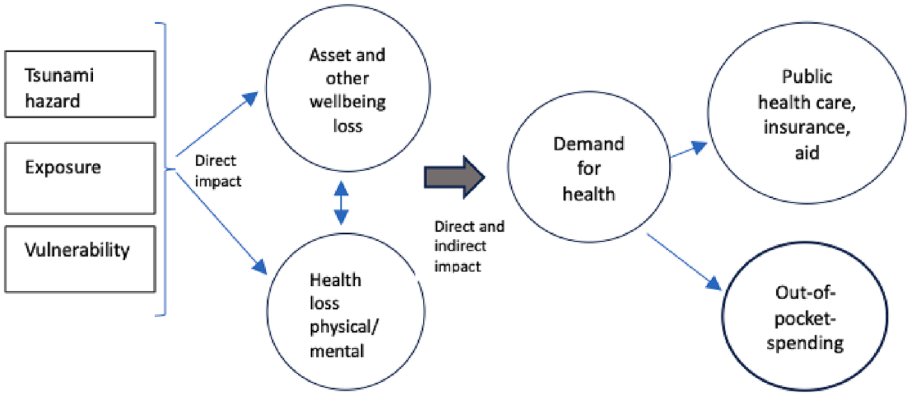

Fig. 1. Impact of tsunami on household demand for health, and how it is financed. Note: The figure is a relationship diagram that shows how the tsunami hazard, exposure and vulnerability can directly and indirectly impact household demand for health and out-of-pocket spending on health, during the months after the event.

consumption, poverty, wages, and business recovery (Ferreira and Schady, 2009, Kirchberger, 2017, Shoji, 2010) rather than health costs to individuals and households. One of the few empirical studies that look at the latter, Chang and Meyerhoefer (2022), argues that the drop in income due to hazards that occurred between 2009 and 2012 in Taiwan, reduced the elasticity of demand for health care among farmers. In contrast, demand for health seems to have increased in the case of urban poor in Indonesia with Escobar Carías et al. (2022) finding that medical costs increased by 24.6% a year after flood events between 2002 and 2015. The sample came from urban poor households in 13 of Indonesia's 27 provinces excluding Aceh.

Secondly, the paper contributes to the literature on how insults to mental and physical health induced by a hazard can affect employment earnings. The literature notes significantly higher levels of post-traumatic stress in the aftermath of a hazard, with some papers noting a higher incidence among women than men (Pynoos et al., 1993, Van Griensven et al., 2006). Other works such as Escobar Carías et al. (2022) note how urban poor rather than urban wealthy were likely to have a higher chance of suffering from depressive symptoms following flooding events using data from Indonesia. In contrast, Frankenberg et al. (2008) find that markers of pre-tsunami socioeconomic status such as wealth were not significant predictors of post-traumatic stress following the event. Instead, individual-level severity of exposure to the tsunami was a key risk factor. One of the few studies that look empirically at post-disaster mental wellbeing and household economic recovery is De Mel et al. (2008) who find that mental health recovery depends on the time since the disaster rather than earnings recovery for small business owners in Sri Lanka during the 18 months following the 2004 tsunami. However, there is no available work, as far as the authors are aware, regarding longer-term correlations between post-disaster mental health outcomes and earnings.

Thirdly, the results of the paper are important to build the evidence base around tsunamis and their impact on direct and indirect health-related monetary costs in the short and medium terms to inform disaster mitigation, aid, and its targeting. A better post-disaster policy can have significant permanent improvements in household welfare (Skoufias, 2003). The work also contributes to the literature that looks beyond the immediate effects of a disaster by focusing on outcomes in the medium term, two and three years later. This helps understand the financial support households may require beyond the immediate aftermath of an event. Finally, empirical evidence on the relationship between hazards, their intensity, and impact on households' outcomes are important to generate damage curves that are used in disaster risk quantification efforts through catastrophe modelling, as done in papers such as (Salmanidou et al., 2021) that links microeconomic outcomes in a risk modelling framework used mainly in the insurance industry. Such work can support risk informed anticipatory action for disaster management. For example, a better understanding of the costs and risks can help set appropriate health insurance or cash pay-outs based parametric triggers. This can avoid scenarios of resource waste, poor targeting, and inequalities in distribution that sometimes happens in disaster relief operations.

When considering direct and indirect health impacts, an important point to note is that the aftermath of the 2004 tsunami was unique due to unprecedented aid flows to ensure that around US$500 million was spent on health financing in the first year after the tsunami. By July 2006, 25% of the damaged health infrastructure in Aceh had been rebuilt (World Bank, 2006). The government of Indonesia also provided'jadup' as an emergency direct cash disbursement of around US$9 per month per person for the first 3–6 months after the tsunami to help cover the basic daily needs of the survivors with a US $ 8.4 million budget. The immediate and massive responses by the World Health Organization (WHO), World Food Organization (WFO), and health authorities meant that public health emergencies such as epidemics of cholera or vector borne diseases were averted. However, there were several deaths due to tetanus infections (Jeremijenko et al., 2007). There were also reports of waste and inefficient resource allocation due to poor coordination. For example, some children were given a measles vaccination 5 times following the tsunami (Sondorp and Bornemisza, 2005). But what exactly were the costs borne by households despite the large aid influx and were the effects persistent? These are issues this paper attempts to address in the analysis to follow.

2. Conceptual framework

Fig. 1 illustrates the ways in which the tsunami can impact household demand for health products and services and how such demand relates to out-of-pocket spending on health. Adapting the standard framework for risk assessment, the left hand side of the figure notes that (a) the probability of the tsunami occurring (hazard), (b) the population and assets located in the affected area (exposure) and (c) the characteristics and circumstances of the household that make it susceptible to the damaging effects of the hazard (vulnerability) can together determine the direct impact of the tsunami on health (physical and mental), assets and other dimensions of wellbeing. Health losses can be physical (illness, injury, infection, and death) as well as mental (anxiety, depression, trauma). Asset losses include losses to land, buildings, livestock, furniture, durables, vehicles, crops, raw materials, etc. Other wellbeing losses refer to losses to livelihoods, community and networks, security, infrastructure, and freedoms. The losses are interconnected and reinforcing, generating both direct and indirect impacts on the demand for health services and products. A direct positive impact on health care demand comes from injuries, trauma, and potential disease outbreak especially if there was substantial population displacement (Datar et al., 2013, Watson et al., 2007). But directly reducing demand for health is the loss of assets and livelihoods and subsequent financial pressure

Table 1
Pre-tsunami Household Characteristics and Post-tsunami Outcomes.

	Location of household according to damage Light	Medium	Heavy	*Diff in means (standard error)*	
	(1)	(2)	(3)	(1)-(2)	(1)-(3)
Panel A: Pre-tsunami characteristics					
Wealth index (0 = no wealth; 1 = most wealth)	0.439	0.437	0.568	0.003	−0.129***
				(0.007)	(0.009)
Rural (proportion)	0.765	0.766	0.568	−0.002	0.197***
				(0.015)	(0.019)
Farming (proportion)	0.478	0.492	0.443	−0.015	0.034
				(0.017)	(0.209)
Panel B: Post-tsunami outcome 5–17 months after the event					
Worse health compared to pre-tsunami (proportion)	0.41	0.53	0.64	−0.11***	−0.23***
				(0.017)	(0.020)
Mental wellbeing- PTSR score	7.38	8.41	11.13	−1.03***	−3.75***
				(0.121)	(0.166)
Change in monthly health expenses between 2004 and 2005 as a proportion of health expenses in 2004	0.07	0.15	0.31	−0.08	−0.24***
				(0.101)	(0.098)
Change in monthly total income between 2004 and 2005 as a proportion of total income in 2004	0.03	−0.13	0.72	0.17*	−0.69
				(0.100)	(0.890)
Panel C: Post-tsunami outcome 18–30 months after the event					
Worse health compared to pre-tsunami (proportion)	0.30	0.33	0.49	−0.03*	−0.19***
				(0.016)	(0.02)
Mental wellbeing- PTSR score	6.22	6.60	8.38	0.38***	2.16***
				(0.117)	(0.156)
Change in monthly health expenses between 2006 and 2004 proportion of health expenses in 2004	−0.21	−0.11	−0.00	−0.10	−0.21**
				(0.064)	(0.084)
Change in monthly total income between 2006 and 2004 as a proportion of total income in 2004	0.99	2.17	1.50	−1.17	−0.50
				(1.70)	(0.85)
Panel D: Post-tsunami outcome 31–40 months after the event					
Worse health compared to pre-tsunami (proportion)	0.12	0.14	0.12	−0.02	−0.00
				(0.01)	(0.013)
Mental wellbeing- PTSR score	5.83	5.93	6.37	−0.105	−0.56***
				(0.112)	(0.141)
Change in monthly health expenses between 2007 and 2004 proportion of health expenses in 2004	−0.12	−0.10	−0.10	−0.02	−0.02
				(0.068)	(0.087)
Change in monthly income between 2007 and 2004 as a proportion of income in 2004	1.89	0.42	0.71	1.47	1.17
				(1.06)	(1.87)
Observations (households)	1,202	3,217	1,076		

Notes: Columns 1–3 present mean values under each damage category for the respective variables. An asterisk against a value in column 4 indicates that the difference in the relevant mean for medium areas is statistically significantly different to that of no/light damage areas. Similarly, an asterisk against a value in column 5 indicates the relevant mean for heavy damage areas is significantly different to that of no/light damage areas. Robust standard errors in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01 To ensure that all monetary measures are comparable, the health expenses are reflected in 2004 prices. The conversion of expenses uses the consumer price index (CPI) released from the Indonesian Office of Statistics (BPS).

(García-Gómez et al., 2013). Indirect impacts on health demand arise as lower incomes cause households to substitute away from health care into other areas such as food consumption or education expenses. Indirect effects also arise through household labour market decisions post-tsunami as high and persistent post-traumatic stress, depressive symptoms or poor physical health may interfere with daily activities and concentration at the workplace, thereby reducing earnings. Some households may compensate for loss in income through spending more time working, with reduced time devoted to health production and therefore healthcare demand. But subsequent stress or a reduction in sanitary living conditions could increase demand for health care.

A part of the post-tsunami demand for health may be met financially by the public health care system, social protection schemes or insurance schemes. Support can also come through aid and assistance. However, if the healthcare system and aid are not adequate, poor in quality and/or aid is mis-targeted, health demand may be financed by private spending (households) in the form of out-of-pocket spending.

How does post-tsunami out-of-pocket spending compare with the one pre-tsunami? This depends on the change to demand and to what extent it is met by sources other than private spending. If the post tsunami scenario is one with a high influx of aid, subsidies and increased free services in the short to medium terms, this may mean that households need to spend less, out-of-pocket, than what they did pre-tsunami even with health outcomes that are worse than before. On the other hand, an increase in demand for health services and products may increase health spending compared to pre-tsunami levels. Overall, therefore, the effect of a hazard in household health demand and subsequent out-of-pocket spending is ambiguous. This has been noted in the context of other natural hazards as well (Chang and Meyerhoefer, 2022). It remains to be seen empirically, therefore, how out-of-pocket health expenses in the short and medium term evolved in the case of Aceh and North Sumatra following the devastating tsunami and subsequent large flows of aid.

While a change to out-of-pocket spending captures direct financial health costs to a household due to the tsunami, indirect costs can be captured by the impact of hazard-related mental well-being changes on individual earnings in the short and medium terms. Several studies in non-disaster contexts show that poorer mental well-being can affect hours worked, productivity and earnings (Bubonya et al., 2017, Loughran and Heaton, 2013). Similarly the loss of livelihood, employment and economic shocks may affect mental well- being bringing about depressive symptoms (De Quidt and Haushofer, 2019). However, the loss of income may be cushioned somewhat in the short-run if massive humanitarian support provides opportunities for income support through schemes such as cash-for work and micro-enterprise programs, as was the case in Indonesia after the 2004 tsunami (Himaz, 2022). Post-disaster labour markets may also cause wages to increase in some sectors, thus improving overall earnings compared to pre-tsunami levels (Groen et al., 2020, Kirchberger, 2017). How these factors contributed to the association between mental well-being and individual earnings in the case of post-tsunami Aceh and North Sumatra, also remains to be seen empirically.

3. Data and descriptive Statistics

The data for all estimations and discussion in this paper come from the Study of the Tsunami Aftermath and Recovery round 1 survey (STAR1) conducted 5–17 months after the tsunami, while rounds 2

(STAR2) and 3 (STAR3) carried out 18–30 months and 31–40 months after the event, respectively. The sample contains 5,495 panel households with information about household level out-of-pocket on health and other relevant variables. We also have 3,049 males from these households over age 15 with information on employment earnings, mental wellbeing and physical wellbeing.

Of the sample, 20% households were located in areas that suffered heavy damage due to the tsunami, 59% medium damage and 22% no/light damage. The 'heavy', 'medium', 'no/light' categorisation by level of damage to the area has been constructed by the STAR survey team, based on satellite imagery of the destruction to physical structures and the environment just before and after the event for every 0.6 km^2 validated using interviews at the village level while collecting data.[1]

As Table 1: Panel A shows, households in heavy damage areas at the time of the tsunami were significantly wealthier and located more in urban areas compared to those from no/light damage areas. Pre-tsunami household wealth is measured using the variable *wealth index* that ranges from 0 (least wealthy) to one (wealthiest). It has been constructed using data on common assets the household owns such as a house, land and durable goods. More details on how the wealth index and several other variables in this paper are constructed are available in the appendix.

The households in medium damage areas were also located more in urban areas compared to those in no/light damage areas at the time of the tsunami. The sector of residence (rural versus urban) is often a proxy for health care access. Farming households are argued to have higher rates of disability and illness than the general population (Chang and Meyerhoefer, 2022) and this may mean these households are more vulnerable to tsunami-related losses to health. In our sample the percentage of households engaged in farming does not vary significantly by area of damage.

Table 1: Panel B presents selected post-tsunami outcomes 5–17 months later. Its first row shows the proportion of households where at least one member reported to have physical or mental health outcomes that were worse 5–17 months after the tsunami struck than pre-tsunami outcomes. We create a variable called *worse health* where this binary variable is coded 1 if at least one adult member of the household over 15 years of age reports to experience worse physical or mental health at the time of the interview compared to pre-tsunami levels. Unsurprisingly, there are significantly more households in heavy damaged areas where members report worse health compared to no/light damage areas, at 64% versus 41%. Similar results are seen if we focus on mental well-being outcomes alone. Mental well-being is measured by looking at the post-traumatic stress reaction (PTSR) based on an 8-item scale from the 17 symptom items of the PTSD Checklist-Civilian Version (Weathers et al., 1993). The score is based on responses in the interviews by those over 15 years of age about the intensity of psychological reactions that are symptomatic of post-traumatic stress. These include trouble with concentration, avoiding people or places that remind the respondents of the tsunami or repeated, disturbing memories, thoughts, or dreams. The responses ranged from no experience (coded 0) to those quite frequent (coded 3). Summing the responses across the 8 items gives a raw PTSR score ranging from 0 to 24. The higher the score the worse is an individual's mental well-being in terms of post-traumatic stress reaction. Details regarding the construction of this index can be found in the Appendix. The average scores by area of damage show that at the time of the interview in 2005, the psychological distress experienced was significantly high among those in heavy and medium damage areas compared to no/light damage areas.

Matching trends of higher PTSR and higher reports of worse household health immediately after the tsunami in heavy damage areas, out-of-pocket health spending in these areas increased by 31% on average compared to pre-tsunami spending, significantly higher than the corresponding 7% of no/light damage areas. The measure for household out-of-pocket health spending used in this paper includes spending on inpatient and out-patient treatment in health facilities, traditional treatment and medication, self-medication and other health products such as eyeglasses. The difference in such expenses before and after the tsunami as a proportion of pre-tsunami health spending is the health cost variable of interest. A caveat is that it is a crude proxy for actual changes in out-of- pocket health spending. This is because although post-tsunami health spending is available in the survey, pre-tsunami values had to be estimated using STAR1 data as outlined in the Appendix.[2]

Did these health outcomes and spending patterns persist to the medium term? Overall, health outcomes measured through variables *worse health* and *PTSR* improved from round 1 to round 2 but as Panel C shows, households in heavy and medium damage areas continue to show significantly poorer scores that no/light damage areas 2 years after the tsunami. To elaborate, 49% of households in heavy damaged areas reported to have at least one member of the household with worse mental or physical health compared to pre-tsunami levels compared to a significantly lower 30% in no/light damage areas. Mental health scores continue to be significantly poorer in heavy and medium damage at the time of the tsunami compared to the other area. Despite decreasing, differences in out-of-pocket expenses between areas still appeared to be significantly different, especially between the areas with heavy destruction compared to those with no/light damage. Three years later, we observe that out-of-pocket expenses on health between areas are no longer different. We also observed that the scores fell in the years after the event in all areas. However, even three years after the event, mental well-being was significantly worse in heavy damage areas compared to no/light damage areas at 6.38 compared to 5.83.

In terms of the change in income (wages, profits and other earned and non-earned income) pre and post tsunami, those in medium damage areas at the time of the tsunami indicate a higher change compared to those in no/light damage areas in the short and medium terms. The change is greatest in the short term. Such differences are not seen between earnings of those in heavy damage areas and no/light damage areas.

4. Empirical framework

4.1. Direct health cost: Effect of tsunami on out-of-pocket health expenses

To understand the effect of the tsunami on household out-of-pocket health spending, the identification strategy relies on the exogenous nature of the tsunami. Denoting the time just before the tsunami by t = 0 and 5–17, 18–30 or 31–40 months after the event by *s*, we specify the following model:

$$\Delta y_{j,t+s} = \beta_0 + \beta_1 M_j + \beta_2 H_j + \beta_3 X_{j0} + u_{j,t+s} \quad (1)$$

[1] Alternative indicators for intensity could have been proxies commonly used in the engineering literature when assessing tsunami damage to buildings and infrastructure such as inundation depth, tsunami velocity, moment flux, moment of momentum flux, drag force, the quasi-steady tsunami force (*F*QS), and the debris impact as it affected each dwelling (Charvet 2017). This type of information is not available for a dataset covering such a large geographic area. Even if it were available, it would measure intensity as it affected physical infrastructure rather than people. An alternative indicator of how intensely the tsunami affected a household would be individual household-level exposure to the tsunami based on seeing people drown, and hearing screaming. We use this index of intensity as an alternative to damage intensity later on in the paper.

[2] Our estimates show that pre-tsunami household out-of-pocket health expenditure was about 3.7% of household income, on average. This matches WorldBank (2006) estimates of 3.7% for monthly household health expenses as a percentage of all household spending in 2004 for Indonesia, based on the SUSENAS, a national government survey on household income and expenditure.

Table 2
The Effect of Tsunami and pre-tsunami characteristics on Change to Households' Out of Pocket Health Spending.

	OLS			IPW		
	2005	2006	2007	2005	2006	2007
	(1)	(2)	(3)	(4)	(5)	(6)
Medium	0.08	0.10	0.02	0.08	0.07	−0.00
	(0.09)	(0.07)	(0.07)	(0.09)	(0.07)	(0.07)
Heavy	0.26**	0.22**	0.05	0.35**	0.15	0.05
	(0.12)	(0.08)	(0.09)	(0.15)	(0.10)	(0.10)
Wealth Index	−0.17	−0.13	−0.03	−0.26	−0.13	0.06
	(0.18)	(0.13)	(0.14)	(0.27)	(0.20)	(0.19)
Rural	−0.02	−0.08	0.19***	0.20	−0.18**	0.18**
	(0.09)	(0.07)	(0.07)	(0.13)	(0.08)	(0.09)
Farming	0.03	0.11*	−0.14**	−0.10	0.15**	−0.25***
	(0.08)	(0.06)	(0.06)	(0.12)	(0.08)	(0.08)
Constant	0.14	−0.15	−0.19*	0.22	−0.08	−0.15
	(0.13)	(0.09)	(0.10)	(0.17)	(0.12)	(0.11)
Observations	5,495	5,495	5,495	5,495	5,495	5,495

Notes: The dependent variable is the difference in household per-capita out-of-pocket health spending at the time of the interview and pre-tsunami as a proportion of pre-tsunami per-capita out-of-pocket health spending. Tsunami damage is represented by medium and heavy with no/light omitted. All other independent variables are pre-tsunami values. OLS refers to results using the ordinary least squares estimator. IPW refers to inverse probability weight adjusted OLS estimates. Robust standard errors in parentheses $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3
Effect of changes to Mental and physical well-being on changes to employment earnings for men.

	2005	2006	2007	2005	2006	2007
	(1)	(2)	(3)	(4)	(5)	(6)
Mental wellbeing (PTSR)	−0.014	−0.042**	0.010			
	(0.010)	(0.018)	(0.015)			
Physical wellbeing				−0.049	0.341	−0.340**
				(0.140)	(0.242)	(0.163)
Wealth index	−0.010	−0.284	−0.049	−0.034	−0.339	−0.046
	(0.250)	(0.422)	(0.349)	(0.250)	(0.421)	(0.349)
Rural	−0.178	−0.143	0.490**	−0.192	−0.115	0.498**
	(0.142)	(0.240)	(0.199)	(0.142)	(0.240)	(0.199)
Education	−0.014	0.041**	0.033*	−0.014	0.047**	0.029*
	(0.012)	(0.020)	(0.017)	(0.012)	(0.020)	(0.017)
Household size	0.006	0.025	0.028	0.007	0.025	0.032
	(0.024)	(0.040)	(0.033)	(0.024)	(0.040)	(0.033)
Constant	0.215	0.895**	0.163	0.121	0.533	0.304
	(0.245)	(0.416)	(0.338)	(0.235)	(0.398)	(0.330)
Observations	3,049	3,049	3,049	3,047	3,049	3,049

Note: The dependent variable is the difference in real monthly wage earnings at the time of the interview and pre-tsunami as a proportion of pre-tsunami real wages. Tsunami damage is represented by medium and heavy with no/light omitted. All other independent vairables are pre-tsunami values. OLS estimator used with sample weights. Sample includes only men who had positive pre-tsunami employment earnings. Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1.

for households $j = 1 \ldots J$ where $\Delta y_{j,t+s}$ is the difference in a household's monthly out-of-pocket health expense between period s and just before the tsunami as a proportion of pre-tsunami health spending before the tsunami winsorised at the 1st and 99th percentiles. M and H are dichotomous variables that equal 1 if the household was in an area where the damage from tsunami was moderate or heavy, respectively. X is a vector of pre-tsunami household characteristics, which includes the household wealth index, sector of residence that equals 1 if it is a rural area and 0 otherwise, and whether it is a household engaged in farming. u is an idiosyncratic shock.

As noted in Table 1, the pre-tsunami characteristics are not always balanced between heavy, medium, and no/light areas of damage. Thus, the sample affected by different damage intensities ('treatments') may differ in their distributions of pre-treatment variables and, therefore, possibly differ in terms of out-of-pocket health expenses in ways that are not attributable to the treatment. If all the variables with pre-treatment differences are observed and the areas by damage (i.e., the treatment groups) have at least some households with similar covariates (i.e., conditional independence and overlap hold), then in principle, a treatment sample can be re-weighted to make the distribution of covariates match that of any of the other treatment groups (Rosenbaum and Rubin, 1983). We therefore use the available pre-tsunami characteristics such as rural, wealth index and farming as matching variables to estimate a propensity score. Observations are then weighted inversely proportional to their propensity score, similar to papers by Deryugina et al. (2018); Kirchberger (2017). Identification relies on the exogenous nature of the tsunami just like most other natural disasters, that was unanticipated and unpredictable −the first in 600 years- with the first waves reaching landfall around 20 min after the earthquake. The identifying assumption in the model is that $E(\varepsilon_{j1}|M_j, H_j, X_{j1}) = 0$, so that tsunami intensity, wealth, rural residence and being a farming household in t = 0 are not correlated with unobservables determining health spending between t = 0 and t + s. This assumption may be violated if, for example, those who are wealthier have a higher ability to cope with shocks to a growth in health spending, thereby indicating a higher growth in health spending. But this assumption seems more convincing than assuming that current household characteristics are uncorrelated with current unobservables determining household health spending once time invariant household characteristics are controlled for, as is the case of a standard fixed effects model. Nonetheless, in our robustness checks we estimate the following fixed effects model:

$$y_{ij} = \beta_0 + \beta_1 M_{ij} + \beta_2 H_{ij} + \beta_3 X_{ij} + \delta_t + u_{ij} \quad (2)$$

where y is the log of real per capita health spending of household j at

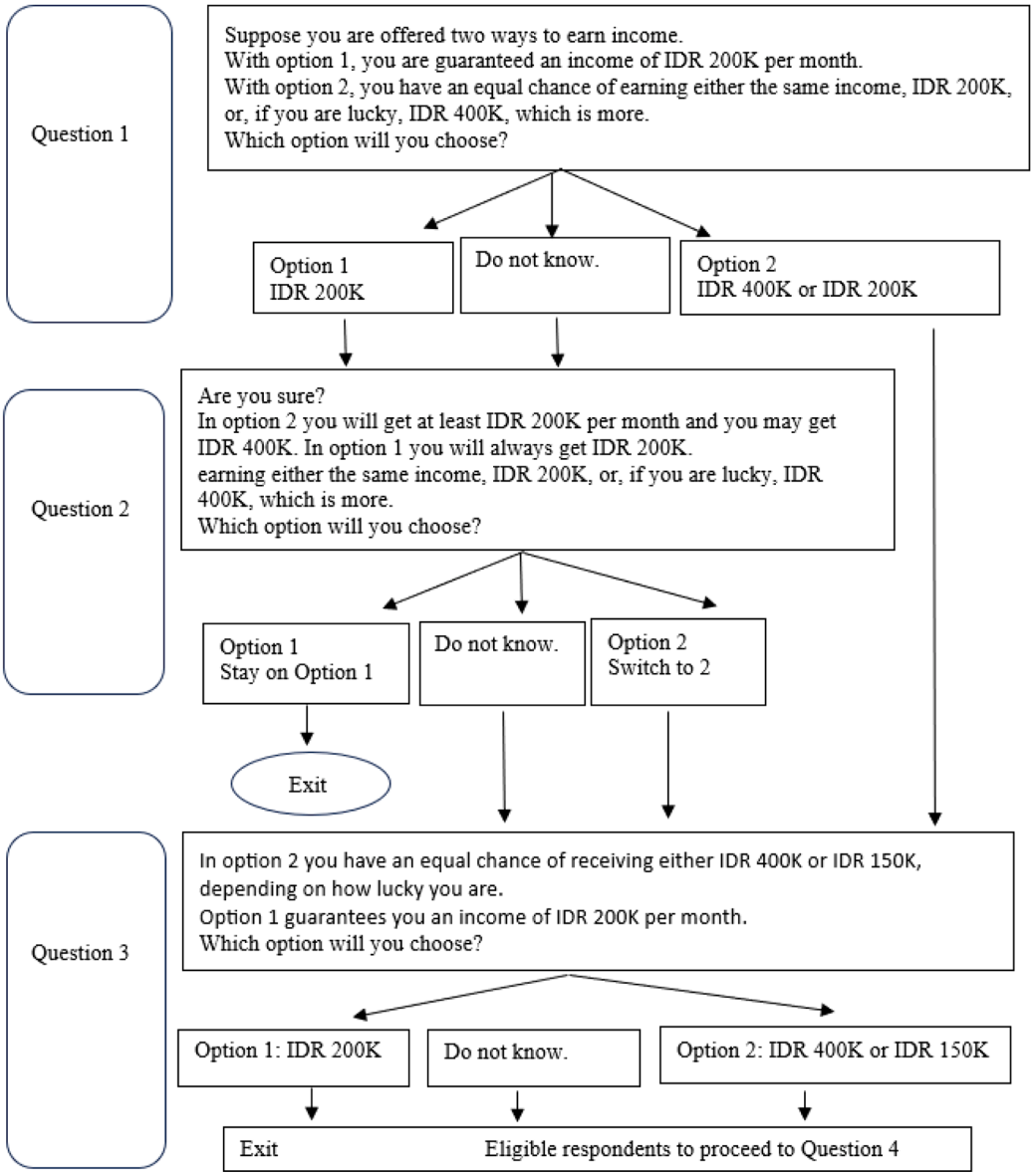

Fig. 2. Risk aversion index construction based on evolution of lottery questions.

time t with t = 0, 1, 2 or 3 (represent pre-tsunami or 5–17, 18–30, 31–40 months after the tsunami respectively), M and H indicate whether the household was in a medium or heavy damage area, X is a vector of household characteristics such as wealth index, health status (=1 if worse health due to tsunami or 0 otherwise), log of household income from employment, subsidies, aid and other sources, farming status (=1 if household engaged in farming activity and 0 otherwise), household migration (=1 if migrated due to displacement or other reason and 0 otherwise). δ_t are between-context contrasts, and the u_{tj} are assumed to be classical Gaussian errors.

4.2. Indirect health cost: Mental/physical wellbeing and effect on income

To understand the effect of mental wellbeing on income we estimate the following model using Ordinary Least Squares clustered at the household level with t and s related to time defined as before:

$$\Delta w_{i,t+s} = \delta_0 + \delta_1 D_{i,t+s} + \delta_2 X_{i0} + u_{i,t+s} \quad (3)$$

for individuals $i = 1 \ldots N$ where $\Delta w_{i,t+s}$ is the difference in employment earnings between s and pre-tsunami levels as a proportion of pre-tsunami earnings for those individuals with positive pre-tsunami earnings. $D_{i,t+s}$ is the difference in mental wellbeing measured using PTSR between time $t+s$ and $t=0$ (i.e., pre-tsunami). We restrict the sample to those individuals who reported that they did not have any mental health issues prior to the tsunami and therefore assume pre-tsunami PTSR to equal 0 (i.e., assume individuals do not indicate post-traumatic stress reaction symptoms before the event). We do not include a measure of tsunami intensity in this specification as this is strongly correlated to mental health outcomes. X_0 is a vector of individual characteristics such as male (=1 if male), pre-tsunami years of education (ranging from 0 to 16), household wealth and sector of residence (rural = 1, 0 otherwise). $u_{i,t+s}$ is the idiosyncratic error term.

Coefficient $\delta 1$ shows the association between mental wellbeing change and change in earnings. A causal relationship between the two variables relies on the conditional independence assumption i.e., the variation (net of the core set of control variables) in mental wellbeing is not confounded with any further factors correlated with earnings. It also assumes that the control group of individuals were not affected by the post-traumatic stress reaction and adverse mental wellbeing effects of their neighbours (i.e., the stable unit treatment value assumption). Even

if robustness checks can check for these conditions, the possibility of reverse causality between the variables is high (i.e., mental wellbeing affects earnings and vice versa). Thus, we only claim the results are indicative of an association rather than providing evidence of causality.

To capture the effect of physical wellbeing on income, we replace variable $D_{i,t+s}$ in (3) with a dichotomous indicator *physical health* that captures the change to physical health status between time $t+s$ and $t=0$ (i.e., pre-tsunami) for those who earned a positive income in $t=0$. If the physical health status is reported to have worsened at the time of interview compared to pre-tsunami levels, then *physical health* $=1$ and is 0 otherwise.

5. Results

5.1. Direct health costs

The results of the OLS and propensity score weighted estimations of (1) are presented in Table 2. The weighted estimates in column 4 show that in heavy damage areas, household out-of-pocket health spending was 35% higher than that for no/light damage areas. This is statistically significant. Apart from this, being a farming household and being in a rural area were also significant in the medium term (2 and 3 years after the tsunami) but the sign is different in each of the years suggesting that the way these variables influenced health spending was different over time. Our results (unreported) are robust when we employ a less parsimonious specification, including household demographic decomposition (share of males and females aged 0–14, 15–30, 31–50, 51 +) and education level of the most educated. As a final check of robustness, we reconstruct the dependent variable, change to health spending based on an alternative estimation of pre-tsunami health as outlined in the Appendix. By this estimation (unreported), health spending is on average 36% higher 5–17 months after the tsunami compared to pre-tsunami levels in heavy damage areas compared to no/light damage areas. The rest of the results remain the same in terms of sign and significance.

Results of fixed effects estimations according to model (2) above are presented in Appendix 2 Table A1. The first three columns (1)-(3) show the impact of the tsunami in the immediate aftermath using pre-tsunami and round 1 data. Column 1 shows that when accounting for variations in household wealth and other variables, heavy damage areas on average see a significant increase in health spending of 18.6%. This figure is around 16.9% when allowing for changes in total income (from various sources such as employment, business profits/loss, aid, remittances, formal and informal insurance) and perception of risk. Attitudes towards risk influence many economic decisions and may vary across individuals, especially during the occurrence of natural disasters. We construct a risk aversion index in our sample to measure an individual's risk attitude over a series of questions on lotteries by choosing a guaranteed monetary payoff (G) or other alternative payoffs based on a certain probability which can be higher (H) or lower (L) than the promised monetary payoff (G). We take the insight from Thamarapani and Rockmore (2022) in developing the index of risk aversion and instead of four levels of risk aversion, we create a binary risk aversion index to group those who are the most risk averse and second risk averse into one category (1) and the least risk averse and second least risk averse individuals into another category (0). Column (3) uses household exposure to the tsunami as an alternative measure of intensity. The exposure to tsunami of all adults in the households is constructed as the sum of positive responses to 18 items regarding individual household members experiences during the tsunami such as 'Felt the earthquake', 'Heard the sound of water rushing', 'Heard people shouting about in the water', etc. More details regarding this index are available in the appendix. Matching results for the 'medium', 'heavy' indicator, exposure also shows that higher was the intensity higher was subsequent health costs, controlled for variations in wealth and household health conditions. The results follow a similar trend when the fixed effect estimator is applied to data from all rounds: health spending was significantly higher for those in heavy damage areas (columns 4 and 5). This matches the trend in results in our baseline estimations.

5.2. Indirect health costs

The association between changes to PTSR (representing mental wellbeing) and individual employment earnings is presented in Table 3. As the result in column 2 shows there was a significant association at the 5% level with a unit increase in post-traumatic stress reaction reducing employment earnings by 4% for men two years after the event. The results are robust incorporating other factors that could potentially influence the changes in incomes such as pre-tsunami household demographic composition, education level or household size. As a further check of robustness, the change to raw PTSR scores was replaced by change to the PTSR z-score. Again, the results (unreported) were robust to this change in specification.

In terms of physical health, those reporting worsening physical health compared to pre-tsunami levels 2 years after the event correlate with employment earnings falls of about 34% although there are no significant changes to earnings in the immediate aftermath. The data does not allow us to investigate what type of physical injuries, symptoms or deterioration is closely associated with lower earnings and this indirect medium-term impact of the tsunami remains to be researched further.

The effects were also estimated using the fixed effects estimator for those who had positive earnings pre-tsunami, with the dependent variable being log earnings and the time variant dependent variables including PTSR (or a binary indicator that equals 1 if physical health is worse compared to the tsunami), age, wealth index, household size, perception of risk and round. These results provided in Appendix Table A2 show even stronger associations between PTSR, physical health and earnings. Around 5–12 months after the tsunami, earnings fall by about 1.7% for every unit increase in the PTSR score and by 16.7% if physical health is reported as worsening. Using all four rounds, the average fall to earnings due to mental well-being worsening by a unit is nearly 1 % and physical health worsening is 8.7%.

6. Discussion

Although conceptually the effect of natural hazards on household level out-of-pocket health-related expenses is ambiguous as discussed in Section 2, our results showed that at least in the short-run, health costs to households was around 35% higher in heavy damage areas compared with no/light damage areas, despite the influx of aid and the effective containment of a disease outbreak following the 2004 tsunami as noted by the World Health Organisation (2005). What type of health spending contributed the most to household out-of-pocket spending in the short term? To understand this, we used information on disaggregated health spending for the month before the interview took place available under 5 categories: inpatient treatment in health facilities, outpatient treatment in health facilities, traditional treatment/medication, self-medication and other spending on health products and services besides those described above such as consultancy fees, pregnancy check-up, circumcision, eyeglasses, dentures, etc. We find that 5–17 months after the event, for households living in heavy damage areas the proportion of total health expenses devoted to inpatient care and self-treatment was 3.5% and 55% respectively, significantly higher than the corresponding proportions for no/light damage areas of 2% and 51%. Outpatient care comprised 33% of health spending in heavy damage areas. Later rounds of the STAR survey (not yet publicly available) show that five years after the tsunami a notable health impact was the higher fertility, the formation of new families through marriage and childbearing in households that were affected by the tsunami compared to those that were not (Nobles et al., 2015). Moreover, children who were *in utero* at the time of the tsunami and born 3 to 6 months afterward

had lower height-for-age at eighteen months compared to counterparts in earlier cohorts, reflecting both maternal stress during pregnancy and possibly reduced resources. However, three years later these children had caught up or surpassed heights for age of those in older cohorts (Cas et al., 2014). This suggests the positive impact of well financed and well organised post-tsunami reconstruction efforts on health outcomes and the remarkable recovery of the affected regions.

A caveat with our result on out-of-pocket spending changes is that the measure of pre-tsunami spending is based on estimation, given that the survey does not contain this information. This may mean the estimates are biased. However, the result of an increase in health spending of 35% in heavy damage areas compared to no/light damage areas is in line with another study by Escobar Carías et al. (2022) who estimate the effect of flood exposure among the Indonesian urban poor population, where they showed using the Indonesian Family Life Survey (IFLS) that households had to spend 24.6% higher on medical expenses one year after the flood. The effect to mental and physical caused by a destructive tsunami with waves up to 25 m high as it headed inland (Borrero, 2005), generated from an earthquake recording magnitude 9.1–9.3 MW is likely to be higher than that caused due to other forms of flooding so it can be expected that health consequences of such an event are higher than that of other flooding events. Indeed, the effect we derive may be an under-estimate given the Indian Ocean tsunami saw unprecedented aid flows. Around 92% of those in heavy damage areas received some form of transfer in the immediate aftermath compared to 61% and 42% in medium and no/light damage areas respectively. Thus the 35% increase on average in health spending in heavy damage areas may be lower than that of a natural hazard of similar magnitude, had the transfers been lower. The aid flows, successful curbing of epidemic outbreaks, the introduction of mental health support and community rebuilding initiatives (Marthoenis et al., 2016) and the rapid rebuilding of infrastructure may have also contributed to the non-persistence of higher health costs into the medium term that is noted in our results.

There were significant mental well-being effects of the tsunami that lasted well into three years after the tsunami. The paper found a correlation between post-traumatic stress reaction and employment earnings two years after the event with earnings falling by around 4% for men as PTSR scores increased by a unit. Shocks to physical health indicated an impact on earnings two years after the event by reducing earnings by about 34% for men, set in the wider context of reducing external aid.

7. Conclusion

This paper looked at the effect the 2004 Indian Ocean tsunami had on direct and indirect health costs among households in Aceh and North Sumatra around 5–17, 18–30 and 31–40 months after the event. We consider outcomes in the first round to reflect short-run impact and the two later rounds medium term impacts. The results showed that in heavily damaged areas, health costs were about a third higher than pre-tsunami values compared to areas with no/light damage. These effects did not persist to the medium term and the expenses on health seem to rebound to the pre- tsunami period. The massive influx of aid and support with health post-tsunami together with the rapid infrastructure redevelopment in affected areas may have explained some of the health-based recovery.

The study also noted how there were significant adverse effects to mental well-being in the short run that persisted to the medium term. These negative mental well-being outcomes, measured using a raw score for post-traumatic stress reaction, correlated with individual earnings falling by around 4% on average for every unit increase in the score, 2 years after the event. Worse physical health affected employment earnings for men by reducing it by 34% 3 years after the event. Before the tsunami Aceh was one of the poorest provinces in Indonesia with health infrastructure were relatively less developed compared to other parts of Indonesia. Although there is evidence to show that health infrastructure may have been built back better in many respects with the help of unprecedented aid, for those mentally and physically affected, indirect negative consequences of poor health on earnings seems to have been emerging a few years after the event. This aspect needs further investigation.

The findings contribute to an area that has little empirical information on the extent of correlation between natural hazards and their costs to the health of individuals. We use the term correlation given the limitations of the study, discussed in previous sections, that do not allow us to confirm causality. This is a common issue in impact evaluation. The methodology we used in this paper was limited by the data that was available to us. For example, pre-tsunami data, although available, is not available to researchers due to Indonesian data protection laws. There was also no geo-referenced, administrative or remote sensed data that could have been of avail. Although satellite data is available for the period and machine learning techniques could be applied to look at recovery speed and patterns, it will not shed light on household health spending. Given the limitations inherent to impact evaluation using non-experimental historical data our paper offers some first insights, as far as we are aware, of the persistent effects of the 2004 tsunami on household-level health costs.

CRediT authorship contribution statement

Daim Syukriyah: Writing – original draft, Formal analysis, Conceptualization, Data curation, Visualization, Writing – review & editing. **Rozana Himaz:** Writing – review & editing, Supervision, Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Variable definitions and construction

Wealth Index

Ranges from 0 to 1 and indicates how wealthy a household was just before the tsunami struck, with 0 being least wealthy and 1 being wealthiest. In

order to create a wealth index, we use the list of common assets including 8 items of household assets such as a house, land, livestock, vehicles (bicycles and cars), household durable goods such (furniture and appliances), gold, cash and financial instruments such as stocks, shares and bonds), without taking into account its monetary value, and converted into an index below (Salmanidou et al., 2021):

$$\frac{\sum_i assets_i - assets_{min}}{assets_{max} - assets_{min}}$$

where $assets_{min}$ to $aseets_{max}$ is the range of these items in the dataset.

Change in Out-of-pocket Health Expenses

The difference in monthly out-of-pocket health spending per capita at the time of the interview and pre-tsunami as a proportion of pre-tsunami health expenses. Household out-of-pocket health spending includes those on inpatient and out-patient treatment in health facilities, traditional treatment and medication, self-medication, health insurance payments and other health products such as eyeglasses. Pre-tsunami health expenses are not available in the surveys and have to be estimated to reflect what hypothetical health expenses would have been for a given household before the tsunami. To do this, we take the sample of households who did not see a worsening of health post-tsunami compared to pre-tsunami levels using round 1 data and use OLS regression analysis to estimate health spending controlled for pre-tsunami characteristics wealth, sector of residence and farming status of household. Since the pre-tsunami characteristics used are not balanced for households with and without a worsening of health, the regression is weighted inversely proportional to a propensity score estimated using rural, wealth index and farming. The estimated coefficients are then used to predict health spending for the entire sample. The predicted health spending is assigned as pre-tsunami health spending.

An alternative estimate of pre-tsunami health spending is used in our checks for robustness of results in Table 2. Under this measure, if household health did not worsen between 2004 and 2005 (i.e., *worse health* round 1 = 0) then pre-tsunami health expenditure for that household was assigned to be the same as that at the time of the interview. If health worsened between rounds (i.e., *worse health* round 1 = 1) then the pre-tsunami health spending for that household was assigned to be the average value of health expenses for those households in the same pre-tsunami wealth quartile but with no worsening of health. The assumption here is that pre-tsunami per capita health spending was broadly equal among households in each wealth quartile. For rounds 2 and 3, if no one in the family reported of worsening health in any of the previous rounds then pre-tsunami health expenditure for that household was assigned to be the same as that at the time of the interview. All other households experience some volatility in health over the two years. Pre-tsunami health spending for these households was assigned to be the average value of health expenses at the time of the interview for those households in the same pre-tsunami wealth quartile with no worsening of health in all previous rounds.

Post Traumatic Stress Reaction (PTSR) for Adults (aged 15 and older)

PTSR is assessed by using 8 symptoms items from the 17-item PTSD Checklist-Civilian Version validated in various settings (Blanchard et al., 1996, Weathers et al., 1993). The leading question in the survey was "Now, I am going to describe some problems people often have after something very bad such as a tsunami happens. I will ask you if you have experienced the feelings, and, if so, how often over the past month", where: never = 0, rarely = 1, sometimes = 2, often = 3. The 8 symptom items were: "Had upsetting thoughts or pictures of what happened come into your mind when you do not want them to?"; "Gotten upset, afraid or sad when something makes you think about the tsunami happened?"; "Nightmare including dream about tsunami"; "Tried not to think about the tsunami"; "Tried to stay away from people, places, or things that make you remember the tsunami"; "Had trouble going to sleep, or wake up often during the night"; "Felt grouchy, or are you easily angered; Had trouble concentrating or paying attention".

The PTSR score in absolute terms can range from 0 to 24. An alternative presentation is to normalise all responses to z-scores (subtract mean and divide by the standard deviation) and then take an average of the relevant z-scores across the questions that have no missing values. The normalization aims at correcting the metrological properties of the psychometric tests such as the ceiling and floor effects and the curvilinearity (unequal interval scaling). Please see Philipps et al. (2014) for details. Chronbach's alpha for PTSR in round 1 is 0.7252 and round 2 is 0.6874 while PTSR score in round 3 is 0.7190. Chronbach's alphas between 0.6–0.8 suggest that the outcomes are reliable and acceptable meaning that the scores measuring some post-traumatic symptoms were relatively stable over three years. The change to PTSR used in the regressions is calculated as the difference in an individual's PTSR between a given survey round and pre-tsunami. The paper assumes that the PTSR scores pre-tsunami were zero for those individuals who did not report mental well-being related concerns for the period just before the tsunami.

Change in total Income

Difference in average monthly income during the year of the survey (i.e., 2005, 2006 or 2007) and pre-tsunami income as a proportion of pre-tsunami income. Income includes those from employment from earnings, profit/losses from businesses, transfers from government, NGOs or received as aid, pension, formal and informal insurance, net remittances. Household income is calculated as the average of all income of household members. To ensure that all monetary measures are comparable, all monetary values are first converted to 2004 prices. The conversion of expenses uses the consumer price index (CPI) released from the Indonesian Office of Statistics (BPS).

Exposure

The exposure to tsunami of all adults in the households is constructed as the sum of positive responses to 18 items, preceded by the following question: 'Now I would like to ask you some questions about things you may have experienced during the tsunami': 1. Felt the earthquake 2. Heard the sound of water rushing 3. Heard people shouting about in the water. 4. Saw tsunami come ashore 5. Swept away in the water 6. sustained injuries 7. Saw family members struggle in the water 8. Saw family members disappear 9. Saw friends/neighbours struggle in the water 10. Saw friends/neighbours disappear 11. Waded through afterwards12. Lived afterwards in destroyed areas 13. Searched for family members in refugee camps 14. Saw dead bodies 15. Searched for bodies of family members 16. Found or identified bodies of family members 17. Were you scared that you would die? 18. Were you scared that you would be hurt badly? Thus, the sum of this measure e_{ij} for an individual adult in a household j ranged from 0 to 18. The average of this measure for all m adults in household j also ranged from 0 to 18. The average exposure experienced by all households n in a cluster can be expressed as $\frac{1}{n}(\sum_j^n \frac{1}{m}\sum_i^m e_{ij})$ also ranging from 0 to 18. A cluster with an average exposure of 0 would comprise individuals who did not feel the

earthquake, hear the water or experience any of the 18 items listed above. This type of cluster would mostly occur in no/light damage areas. By contrast a cluster that registers 18 would have households that were exposed to the tsunami in its highest intensity, experiencing all the 18 items listed. This raw indicator for exposure can be converted to a standard normal distribution with mean 0, since the scale 0–18 is not necessarily linear. The survey clusters constitute groups of households from ecologically similar areas with respect to the degree of tsunami damage, distance to the coast, elevation and rural urban status. Each cluster has about 5–92 households with the average being 40.

Risk perception

The index is first constructed for the individual and is binary with 1 being risk averse and 0 otherwise. The household risk aversion index is also binary and equals 1 if the mean of the risk index for individuals is greater than 0.5 and 0 otherwise. To construct the index, we use 5 sequential questions in the survey, in which every member of the household had to answer which option they chose over lottery questions. The survey enumerator randomly assigned respondents to type A, B, C or D risk-related attitude questions where these four sets of lottery questions offered different amounts of guaranteed monetary payoff or probability-alternative payoffs that the respondent is going to receive every month. We later create four categories based on an individual's answers and narrow those categories down into 2 groups, the risk averse and non-risk averse groups. The first group is called the most risk averse category where a respondent will keep choosing option 1 or the promised earning monthly regardless of the amount of alternative offers they are going to receive with a certain probability depending on their luck for all 5 sequential questions. The second category is the second most risk averse group where an individual responded to *"Do not know"* suggesting that he or she might be unsure to either stick to the guaranteed payoff or choosing option 2 by taking a risk of getting a higher (lower) amount of earning in the following month. The third category is for those individuals who preferred to take risk in the first question and subsequent questions by choosing option 2 but they switched to option 1 or the certain payoff when it came to the final 5th or 4th questions. The last category of respondents is for those who consistently opted riskier payoffs until question 5 and considered to be unclear if they kept picking the *"Do not know"* answer. We drop respondents who consistently picked *"Do not know"* answers over the five questions. The first two categories belong to the risk averse group and the latter fall onto the non-risk averse one. See Fig. 2. For the fixed effects estimations, risk perception pre-tsunami is coded as 0 for all households given the lack of data availability. It is acknowledged that this is imprecise and assumes that attitudes to risk post-tsunami are due entirely to the tsunami and that any inherent attitudes are captured by the fixed effects.

Appendix 2

Table A1: Impact of tsunami on household health spending: Fixed effects estimations.

	Using data for rounds 0 and 1 (pre-tsunami 2004 and 2005)			Using data for all rounds (pre-tsunami 2004 and 2005, 2005, 2007)		
	(1)	(2)	(3)	(4)	(5)	(6)
Medium	−0.016	−0.030		0.021	0.022	
	(0.040)	(0.042)		(0.046)	(0.048)	
Heavy	0.186***	0.169**		0.130*	0.151**	
	(0.069)	(0.072)		(0.071)	(0.073)	
Exposure			0.098***			0.017
			(0.027)			(0.021)
Wealth index	0.190	0.177	0.252	0.391***	0.406***	0.377***
	(0.168)	(0.181)	(0.171)	(0.091)	(0.095)	(0.091)
Income		0.014			−0.008	
		(0.023)			(0.014)	
Worse Health	−0.458***	−0.453***	−0.468***	0.034	0.012	0.032
	(0.037)	(0.039)	(0.037)	(0.032)	(0.033)	(0.032)
Farming	0.067	0.049	0.069	0.081**	0.094***	0.084**
	(0.046)	(0.049)	(0.046)	(0.034)	(0.036)	(0.034)
Risk		0.032			−0.015	
		(0.060)			(0.049)	
Time since	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Migrated	−0.060	−0.060	−0.078**	−0.036	−0.050	−0.029
	(0.039)	(0.040)	(0.039)	(0.033)	(0.034)	(0.033)
	−0.180**	−0.171	−0.135*	−0.390***	−0.364***	−0.342***
	(0.085)	(0.110)	(0.077)	(0.076)	(0.094)	(0.065)
Constant	9.102***	8.950***	9.072***	9.014***	9.101***	9.019***
	(0.080)	(0.274)	(0.082)	(0.046)	(0.175)	(0.047)
Observations	7,646	7,317	7,640	15,449	14,460	15,426
R-squared	0.075	0.076	0.076	0.075	0.078	0.076
No of ID round 1	3,823	3,754	3,823	5,249	5,180	5,244

Note: The dependent variable is log household real per capita monthly spending on health An indicator variable for round included in regression but results not reported. Columns 1-3 show the immediate effect of the tsunami. Columns 4-6 show the average effect over the 3 years. See text for more details. Errors clustered at household level. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2: Fixed Effects estimations of impact of health changes on employment earnings for men.

	Using data for rounds 0 and 1 (pre-tsunami 2004 and 2005)		Using data for all rounds (pre-tsunami 2004 and 2005, 2005, 2007)	
	(1)	(2)	(3)	(4)
PTSR	−0.017***		−0.008***	
	(0.003)		(0.002)	
Physical health		−0.167***		−0.087***
		(0.044)		(0.030)
Age	−0.251***	−0.352***	−0.020	−0.029**
	(0.053)	(0.047)	(0.014)	(0.013)
Wealth Index	0.950***	1.008***	0.397***	0.404***
	(0.150)	(0.153)	(0.068)	(0.068)
Household size			0.014	0.014
			(0.016)	(0.016)
Risk	−0.050	−0.042	0.012	0.016
	(0.046)	(0.046)	(0.036)	(0.036)
Migrated	−0.112***	−0.143***	−0.076***	−0.085***
	(0.032)	(0.031)	(0.024)	(0.024)
Constant	22.410***	26.345***	13.634***	13.987***
	(2.054)	(1.843)	(0.556)	(0.540)
Observations	5,866	5,864	11,829	11,827
R-squared	0.332	0.327	0.080	0.079
Number of ID	3,049	3,049	3,049	3,049

Note: The dependent variable is the log of real monthly per capita earnings. Sample includes only men who had positive pre-tsunami employment earnings. An indicator variable for round included in regression but results not reported.Columns 1–3 show the immediate effect of the tsunami. Columns 4–6 show the average effect over the 3 years. See text for more details. Error clustered at household level.

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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