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EVOLUTION OF RISK AVERSION OVER FIVE YEARS AFTER A MAJOR NATURAL DISASTER

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ABSTRACT

The impact of exposure to a major unanticipated natural disaster on the evolution of survivors' attitudes toward risk is examined, exploiting plausibly exogenous variation in exposure to the 2004 Indian Ocean tsunami in combination with rich population-representative longitudinal survey data spanning the five years after the tsunami. Respondents chose among pairs of hypothetical income streams. Those directly exposed to the tsunami made choices consistent with greater willingness to take on risk relative to those not directly exposed to the tsunami. These differences are short-lived: starting a year later, there is no evidence of differences in willingness to take on risk between the two groups. These conclusions hold for tsunami-related exposures measured at the individual and community level. Apparently, tsunami survivors were inclined to assume greater financial risk in the short-term while rebuilding their lives after the disaster.

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Attitudes toward risk are important determinants of many behavioral choices, but whether and how attitudes toward risk evolve in the face of large-scale loss of resources and destruction of livelihoods is not well understood. Disasters and other extreme events are key reasons for livelihood destruction, and with the force and frequency of such events rising across the globe, it is important to advance understanding of their impacts on willingness to take on risk.

This study documents how individuals' attitudes toward risk evolved over five years in the aftermath of a major disaster—the 2004 Indian Ocean earthquake and tsunami—and the subsequent reconstruction effort in Aceh and North Sumatra, Indonesia, the area hardest hit by the tsunami. Leveraging the fact that the tsunami was completely unanticipated, in combination with detailed local-area information of tsunami destruction based on satellite imagery and direct observations, we develop plausibly exogenous measures of tsunami exposure. We combine these measures with uniquely rich longitudinal population-representative survey data of individuals who were first interviewed 10 months before the tsunami to investigate the evolution of their attitudes towards risk, which we elicited using hypothetical financial choices. Respondents were assessed annually for five years after the natural disaster as part of the Study of the Tsunami Aftermath and Recovery (STAR).

We find that in the year following the disaster, individuals who were directly exposed to the devastation of the tsunami were more willing to take on financial risks than those not directly exposed. The differences are significant whether exposure is measured at the individual or community level. Importantly, these differences appear to be short-lived, disappearing within two years of the disaster as the post-disaster reconstruction effort was launched and a period of sustained economic growth ensued.

The transitory nature of the effects of large adverse events on risk aversion in the context of a developing economy is a novel finding in an observational study and an important contribution to the economics literature. It is consistent with the predictions of prospect theory (Kahneman and Tversky 1979, Page et al. 2014) and suggests a potential link with evidence from experimental studies in the neuropsychological literature on short-term elevations in cortisol and lower aversion to financial risk (van den Bos et al. 2009). This result has implications for the design of post-disaster aid and reconstruction programs that rely on the willingness of survivors to take on risks. For example, COVID-19 support in the form of small business loans and the paycheck protection program are likely to have had a different impact on behavior relative to parallel programs before or after the COVID pandemic.

Psychologists and economists have investigated the link between exposure to stressors and risk behaviors and attitudes. Research from psychology indicates that risky sexual practices and substance abuse are more common among those who have experienced psychological trauma and those who present with symptoms of posttraumatic stress (Gore-Felton and Koopman 2002, Brady and Donenberg 2006, Pat-Horenczyk et al. 2007, Dell'Osso et al. 2013, Kianpoor and Bakhshani 2012). That literature has not explored links with attitudes toward risk.

Economists have investigated how adverse events affect attitudes toward risk using methods specifically designed to elicit risk attitudes in the context of financial decisions. This literature has studied the impacts of exposure to a variety of adverse events, including storms and cyclones, tsunamis, floods, earthquakes, violent conflicts, and pandemics.[1] The results from

[1] See, for example, Eckel et al. (2009), Voors et al. (2012), Ahsan (2014), Callen et al. (2014), Kim and Lee (2014), Page et al. (2014), Cameron and Shah (2015), Said et al. (2015), Cassar et al. (2017), Brown et al. (2018), Hanaoka et al. (2018), Kahsay and Osberghaus (2018), Moya (2018), Brown et al. (2019), Chantarat et al. (2019), Jakiela and Ozier (2019), Abatayo and Lynham (2020), Bourdeau-Brien and Kryzanowski (2020), Reynaud and Aubert (2020), de Blasio et al. (2021), Drichoutis and Nayga (2021), Fatas et al. (2021), Meunier and Ohadi (2021), and Shachat et al. (2021).

these studies are mixed. Some studies find that exposure to disruptive events leads to an increase in observed aversion to risk, but others find a decrease in risk aversion or heterogeneous effects across different groups or durations since exposure.[2] At least part of the heterogeneity in these findings is likely attributable to methodological challenges, described below. This study is designed to address many of these challenges and thereby contribute to the literature.

A key challenge for many studies is that those who are exposed to adverse events are selected on characteristics that are likely related to attitudes toward risk. For example, periodic floods and violent conflicts occurring over extended periods of time are to some extent predictable. Those who are exposed to these events are likely to be self-selected on characteristics related to risk and given the predictability of the events, they may have invested in risk-mitigation strategies. In contrast, the 2004 tsunami was completely unexpected. No tsunami had affected the island of Sumatra for at least 600 years. In the pre-tsunami baseline, of the 9.5% of households that said their place of residence was at high risk of a natural disaster, only 8.5% of those people—less than 1% of all sampled households—reported that an earthquake or hurricane/tsunami were the most likely type of disasters they might experience. That percentage is the same for those living in communities that were subsequently directly affected by the tsunami and those living in other communities in coastal Aceh and North Sumatra.

Second, we avoid biases that arise from drawing a sample post-event, typically in the area affected by the adverse event, which are unlikely to represent the population at risk of being affected by the event. This concern is particularly important in the aftermath of a natural disaster

[2] For example, Eckel et al. (2009), Voors et al. (2012), Page et al. (2014), Kahsay and Osberghaus (2018), Abatayo and Lynham (2020), Fatas et al. (2021), and Shachat et al. (2021) find a decrease in observed risk aversion. However, Hanaoka et al. (2018) find heterogenous effects (see Footnote 4), and Said et al. (2015) document a decrease in risk aversion with recent exposure but an increase in risk aversion with cumulative exposures.

that results in substantial population displacement, as is the case in Aceh and North Sumatra after the tsunami (Gray et al. 2014).

Third, many of the studies in the literature use high level administrative boundaries to identify exposure, a blunt instrument in comparison with our fine-grained measures of exposure at the community level using high-resolution satellite imagery. We also construct measures of exposure at the individual level that can be plausibly treated as exogenous. Few studies have investigated the impacts of individual-level exposures, and almost no evidence contrasts the impact of community and individual-specific exposures. Our research contributes to filling these gaps.

Fourth, there is a paucity of evidence in the literature contrasting shorter- versus longer-term effects of exposure to adverse events on risk aversion because very few studies rely on longitudinal data, especially from developing countries.[3] The longitudinal dimension of our research makes an important contribution: without measures from the immediate aftermath of the tsunami and from subsequent years collected in STAR, it would not be possible to document the transitory nature of the differences in willingness to take on risk in this context.

1. The Disaster: 2004 Indian Ocean Tsunami

Background

At 8 a.m. on December 26, 2004, an earthquake with an estimated magnitude between 9.1 and 9.3 M_w on the Richter scale occurred 160 kilometers off the west coast of the island of Sumatra in Indonesia. The earthquake produced a rupture that extended 1200 kilometers northwest from its epicenter to the Andaman and Nicobar Islands. The sea floor rose suddenly

[3] One exception is Hanaoka et al. (2018), who used nationally representative panel data from Japan, a high-income country, to examine shorter- and longer-term impacts of exposure to the 2011 Great East Japan Earthquake on risk aversion. They observe a decrease in risk aversion among men in municipalities with more intense exposure to the earthquake one and five years later but find no evidence of shorter- or longer-term impacts among women.

along the rupture, displacing over 25 trillion tons of water and sending out waves of water that radiated away from the rupture at up to 1000 kilometers per hour. As the displaced water reached shallow locations, large waves formed and crashed into the coast of Sumatra, at heights up to 35 meters in some places (Tsuji et al. 2006).

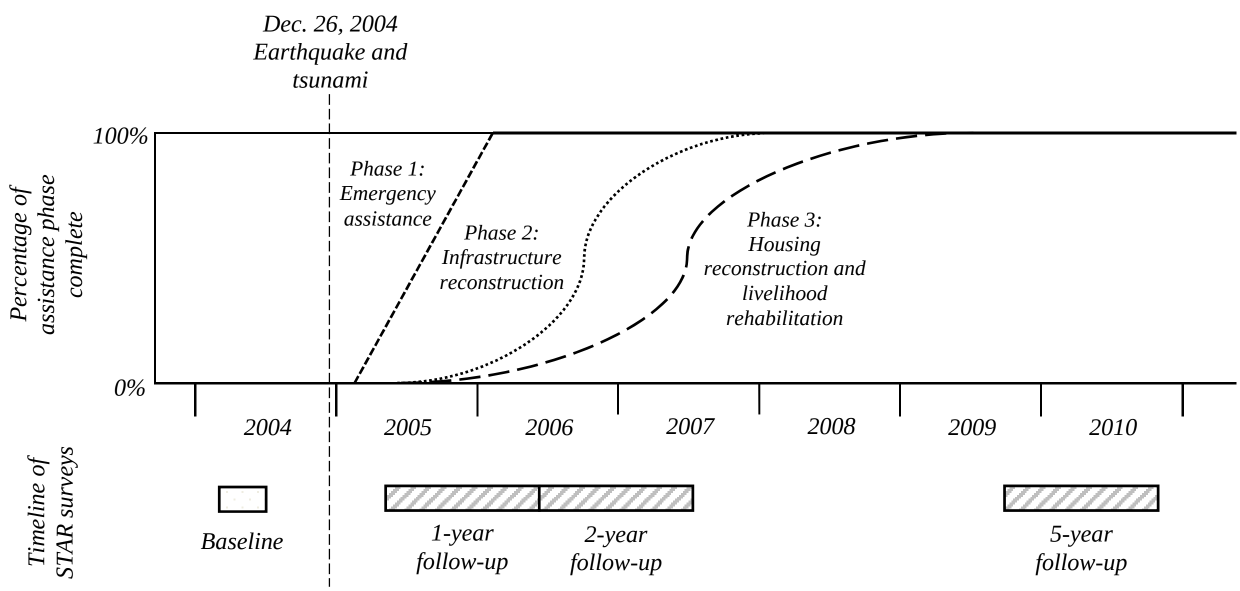
Coastal communities near the rift zone, in the provinces of Aceh and North Sumatra in Indonesia, were the most heavily impacted by the tsunami. The first waves struck Aceh within 20 minutes of the earthquake, killing an estimated 160,000 people (over 4% of the population of the province) and displacing over 500,000 people. Estimates put the cost of the disaster at around $4.5 billion in lost income and physical assets in Aceh (roughly the GDP of the entire province the prior year). The tsunami damaged or destroyed an estimated 12% of homes, 40-60% of coastal aquaculture ponds, 65-70% of all fishing capital, 10% of cultivated rice fields, 3,000 km of roads, and the primary income source of an estimated 265,000 people (Jayasuriya and McCawley 2010). This destruction resulted in substantial declines in household per capita consumption in the first year after the disaster (Lawton et al. 2023). The disaster was also a psychologically traumatic event, elevating posttraumatic stress reactivity levels in survivors, especially among those who were physically exposed to the tsunami (Frankenberg et al. 2008).

Post-disaster assistance

The destruction was followed by an unprecedented influx of assistance from domestic and international sources, including the Indonesian and foreign governments, NGOs, local organizations, and private individuals. By the end of 2007, governments and NGOs had committed over $7.7 billion in assistance, exceeding disaster relief efforts in any developing country up to that time. Family members and friends of survivors also provided substantial assistance, especially in the immediate aftermath of the tsunami before formal emergency relief efforts were fully in place (Jayasuriya and McCawley 2010).

As shown in Figure 1, assistance from the public sector, non-governmental organizations and aid agencies focused on providing emergency relief (such as short-term shelter, food, potable water, medical care, and direct income support) during the first year after the tsunami and targeted communities that sustained the greatest damage. There was no attempt to target households within those communities based on income or wealth, and we have found no evidence that either is predictive of receipt of assistance (Frankenberg et al. 2009). In the second phase, the focus of that assistance effort shifted towards reconstruction of infrastructure (primarily roads, bridges, ports, and public buildings).

Figure 1. Schematic timeline of assistance phases and the STAR surveys



It was during the third phase, when the program provided new houses or aid to rebuild houses damaged or destroyed by the disaster, that substantial resources went directly into the hands of those who had been exposed to the tsunami. During this phase there was also support for rehabilitation of livelihoods, including programs to restore agricultural and fishing production, promote small businesses, and support cash-for-work and job training programs, although these programs were small relative to the housing reconstruction. Housing support was also the program that was the slowest to be implemented because of problems with poor titling of land ownership prior to the tsunami, the need to engage communities in the planning, and a commitment to the stated goal to "Build Back Better" as the reconstruction program was called.

As a result of these delays, although 21% of all STAR households received housing aid within 10 years of the disaster, only 1.8% had received any housing aid by the end of the 1-year follow-up in mid-2006. The housing program ramped up in the following year so that by the end of the 2-year STAR follow-up in mid-2007, 9.6% of households had received some aid, which is roughly half the total number of recipients of housing aid. The majority of aid was received during the following three years, with less than 1% of the STAR households receiving housing aid for the first time after the 5-year follow-up. This timeline is consistent with other descriptions of the Build Back Better program (Masyrafah and McKeon 2008, Purwanto, 2009, Jayasuriya and McCawley 2010).[4]

The timeline also parallels changes in the socio-economic status of STAR households. There was a large decline in real household per capita expenditure (PCE) in the year following the tsunami, driven by reduced resources and high levels of inflation; after the 1-year follow-up, real PCE grew in all the study area communities with the fastest growth among those who were living in the areas that sustained heavy damage. On average, by the end of the 5-year follow-up, real PCE had grown by 50% relative to the 1-year follow-up. The same patterns are reflected in a measure of individual socio-economic wellbeing (based on a 6-step Cantril-type ladder question)

[4] We conduct an additional analysis to test the potential impact of the early reconstruction and rehabilitation program on our results in the 1-year follow-up and find no impact on our results (see Table 6).

(Lawton et al. 2023). The evolution of the real value of wealth also tracks the timeline for the receipt of housing aid in STAR (Lombardo et al. 2023).

The key point for this research is that estimates based on the 1-year STAR follow-up reflect the immediate impact of the tsunami and the effects of emergency aid that was distributed in the months after the tsunami. Estimates based on the 2-year follow-ups also reflect the early effects of the reconstruction effort, although given the slow ramp-up, especially of housing aid, those influences are more likely to be reflected in estimates based on the later follow-ups.

Natural experiment

Two characteristics of the 2004 Indian Ocean tsunami suggest that exposure to the tsunami is plausibly exogenous and provides a credible natural experiment for the study of adverse events on attitudes toward risk.[5] The first is that the tsunami was unanticipated by individuals living on the coast. Geologic evidence indicates that the last tsunami to strike the island of Sumatra occurred over 600 years ago (Monecke et al. 2008). Accordingly, anticipation of a tsunami was likely not a factor in household residential location decisions prior to the disaster. In addition, people in coastal communities had no formal warning of the impending tsunami waves. No early warning system was in place in the Indian Ocean at the time of the tsunami, and the tsunami waves reached the coast less than 20 minutes after the earthquake.

Second, the level of community inundation by tsunami waves resulted from a complex interaction of geographic and topographic features. These include the location of the earthquake in the Indian ocean, exposure of the local coastline to the line of the resultant undersea rupture,

[5] We focus on the impact of exposure to the tsunami specifically because virtually everyone in coastal communities in Aceh experienced the December 26 earthquake (99% of survivors in STAR reported that they felt the earthquake), as well as the 8.6 magnitude 2005 Nias–Simeulue earthquake (98% of STAR survivors) that struck three months later. Although we do not have data in STAR measuring exposure to the several aftershocks of the December 26 earthquake, we indirectly control for exposure to the aftershocks by including *kecamatan* (sub-district) fixed effects in our regression analyses. *Kecamatan* is the third-largest administrative unit in Indonesia, one unit above *desa/kelurahan* (or village/town). Broadly speaking, a *kecamatan* parallels a U.S. county.

and variation in the sea floor topography (Ramakrishnan et al. 2005, Degueldre et al. 2016). The important point is that coastal communities that directly faced the rupture and the waves it produced bore the full brunt of the tsunami, whereas otherwise similar communities were at an angle to the rupture or were physically protected from the waves by a promontory, feature of the seafloor that dampened wave height, or other geographic features had less intense exposure to the tsunami. Because these features are plausibly unrelated to attitudes toward risk at a local level, local variation in exposure to the 2004 tsunami that remains after controlling for possibly endogenous features, such as distance to the coast and elevation, can arguably be treated as an exogenous shock to residents of coastal communities.

One potential confounding factor for an analysis of survivors of a high mortality event such as the tsunami is the influence of selective mortality on the population. If survival chances were related to attitudes toward risk, then selective mortality will confound the analysis by altering the distribution of pre-existing risk attitudes in the population of survivors. However, although prior research suggests that mortality in the tsunami was selective in favor of physical strength, there is no evidence that selection is linked to correlates of attitudes toward risk, such as education, wealth, income, or household consumption measured before the tsunami (Frankenberg et al. 2011). In addition, our conclusions are not affected by the addition of controls for community tsunami mortality rates or by restricting our sample of coastal communities to those without tsunami-induced mortality, which suggests that they are not driven by selective mortality.

2. Potential Pathways for Changes in Attitudes toward Risk

Exposure to the tsunami and its aftermath may have affected attitudes toward risk through a number of pathways, including changes in economic circumstances (such as wealth, economic opportunities, or perceptions of environmental risk) or tastes for risk (through, for example, psychological and physiological factors). These potential pathways offer competing predictions on how risk aversion may change with exposure to the disaster, some of which we can test using the natural experiment provided by the 2004 tsunami. For example, the tsunami and subsequent assistance had large effects on the economic wellbeing of residents of coastal communities in Aceh and North Sumatra, which, under expected utility maximization with convex preferences would result in an increase in absolute risk aversion in the immediate aftermath of the disaster that may decline as assistance programs and improved economic opportunities help restore lost economic wellbeing.

Page et al. (2014), however, argue that under prospect theory, the risk aversion of individuals whose economic wellbeing declines in a disaster may decrease in the immediate aftermath of the disaster as their economic resources drop below their reference point for their household's typical level, but then may increase over time as they restore their lost economic resources and/or their reference point changes to reflect their post-disaster circumstances.[6] Under prospect theory, evidence of declines and subsequent improvements in both household resources and perceptions of socioeconomic wellbeing among tsunami survivors in STAR (Lawton et al. 2023) suggest that we may instead observe an initial decline in risk aversion that would disappear over time as assistance efforts ramped up and subjective socioeconomic wellbeing improved.

Opportunities to earn income were initially reduced in the tsunami-affected areas in the aftermath of the disaster, but new opportunities emerged that are likely to have seemed risky at the time, such as moving to a new community or shifting agricultural production from rice to

[6] Page et al. (2014) find evidence of a short-term decline in risk aversion following a disaster (in their case, flooding) but do not have the data to investigate longer-run impacts.

crops better suited for soil that had been inundated by seawater. Individuals who embraced these new opportunities may have had lower levels of risk aversion in the short term, but the long-term impacts on risk aversion are not obvious.

Attitudes toward risk may also change because of changes in perceptions of general levels of environmental financial risk or because of physiological responses to the disaster that could change tastes for financial risk. For example, evidence from a laboratory experiment conducted by He and Hong (2018) suggests that increasing the perceived environmental risk involved with financial behavior, which seems plausible following a destructive natural disaster like the tsunami, could lead to an increase in risk aversion related to financial behaviors. However, experimental research in endocrinology by van den Bos et al. (2009) suggests that willingness to take on financial risk could temporarily decrease after a stressful event like the tsunami because of acute short-term elevations in cortisol (a hormone released as a result of stress).

3. Data

Data are drawn from STAR. The baseline, collected by Statistics Indonesia as part of the cross-sectional National Socioeconomic Survey (SUSENAS), was conducted in February/March 2004 (9 to 10 months before the disaster) and is representative of the population at the *kabupaten* (district) level.[7] STAR is designed to follow-up every 2004 SUSENAS respondent interviewed in any of the SUSENAS enumeration areas located in *kabupaten* along the coast of the province of Aceh and along the west coast of the province of North Sumatra.[8] We selected these

[7] There are four primary administrative subdivisions in Indonesia (from largest to smallest): *propinsi* (province), *kabupaten* (district), *kecamatan* (sub-district), and *desa/kelurahan* (village/town). At the time of the 2004 SUSENAS, the province of Aceh consisted of 21 *kabupaten.*

[8] An enumeration area is a census block defined by Statistics Indonesia and used in their sample surveys. The census block which typically includes 80 to 120 households does not traverse *desa* or other administrative boundaries.

kabupaten because they spanned the area that was at risk of being directly impacted by the tsunami.

As a general rule, low lying communities near the coast experienced deeper, faster flowing water from the tsunami (and thus more damage) than communities that were higher or further inland. However, many other idiosyncratic geographic and topographic factors (see Section 1) influenced the force and depth of the waves. As a result, even within groups of communities at similar elevations and distances from the coast, there is wide variation in the level of damage the tsunami caused. This variation provides us with a group of tsunami-affected enumeration areas and a comparison group of less tsunami-affected enumeration areas who share similar geographic characteristics and general vulnerability to tsunamis.

We conducted the first ("1-year") STAR follow-up survey from May 2005 to April 2006, in collaboration with Statistics Indonesia (coinciding with the beginning of the post-disaster reconstruction and rehabilitation efforts; see Figure 1). We conducted annual follow-ups thereafter through August 2010.[9] We obtained survival status for over 98% of individual in the baseline sample: 6% of those people died in the tsunami (Frankenberg et al. 2011). All survivors, including migrants, were eligible for follow-up in every subsequent follow-up. Tracking migrants is especially important in this context because migration rates were high and the decision to move is potentially related to attitudes toward risk since migration, itself, is a risky choice. Mobility was related to tsunami exposure. Over half the survivors who were living in the most damaged communities moved to another *desa*/*kelurahan* (village/town), which is almost 8 times the inter-*desa* mobility rate of 6.6% in all other communities (Gray et al. 2014).

[9] We conducted the 2-year follow-up survey between June 2006 and March 2007 (as the reconstruction and rehabilitation efforts began to ramp up) and the 5-year follow-up between November 2009 and August 2010 (after the reconstruction and rehabilitation efforts had completed the vast majority of their work).

Drawing on extensive experience with tracking in longitudinal surveys in Indonesia and elsewhere, we developed protocols to maximize re-contact in this extremely challenging environment, with much of the infrastructure destroyed in the hardest-hit areas. We invested substantial resources in tracking, including developing a technology-based platform to assist the fieldworkers. The most important input in this production function is the commitment of the field team and especially the team leadership. They deserve much of the credit for the extremely high recontact rates that STAR has achieved. We interviewed over 91% of eligible survivors in the 1-year follow-up, and 98% of all surviving baseline respondents have been interviewed in at least one of the first five annual follow-up surveys.

In addition to comprehensive information about household demographic and socio-economic characteristics collected in each survey round, each adult respondent provided details about their own experiences of the tsunami and their loss of livelihoods and economic assets. The first follow-up survey also elicited individual attitudes toward risk from all respondents who were at least 15 years of age using a survey instrument described in the next section. (The baseline survey did not elicit attitudes toward financial risk.) As discussed in detail below, we revised the survey instrument to measure aversion to variance in income rather than "risk aversion" per se in subsequent follow-ups.

4. Measurement of attitudes toward risk

STAR instrument

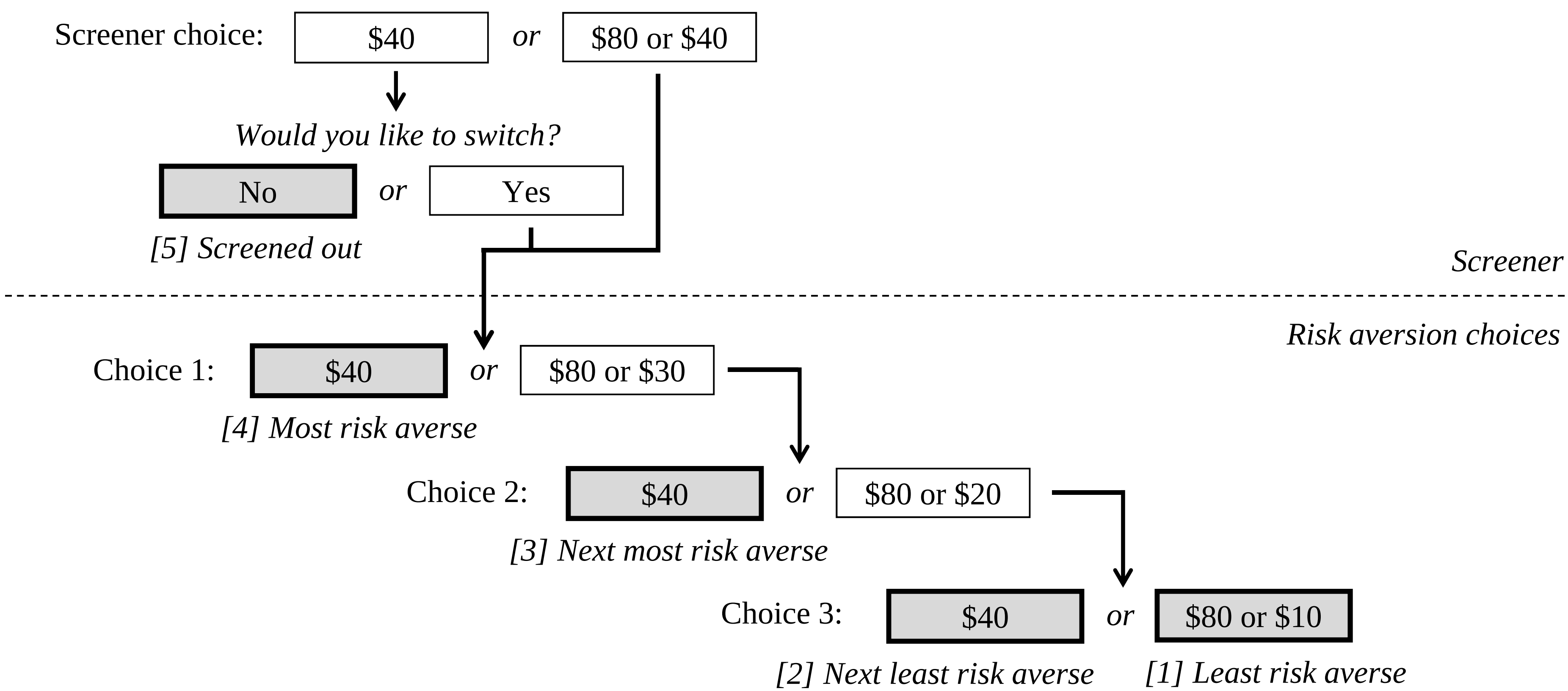
Attitudes toward risk were elicited in the 1-year follow-up survey using an adaptive series of binary choices between hypothetical income streams, as illustrated in Figure 2.

Figure 2. Example of STAR risk instrument in 1-year follow-up

Responses collected from each respondent aged 15 years or older.

In each choice, the respondent is asked which of two hypothetical monthly income streams they prefer.
In this example, the "$40" options would provide $40 guaranteed, whereas the "$80 or $X" options would provide $80 or $X with equal chance.
In the screener, if the respondent picks the "$40" option, the interviewer explains that the resulting income stream would be no worse and potentially better with the other option. The respondent is then given the opportunity to switch options.

The fives stopping points are highlighted and can be used to construct a rank-order of risk aversion from [1] Least risk averse to [4] Most risk averse, along with respondents who are [5] Screened out.



We designed the instrument with binary choices and simple probabilities, and we provided respondents with flashcards describing each choice to reduce the cognitive burden on the respondent and assure that every respondent understood the choices.

The approach of using hypothetical financial questions to elicit attitudes toward risk has been used in other economic studies of attitudes toward risk (for example, Barsky et al. 1997, Holt and Laury 2002, Bonin et al. 2007, Guiso and Paiella 2008). In addition, as discussed later, the correlation we find between the responses to the 1-year follow-up instrument and (1) potentially risky economic behaviors and (2) demographic and socioeconomic characteristics is consistent with our instrument capturing meaningful variation in tolerance for financial risk.

In the 1-year follow-up instrument, the respondent chooses between pairs of hypothetical monthly income streams. For example, as shown in Figure 2, the respondent is asked in Choice 1 to choose between (1) receiving a guaranteed monthly income in Indonesian rupiah that is equivalent to about $40 USD (close to average monthly per capita household expenditure) and (2) having an equal chance of receiving either $80 per month or $30 per month.[10] In each choice, option 2 is accompanied by uncertainty and is financially attractive but carries risk—that is, option 2 has a higher expected value but also a chance of generating less income than the certain option 1. As a result, the respondents who choose an uncertain option reveal that they are willing to take on more risk than respondents who choose the certain option.

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[10] Each respondent was randomly given one of four versions of the risk instrument that presented income streams of different magnitudes (i.e., certain monthly income streams of $20, $40, $80, $120), while maintaining the same implied risk parameters under CRRA utility for each choice across the four versions. We included this magnitude variation for two reasons: first, to reduce the likelihood that individuals in the same household are exposed the exact same questions about risk attitudes (thereby reducing the risk of respondents simply repeating the responses that they observed from other household members), and second, to test whether the size of the income streams affected responses. We find that responses to the assessment do not vary significantly with size (Appendix Table 1). Because of the consistency of the implied CRRA risk parameters and of the response patterns we observe across the modules, we combine the response categories across the modules in our analyses but will also include indicators for the modules in our regression models.

The instrument further differentiates the respondents who choose an uncertain option by giving them an additional choice in which the certain option remains the same, but the uncertain option carries even more risk. For example, respondents who pick the uncertain option in Choice 1 in Figure 2 proceed to Choice 2, in which the uncertain option is now less attractive and involves more risk (i.e., lower expected value and lower minimum payment).

The instrument ends either when a respondent picks an option that has an outcome that is certain or after completing Choice 3. This results in four potential stopping points, highlighted in Figure 2. The instrument is designed so that if a respondent exits the instrument by choosing a certain outcome in a pair of choices, it is reasonable to assume the respondent would have chosen the certain outcome in subsequent choices, which allows us to use the four stopping points to create a group of rank-ordered response categories with decreasing relative risk aversion: [4] “Most risk averse”, [3] “Next most risk averse”, [2] “Next least risk averse”, and [1] “Least risk averse”.[11]

Screener question

Drawing on what we have learned from prior studies in Indonesia and our pilots of the risk instrument in this population, we included a screener question (Choice 0 in Figure 2) presented before the first choice in which the uncertain income stream first order stochastically dominates the certain outcome. Specifically, the lower payout for the uncertain option is the same as the certain option payout ($40 as shown in Figure 2). The uncertain option carries no risk compared to the certain option. Under expected utility maximization, the stochastically dominating uncertain option is the optimal choice and is expected to be selected by all

[11] The associated constant relative risk aversion (CRRA) parameters for the four response categories are (2.915,∞) for [4] “Most risk averse”; (0.999,2.915) for [3] “Next most risk averse”; (0.306,0.999) for [2] “Next least risk averse”; and (-∞,0.306) for [1] “Least risk averse”.

respondents who understand the choices (see, for example, Loomes and Sugden 1998, Birnbaum et al. 1999, Moffatt and Peters 2001).

In practice, however, half of the respondents in the 1-year follow-up survey select the stochastically dominated certain option. (For convenience, we will refer to these respondents as “screened-out respondents” because they are screened out of the rest of the risk questions.) While it is possible that the screened-out respondents simply do not understand the choices, we think that is unlikely based on three pieces of evidence: (1) the instrument’s cognitively simple design, (2) the sizeable presence of screened-out respondents across all education levels in this study (and parallel evidence from other studies in Indonesia and elsewhere), and (3) the presence of screened-out respondents in a similar instrument with real payouts. We next discuss each of these pieces of evidence in more detail.

First, we designed the screener to assure that the options are understood. Not only does the screener choice have only two options, but if the respondent chose the stochastically dominated certain income stream, the interviewer probed the respondent to assure the choices were understood. Specifically, the interviewer explained the two options again and pointed out that the uncertain option yielded an income that is at least as high as the certain income stream. The interviewer then asked whether the respondent wanted to change their choice. Only a very small percentage of respondents who chose the dominated option switched away from it when asked the second time. (In the 1-year follow-up, 7% of those who chose the certain income stream switched their answer when probed.)

Second, the decision to select the stochastically dominated option is not limited to respondents with little education, nor to respondents in Aceh and North Sumatra. Overall, about half the STAR respondents were screened out in the 1-year instrument. Even among those respondents who had completed at least four years of college, 44% were screened out. Evidence from other studies establishes that this response pattern is widespread across Indonesia and observed outside Indonesia. For example, in the fourth wave of the Indonesia Family Life Survey (IFLS) 41% of respondents were screened out because they selected the dominated certain income stream in a parallel instrument (Strauss et al. 2009). Additionally in Mexico 13% of respondents selected a dominated certain outcome with a similar instrument in the Mexican Family Life Survey (Brown et al. 2019).

Third, the response pattern cannot be fully explained by our use of hypothetical payouts. After the 5-year STAR follow-up was completed, we conducted a pilot study on a sub-sample of STAR respondents to evaluate the instrument and measure social preferences. Respondents were paid based on their choices for one randomly-selected task of six they completed. One of those tasks elicited attitudes toward risks using the same instrument but with smaller stakes. One-quarter of those respondents selected the dominated certain income stream, even when that decision had real financial consequences. These data suggest that while the social norms or preferences behind the screened-out response pattern may have been weaker with real (or smaller) stakes, they still persisted and therefore likely reflect a difference between screened-out and other respondents that extends into real financial decision-making.

These three pieces of evidence provide a strong argument that being screened out is not the result of respondents' failure to understand the screener choice but instead captures meaningful variation in attitudes. Screened-out respondents, for example, may prefer certainty or be averse to disappointment (Andreoni and Sprenger 2011, Callen et al. 2014). Being screened out could also indicate an aversion to behaving in a way the cultural context deems inappropriate, for example participating in gambling (which is forbidden in Islam) or appearing to be greedy.[12] We do not have the data to identify the specific attitudes that are driving the screened-out responses in our sample, but two additional pieces of evidence suggest that screened-out respondents (whose relative level of risk aversion was not directly captured in the instrument) are likely more risk averse on average than the respondents who were not screened out.

The first piece of evidence is that screened-out respondents behave "as if" they are more risk averse, on average, than respondents who were not screened out in relation to behaviors that involve some level of financial risk. In Table 1, we present comparisons of households headed by screened-out respondents (column 1) and households headed by respondents who were not screened out (columns 2 to 4) across three contemporaneous economic behaviors that involve taking on financial risk: (1) starting a household business (among households that did not have a business in the previous survey round), (2) investing in assets for a household business (among households that have a business), and (3) taking out a loan.[13] (Because all three of these behaviors involve financial risk, attitude toward financial risk is likely a major driver, although other factors including resource availability and prior experience are important.)

Table 1 presents the percentage of households who reported each behavior for each group, along with the difference between each group and its standard errors (estimated using linear regressions with standard errors clustered at the pre-disaster survey enumeration area). Across all three risky financial behaviors, we observe that a smaller percentage of households headed by screened-out respondents exhibited the behavior than among households headed by

[12] To examine the potential role of social pressure or expectations on responses, we extended the primary model by adding an indicator for the presence of other people during the interview (not reported). The indicator is not predictive of choices, and there is no impact of its inclusion on our findings.
[13] In this analysis, we define household-run businesses to include both non-farm businesses and farm businesses that produce crops other than rice. We exclude rice farming because the Indonesian government provided price supports for rice production through the Ministry of Logistics, which reduced the market risk of producing rice relative to other types of self-run businesses.

respondents who were not screened out, which suggests that in practice, the screened-out respondents behave as if they are the most risk averse group in relation to behaviors related to financial risk. It is reassuring that households are more likely to report each potentially risky financial behavior as the risk aversion of the household head decreases suggesting the instrument is capturing meaningful variation in attitudes towards risk among respondents who were not screened out.

This interpretation is further supported by evidence in Table 2, which presents mean levels (across the risk aversion categories measured in the 1-year follow up) of several baseline demographic and socioeconomic characteristics that are commonly associated with risk aversion. The patterns are largely consistent with screened-out respondents being, on average, more risk averse than respondents who were not screened out. Screened-out respondents are less likely to be male, were older at the time of the tsunami, had fewer years of education, belonged to poorer baseline households, and were less likely to live in urban areas at baseline.

The associations between the four rank-ordered risk aversion response categories and the characteristics in Table 2 are also largely consistent with our responses categories capturing a meaningful decline in relative risk aversion. For example, decreasing levels of relative risk aversion are associated with a greater likelihood of being male, having more average years of education, and a greater likelihood of living in an urban area at baseline. The least risk averse respondents, on average, also belonged to households with relatively high PCE at baseline.

Analytic measures and sample

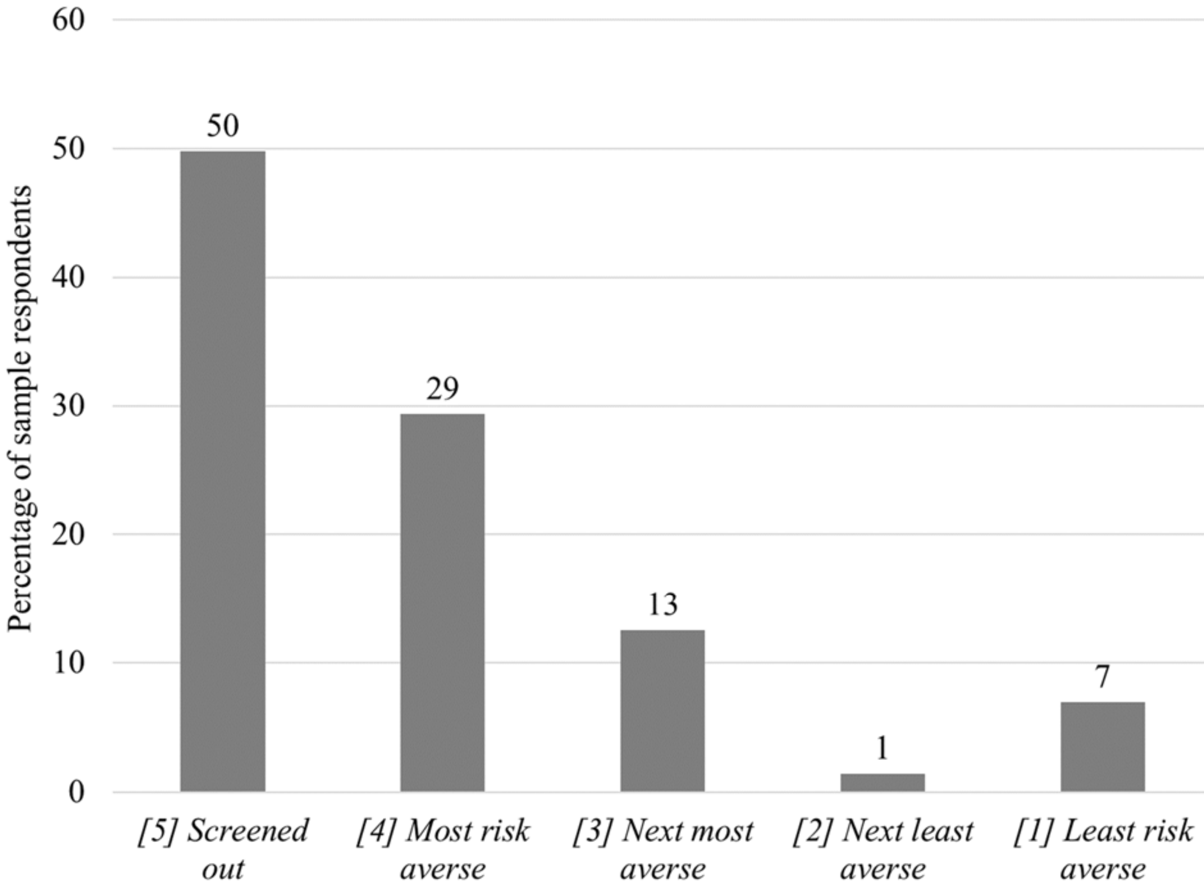
Our primary analyses treat the screened-out respondents as the most risk averse group. We also test the sensitivity of our findings to this assumption by reporting additional analyses that make different assumption about these respondents.[14] However, because being screened-out does not have an associated range of risk parameters under expected utility maximization, the analyses rely on a rank-ordered categorical measure of risk aversion that combines the screened-out respondents with the four response categories derived from the rest of the risk instrument: [5] "Screened-out", [4] "Most risk averse", [3] "Next most risk averse", [2] "Next least risk averse", and [1] "Least risk averse".

The analytic sample consists of 9,860 baseline respondents age 15 years or older at the time of the 1-year follow-up who survived the tsunami and completed the risk aversion assessment in the 1-year follow-up, as well as the assessments fielded in the 2-year and 5-year follow-ups (to avoid changes in sample composition over time).[15] Figure 3 presents the distribution of the rank-ordered response categories in the 1-year follow-up for the primary analytic sample. The responses are distributed across all five categories with most falling under the two most risk averse categories ("[5] Screened out" and "[4] Most risk averse").

[14] First, we combine the screened-out respondents with the most risk averse of the respondents who were not screened out ([4] "Most risk averse") under the assumption that the screened-out respondents would have chosen the certain option in Choice 1, given the opportunity. Second, we estimate the impact of exposure to the disaster in the 1-year follow-up using the associated CRRA ranges (with screened-out respondents again combined with the [4] "Most risk averse" group). As shown in Table 6, the results of both analyses are consistent with those of our primary analyses.

[15] Of 16,870 STAR baseline respondents who were at least 15 years of age at the 1-year follow-up (and therefore eligible to complete the risk assessment) and alive at the time of the 5-year follow-up survey, we found 91% and completed risk assessments for 80% in the 1-year follow-up, reflecting our commitment to follow and interview movers and using innovative tracking protocols to find respondents displaced by the disaster. To remove the influence of changes in sample composition from our analyses across follow-up survey rounds, we restricted our primary analytical sample to the 58% of the eligible respondents who were assessed in both the 1-year, 2-year, and 5-year follow-ups. However as described in more detail in the Section 5, our findings are not sensitive to this sample restriction. In addition, because non-measurement was more common among the youngest and oldest respondents, we further tested the robustness of our findings by estimating our primary results for the 66% of eligible respondents aged 30-60 years who completed the risk instrument in all three follow-up survey rounds (not reported) and find that the results are consistent with those of our primary analytic sample.

Figure 3. Responses to 1-year follow-up risk instrument



5. Empirical evidence on the impacts of exposure to the tsunami

Estimation strategy

To explore the impact of exposure to the tsunami on responses to the risk instrument we assume the following relationship between risk aversion and exposure:

$$RA_{ir}^{*} = \alpha + \beta Exp_{ihe} + \gamma RC_{ihe} + \delta EC_{ihek} + \theta X_{ir} + \varepsilon_{ir} \quad [1]$$

where RA_{ir}^{*} is a latent continuous measure of risk aversion of individual *i* in survey round *r*; Exp_{ihe} is a vector of three measures of exposure to the tsunami (defined below) of individual *i* in household *h* in enumeration area *e*; RC_{ihe} is a vector of pre-disaster individual, household, and community-level correlates of risk aversion; EC_{ihek} is a vector of tsunami exposure risk factors associated with the baseline location, including fixed effects for *kecamatan* (sub-district) *k*; X_{ir} is a vector of survey specific controls that consists of the month-year of interview and the randomly-assigned risk instrument module of individual *i* in survey round *r*; and ε_{ir} is a random error term.

Although we do not observe the latent continuous measure RA_{ir}^{*}, our rank-ordered categorical response measure of risk aversion, RA_{ir}, provides a categorical version of RA_{ir}^{*}, which is the dependent variable in model [1] and estimated as an ordered logit (under the assumption that ε_{ir} has a standard logistic distribution) with standard errors clustered at the level of the survey enumeration area. (Although the rank-ordered outcome in this model represents a combination of the responses of screened-out respondents and respondents who completed the rest of the risk instrument, for convenience and based on the economic behavior and characteristics of screened-out respondents discussed in the previous section, we refer to the estimated coefficients of this model as representing differences in attitudes to risk.).

The first exposure measure in the vector Exp_{ihe} is "heavy community damage", a binary measure of whether a respondent's pre-disaster survey enumeration area sustained relatively high levels of damage in the tsunami based on remote sensing measures of damage from water, direct observations from our field supervisors, and reports from *desa* leaders.[16] The second exposure

[16] We constructed the satellite-based damage measures using remote-sensed imagery from NASA's MODIS sensor, the highest resolution sensor that covered the geographic area with sufficient frequency at that time. Each pixel covers a 250m-by-250m area. We compared MODIS images from 9 days before the disaster with images 3 days after the disaster (December 17 and 29, 2004, respectively). Images were linked to the center of each STAR enumeration area, using GPS we collected and the MODIS re-projection tool. We identified the 3x3 block of pixels (750m x750m=0.56km^2) around the center of each enumeration area and visually compared the groundcover before and after the tsunami, counting the number of pixels converted to bare earth. We also obtained satellite-based classifications from the United States Agency for International Development and the German Remote Sensing Data Center and classifications based on physical models from the Dartmouth Flood Observatory (DFO). Using the remote sensing and model-based data (DFO) in combination with reports from survey field supervisors and community leaders, we developed two indices, one based on evidence of inundation and the other based on evidence of physical damage. Communities are classified as heavily damaged if the index value for either inundation or physical damage is high.

measure, "physically exposed", indicates whether the respondent personally experienced at least one of nine unanticipated and largely unavoidable physical exposures to the tsunami, covering a wide range of intensities.[17] The last exposure measure, "any household asset loss", captures tsunami-induced economic losses through a binary measure of whether the respondents' household lost any assets in the disaster.[18]

We present the proportion of respondents in the analytic sample who experienced each type of exposure in Table 3. As shown in the first column, 18% of the sample respondents were from survey enumeration areas that experienced heavy damage, 49% were physically exposed to the disaster as individuals, and 36% experienced the loss of household assets. As shown in the second column, individual exposure is higher in enumeration areas that experienced heavy damage, but a substantial proportion of respondents in less damaged enumeration areas also experienced physical exposure (41%) and household asset loss (27%) (column 3).[19]

The vector of tsunami exposure risk factors, EC_{ihe}, includes several measures that are intended to account for factors that influenced the risk of exposure to the tsunami but likely also relate to pre-existing attitudes to risk. The first of these tsunami risk factors are the elevation and distance to the coast of the baseline survey enumeration area. These help account for geographic

[17] The physical exposures consist of whether the respondent (1) heard the sound of rushing water, (2) heard people shouting about the water, (3) saw the tsunami come ashore, (4) was swept away in the water, (5) sustained injuries, (6) saw family members struggle in the water, (7) saw family members disappear, (8) saw friends/neighbors struggle in the water, and (9) saw friends/neighbors disappear. As discussed before, we are excluding exposure to the related earthquakes from this measure (and analysis) because essentially everyone in our sample reported feeling the earthquakes.

[18] Households that owned assets but did not experience asset loss in the tsunami serve as the omitted category and comparison group for the households that lost assets. The model also includes a binary measure for the 1% of respondents whose households reported not owning any assets before the tsunami, but we do not report these estimates. We use a household-level measure of asset loss because households tend to share resources among their own members, so the loss of assets within a household likely impact individual wellbeing and economic decision-making, especially among dependents and young adults who may rely more heavily on assets owned by other household members. We choose to focus on the incidence rather than the value of asset loss in this study to reduce the potential influence of measurement error in our analysis.

[19] Variation in physical exposure in heavy damage areas likely resulted from idiosyncratic factors, such as respondents' precise locations at the time of the disaster.

and topographic risks of community exposure to a tsunami that may be systematically related to pre-existing risk aversion (we also include the squares of these measures to allow for non-linearity in the relationship between elevation and distance to the coast and risk of exposure).

Second, we include indicators of pre-tsunami household ownership of several types of household and business assets (to account for varying risk of household asset loss among households who owned different amounts of assets) and an indicator of whether respondents reported taking care of household members in the week before the pre-tsunami survey (to help account for varying likelihood of being out of the house at the time of the tsunami). Finally, in line with our estimation strategy, we include *kecamatan* fixed effects to restrict our analysis to variation in tsunami exposure among respondents who lived within local geographic areas.[20]

Although the exposure risk factors we include in EC_{ihe} likely do not perfectly capture all variation in exposure related to pre-existing risk attitudes, our identification strategy relies on the assumption that after accounting for these factors, the remaining variation in exposure will be primarily driven by factors exogenous to pre-existing risk attitudes (such as variations in the sea floor and the exposure of the coastline to the rupture that caused the tsunami, as discussed in section 2). Because of its central importance to our identification strategy, we examine the validity of this exogeneity assumption in Table 4 by examining the relationship of our measures of exposure and our pre-disaster demographic and socioeconomic risk aversion correlates (our best proxies for pre-existing risk attitudes), both before and after controlling for our exposure risk factors in EC_{ihe}.[21]

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[20] The median *kecamatan* in our sample is approximately 121 square kilometers, consists of 20 *desa*, and has a total population (in 2010) of approximately 17,000 people.
[21] We summarize these demographic and socioeconomic characteristics and exposure risk factors among our analytic sample in Appendix Table 2.

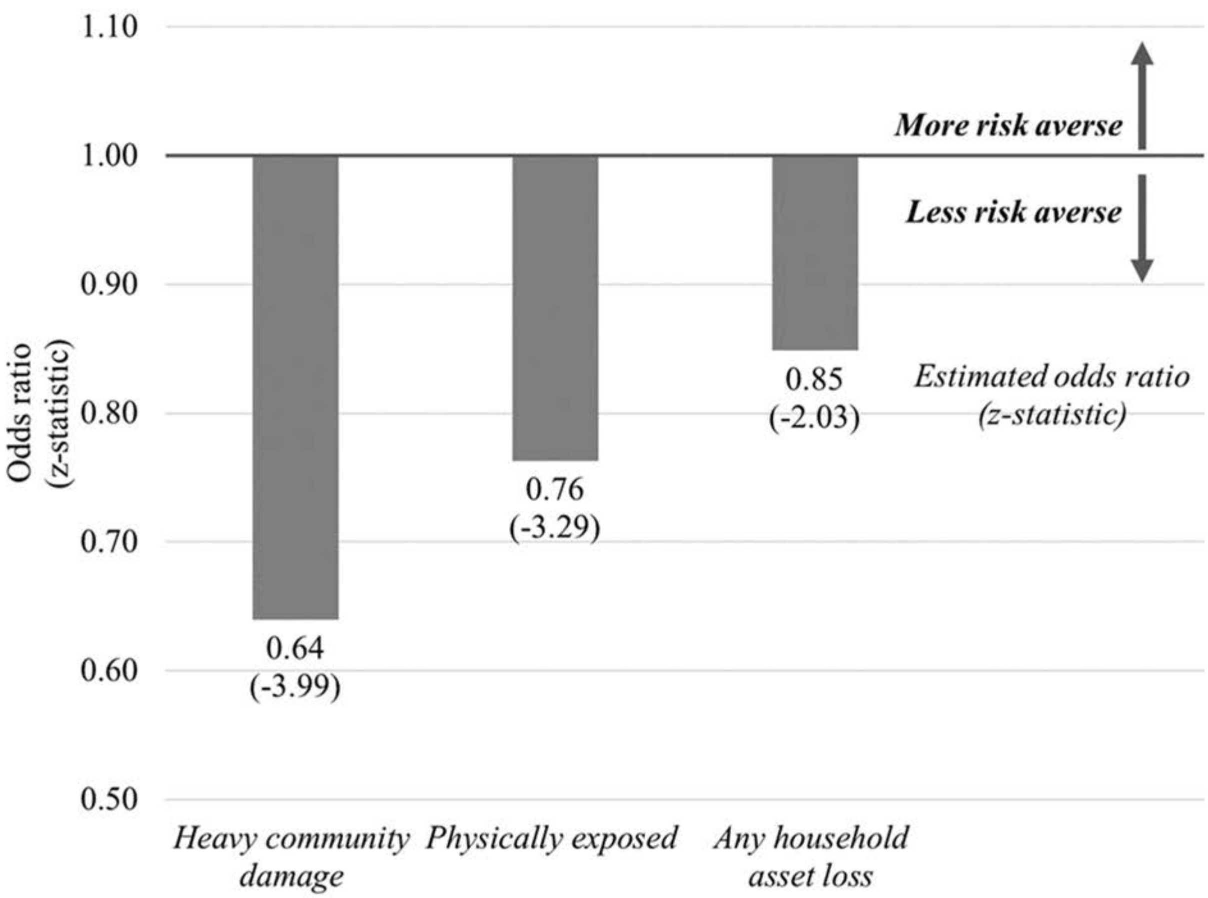
In the first two columns of Table 4, we present the means (for our analytic sample) of our pre-disaster demographic and socioeconomic risk aversion correlates—sex, age, household PCE, years of education, and urban-rural status of the *desa*—contrasting respondents who were and were not exposed, as indicated by each of our exposure measures. Column 3 presents the unadjusted difference between columns 1 and 2, and column 4 presents the same difference estimated with additional controls for the exposure risk factors in EC_{ihc}. Both unadjusted and adjusted differences are estimated using OLS regressions with standard errors clustered at the pre-disaster enumeration area. We also present the chi-squared statistic and corresponding p-value of a joint test of significance of all five differences in columns 3 and 4 for each type of exposure.

The unadjusted differences in column 3 show small, systematic differences in the demographic and socioeconomic characteristics of exposed and unexposed respondents, indicating that there is likely selection in our exposure measures on pre-disaster risk attitudes. However, once we include controls for our exposure risk factors (column 4), these differences and the associated chi-squared statistics become substantially smaller and statistically insignificant. This, combined with our understanding of the remaining exogenous sources of variation in water inundation (see section 2), suggests that the remaining variation in exposure is plausibly exogenous to pre-existing risk attitudes and we can therefore assign a causal interpretation to the estimated values of β, the average relationship between our rank-ordered measure of risk aversion, RA_i, and our measures of tsunami exposure, Exp_{ihc}.

Shorter-term impact analyses

In Figure 4, we present odds ratios and asymptotic z-statistics for the estimated coefficients of three ordered logit regressions of model [1] estimated for our rank-ordered measure of risk aversion in the 1-year follow-up on each the three exposure measures. An odds ratio below 1 would indicate that exposed respondents have lower average risk aversion than unexposed respondents, and an odds ratio above 1 would indicate higher average aversion among exposed respondents.[22]

Figure 4. Estimated impact of tsunami exposures on risk instrument responses at 1-year



Note: Estimated odds ratios and z-statistics of ordered logit models reported. Standard errors are clustered at the pre-disaster enumeration area. The base regression model includes controls for sex, birth cohort, pre-disaster years of education, pre-disaster household PCE, urban-rural status of pre-disaster *desa*, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk assessment module, month-year of interview, and *kecamatan* fixed effects.

[22] The odds ratio for each exposure can be interpreted as the odds of being in each response category or in a more risk averse category compared to the odds of being in less risk averse categories (for example, being in category [5] "Screened out" vs. categories [1]-[4], being in categories [4] or [5] vs. categories [1]-[3], and so on) among exposed respondents compared to the same relative odds for unexposed respondents.

We find that those who were living in an enumeration area that was heavily damaged by the tsunami ("Heavy community damage") have significantly lower levels of average risk aversion than those from other enumeration areas. Individuals who were physically exposed to the tsunami ("Physically exposed") and those living in households that lost any assets ("Any household asset loss") also have significantly lower levels of average risk aversion.

The estimated impact for heavy community damage is significantly larger than the estimated impact of asset loss and descriptively larger than the estimated impact for physical exposure, which is consistent with the fact that the community-level measure is capturing an especially intense and expansive exposure, whereas the individual measures encompass a wider range of exposure intensities, including both lower intensity exposures (e.g., hearing the tsunami, losing a small percentage of household assets) and higher intensity exposures (e.g., being caught in the tsunami waves, losing all household assets).

Longer-term impact analyses

We next examine the potential for longer-term impacts of the disaster on risk aversion using responses to the instrument fielded in the 2-year and 5-year follow-up survey rounds of STAR. Unlike the 1-year follow-up risk instrument (detailed in Section 3), the instrument fielded in the later survey rounds captures variation in tolerance for variance but not variation in "risk aversion" per se (this is because the uncertain options in the updated instrument increase in variance with each choice but the expected value remains unchanged).[23] As a result, the responses from the 1-year risk instrument and later instrument are not directly comparable, but examining the impact of tsunami exposure on responses to the instrument in later survey rounds

[23] These structural changes were made to highlight the uncertainty involved in different income streams and untangle it from changes in the expected return to alleviate any remaining concerns that the income streams in the 1-year instrument could be construed as a gamble or as an interest rate (both of which are forbidden under Islamic law).

can provide suggestive evidence of longer-term impacts on risk aversion.[24] For example, the correlations between the response categories in the 2-year and 5-year follow-up and the three financially risky behaviors in Table 1 are similar to those between the 1-year responses and the risky behaviors (see Appendix Table 4), which suggests that, in practice, the 2-year and 5-year follow-up instruments are capturing meaningful variation in behaviors related to financial risk.[25]

We present our estimated impacts on the responses to the 2-year and 5-year follow-up instruments in Panel B of Table 5. In contrast to the results for the 1-year follow-up in Panel A, we find no evidence that tsunami exposure had any impact on responses to the instrument in the 2-year or 5-year follow-ups (columns 1 and 2). The effect sizes are small (community damage) or non-existent (physical exposure and household asset loss), and none is individually or jointly statistically significant. These findings provide suggestive evidence that the impact we observed in the 1-year follow-up likely was not sustained in the next year or over the longer-term.

Robustness tests

We next present the results of several robustness tests of our estimated impact on attitudes to risk in the 1-year follow-up (Table 6). We first test the robustness of the 1-year results to sample attrition by comparing the primary results, which used the panel of respondents who completed the instruments all three follow-up waves, to results of estimating the base model using a sample consisting of all respondents measured in the 1-year follow-up round (Panel A, column 1). The results using the full 1-year sample are consistent with our primary results (with a small reduction in the magnitude of the estimated impacts of heavy community damage),

[24] We present the distribution of responses to the 2-year and 5-year instruments in Appendix Table 5. Being screened out was more common than in the 1-year instrument, but we still observe variation across all five stopping points.

[25] In addition, we conducted a field experiment in late 2022 in which a subsample of STAR respondents received both the 1-year instrument and the instrument fielded in the 2-year and 5-year follow-ups (in a random order). There are no significant or substantive difference in the choices the respondent made in either instrument.

which suggests that sample attrition among the baseline respondents measured in the 1-year follow-up is not driving our primary findings.

We also examine the role that selective mortality may have played in our 1-year findings. If respondents who died in the tsunami were more risk averse, on average, than those that survived the tsunami, then our 1-year results may reflect selective mortality rather than the impact of exposure to the tsunami. To address this concern, we present two additional analyses examining the role of mortality on our estimated impacts. In Panel A, column 2, we restrict our estimate of model [1] to respondents in our analytic sample who were living in survey enumeration areas without any tsunami-related mortality in the baseline sample and without heavy community damage. In Panel B, column 1, we include an additional control for the tsunami mortality rate among baseline respondents in each respondent's baseline enumeration area in model [1]. Both sets of estimates are essentially identical to those of our primary results, so we conclude that mortality selection is also not driving our 1-year results.

In Panel B, column 2, we examine the role that the post-disaster reconstruction and rehabilitation efforts may have played in our 1-year findings. Because the 1-year follow-up survey coincided with the earliest phase of the reconstruction and rehabilitation efforts, which was largely targeted at survivors who had been exposed to the tsunami (Frankenberg et al. 2009), it is possible that our 1-year results reflect the impact of aid receipt rather than exposure to the disaster itself. Because housing reconstruction assistance made up the bulk of the assistance that went directly to individuals, we examine the potential role of aid in our findings by including an additional control in our base model for whether each respondent's household had received aid in the form of a new or rehabilitated house by the date of the 1-year follow-up interview. We find no changes to our estimated 1-year impacts with the inclusion of the housing aid control, which suggests that early post-disaster reconstruction is not likely to be a factor in our estimated 1-year impacts.

In Panel C, we examine the importance of our assumption that screened-out respondents are more risk averse, on average, than other respondents (columns 1 to 3) and the sensitivity of our 1-year results to our use of a categorical measure of risk aversion compared to using risk parameter ranges implied by those categories (column 4). In columns 1 and 2, we examine the relative contribution of being screened out or not to our primary 1-year results by estimating two versions of model [1] with different outcomes: (1) being screened out and (2) our rank-ordered categorical measure of risk aversion excluding screened-out respondents. The results are largely similar across the two models, particularly for physical exposure, with no statistically significant differences in the coefficients between the models.[26]

In column 3, we relax the assumption that screened-out respondents are more risk averse on average than the [4] "Most risk averse" group by estimating model [1] using our rank-ordered measure of risk aversion with respondents in [5] "Screened out" and [4] "Most risk averse" categories combined into one group. The estimated impacts on this condensed outcome are very similar to those with the full rank-ordered outcome, so this assumption does not appear to be driving our results either.

Finally, we tested the sensitivity of our findings to our use of a rank-ordered categorical measure by estimating model [1] with the implied CRRA parameter ranges as outcomes using an interval regression. (Because [5] "Screened out" does not have an implied parameter range, we assumed that it has the same parameter range as the [4] "Most risk averse" category: 2.915 to ∞). These results are consistent with our primary findings using a rank-ordered measure: a

[26] The chi-squared statistics (and p-values) for the heavy community damage, physical exposure, and household asset loss coefficients are 0.32 (p-value = 0.570), 0.06 (p-value = 0.802), and 2.29 (p-value = 0.130), respectively.

significant decline in risk aversion among respondents in heavily-damaged communities and a smaller, significant decline among respondents who were physically exposed.

Sub-group analyses

In Table 7, we examine heterogeneity in our estimated short-term impacts by estimating the impact of our three exposure measures in the 1-year follow-up on the risk aversion of different demographic and socioeconomic sub-groups. We formed our sub-groups by stratifying the sample by sex, birth cohort, pre-disaster education, pre-disaster household per-capita expenditure (PCE), and urban-rural status of pre-disaster *desa*. To start, there is no evidence of differences in the impacts on males and females (columns 1 and 2).

The impacts of exposure to heavy community damage on risk aversion are concentrated among respondents who are younger, better educated, from households with higher pre-disaster PCE, and from urban baseline communities. This may be driven, for example, by younger respondents having longer time horizons or by respondents with higher socioeconomic status (i.e., more educated, wealthier, from urban areas) being better able to exploit new opportunities in the aftermath of the disaster.

The impacts of physical exposure, on the other hand, are experienced equally across all sub-groups. The impact of household asset loss is descriptively larger among younger, less educated, poorer, and rural respondents, but the estimate is only significant among respondents from households with lower pre-disaster PCE and there are no significant differences across related sub-groups. Despite evidence of selective mortality on sex, age, and socioeconomic status

(Frankenberg et al. 2011), the sub-group results do not appear to be driven by selective mortality.[27]

6. Discussion and conclusions

Using plausibly exogenous variation in exposure to the 2004 Indian Ocean tsunami across respondents from coastal communities in Aceh and North Sumatra, Indonesia, we find strong evidence that heavy community exposure and individual physical exposure to the tsunami (coupled with a short period of temporary emergency aid, including temporary housing, food, and medical care) led to an average increase in survivors' willingness to assume financial risk in the first year after the disaster. These findings are robust to several potential confounding factors, including selective tsunami mortality, receipt of housing reconstruction aid, and sample attrition, and to alternative risk aversion measures, including the CRRA parameter ranges implied by the response categories. We find consistent impacts of physical exposure across demographic and socioeconomic groups, but we find that the impacts of heavy community damage are concentrated among respondents who are young, better educated, better off economically, and from urban areas. We also find no evidence that suggests these impacts persist over time.

The impact of household asset loss on risk aversion is less clear-cut, presumably because wealth is only one component of economic wellbeing and the massive destruction of the tsunami had wider-reaching economic impacts than on wealth alone. For example, respondents who were living in communities that were directly affected by the tsunami or who were, themselves, physically exposed to the tsunami likely experienced significant loss of livelihoods through the tsunami's impact on work opportunities, local markets, and infrastructure.

[27] The results do change substantially after including survey enumeration area mortality rate among baseline respondents in the regression model or after restricting the analysis to survey enumeration areas without tsunami mortality or heavy damage (see Appendix Tables 6 and 7).

The temporary reduction in risk aversion among exposed respondents in the 1-year follow-up and its disappearance in later follow-up rounds coincide with a reduction and subsequent recovery in household consumption and survivors' perceptions of their socioeconomic wellbeing (Lawton et al. 2023). As discussed in Section 2, these findings are largely consistent with the prediction of prospect theory as posited by Kahneman and Tversky (1979) and Page et al. (2014) and inconsistent with the predictions of either simple models of expected utility maximization or experimental evidence of increasing risk aversion following increased perceptions of environmental risk related to financial behaviors (for example, He and Hong 2018). These findings highlight the value of insights from the behavioral sciences and the value of research that includes evidence both soon after a large-scale natural disaster and in the following years to document the transitory nature of the differences in risk attitudes.

Our findings of similar temporary declines in risk aversion among both men and women contrasts from those of Hanaoka et al. (2018), who used arguably exogenous variation in exposure to a massive earthquake in Japan to estimate its impact on risk aversion. They found a persistent decrease in risk aversion among exposed males but no impacts among exposed females. Although we cannot identify the specific reasons that our findings differ, there are important contextual differences between the two studies that are potentially implicated. These include, for example, differences in the level of economic resources, differences in the magnitude and nature of the economic damage caused by the two disasters, differences in the post-disaster reconstruction effort and economic opportunities, and differences in the role of women in the family economy.

Our results also have important implications for the design of post-disaster assistance policies focused on rehabilitation and reconstruction, particularly in developing countries.

Assistance organizations are very adept at providing the short-term humanitarian relief required in the immediate aftermath of a disaster, but the best practices to achieve lasting improvements in the livelihoods of disaster survivors have not been well established by the policy community. The question of how to achieve lasting improvements in a timely manner is critical in the context of disasters like the 2004 Indian Ocean tsunami in which the disaster disrupted the ability of many survivors to provide for themselves and their families (expert informants in the heavily damaged communities reported reduced opportunities to earn income in the year after the disaster).

This study suggests that after a disaster there is a period in which many survivors who are exposed to the disaster (and the temporary period of emergency aid that followed) are willing to take on more financial risk, so providing survivors with rehabilitation and reconstruction assistance in forms that are more consistent with these attitudes (for example, providing loans, capital, and training for running small businesses) during the first year or so after a disaster may be an important component of successful post-disaster recovery efforts.

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Table 1. Prevalence of risky economic behaviors by risk instrument responses at 1-year
Among household heads who completed the risk instrument in 1-year follow-up round

	Responses to risk instrument in 1-year follow-up			
	[5] Screened out	*[4] Most averse*	*[2] or [3] Somewhat averse*	*[1] Least averse*
Household started running a business in 2005				
Among household heads not running a business in previous survey round (N = 4,622)				
Mean (%)	8.0	8.1	9.4	13.4
Difference: relative to [5] screened out		*0.1*	*1.3*	*5.3*
(standard error)		*(1.0)*	*(1.3)*	*(1.6)*
relative to [4] most averse			*1.2*	*5.2*
			(1.4)	*(1.7)*
relative to [2] or [3] somewhat averse				*4.0*
				(2.0)
Household purchased assets for business in 2005				
Among household heads running a business in 2005 (N = 4,733)				
Mean (%)	11.5	13.5	15.4	19.7
Difference: relative to [5] screened out		*2.0*	*3.9*	*8.2*
(standard error)		*(1.4)*	*(1.6)*	*(1.8)*
relative to [4] most averse			*1.9*	*6.2*
			(1.8)	*(2.0)*
relative to [2] or [3] somewhat averse				*4.3*
				(2.1)
Household took out a loan in 2005				
Among all household heads (N = 9,422)				
Mean (%)	18.2	20.1	22.7	25.7
Difference: relative to [5] screened out		*2.0*	*4.6*	*7.5*
(standard error)		*(1.2)*	*(1.3)*	*(1.5)*
relative to [4] most averse			*2.6*	*5.5*
			(1.5)	*(1.7)*
relative to [2] or [3] somewhat averse				*2.9*
				(1.8)

Notes: Reported differences in means and standard errors estimated using OLS regression models, with standard errors clustered at the pre-disaster enumeration area.

Table 2. Mean of correlates of risk aversion by risk instrument responses at 1-year
Sample of 13,428 baseline respondents who completed the risk instrument in 1-year follow-up round

	Responses to risk instrument in 1-year follow-up			
	[5] Screened out	*[4] Most averse*	*[2] or [3] Somewhat averse*	*[1] Least averse*
Male *(%)*	45.8	45.8	52.6	61.1
Difference: relative to [5] screened out		*0.0*	*6.8*	*15.3*
(standard error)		*(1.0)*	*(1.2)*	*(1.6)*
relative to [4] most averse			*6.8*	*15.3*
			(1.4)	*(1.7)*
relative to [2] or [3] somewhat averse				*8.5*
				(1.9)
Age at time of tsunami *(mean years)*	34.35	33.82	32.52	33.41
Difference: relative to [5] screened out		*-0.53*	*-1.83*	*-0.93*
(standard error)		*(0.29)*	*(0.38)*	*(0.48)*
relative to [4] most averse			*-1.30*	*-0.41*
			(0.39)	*(0.5)*
relative to [2] or [3] somewhat averse				*0.90*
				(0.55)
Completed education *(mean years)*	7.6	8.3	8.3	8.8
Difference: relative to [5] screened out		*0.7*	*0.7*	*1.2*
(standard error)		*(0.1)*	*(0.2)*	*(0.2)*
relative to [4] most averse			*0.0*	*0.5*
			(0.2)	*(0.2)*
relative to [2] or [3] somewhat averse				*0.5*
				(0.2)
Baseline log HH PCE *(mean 10,000 Rp)*	12.51	12.64	12.58	12.70
Difference: relative to [5] screened out		*0.13*	*0.07*	*0.19*
(standard error)		*(0.02)*	*(0.03)*	*(0.03)*
relative to [4] most averse			*-0.05*	*0.07*
			(0.03)	*(0.03)*
relative to [2] or [3] somewhat averse				*0.12*
				(0.04)
In urban community at baseline *(%)*	27.7	32.0	34.5	51.1
Difference: relative to [5] screened out		*4.2*	*6.7*	*23.3*
(standard error)		*(2.5)*	*(2.9)*	*(3.7)*
relative to [4] most averse			*2.5*	*19.1*
			(2.6)	*(3.9)*
relative to [2] or [3] somewhat averse				*16.6*
				(4.1)

Notes: Sample size = 13,428 respondents. Reported differences in means and standard errors estimated using OLS regression models, with standard errors clustered at the pre-disaster enumeration area.

Table 3. Summary of respondent exposure to the tsunami

Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

		By community damage	
	All communities	*Non-heavy damage*	*Heavy damage*
Heavy community damage (%)	18	0	100
Physically exposed to tsunami (%)	49	41	85
Any damage or loss of household assets (%)			
Owned assets, no damage or loss	63	72	20
Owned assets, damage or loss	36	27	79
Did not own assets	1	1	1
N	9,860	8,126	1,734

Notes: "Heavy community damage" indicates relatively high levels of tsunami damage in the community and is based on remote sensing measures of damage, direct observations from our team supervisors, and reports from community leaders (see footnote 16 for more details). "Physically exposed to the tsunami" indicates whether the respondent experienced at least one of nine unanticipated physical exposures to the tsunami (see footnote 17 for more details). "Any damage or loss of household assets" is a categorical variable which indicates whether the household owned any assets before the tsunami and if so, whether they experienced any damage or loss of those assets in the tsunami.

Table 4. Balance table of demographic and socioeconomic correlates of risk aversion, by tsunami exposure
Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	Mean, by tsunami exposure		*Difference in means (standard error)*	
	Unexposed	*Exposed*	*Unadjusted*	*Regression-adjusted*
		Heavy community damage from tsunami		
Male (%)	42.9	46.8	*4.0*	*-1.8*
			(1.4)	*(2.0)*
Age at time of tsunami (years)	34.2	33.8	*-0.4*	*0.1*
			(0.4)	*(1.0)*
Years of education	7.7	9.0	*1.3*	*-0.1*
			(0.3)	*(0.3)*
Baseline log HH PCE (10,000 Rp)	12.51	12.74	*0.23*	*0.11*
			(0.05)	*(0.08)*
Baseline urban community (%)	25.3	46.5	*21.2*	*11.7*
			(6.3)	*(10.0)*
Joint tests (chi-squared [p-value])			*38.93 [0.000]*	*7.44 [0.190]*
		Physically exposed to tsunami		
Male (%)	41.6	45.6	*4.0*	*1.4*
			(1.0)	*(1.0)*
Age at time of tsunami (years)	34.3	34.0	*-0.3*	*-0.2*
			(0.3)	*(0.3)*
Years of education	7.2	8.6	*1.4*	*0.1*
			(0.2)	*(0.1)*
Baseline log HH PCE (10,000 Rp)	12.46	12.65	*0.18*	*0.02*
			(0.03)	*(0.02)*
Baseline urban community (%)	19.2	39.3	*20.1*	*-0.7*
			(3.1)	*(1.5)*
Joint tests (chi-squared [p-value])			*127.79 [0.000]*	*6.85 [0.232]*
		Any household asset loss from tsunami		
Male (%)	41.1	47.7	*6.6*	*0.8*
			(0.9)	*(1.2)*
Age at time of tsunami (years)	34.2	34.5	*0.3*	*0.3*
			(0.3)	*(0.4)*
Years of education	7.9	7.9	*0.0*	*0.0*
			(0.2)	*(0.1)*
Baseline log HH PCE (10,000 Rp)	12.56	12.54	*-0.02*	*0.01*
			(0.03)	*(0.02)*
Baseline urban community (%)	29.1	28.9	*-0.2*	*2.1*
			(3.5)	*(1.9)*
Joint tests (chi-squared [p-value])			*58.13 [0.000]*	*4.45 [0.486]*

Note: Sample size = 9,860 respondents. Reported differences and standard errors (clustered at the pre-disaster enumeration area) estimated using OLS regression models of exposure on each characteristic. Within each exposure, we also report chi-squared and p-values of Wald tests of joint significance of mean differences of all five characteristics. The "Regression-adjusted" models include additional controls for all five characteristics, plus distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, and kecamatan fixed effects.

Table 5. Estimated impact of tsunami exposures on risk instrument responses at 1-year, 2-year, and 5-year

Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	Panel A. Estimated impact at 1-year				*Panel B. Estimated longer-term impacts*	
	[1]	[2]	[3]	[4]	[1]	[2]
Survey round	*1-year follow-up*				*2-year follow-up*	*5-year follow-up*
Estimation model	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*
Type of estimate reported	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*
Heavy community damage	0.64			0.66	0.84	0.86
	(-3.99)			(-3.82)	(-1.00)	(-1.23)
Physically exposed		0.76		0.78	1.01	1.06
		(-3.29)		(-2.92)	(0.18)	(0.92)
Any household asset loss			0.85	0.89	0.97	0.98
			(-2.03)	(-1.48)	(-0.40)	(-0.25)
N	9,860	9,860	9,860	9,860	9,860	9,860
Tests (chi-squared [p-value])						
Joint tests						
All three exposures				*29.22 [0.000]*	*1.24 [0.743]*	*2.37 [0.499]*
Physical, asset loss				*11.52 [0.003]*	*0.18 [0.916]*	*0.85 [0.653]*
Equality across exposures						
Comm damage, physical				*1.40 [0.236]*	*0.94 [0.332]*	*2.31 [0.129]*
Comm damage, asset loss				*4.32 [0.038]*	*0.52 [0.471]*	*0.85 [0.357]*
Physical, asset loss				*1.03 [0.310]*	*0.15 [0.700]*	*0.54 [0.460]*

Notes: Estimated odds ratios and z-statistics of ordered logit models reported, along with chi-squared and p-values for Wald tests of joint significance and tests of equality of exposure measures. Standard errors are clustered at the pre-disaster enumeration area. The base regression model includes controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, and kecamatan fixed effects.

Table 6. Estimated impact of tsunami exposures on risk instrument responses at 1-year, alternative specifications

Sample of baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	Panel A. Alternative samples		*Panel B. Alternative models*		*Panel C. Alternative outcomes*			
	[1]	[2]	[1]	[2]	[1]	[2]	[3]	[4]
Alternative specification	*All respondents in 1-year follow-up*	*Communities without tsunami mortality*	*Include control for EA tsunami mortality rate in baseline sample*	*Include control for receiving housing aid in 2005 or 2006*	*Screened out*	*Response categories excluding screened out*	*Screened out and "most risk averse" responses combined into one category*	*CRRA parameter ranges*
Estimation model	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Logit*	*Ordered logit*	*Ordered logit*	*Interval regression*
Type of estimate reported	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Coefficient (z-statistic)*
Heavy community damage	0.78		0.66	0.65	0.66	0.75	0.69	-0.71
	(-2.27)		(-3.78)	(-4.04)	(-3.20)	(-1.66)	(-2.78)	(-2.92)
Physically exposed	0.75	0.79	0.78	0.78	0.80	0.82	0.75	-0.49
	(-3.68)	(-2.47)	(-2.92)	(-2.94)	(-2.50)	(-1.70)	(-2.82)	(-2.79)
Any household asset loss	0.89	0.91	0.89	0.88	0.85	1.09	0.95	-0.10
	(-1.68)	(-1.00)	(-1.47)	(-1.59)	(-1.64)	(0.72)	(-0.57)	(-0.62)
N	13,428	7,617	9,860	9,860	9,790	4,951	9,860	9,860
Tests (chi-squared [p-value])								
Joint tests								
All three exposures	*24.63 [0.000]*		*29.03 [0.000]*	*30.97 [0.000]*	*23.09 [0.000]*	*6.36 [0.095]*	*17.84 [0.000]*	*18.47 [0.000]*
Physical, asset loss	*17.32 [0.000]*	*7.40 [0.025]*	*11.50 [0.003]*	*11.98 [0.003]*	*10.22 [0.006]*	*2.98 [0.226]*	*8.80 [0.012]*	*8.82 [0.012]*
Equality across exposures								
Comm damage, physical	*0.06 [0.800]*		*1.43 [0.232]*	*1.84 [0.175]*	*1.35 [0.245]*	*0.19 [0.666]*	*0.24 [0.626]*	*0.52 [0.469]*
Comm damage, asset loss	*0.85 [0.355]*		*4.31 [0.038]*	*4.86 [0.027]*	*2.25 [0.134]*	*3.18 [0.075]*	*3.79 [0.052]*	*4.06 [0.044]*
Physical, asset loss	*2.23 [0.136]*	*1.09 [0.295]*	*1.03 [0.310]*	*0.90 [0.342]*	*0.24 [0.624]*	*2.32 [0.128]*	*2.57 [0.109]*	*2.25 [0.133]*

Notes: For logit and ordered logit models, estimated odds ratios and z-statistics reported. For interval regression, estimated coefficients and z-statistics reported. We also report chi-squared and p-values for Wald tests of joint significance of exposure measures in each model. Standard errors are clustered at the pre-disaster enumeration area. The base regression model includes controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, and kecamatan fixed effects. In column 1 of Panel C, 70 of 9,860 observations omitted from estimation because of perfect collinearity of "Screened out" outcome within two kecamatans. In column 4 of Panel C, the CRRA range of the screened out group is assumed to the same as the most risk averse group: (2.915, ∞).

Table 7. Estimated impact of tsunami exposures on risk instrument responses at 1-year, by pre-tsunami demographic and socioeconomic characteristics

Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Pre-tsunami characteristic	*Sex*		*Birth cohort*		*Pre-disaster education*		*Pre-disaster HH PCE*		*Pre-disaster location*	
Sub-group	*Female*	*Male*	*Under age 40 at tsunami*	*Age 40 or over at tsunami*	*Completed less than 6 years*	*Completed 6 years or more*	*Below sample median*	*At or above sample median*	*Rural community*	*Urban community*
Estimation model	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*
Type of estimate reported	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*
Heavy community damage	0.65	0.75	0.63	0.83	1.00	0.64	0.87	0.60	0.80	0.50
	(-3.48)	(-2.18)	(-3.76)	(-1.26)	(0.01)	(-3.88)	(-0.96)	(-3.82)	(-1.82)	(-3.52)
Physically exposed	0.81	0.76	0.81	0.73	0.71	0.80	0.79	0.78	0.80	0.76
	(-2.40)	(-2.72)	(-2.33)	(-2.96)	(-2.39)	(-2.77)	(-2.25)	(-2.41)	(-2.31)	(-2.30)
Any household asset loss	0.91	0.88	0.87	0.94	0.80	0.92	0.78	0.99	0.85	0.94
	(-1.04)	(-1.34)	(-1.62)	(-0.56)	(-1.59)	(-1.05)	(-2.29)	(-0.06)	(-1.60)	(-0.44)
N (Total)	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860
N (Subgroup)	5,564	4,296	6,610	3,250	1,930	7,930	5,160	4,700	7,000	2,860
Tests										
Joint tests										
(chi-squared [p-value])										
All three exposures	*24.10 [0.000]*	*20.12 [0.000]*	*28.46 [0.000]*	*13.94 [0.003]*	*11.28 [0.010]*	*28.99 [0.000]*	*14.97 [0.002]*	*27.89 [0.000]*	*13.96 [0.003]*	*29.07 [0.000]*
Physical, asset loss	*7.81 [0.020]*	*9.92 [0.007]*	*8.89 [0.012]*	*9.65 [0.008]*	*10.55 [.005]*	*9.32 [0.009]*	*11.51 [0.003]*	*6.11 [0.047]*	*8.24 [0.016]*	*6.19 [0.045]*
Equality across exposures										
(chi-squared [p-value])										
Comm damage, physical	*1.91 [0.167]*	*0.01 [0.938]*	*2.46 [0.117]*	*0.45 [0.501]*	*1.98 [0.159]*	*2.11 [0.146]*	*0.30 [0.587]*	*2.13 [0.145]*	*0.00 [0.946]*	*2.70 [0.101]*
Comm damage, asset loss	*4.35 [0.037]*	*0.77 [0.381]*	*4.04 [0.044]*	*0.34 [0.560]*	*0.79 [0.374]*	*5.66 [0.017]*	*0.31 [0.580]*	*7.49 [0.006]*	*0.13 [0.722]*	*5.78 [0.016]*
Physical, asset loss	*0.85 [0.357]*	*0.89 [0.346]*	*0.27 [0.605]*	*2.29 [0.130]*	*0.29 [0.593]*	*1.29 [0.256]*	*0.00 [0.985]*	*2.32 [0.128]*	*0.24 [0.624]*	*1.27 [0.261]*
Equality across subgroups										
(z-statistic [p-value])										
Heavy community damage		*1.28 [0.200]*		*2.04 [0.041]*		*-2.52 [0.012]*		*-2.30 [0.022]*		*-2.45 [0.014]*
Physically exposed		*-0.56 [0.574]*		*-1.05 [0.295]*		*0.94 [0.349]*		*-0.05 [0.957]*		*-0.33 [0.738]*
Any household asset loss		*-0.46 [0.648]*		*0.72 [0.474]*		*1.00 [0.317]*		*1.82 [0.068]*		*0.64 [0.523]*

Notes: Estimated odds ratios and z-statistics of ordered logit models reported, along with chi-squared and p-values for Wald tests of joint significance of exposure measures and z-statistic and p-values of differences between sub-groups (estimated by interaction terms in model). Standard errors are clustered at the pre-disaster enumeration area. The sub-group regression models include interaction terms between each exposure measure and an indicator for the omitted sub-group (for example, for "males" in column 1). The regression models also include controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, and kecamatan fixed effects.

Appendix Table 1. Responses to 1-year follow-up risk instrument, by module
Sample of 13,428 baseline respondents who completed the risk instrument in 1-year follow-up round

	1-year follow-up round			
	Module 1	*Module 2*	*Module 3*	*Module 4*
Value of certain option in all choices (Rp)	*200k*	*400k*	*800k*	*1.2M*
Uncertain option in Choice 0 (Rp)	*200k or 400k*	*400k or 800k*	*800k or 1.6M*	*1.2M or 2.4M*
Uncertain option in Choice 1 (Rp)	*150k or 400k*	*300k or 800k*	*600k or 1.6M*	*900k or 2.4M*
Uncertain option in Choice 2 (Rp)	*100k or 400k*	*200k or 800k*	*400k or 1.6M*	*600k or 2.4M*
Uncertain option in Choice 3 (Rp)	*50k or 400k*	*100k or 800k*	*200k or 1.6M*	*300k or 2.4M*
(5) Screened-out of risk instrument (%)	52	50	50	49
(4) Most risk averse (%)	28	29	28	29
(3) Next most risk averse (%)	11	12	13	13
(2) Next least risk averse (%)	2	1	1	2
(1) Least risk averse (%)	7	8	8	8
N	3,346	3,403	3,304	3,375

Notes: Every adult respondent (age 15 years and above) in STAR households was randomly assigned to one of four risk assessment modules in the 1-year follow-up round.

Appendix Table 2. Summary of demographic and socioeconomic characteristics and correlates of tsunami exposure
Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	N	*Mean*	*SD*
Pre-tsunami demographic and socioeconomic characteristics			
Male (%)	9860	43.6	
Birth cohort (%)			
After 1984	9860	16.6	
1975-1984	9860	24.8	
1965-1974	9860	25.6	
1955-1964	9860	18.6	
1945-1954	9860	9.9	
Before 1945	9860	4.5	
Household PCE (Rp10,000)	9860	32.9	20.8
Years of education (%)			
0 years	9860	6.4	
1-5 years	9860	13.1	
6 years	9860	25.2	
7-9 years	9860	22.1	
10-12 years	9860	24.2	
13+ years	9860	8.9	
Urban community (%)	9860	29.0	
Pre-tsunami correlates of tsunami exposure			
Distance of community to coast (km)	9860	6.5	8.8
Elevation of community (m)	9860	27.4	44.0
Household owned household assets (%)			
House	9860	81.0	
Land	9860	27.1	
Livestock	9860	30.4	
Transportation	9860	42.2	
Household furniture/utensils	9860	91.0	
Gold, jewelry	9860	33.1	
Cash, stocks, bonds	9860	20.2	
Household owned business assets (%)			
Wet land	9860	22.4	
Dry land	9860	23.5	
Livestock	9860	10.0	
Buildings	9860	12.7	
Machinery, equipment	9860	44.8	
Transportation	9860	11.9	
Other assets used for business	9860	5.6	
Took care of household member in previous week (%)	9860	46.9	

Appendix Table 3. Estimated impact of tsunami exposures on risk instrument responses at 1-year, with community and individual exposure interactions

Sample of baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Sample and outcome	*Base sample and outcome*		*All respondents in 1-year follow-up*		*Screened out and "most risk averse" responses combined into one category*		*CRRA parameter ranges*	
Estimation model	*Ordered logit*		*Ordered logit*		*Ordered logit*		*Interval regression*	
Type of estimate reported	*Odds ratio (z-statistic)*		*Odds ratio (z-statistic)*		*Odds ratio (z-statistic)*		*Estimated coefficient (z-statistic)*	
Heavy community damage	0.66	0.61	0.78	0.66	0.69	0.86	-0.71	-0.44
	(-3.82)	(-2.17)	(-2.27)	(-1.91)	(-2.78)	(-0.56)	(-2.92)	(-0.93)
Physically exposed	0.78	0.78	0.75	0.74	0.75	0.76	-0.49	-0.47
	(-2.92)	(-2.83)	(-3.68)	(-3.65)	(-2.82)	(-2.61)	(-2.79)	(-2.59)
Any household asset loss	0.89	0.87	0.89	0.85	0.95	0.99	-0.10	-0.04
	(-1.48)	(-1.67)	(-1.68)	(-2.15)	(-0.57)	(-0.13)	(-0.62)	(-0.26)
Interaction with heavy community damage								
Physically exposed		1.03		1.09		0.90		-0.12
		(0.13)		(0.46)		(-0.43)		(-0.28)
Any household asset loss		1.10		1.18		0.82		-0.26
		(0.47)		(0.86)		(-0.91)		(-0.65)
N	9,860	9,860	13,428	13,428	9,860	9,860	9,860	9,860

Notes: For logit and ordered logit models, estimated odds ratios and z-statistics reported. For interval regression, estimated coefficients and z-statistics reported. Standard errors are clustered at the pre-disaster enumeration area. The base regression model includes controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, and kecamatan fixed effects. The models in the even numbered columns (2, 4, 6, and 8) also include interaction terms between "Heavy community damage" and the measures of individual exposures: "Physically exposed" and "Any household asset loss". In columns 7 and 8, the CRRA range of the screened out group is assumed to the same as the most risk averse group: (2.915,∞).

Appendix Table 4. Prevalence of risky economic behaviors by risk instrument responses at 2-year and 5-year
Among household heads who completed the risk instrument in 2-year or 5-year follow-up rounds

	Responses to risk instrument in 2-year follow-up				*Responses to risk instrument in 5-year follow-up*			
	[5] Screened out	*[4] Most averse*	*[2] or [3] Somewhat averse*	*[1] Least averse*	*[5] Screened out*	*[4] Most averse*	*[2] or [3] Somewhat averse*	*[1] Least averse*
Household started running a business in 2006 (2-year) or 2009 (5-year)								
Among household heads not running a business in previous survey round (N = 4,394 in 2-year, 5,670 in 5-year)								
Mean (%)	34.3	33.3	33.9	41.1	22.6	21.8	29.2	30.4
Difference: relative to [5] screened out		*-1.0*	*-0.4*	*6.8*		*-0.8*	*6.5*	*7.8*
(standard error)		*(2.0)*	*(2.7)*	*(3.1)*		*(1.5)*	*(2.8)*	*(2.7)*
relative to [4] most averse			*0.6*	*7.8*			*7.3*	*8.6*
			(3.2)	*(3.4)*			*(3.1)*	*(2.9)*
relative to [2] or [3] somewhat averse				*7.2*				*1.2*
				(4.0)				*(3.4)*
Household purchased assets for business in 2006 (2-year) or 2009 (5-year)								
Among household heads running a business (N = 5,540 in 2-year, 4,861 in 5-year)								
Mean (%)	34.6	36.6	38.0	44.6	10.5	16.0	16.7	15.9
Difference: relative to [5] screened out		*1.9*	*3.4*	*10.0*		*5.5*	*6.2*	*5.4*
(standard error)		*(1.8)*	*(2.8)*	*(2.8)*		*(1.6)*	*(2.0)*	*(1.8)*
relative to [4] most averse			*1.5*	*8.0*			*0.7*	*-0.1*
			(3.2)	*(3.0)*			*(2.3)*	*(2.3)*
relative to [2] or [3] somewhat averse				*6.5*				*-0.8*
				(3.6)				*(2.5)*
Household took out a loan in 2006 (2-year) or 2009 (5-year)								
Among all household heads (N = 10,101 in 2-year, 11,387 in 5-year)								
Mean (%)	20.9	22.9	24.5	25.5	14.5	16.5	16.6	20.4
Difference: relative to [5] screened out		*1.9*	*3.5*	*4.5*		*2.0*	*2.1*	*5.9*
(standard error)		*(1.2)*	*(1.7)*	*(1.7)*		*(0.9)*	*(1.3)*	*(1.5)*
relative to [4] most averse			*1.6*	*2.6*			*0.1*	*3.9*
			(1.9)	*(1.9)*			*(1.6)*	*(1.7)*
relative to [2] or [3] somewhat averse				*1.0*				*3.8*
				(2.3)				*(1.9)*

Notes: Reported differences in means and standard errors estimated using OLS regression models, with standard errors clustered at the pre-disaster enumeration area.

Appendix Table 5. Responses to 1-year, 2-year, and 5-year follow-up risk instruments

Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	1-year follow-up	*2-year follow-up*	*5-year follow-up*
[5] Screened-out of risk instrument (%)	50	71	69
[4] Most averse to risk/uncertainty (%)	29	17	17
[3] Next most averse to risk/uncertainty (%)	13	1	1
[2] Next least averse to risk/uncertainty (%)	1	6	6
[1] Least averse to risk/uncertainty (%)	7	5	6

Appendix Table 6. Estimated impact of tsunami exposures on risk instrument responses at 1-year, by pre-tsunami demographic and socioeconomic characteristics, controlling for EA tsunami mortality

Sample of 9,860 baseline respondents who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Pre-tsunami characteristic	*Sex*		*Birth cohort*		*Pre-disaster education*		*Pre-disaster HH PCE*		*Pre-disaster location*	
Sub-group	*Female*	*Male*	*Under age 40 at tsunami*	*Age 40 or over at tsunami*	*Completed less than 6 years*	*Completed 6 years or more*	*Below sample median*	*At or above sample median*	*Rural community*	*Urban community*
Estimation model	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*
Type of estimate reported	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*
Heavy community damage	0.65	0.75	0.63	0.83	1.00	0.64	0.88	0.59	0.81	0.50
	(-3.39)	(-2.13)	(-3.68)	(-1.23)	(0.02)	(-3.78)	(-0.91)	(-3.70)	(-1.71)	(-3.46)
Physically exposed	0.81	0.76	0.81	0.73	0.71	0.80	0.79	0.78	0.80	0.76
	(-2.40)	(-2.72)	(-2.33)	(-2.96)	(-2.39)	(-2.77)	(-2.24)	(-2.42)	(-2.31)	(-2.30)
Any household asset loss	0.91	0.88	0.87	0.94	0.80	0.92	0.78	1.00	0.85	0.95
	(-1.04)	(-1.34)	(-1.61)	(-0.56)	(-1.58)	(-1.04)	(-2.29)	(-0.04)	(-1.59)	(-0.43)
N (Total)	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860	9,860
N (Subgroup)	5,564	4,296	6,610	3,250	1,930	7,930	5,160	4,700	7,000	2,860
Tests										
Joint tests										
(chi-squared [p-value])										
All three exposures	*23.38 [0.000]*	*19.83 [0.000]*	*27.70 [0.000]*	*13.77 [0.003]*	*11.27 [0.010]*	*28.20 [0.000]*	*14.78 [0.002]*	*26.78 [0.000]*	*13.43 [0.004]*	*28.46 [0.000]*
Physical, asset loss	*7.81 [0.020]*	*9.90 [0.007]*	*8.88 [0.012]*	*9.65 [0.008]*	*10.55 [0.005]*	*9.31 [0.010]*	*11.50 [0.003]*	*6.13 [0.047]*	*8.23 [0.016]*	*6.17 [0.046]*
Equality across exposures										
(chi-squared [p-value])										
Comm damage, physical	*1.84 [0.175]*	*0.00 [0.946]*	*2.37 [0.124]*	*0.45 [0.502]*	*1.97 [0.161]*	*2.04 [0.153]*	*0.32 [0.572]*	*2.08 [0.150]*	*0.01 [0.912]*	*2.67 [0.102]*
Comm damage, asset loss	*4.19 [0.041]*	*0.74 [0.390]*	*3.91 [0.048]*	*0.32 [0.569]*	*0.79 [0.374]*	*5.46 [0.019]*	*0.33 [0.565]*	*7.26 [0.007]*	*0.10 [0.753]*	*5.70 [0.017]*
Physical, asset loss	*0.85 [0.356]*	*0.89 [0.344]*	*0.27 [0.604]*	*2.30 [0.129]*	*0.29 [0.591]*	*1.30 [0.254]*	*0.00 [0.983]*	*2.36 [0.125]*	*0.25 [0.617]*	*1.28 [0.259]*
Equality across subgroups										
(z-statistic [p-value])										
Heavy community damage		*1.28 [0.199]*		*2.04 [0.041]*		*-2.52 [0.012]*		*-2.28 [0.022]*		*-2.48 [0.013]*
Physically exposed		*-0.56 [0.574]*		*-1.05 [0.294]*		*0.94 [0.348]*		*-0.06 [0.950]*		*-0.33 [0.741]*
Any household asset loss		*-0.45 [0.650]*		*0.72 [0.473]*		*1.00 [0.317]*		*1.83 [0.067]*		*0.64 [0.522]*

Notes: Estimated odds ratios and z-statistics of ordered logit models reported, along with chi-squared and p-values for Wald tests of joint significance of exposure measures and z-statistic and p-values of differences between subgroups (estimated by interaction terms in model). Standard errors are clustered at the pre-disaster enumeration area. The sub-group regression models includes interaction terms between each exposure measure and an indicator for the omitted sub-group (for example, for "males" in column 1) and controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, kecamatan fixed effects, and percentage of baseline respondents in enumeration area who died in the tsunami.

Appendix Table 7. Estimated impact of tsunami exposures on risk instrument responses at 1-year, by pre-tsunami demographic and socioeconomic characteristics, in EAs without tsunami-induced mortality or heavy community damage

Sample of 7,617 baseline respondents from communities without tsunami induced mortality or heavy damage who completed the risk instrument in 1-year, 2-year, and 5-year follow-up rounds

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Pre-tsunami characteristic	*Sex*		*Birth cohort*		*Pre-disaster education*		*Pre-disaster HH PCE*		*Pre-disaster location*	
Sub-group	*Female*	*Male*	*Under age 40 at tsunami*	*Age 40 or over at tsunami*	*Completed less than 6 years*	*Completed 6 years or more*	*Below sample median*	*At or above sample median*	*Rural community*	*Urban community*
Estimation model	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*	*Ordered logit*
Type of estimate reported	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*	*Odds ratio (z-statistic)*
Physically exposed	0.80	0.79	0.82	0.75	0.64	0.83	0.76	0.83	0.81	0.77
	(-2.11)	(-2.12)	(-1.99)	(-2.36)	(-2.81)	(-2.02)	(-2.32)	(-1.57)	(-1.90)	(-1.95)
Any household asset loss	0.95	0.90	0.92	0.92	0.81	0.96	0.83	1.04	0.86	1.07
	(-0.55)	(-0.91)	(-0.82)	(-0.64)	(-1.30)	(-0.42)	(-1.58)	(0.32)	(-1.34)	(0.41)
N (Total)	7,617	7,617	7,617	7,617	7,617	7,617	7,617	7,617	7,617	7,617
N (Subgroup)	4,358	3,259	5,094	2,523	1,638	5,979	4,253	3,364	5,712	1,905
Tests										
Joint tests										
(chi-squared [p-value])										
Physical, asset loss	*5.03 [0.081]*	*5.84 [0.054]*	*5.09 [0.079]*	*6.27 [0.043]*	*11.39 [0.003]*	*4.41 [0.110]*	*8.51 [0.014]*	*2.47 [0.291]*	*5.40 [0.067]*	*3.81 [0.149]*
Equality across exposures										
(chi-squared [p-value])										
Physical, asset loss	*1.13 [0.288]*	*0.64 [0.425]*	*0.64 [0.423]*	*1.16 [0.282]*	*1.02 [0.313]*	*1.11 [0.292]*	*0.28 [0.595]*	*1.43 [0.231]*	*0.15 [0.699]*	*1.97 [0.160]*
Equality across subgroups										
(z-statistic [p-value])										
Physically exposed		*-0.15 [0.878]*		*-0.71 [0.479]*		*1.85 [0.064]*		*0.66 [0.508]*		*-0.31 [0.757]*
Any household asset loss		*-0.44 [0.658]*		*-0.02 [0.983]*		*1.06 [0.288]*		*1.54 [0.123]*		*1.14 [0.253]*

Notes: Estimated odds ratios and z-statistics of ordered logit models reported, along with chi-squared and p-values for Wald tests of joint significance of exposure measures and z-statistic and p-values of differences between subgroups (estimated by interaction terms in model). Standard errors are clustered at the pre-disaster enumeration area. Sample restricted to enumeration areas without tsunami mortality and without heavy tsunami damage. The sub-group regression models includes interaction terms between each exposure measure and an indicator for the omitted sub-group (for example, for "males" in column 1) and controls for sex, birth cohort, pre-disaster years of education, pre-disaster household per capita expenditure, urban-rural status of pre-disaster desa, distance of pre-disaster enumeration area to the coast and its square, elevation of pre-disaster enumeration area and its square, pre-disaster household ownership of a variety of household and business assets, whether respondent took care of household members in the week prior to baseline, risk instrument module, month-year of interview, and kecamatan fixed effects.