Do Risk Preferences Change? Evidence from Panel Data Before and After the Great East Japan Earthquake*

Chie Hanaoka† Hitoshi Shigeoka‡ Yasutora Watanabe§

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Abstract

We investigate whether experiencing a natural disaster—the Great East Japan Earthquake in 2011—changes individuals' risk preferences. The novelty of our study is that we use panel data, and we can track the *change* in risk preference of the *same* individuals before and after the Earthquake. Previous studies use cross-section data collected after the negative shocks have occurred, and hence can be biased by unobserved individual heterogeneity. We find that people who experienced larger intensity of the Earthquake become more risk tolerant. Interestingly, all the results are driven by men and we do not observe such a pattern among women. Men's increased risk tolerance after exposure to the Earthquake remains at after-Earthquake level for at least two years. Further, we find corroborative evidence that men become more engaged in gambling and drinking if they were more exposed to the Earthquake. Finally, we demonstrate that the estimate relying on cross-section data may be biased by comparing the estimates from cross-section and panel specifications.

Key words: Risk preference, Panel data, Gender difference, Great East Japan Earthquake, Risk-taking behavior

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†Faculty of Economics, Kyoto Sangyo University, Kamigamo-Motoyama, Kita-ku, Kyoto, JAPAN. Email: hanaoka@cc.kyoto-su.ac.jp

‡Department of Economics, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A1S6, CANADA. Email: hitoshi_shigeoka@sfu.ca

§Kellogg School of Management, Northwestern University, 2001 Sheridan Road, Evanston, IL, 60208, USA. Email: y-watanabe@kellogg.northwestern.edu

1 Introduction

Risk preferences are fundamental determinants of individual decision-making on economic behaviors such as saving, investment, and consumption. Standard economic models assume that individual risk preferences are stable across time (Stigler and Becker, 1977).[1] However, recent literature suggests that individuals' risk preferences and hence risk-taking behaviors can be altered by negative shocks such as early life financial experiences (Malmendier and Nagel, 2011), financial crises (Guiso et al., 2013), conflicts or violence trauma (Voors et al., 2012; Callen et al., 2014), and natural disasters (Eckel et al., 2009; Cameron and Shah, 2010; Cassar et al., 2011).[2]

There is little consensus, however, as to whether negative shocks induce people to become more risk averse or risk tolerant, and also how persistent such an effect is. For both questions, the evidence from past studies is mixed.[3,4] Also, little is known as to who is more likely to be susceptible to negative shocks, if any.

Most importantly, as far as we are aware, past studies rely on cross-sectional data collected only after the negative shocks have occurred.[5] To the extent that unobserved individual characteristics affect both the exposure to the negative shocks, and the risk preference—for example through residential sorting—the estimate based on cross-section can be biased.

In this paper, we use *panel* data to investigate whether experiencing a natural disaster—the Great East Japan Earthquake (the Earthquake, hereafter) in 2011—changes individuals' risk preferences. Specifically, we test whether individuals who lives in locations with higher intensity of the Earthquake become either risk averse or risk tolerate.

[1] "One does not argue over tastes for the same reason that one does not argue over the Rocky Mountains — both are there, will be there next year, too, and are the same to all men." —Stigler and Becker (1977).

[2] It is widely accepted in psychology that large shocks (e.g., Holocaust and traumatic events in Palestine) can have persistent effects on one's preferences and beliefs about the future (Carmil and Breznitz, 1991; Punamäki et al., 1997).

[3] On one hand, Cameron and Shah (2010), and Cassar et al. (2011) showed increased risk aversion after exposure to natural disasters in Indonesia, and Thailand. On the other hand, Eckel et al. (2009) and Voors et al. (2012) demonstrated decreased risk aversion (i.e., increased risk tolerance) after exposure to Hurricane Katrina and civil conflict in Burundi. Also, Malmendier and Nagel (2011) showed that early life financial experiences are associated with more conservative investing behaviors in later life.

[4] Eckel et al. (2009) documented that change in risk preferences disappear in one year while Cameron and Shah (2010) argued that such effects persist up to 9 years after exposure to the natural disasters. Also, Malmendier and Nagel (2011) suggest that the more conservative financial risk-taking behaviors among "Depression babies" might be long-lasting.

[5] Notable exception is Guiso et al. (2013) which use a repeated survey of an Italian bank's clients to test whether investors' risk aversion increases following the 2008 financial crisis. While their data is limited to bank clients, ours are nationally representative. Also the type/nature of negative shocks is different.

The novelty of our study is that we use panel data of 3,221 individuals from 226 municipalities in a nationally representative survey, and thus we can track the *change* in risk preference of the *same* individuals before and after the Earthquake. The risk preference is measured by a hypothetical lottery—asked repeatedly to the same individual.

How the Earthquake or negative shocks in general can potentially alter individuals' risk preferences is theoretically ambiguous. On one hand, an increase in the perceived likelihood that negative shocks will occur may increase the risk aversion (Gollier and Pratt, 1996). On the other hand, psychology literature suggests that an emotional response leads individuals to have greater anger (fear) of any negative event that may induce increase (decrease) in risk tolerance (e.g., Lerner and Keltner, 2001).

We find that people who live in locations with higher intensities of the Earthquake become more risk tolerant. Interestingly, all the results are driven by men and we do not observe such a pattern among women. While previous studies show that men are less risk averse than women in many dimensions[6], this is the first study, to the best of our knowledge, documenting that risk preference of men are more susceptible to a negative shock than that of women, and that men become more risk tolerant. Further, by examining the individual characteristics, we find that the results seem to be driven by old, less educated, and unmarried men.

Our results are very robust to a variety of specification checks. For example, alternative explanations such as windfall income from the government after the Earthquake do not seem to explain our findings since these results are robust to control for the change in income, asset, and house ownership. Also, our results do not seem to be driven by attrition or migration. Moreover, our results are robust to different ways of constructing the intensity measure of the Earthquake.

As our research question concerns the stability of risk preference, a natural question to follow our finding—that risk preferences do change after the Earthquake—is whether the change is persistent or not. Fortunately, the same individuals are tracked for two years after the Earthquake in our data. We find that the change is persistent: men's increased risk tolerance after exposure to the Earthquake *remains* at after-Earthquake level for at least two years after the Earthquake.

We further ask whether risk-taking behaviors are also affected by the Earthquake in addition

[6] See, e.g., Croson and Gneezy (2009) and Eckel and Grossman (2008) for surveys of economics, and Byrnes et al. (1999) for survey of psychology on gender differences in preferences.

to the change in risk preference. We find corroborative evidence that men who live in hardest-hit locations become more engaged in gambling and drinking as the intensity of the Earthquake increase. Since risk-taking behavior is affected not only by risk preferences but also by many other factors (e.g., peer effects), we have to view the results on risk-taking behaviors with a caution.

Finally, we demonstrate that the estimate relying on cross-section data collected *after* the negative shocks may be biased by comparing the estimates from cross-section and panel specifications. In fact, we fail to find the results using cross-sectional specification: men who are exposed to larger intensity of the Earthquake no longer become more risk tolerant. This result indicates that the unobserved individual heterogeneity—that cross-sectional specification cannot fully control—biases the estimate at least in our setting. In fact, we find that risk-averse individuals tend to live in locations with lower probability of future catastrophic earthquake, possibly driven by unobserved characteristics such as heterogeneity in susceptibility to local social norm (Postlewaite, 2011), and physical and mental stress tolerance.

The rest of the paper is organized as follows. Section 2 describes the data, and Section 3 presents our identification strategy highlighting the difference between panel and cross-sectional specifications. Section 4 reports our findings, and Section 5 discusses the implications of our findings. Section 6 concludes.

2 Data

2.1 Intensity of the Great East Japan Earthquake

The Great East Japan Earthquake (the Earthquake) occurred in the afternoon of March 11th, 2011. The Earthquake was the magnitude scale of 9.0, and was the fourth largest earthquake on record in the world, and largest in Japan in the history of modern measurement of earthquakes. The Earthquake triggered a tsunami, and caused more than 15,800 deaths and 3,000 missing (Fire and Disaster Management Agency, 2013). About 130 thousand homes are fully destroyed. One of the feature of the Earthquake was that its effect were spread to a very wide area of East Japan in various ways. More than 8.6 million households experienced power outage, and 2.3 million households had disruption in water supply (Ministry of Education, Culture, Sports, Science and Technology, 2011). Both cellular and landline phone were not functional for a few days for a wide area (Ministry of Internal Affairs and Communications, 2011). Furthermore, approximately 4.4 million households experienced power outage, and further planned outage was inevitable due to the accident at the Fukushima Daiichi Nuclear Power Station.

The degree of the negative shock differs significantly depending on the location. As our interest is to understand how risk preferences are affected by negative shocks, an ideal explanatory variable would be the one that captures the wide variation of negative shocks for people who are most severely suffered to people who are not at all affected. One straightforward variable would be a distance from the epicenter of the Earthquake. This variable, however, is not necessarily an ideal variable because it may not necessarily capture the local differences in the intensity of negative shocks—because how severe the Earthquake hits a particular location depends heavily on subsurface structure as well. Instead of the distance from the epicenter, we use seismic intensity of the Earthquake (*Shindo* in Japanese) as our main explanatory variable, which is a metric of the strength of earthquake *at a specific location* (see, e.g., Scawthorn, 2003).[7]

The seismic intensity of the Earthquake (*Shindo*) is constructed by Japanese Meteorological Association (hereafter JMA).[8] Intensity is location specific, and JMA locates more than 1,700 observation stations to measure the intensity of earthquakes. People in Japan are very familiar with this intensity measure, *Shindo*. In fact, *Shindo* is always used in the media coverage on the intensity of an earthquake at each location (similar to weather forecast). Another variable that would come up to most people's mind is the level of radiation following an accident at the Fukushima Daiichi Nuclear Power Plant. We collected the data on the level of radiation as well. However, we only use the level of radiation as a complementary explanatory variable as a robustness check (in Section 5.4) mainly because the relevant level of radiation is too concentrated in small number of municipalities, and little variation exists for the municipalities covered in our nationally representative survey data (see Appendix Table A6 for the details of this variable). For the same reason, we do not use the regional fatalities as our explanatory variable.[9]

Figure 1 displays the intensity of the Great East Japan Earthquake measured by *Shindo* in

[7] A magnitude of an earthquake is a metric of the energy released by the earthquake, hence takes a single value for each earthquake, while a seismic intensity varies by the location for each earthquake.

[8] Torch (2011) also uses seismic intensity as a proxy for maternal stress to study the effect of stress on birth outcomes. Appendix A provides more details on *Shindo*, an intensity measure constructed by JMA.

[9] We add the level of fatalities as a control in our main specifications, but all the results reported in this paper are hardly affected (available upon request).

quintiles, together with the location of the epicenter. The darker color indicates the higher level of intensity. As the intensity of an earthquake depends not only on distance from the epicenter but subsurface structure, there are reasonable variations in intensity measure even within the same distance from the epicenter.[10] There are total of 1,724 municipalities in Japan (as of April 1, 2011), and 226 municipalities in our survey (as described in Section 2.2) are boxed with black line. The figure shows that our survey data covers throughout Japan, and there are considerable variations in intensity level among our surveyed municipalities.

2.2 Panel survey on risk preference

Our measure of risk preferences are directly elicited using a hypothetical lottery question in the Japan Household Panel Survey on Consumer Preferences and Satisfactions (hereafter, JHPS) between 2011 and 2013. The JHPS is a nationally representative annual panel survey of the resident population in Japan. The sample is stratified according to two criteria, geographical area and city size.[11] The data is collected using self-administered paper questionnaires, which is hand-delivered to and also picked up from the houses of participating households. The initial wave of the survey was conducted in 2003. The data before the Earthquake comes from the 2011 survey, and the data one-year and two-year after the Earthquake come from the 2012 and 2013 surveys.[12] All surveys between 2011 and 2013 are run in January and February.

The JHPS asks a respondent about his/her willingness to pay for a hypothetical lottery with a 50 percent chance of winning JPY100,000 (USD1,000) or nothing otherwise.[13] Appendix B shows the exact format of the survey question. A respondent is presented with 8 different prices in ascending order, from the price of JPY10 (USD0.1) in the first row to the price of JPY50,000 (USD500) in the last raw in the survey question. For each row, a respondent is required to choose one of the two options: to buy the lottery ticket at the price (option A), or do not buy the ticket

[10] The correlation between the distance from the epicenter of the Earthquake, and our seismic intensity measure (*Shindo*) at the municipality level is -0.896 (N=226), -0.662 (N=79), and -0.837 (N=147) in all locations, the locations with intensity four and higher, and the locations with lower than four.

[11] All municipalities are classified into 40 stratums: 10 geographical areas and 4 categories corresponding to their population sizes. The number of sample subjects in each stratum is distributed in proportion to the resident population from 20 to 69 years old. The unit of sampling spot in each stratum is the Census unit and selected by the random systematic sampling.

[12] We do not use the data before 2011, because the queries on risk aversion differ from those between 2011 and 2013 years.

[13] The approach is similar to the one used in Cramer et al. (2002), Hartog et al. (2002) and Guiso and Paiella (2008).

(option B). The reservation price (λ) should lie in the interval between the two prices: the price at which a respondent switches from option A to option B and the price in the row immediately before the switch. We define the reservation price as the midpoint of the two prices in this study.[14] This provides an implicit point estimate of the measure of individual's risk preference.

Respondents who switch more than once (multiple switches, 5.8 percent of the sample) are eliminated.[15] For those who choose option A in all choices (1 percent of the sample), the upper bound of the reservation price, i.e., the price in the first decision raw, is used to estimate risk preference. Similarly, for those who choose option B in all choices (4 percent of the sample), the lower bound of the reservation price, i.e., the price in the last decision raw, is used.

Our measure of risk aversion has several advantages. First, because we present survey respondents with the same explicit stakes and probabilities for all survey years, we holds risk perceptions constant across individuals, as well as across times. Hence, changes in the measure between before and after the Earthquake reflect changes in individuals' risk preferences. Second, because of low complexity of the lottery question in the JHPS, a nonresponse rate is quite low—2.4 percent of the original data—in contrast to a high nonresponse rate observed in previous studies with more complex questions.[16] Third, while the samples in previous studies are highly restricted (e.g., investors or clients), the measure in this study is obtained using a large representative sample.

One concern of self-reported measures based on a non-incentivized hypothetical question is whether they actually reflect an individual's underlying risk traits. Several studies have documented that risk measures obtained by hypothetical survey questions are reliable predictors of actual risk-taking behaviors (e.g., Barsky et al., 1997; Donkers et al., 2001; Dohmen et al., 2011). In order to check the validity of our risk measures, described in detail below, we simply run the regression of risky behaviors on our risk measures. One expects a negative correlation between risk-aversion measure and risk-taking behaviors. Appendix Table A2 confirms the validity of our risk measures; the results show a significant correlation between our risk measures and risky behaviors (gambling, drinking, and smoking) with expected signs.

[14] One can alternatively think of using interval regression. However, for panel data, distribution of the discrete responses of the lottery question before the Earthquake and the distribution after would differ. Thus a same individual who make the same responses before and after the Earthquake would have a different value. Hence, the standard interval regression method cannot be applied.

[15] As a robustness check, for multiple switches, we use the first switch as the reported willingness to pay and re-estimate the models. The estimates are quantitatively unchanged (available upon request).

[16] For example, Guiso and Paiella (2008) report 27 percent of nonresponse rate.

We take two approaches to covert the reservation price (λ)—obtained from a respondent's choice in hypothetical lottery—to a measure of risk aversion, following Cramer et al. (2002). Denote Z as a prize of the lottery and α as a probability of winning a prize. In our case, Z is JPY100,000 (USD1,000), and α is 0.5.

First approach is a simple transformation of the reservation price:

$$\textit{Transformed price} = 1 - \lambda/\alpha Z \tag{1}$$

Note that the greater a respondent's value of transformed price, the more risk averse the respondent is. In our setting, the values of transformed price only take values between 0 and 1, where the value of 0 corresponds to the case of perfectly risk-neutral preference. The first table in Appendix Table A1 shows the raw values of transformed price in our settings.

Second approach is to use the Arrow-Pratt measure of absolute risk aversion (Pratt, 1964), $\rho = -U''/U'$, where $U(W)$ is a standard concave utility function of wealth, W. In expected utility theory, the utility of wealth without participation in the lottery is equal to expected utility when participating at reservation price λ: $U(W) = (1-\alpha)U(W-\lambda) + \alpha U(W+Z-\lambda)$. By taking a second-order Taylor expansion around $U(W)$, we obtain an estimate of the Arrow-Pratt measure of absolute risk aversion as,

$$\textit{Absolute risk aversion} = (\alpha Z - \lambda)/(1/2)(\alpha Z^2 - 2\alpha Z\lambda + \lambda^2) \tag{2}$$

See Cramer et al. (2002) for a detail derivation. Again note that the greater a respondent's value of absolute risk aversion, the more risk averse the respondent is. In our setting, the values of absolute risk aversion are also bounded below and above similar to transformed price, where the value of 0 corresponds to the case of perfectly risk-neutral preference. The first table in Appendix Table A1 reports the raw values of absolute risk aversion. As shown later, our results are fairly robust to the choice of two risk aversion measures.

In the empirical implementation, the logit transformation of each measure is used in linear regression analysis because both risk aversion measures are bounded above and below. The method is conventionally used for regression analysis when a dependent variable is a fractional variable bounded between zero and one such as fractions (McDowell and Cox, 2001).[17]

The original data consists of 4,934 respondents in 2011 survey. The attrition rates are fairly low: 7.0 percent at 2012, and 5.4 percent at 2013. We focus only on those who have non-missing values for the lottery question, risk-taking behaviors, age, gender, and household income in both 2011 and 2012. This procedure reduces the sample to 3,829. Of those remaining, 198 respondents who switched more than once in the lottery question are eliminated. Of the remaining 3,631 samples, 147 respondents who moved municipalities between surveys in 2011 and 2012 are also eliminated. Of those remaining 3,484 samples, 263 respondents who drop from the sample in 2012 are further eliminated. This explains the final sample size of 3,221 respondents located across 226 municipalities. We later demonstrate that attrition, multiple switch, and migration do not seem to affect our results (Section 5.5).

3 Identification strategy

We examine the effect of the Earthquake on risk preference using panel data before and after the Earthquake. Our identification strategy exploits the variation in the intensity of the Earthquake, while controlling for time-invariant individual characteristics using the individual fixed effects model. Our basic idea is similar to difference-in-difference: we capture the effect of the Earthquake by comparing individuals with zero intensity (no treatment) and non-zero intensity (treated) assuming that the response would have been the same in the absence of the Earthquake. By using panel data, we can isolate the effects of the exogenous treatment (the Earthquake) by taking the differences before and after the Earthquake and compare them across individuals who experienced different levels of the intensity of the treatment. The departure from difference-in-difference is that our treatment is not binary, and we can exploit the variation in the intensity of the exogenous treatment.

More formally, the basic model to test whether the Earthquake influences risk preference can be written as follows:

$$Y_{ijt} = \alpha I[Earthquake] + \beta X_{jt} + \gamma Z_{ijt} + \pi W_{ij} + \varepsilon_{ijt} \tag{3}$$

[17] Only a small fraction of the sample (1.4 percent in 2011, and 1.3 percent in 2012) contains zero values in the measures. The zero values are replaced by 0.0001.

where $I[Earthquake]$ is an indicator that takes value 1 after the Earthquake and 0 otherwise, and Y_{ijt} is a measure of risk preference for individual i at location j at time t. X_{jt} is intensity of the Earthquake at location j at time t, and it takes the value of zero before the Earthquake. Z_{ijt} is time-varying individual characteristics, W_{ij} is unobserved time-invariant individual characteristics, and ε_{ijt} is a random shock. The coefficient α captures the effect of the Earthquake that is common to all individuals, and β measures the effect of the Earthquake on risk preference depending on the intensity of the Earthquake.

A major econometric issue is the possible presence of unobserved fixed effects, W_{ij}. It can well be the case that basic part of risk preference Y_{ijt} is driven by some unobserved individual characteristics such as physical and mental stress tolerance and susceptibility to local social norm (Postlewaite, 2011). At the same time, these unobserved individual characteristics could be correlated with X_{jt} through factors such as residential sorting. In fact, Figure 2 shows that there is a correlation between the risk preference before the Earthquake and the pre-Earthquake hazard predictions for each individual's location. Furthermore, Figure 3 presents the correlation between the hazard predictions and the actual intensity of the Earthquake. Though these relationships are not necessarily linear, these facts point to the possibility that the intensity of the Earthquake is correlated with some unobserved characteristics W_{ij} through factors such as residential sorting before the Earthquake.

Fortunately, we have panel data, and can take advantage of the fixed-effects estimator to isolate the effects of the unobserved characteristics by considering the following specification:

$$\Delta Y_{ijt} = \alpha + \beta X_j + \gamma \Delta Z_{ijt} + \Delta \varepsilon_{ijt} \tag{4}$$

where Δ indicates the difference of variables before and after the Earthquake, and denote ΔX_{jt} as X_j for notational convenience (given that $X_{jt} = 0$ for all observations before the Earthquake). The specification is difference-in-difference with X_j taking continuous variable (X_j takes value 0 if the intensity of the Earthquake were zero.)

If unobserved characteristics W_{ij} does not play an important role, the estimates from fixed-effects specification (4) and the estimates using cross-section specification must be similar. We, however, find significant difference between the estimates from the two specifications (see Section

5.1), which implies the potential bias resulting from the unobserved fixed effect.

In addition to the issue of unobserved fixed effects, another econometric issue is the possible non-linearity in the effects of intensity of the Earthquake. An inspection of Figure 4 that plots the relationship between the changes in risk preferences and intensity of the Earthquake reveals a non-linear pattern, especially for men. It seems that the risk preference measure of men increases (i.e., becoming more risk averse) as the intensity increases up to the intensity level of four, then decreases (i.e., becoming less risk averse) as the intensity increases for the most intense locations with intensities four and higher.

In fact, the intensity level of four corresponds to the JMA's classification that describes it as the level at which "many people are frightened."[18] Reflecting the above observation from Figure 4 as well as the characterization of intensity scale by JMA, our main specification considers the possibility that the effect of the Earthquake can be kinked as follows:

$$\Delta Y_{ijt} = \alpha + \beta X_j + \rho I[X_j \geq 4]X_j + \gamma \Delta Z_{ijt} + \Delta \varepsilon_{ijt} \tag{5}$$

where the coefficient ρ captures the effect of the Earthquake intensity for the locations with intensity higher than four.[19] We also consider specifications in which we use $I[X_j \geq 4.5]$ and $I[X_j \geq 5]$ instead of $I[X_j \geq 4]$ as reported in Tables 2(a) and 2(b), and most of our results are robust to the change in the cut-off between 4, 4.5, and 5.[20] We cluster the standard error at the municipality level, to allow for an arbitrary serial correlation within municipality (Bertrand, Duflo, and Mullainathan, 2004).

4 Results

4.1 Main results

Figure 4 shows the relationship between intensity of the Earthquake and risk aversion (logit-converted transformed price) *before* the Earthquake, *after* the Earthquake, and the *difference* between before and after, separately. Note that for "before" graph, the intensity on x-axis is the

[18] See Appendix A for the definition of JMA's intensity scale as well as its description for different levels of intensity.

[19] The number of individuals and municipalities above the intensity level of four are 1,100 and 79, respectively.

[20] The results using $I[X_j \geq 4.5]$ and $I[X_j \geq 5]$ for tables other than Tables 2(a) and 2(b) are not reported, but they are very similar to the results using $I[X_j \geq 4]$ (available upon request).

same as the one for “after” Earthquake since Japan has not yet experienced the Earthquake at the time. Each dot in the graph represents the mean of observations within each bin of 0.2 in intensity measure, and the size of the dot reflects the number of the observations in each bin.[21] The solid fitted line is *lowess* curve with the bandwidth of 0.5. Panels (a)–(c) show that the figures for full sample, men, and women, respectively.

Panel (a) shows that there is no systematic change in risk aversion with respect to intensity of the Earthquake for full sample. While there is slight upward trend at the highest intensity locations in both “before” and “after” the Earthquake, the “difference” indicates that the change is very small if anything.

Panel (a), however, masks the striking gender differences as shown in Panels (b) and (c) for men and women, respectively. The graph on the right in Panel (b) (i.e., “difference”) shows that men who live in the locations above the intensity level of roughly four become more risk tolerant as the intensity of the Earthquake increases (recall that a higher number indicates higher risk aversion). This pattern is all the more striking since men who lives in locations with the ranges of 0–4 intensity level show the opposite pattern; the risk aversion clearly shifts up after the Earthquake, suggesting that men—who live outside of the most severely-hit locations— become more risk averse after the Earthquake.[22]

Interestingly, Panel (c) shows that the same pattern is not observed among women. Unlike men, the fitted line is smooth and stable both before and after the Earthquake. As a result, we do not observe much change in risk aversion before and after the Earthquake except the slight *increase* in the risk aversion at the very high intensity locations.

Here it is important to note that risk aversion is much higher among women than men at the level before the Earthquake. Comparing the left graphs (i.e., “before”) in Panels (a) and (b), the fitted solid line for women is clearly above than that of men on average. In fact, the mean of risk aversion (logit-converted transformed price) before the Earthquake is 1.429 and 2.823 for men and women, respectively. This observation is consistent with large literature documenting that men are less risk averse than women in the vast majority of environments and tasks (see Croson and

[21] Each bin includes 12.4 municipalities on average ranging from 1 to 30 municipalities and includes 173.5 individuals on average ranging from 6 to 400 individuals.

[22] See the 2nd table of Appendix Table A1 for transition matrix of risk aversion category before and after the Earthquake (men only).

Gneezy (2009), and Eckel and Grossman (2008) for a review).[23] However, the literature is silent on whether men's risk preference is more "malleable" to the experience of negative events than women, and to which direction risk preferences may change. Our findings suggest that men's risk preferences are more likely to *change* than those of women and that men further become less risk averse despite the already low *level* of risk aversion at least in this setting.

Table 2(a) confirms our findings in the figures. Table 2(a) summarizes the estimates for running specification (5) where outcome is the logit-converted transformed price. Note that negative coefficient implies a decrease (increase) in risk aversion (tolerance). Because our coefficient of interest is the interaction term of intensity measure with a dummy for intensity threshold above four, we mainly only focus on this estimate.

Each three columns in Table 2(a) report the estimates for full sample, men, and women, respectively. Columns (1)–(3) show that we do not observe any relationship between the intensity of the Earthquake and risk aversion among the full sample as seen in Panel (a) in Figure 4.

However, Column (4) shows that men become more risk tolerant as the intensity of the Earthquake increases in the range of the intensity above 4. As the intensity of the Earthquake increase by one, the risk aversion decline by 0.115—roughly one-tenth of the mean difference in risk aversion between men and women (1.394= 2.823-1.429) before the Earthquake. Columns (5) and (6) show that our estimates are robust to the alternative intensity thresholds of 4.5 and 5; the estimates are very similar across specifications and are statistically significant at 5 percent level.

We do not observe the same pattern among women in Columns (7)–(9). Most of the estimates on the interaction term of intensity measure with a dummy for intensity threshold above four are very small and statistically insignificant. If anything, Column (9) shows that the estimate is positive (more risk averse), which is the opposite of the findings among men.

We repeat the same exercise in Table 2(b) using the alternative risk aversion measure, which is logit-converted absolute risk aversion. Columns (4)–(6) for men show similar patterns as the corresponding columns in Table 2(a) except that the estimate is not statistically significant when intensity threshold is 5. Columns (7)–(9) for women show that none of the interaction terms are

[23] The gender difference in risk aversion is in line with the emotional responses stories suggested by psychologists. Some studies show that men tend to feel anger while women tend to feel fear for the same situations (e.g., Grossman and Wood, 1993). Also some studies show that fear may cause pessimistic risk assessments while anger may cause optimistic risk assessments (Carver and Harmon-Jones, 2009; Lerner and Keltner, 2001; Lerner et al. 2003; Kuhnen and Knutson, 2011). See also Loewenstein et al. (2001).

statistically significant as the corresponding columns in Table 2(a). It is reassuring that our results are robust to the alternative measure of risk aversion.

Also Appendix Table A3 demonstrates the robustness of our results to different ways of constructing the intensity measure. Column (1) replicates our baseline estimate where we use the weighted average of three closest observation points where the weight is the inverse of the distance from the center of each municipality to each observation point. Columns (2)–(4) construct the intensity measure using only two closets observation points, the simple average of intensity at three closest points, and the only closest point, respectively. The estimates are quantitatively very similar to the baseline estimate.

4.2 Income and wealth effects

An alternative explanation for our finding is that households/individuals hit hardest by the Earthquake gained the income windfall after the Earthquake. If there is a significant increase in the income, this might have an effect on risk aversion. We did not include income or assets as controls in the regressions in Table 2(a) and Table 2(b) as they are potentially endogenous.[24]

Broadly speaking, there are two types of income windfall to households that are hit by the Earthquake. One source is the income transfer from (the donation to) the Japanese and International Red Cross and other organizations that are channeled through local governments to the affected household. The requirement for eligibility for this transfer includes either a family member is lost or housing has half or completely damaged. In fact, our sample of 226 municipalities include only 25 municipalities that channeled the transfer, and also the possibility that the surveyed individuals in the municipality happened to be eligible for the transfer is extremely small for the municipalities in our data set. Furthermore, the amount of payment is rather small.[25] Hence, by construction of the dataset, our results are unlikely to be driven by the government transfer to the households in these municipalities.

The second channel of income transfer is the compensation from the Tokyo Electric Power Company (TEPCO, hereafter) to households and organizations that are directly affected by the

[24] Specifically, income is the total income of respondent's entire household before taxes from all earnings including bonus payments, transfers, and other sources of income. Also, assets are financial assets and house ownership: financial assets are the balance of financial assets (savings, stocks, bonds, insurance, etc.) of respondent's entire household, and house ownership is whether any household member is the owner of their residence.

[25] For example, family with one family member lost receives JPY350,000 (about USD3,500) as compensation.

accident of the Fukushima Daiichi Nuclear Power Plant. Total cumulative amount of payment is roughly 2 trillion yen (about US$ 2 billion) at the end of March 2013, about 6 times larger than the first channel. Compensation to households are limited to the ones located in 11 municipalities that are within 30 kilometers from the power plant or the ones that the government have specified.[26] None of these 11 municipalities are included in our data set. The only way TEPCO compensation may matter systematically to the individuals in our data set is through the compensation to organizations such as agricultural and fishing cooperatives. Compensation to organization accounts for 21 percent of the total compensation, and payment to Agricultural and Fishing Cooperatives dominates (87 percent) among the payment to organizations. However, the fraction of workers in these two industries is very small in municipalities in our data set. In fact among 1,514 men, only 43 individuals (2.8 percent) work in agriculture and fishery industry in our sample. When we limit the sample to individuals who live in locations hit by more than the intensity level of four, only 20 individuals (1.3 percent) work in these two industries.

We argue below that change in income as well as assets do not seem to explain our results. Since we only find an effect on men's risk preferences, we focus on the sample of men in our robustness checks for income and assets below.[27] Again, we use the intensity threshold of four, and the outcome is the logit-converted transformed price as before. In short, the results are very robust even after considering the possible effects of income and assets. Also, the robustness check for income and assets hold for the alternative measure of risk aversion and the different intensity threshold as well (available upon request).

Table 3 summarizes our robustness checks against a concern on income transfer. To facilitate the comparison, Column (1) in Table 3 replicates the estimate from our baseline in Table 2(a). Column (2) adds a dummy that takes one for the men who work in agriculture, and fishery industries. The estimates barely change, which is not surprising given that the proportion of workers in these two industries are very low. Column (3) controls for self-reported income, but the estimate is again hardly affected. We need to view this result with a caution since the income is reported in JPY 10,000 (roughly USD 100 in 2012) brackets, and thus it is possible that income

[26] The eleven municipalities are Ookuma, Futaba, Namie, Tomioka, Naraha, Hirono, Kawachi, Tamura, Minami-soma, Iidate, and Kawamata.

[27] Unfortunately, the survey does not ask questions to both husband and wife within the same household, and thus we cannot examine the change in risk preferences within a couple.

still changes within the bracket.

To compensate for the rough measure of income, while it is far from perfect, Columns (4)–(6) show the separate estimates for those who experience increase, decrease, and no-change in reported income across brackets. Column (4) shows that our results are mainly driven by the men whose income does not change within brackets. Further, it is very reassuring that we do not observe any decrease in risk aversion for the subsample of men who experienced income *increase* across brackets in Column (5).

We also control for the assets in Columns (7) and (8). Column (7) controls the asset measured in JPY 100,000 brackets, and the estimates are in fact hardly affected. Column (8) adds a dummy which takes one if the person owns a house but estimates are once again unaffected.[28] The result is in accordance with the prior literature that did not find wealth effects on elicited risk tolerance or risk-taking behaviors (e.g., Sahm 2007; Brunnermeier and Nagel, 2008).[29]

4.3 Heterogeneous effects

Table 4 summarizes the results from the same specification as specification (5) for different subsamples of men. Following the previous subsection, we use the intensity threshold of four, and the outcome is the risk aversion using logit-converted transformed price.

Before showing the *change* by subgroups using panel data, we briefly document whether our risk aversion measures are correlated with usual covariates for risk preferences at the *level*.[30] The mean risk aversion measure before the Earthquake in Table 4 shows that younger and high-educated men are less risk averse than older and low-educated men—both results are consistent with the literature.[31] The mean of risk aversion before the Earthquake is much higher among the older men (1.714) than that of younger men (1.096). Also the mean risk aversion before the Earthquake is higher for the low-educated (1.672)—whose education attainment is high school graduates or below

[28] For Columns (7) and (8), we replace the missing value for assets and housing ownership with zero, and add a dummy for such observations in the estimation. We also dropped these observations and re-estimated, but the estimates are essentially identical.

[29] While the Earthquake may destroy physical property (e.g., housing), and hence reduce the wealth of those affected, the loss in wealth may make people more risk averse, which is contrary to our findings. Also the assets are potentially endogenous.

[30] In fact, numerous studies demonstrate that risk aversion differs by demographic characteristics such as gender, age, education, race, marital status, income, and parental background (e.g., Dohmen et al., 2011; Sahm, 2007).

[31] See e.g., Heckhausen et al. (1989), Gardner and Steinberg (2005), Mather et al. (2012), Dohmen et al. (2011), Barsky et al. (1997), Guiso and Paiella (2006, 2008), and Guiso et al. (2013).

(55 percent of the sample)—than the high-educated (1.176). We do not observe much difference between married and unmarried men in our sample.

Now we focus on the "change" in response to the Earthquake using panel data. First, we divide the men's sample by median age of 52. Columns (1) and (2) show that our results on increased risk tolerance are all driven by men who are older than the median age, suggesting that older men are more susceptible to the exposure to a negative shock, and become more risk tolerant. Second, we divide the sample by the level of educational attainment. Columns (3) and (4) show that our results are entirely driven by the men whose education attainment is high school graduation or below. On the other hand, we do not observe any effects among those who are more than high school graduation. Finally, we divide the sample by marital status in Columns (5) and (6).[32] While the estimates on unmarried sample is larger than that of married sample, due to small sample size of unmarried population in the data, the estimate on unmarried is not statistically significant at the conventional level.

In sum, our estimates on risk tolerance seem to be driven by old, less educated, and unmarried men. However, note that the null hypothesis that the coefficients are the same within group cannot be rejected in any within-group comparison due to small size of the subsample.[33]

5 Discussion

5.1 Panel vs. cross-section estimates

The biggest advantage of our research design is that our data is a panel, and thus we can track the change in risk preferences among the same individuals before and after the Earthquake. To the extent that unobserved time-invariant individual characteristics are correlated with both the intensity of the Earthquake and risk aversion, the estimate based on cross-section data collected only after the negative shocks have occurred (i.e., using only "after" data)—which is almost all the cases in the past literature—can be potentially biased.

As we briefly mentioned in Section 3, we find that risk-averse individuals tend to live in locations with lower probability of future catastrophic earthquake, possibly driven by unobserved

[32] We drop 20 respondents who changed the marital status from 2011 to 2012. The estimates are identical if we divide the sample by the marital status in 2011.

[33] $\chi^2(1)$ for the null that the coefficients are the same within age group, education group, and marital status is 1.59 (p-value: 0.208), 1.78 (p-value: 0.183), and 1.39 (p-value: 0.239), respectively.

heterogeneity such as physical and mental stress tolerance and susceptibility to local social norm (Postlewaite, 2011). Figure 2 displays a correlation between the risk preference before the Earthquake and the pre-Earthquake hazard predictions for each individual's location, that is, low probability of experiencing a large earthquake in the next 30 years (see Appendix Table A6 for the details of this variable).[34] Figure 3 also displays the relationship between hazard prediction in Figure 2 and the intensity of this Earthquake. While the relationship is not monotonic, these two variables are clearly correlated. Figure 2 and Figure 3 combined suggest that risk-averse people tend to live in an area with low predicted intensity of earthquakes and that the prediction is correlated with the realized intensity of the Earthquake. To the extent such residential choice is driven by unobserved individual characteristics that cross-section model cannot fully account for, the estimates based on the cross-section data after the natural disaster can be biased at least in this setting.

To investigate whether such unobserved heterogeneity is present and biasing the estimates of cross-section specification, we indeed run the same specification as (5) only using the cross-section data collected after the Earthquake, and compare it to the estimate from panel specification. The results on comparing two specifications are reported in Table 5. To facilitate comparison, Column (1) replicates results from the baseline specification in Table 2(a) using panel data. Column (2) reports the estimates based on cross-sectional data collected after the Earthquake without any individual controls. Column (2) shows that the coefficient on the interaction term is not statistically significant any longer, and the magnitude of the coefficient is much smaller than estimate reported in Column (1). One may argue that the difference between Columns (1) and (2) may be explained by the lack of proper individual controls. To address such a concern, we add the observable individual controls, specifically age, age squared, and income in Column (3). However, the estimate on the interaction term is still not statistically significant at the conventional level, either.[35] Furthermore the estimate on interaction term in Column (3) barely changes from the one

[34] Interestingly, such pattern is more apparent among women than men. Of course, it is difficult to separate whether this result reflects residential sorting (i.e., more risk-averse people migrate to the safer locations) or differential formation of risk preferences at each location. Jaeger et al. (2011) and Bauernschuster et al. (2014) show that individuals who are more willing to take risks are more likely to migrate using data in Germany. On the other hand, Dohmen et al. (2011) document that risk preference among children are significantly related to the prevailing risk preferences in the region, controlling for parental risk preferences.

[35] Recognizing the sample size reduction due to missing values, we further add following controls: marital status, employment status, financial assets, house ownership, and years of education. But the estimate is quantitatively unchanged.

in Column (2). This result implies that *unobserved* individual characteristics that are positively correlated with risk aversion are more likely to bias the estimate obtained from cross-sectional data upward.

In order to further test our claim, we test the null hypothesis that explanatory variables are uncorrelated with unobserved individual-specific error.[36] If this hypothesis is rejected, then it is necessary to consider the model accounting for the correlation between unobserved individual-specific error and the explanatory variables. We use a cluster-robust version of the Hausman test based on the difference between the fixed effect estimator and the random effect estimator, proposed by Wooldridge (2002). The statistics of a Wald test show the null hypothesis is rejected: 34.3 (p-value = 0.0000) for full sample, 18.4 (p–value = 0.0004) for men's sample, and 10.7 (p-value = 0.0132) for women's sample. Again, these findings support the idea that the estimates obtained from cross-sectional approach are likely to be inconsistent due to potential biases.

As for women, Columns (4)–(6) show that estimates are far from statistically significant in both panel as well as cross-sectional models.

5.2 Persistence of effects

As we are interested in the stability of risk preference, a natural question to follow is whether the change is persistent or not. If the effect is only temporary, men's increased risk tolerance should revert to the before-Earthquake level. On the contrary, if the effect is persistent, men's increased risk tolerance should remain at after-Earthquake level.

Fortunately, the same individuals are tracked for two years after the Earthquake in our data, and are asked the same hypothetical lottery question. Thus, we can examine the persistence of our finding at least for two years. We estimate the following specification:

$$\Delta Y_{ijt} = \sum_{t \neq 2011}^{2012,2013} \{(\alpha_t + \beta_t X_j + \rho_t I[X_j \geq 4] X_j + \gamma_t \Delta Z_{ijt} + \Delta\varepsilon_{ijt})\, I[year = t]\} \tag{6}$$

where year 2011 is our base year. This specification is very similar to specification (5), and here we include the interaction of all the variables in specification (5) with year dummy for 2012 (one year after the Earthquake), and that for 2013 (2 years after the Earthquake). Here, we are interested

[36] The test is run using the 'xtoverid' command in STATA developed by Schaffer and Stillman (2006).

whether ρ_{2012} and ρ_{2013} are statistically different or not. The standard errors are clustered at the municipality-year level, allowing for an arbitrary serial correlation within municipality in each year.

Table 6 reports the estimates from specification (6). Column (2) for men shows that the estimates on ρ_{2012} and ρ_{2013} (both -0.93) are almost identical, suggesting that the change is persistent; men's increased risk tolerance remains at after-Earthquake level for at least two years after the Earthquake.[37] The null hypothesis that both estimates are the same (i.e., $\rho_{2012} = \rho_{2013}$) cannot be rejected at the conventional level (p-value of 0.996). As for women, Column (3) shows that the none of ρ_{2012}, and ρ_{2013} are statistically significant.

5.3 Risk-taking behaviors

So far, our focus is how the Earthquake alters individuals' risk. In this section, we examine whether risk-taking behaviors such as drinking also change with the intensity of the Earthquake. It is important to mention that since risk-taking behavior can be affected by many factors (e.g., peer effects) other than risk preferences, we have to view the results on risk-taking behaviors with a caution.

Figure 5 plots the fraction of the people who drink 5 or more cans of beer (12 *oz.* per can) or its equivalent a day for almost every day. Following Figure 4, we plot the means before and after the Earthquake as well as the difference between these two periods in relation to the intensity of the Earthquake. Panels (a)–(c) show that the figures for full sample, men, and women, respectively.

Panel (b) shows that we observe the increasing trend of intense drinking at the very high intensity locations as the intensity of the Earthquake increases among men. While we see similar patterns among women in Panel (c), the magnitude is much smaller.

Table 7 summarizes the estimates from running specification (5) for following three risk-taking behaviors: gambling, drinking, and smoking. Note that all the variables we construct here capture the most extreme form of behaviors that we can observe in the data.[38] Specifically, a gambling dummy takes one if the person is engaged in gambling (such as horse racing, and Japanese pinball

[37] Due to the attrition from 2012 to 2013, ρ_{2012} in Column (2) (-0.093) is slightly different from the baseline estimate (-0.115) in Column (4) in Table 2(a) using only 2011–2012 data.

[38] In fact, we do not observe any statistically significant changes in the mean number of drinks, gambling, and cigarettes.

or *Pachinko* in Japanese) once or more a week. Similarly, a smoking dummy takes one if the person smokes more than 30 cigarettes per day. A drinking dummy is the same variable as in Figure 5. The mean of gambling, drinking, and smoking dummies among men before the Earthquake is quite low—14.5, 2.4, and 2.4 percent respectively.

Column (4) shows that men who live in locations hit by intensity level of four or higher become engaged more in gambling as the intensity of the Earthquake increase. The estimate is statistically significant at 1 percent level. This result is consistent with our results that men become more risk tolerant. Column (5) also shows the men in these locations become more engaged in heavy drinking even though the estimate is marginally statistically significant, and the estimate is economically very small. Column (6) shows that we do not observe similar pattern for smoking.

Alternative interpretation of our results is that men who lost job due to the Earthquake have spare time to spend on risk-taking behaviors such as gambling and drinking. However, the job loss does not seem to drive our results due to the evidence for following specifications. First, we control for the change in employment status, recognizing its endogeneity. Second, we limit the sample to men whose employment status did not change before and after the Earthquake. The point estimates are quantitatively unaffected in either case (available upon request).[39]

On the other hand, consistent with our null finding on women's risk preferences, Columns (7)–(9) demonstrate that we do not observe any effects on risk–taking behaviors for women. Also note that mean of each outcomes among women before the Earthquake is by the order of magnitude smaller than that of men, making it hard to detect any changes if any.

5.4 Radiations

Throughout the paper, we use the intensity of the Earthquake as the measure of the severity of the Earthquake. But one may argue that radiation due to the accident at the Fukushima Daiichi Nuclear Power Station may be another factor that may affect people's risk preferences (Goodwin et al., 2012).[40] As mentioned before, we did not use the level of radiation as our intensity

[39] We also tried to limit the sample to men who are retired (i.e., whose income and time available are subject to less change) but the sample size is too small (N=142) to gain any meaningful estimates.

[40] Using the data collected after 11–13 weeks after the Great East Japan Earthquake, Goodwin et al. (2012) showed that anxiety about future earthquakes and nuclear threat are correlated with the changes in both preventive actions (keeping an earthquake kit, and modifying living quarters) and avoidance behaviors (avoiding certain foods or going outside, wearing masks, and contemplating leaving the country).

measure in the main specification because the relevant level of radiation is too concentrated in small number of municipalities, and little variation exists for the municipalities covered in our surveyed municipalities. Note that while the nuclear accident forced the evacuation of thousands of residents in the vicinity of the plant, none of such municipalities are included in our data. To see that the radiation is not driving our results, we add the level of radiation at each municipality to our baseline specification (5) as a control.

The results are summarized in Table 8. In sum, adding the level of radiation essentially has no impact on our coefficients of interest (i.e., interaction of intensity measure with a dummy for intensity over four). However, the coefficient on radiations shows very interesting sign only for the case of women.

We first focus on men in Columns (1) and (2) in Table 8. Column (1) replicates the baseline estimate from Table 2(a) for the ease of comparison across specifications. In Column (2), we add the level of radiation but the estimate on the interaction term is very similar as baseline in Column (1). In addition, the estimate on radiation is not statistically significant.

Columns (3)–(4) examine the case of women. Again, Column (3) replicates the baseline estimate from Table 2(a). Column (4) adds a control for the level of radiation, but the estimate on the interaction term is not statistically significant either. Interestingly, the estimate on radiation is positive, suggesting that women who live in locations with higher radiation level become more risk-averse. In fact, the coefficient on radiation for women (0.422) in Column (4) is much larger than that of men (0.169) in Column (2), and is statistically significant at 5 percent level.[41] This result is consistent with psychology literature that suggests that women evaluate nuclear waste much riskier than men (e.g., Slovic, 1999) and that the fear makes people more risk averse (e.g., Carver and Harmon-Jones, 2009; Lerner and Keltner, 2001; Lerner et al. 2003; Kuhnen and Knutson, 2011). Strikingly, Appendix Table A4 shows that women's increased risk aversion is persistent at least for two years by running a similar specification as (6) with the addition of the interaction terms between radiation level and a dummy for each year.

[41] Some studies suggest that women are more concerned about human health and safety because they give birth (e.g., Steger and Witt, 1989). Thus, we divide the sample of women by the existence of children to see whether mothers with children become more risk averse due to radiation. However, most of the women in our sample have children (1,462 women with children, and 218 women without children), so we do not find any meaningful differences. Also we divide the sample by the age of youngest children, and also limit the women within reproductive age, but once again we do not find any differences.

5.5 Attrition, multiple switches, and migration

We finally demonstrate here that attrition, multiple switch, and migration do not seem to affect our results. Each factor may pose a problem for our result if it is systematically linked to intensity of the Earthquake at the high intensity locations, and especially if it is systematically differed by gender as the intensity of the Earthquake increase at the high intensity locations. To examine these possibilities, we regress an indicator for each attrition/multiple switch/migration on the same sets of variables in equation (5), as well as the all the interactions with gender dummy, respectively. Appendix Table A5(a)–(c) summarizes the results for attrition, multiple switches, and migration, respectively. Recall that after dropping the following observations, our final sample is 3,221 individuals (1,514 men and 1,707 women).

Attrition.—263 respondents (7.5 percent), who are interviewed in 2011 with non-missing key variables, did not complete the survey in 2012. Appendix Table A5(a) demonstrates that attrition is not systematically associated with intensity of the Earthquake.

Multiple switches.—198 respondents (5.8 percent) have multiple switches in their answers to hypothetical lottery questions in either 2011 or 2012. Appendix Table A5(b) shows that multiple switches are not systematically correlated with intensity of the Earthquake either. We drop such individuals from the final sample since it is difficult to assign the right switch of risk preference for such an individual. We also assume that first switch is the right measure of the risk aversion for individuals with multiple switches and include them in the data. The estimates including such observations are unaffected (available upon request).

Migration.—147 respondents (4.4 percent) moved municipalities between surveys in 2011 ("before") and 2012 ("after"). Out of 147 respondents, 60 are men and 87 are women.[42] Similar to attrition and multiple switches, Appendix Table 5(c) reports that migration is again not systematically correlated with intensity of the Earthquake. We drop such individuals from the final sample as it is difficult to assign the intensity of the Earthquake to such individuals.[43]

[42] The migration after the Earthquake or any negative shocks in general can be problematic in cross-section data if more risk-averse people tend to migrate from the regions with large negative shocks since we only observe data of those who remained the regions, mechanically creating the spurious negative relationship between the intensity of the negative shocks and risk aversion at the regional level.

[43] As a robustness check, we estimate the same specification (5) using all the samples where we assign the intensity measures from the municipalities reported in 2011 to those individuals who moved between 2011 and 2012. The results are essentially unchanged (available upon request).

6 Conclusion

Attitudes towards risk under uncertainty are the key determinants of economic decision-making. Standard economic models assume that risk preferences are stable across time but recent studies suggest that risk preferences may be altered by various shocks. However, little is yet known how the risk preferences can be altered (i.e., direction), and persistence of such changes if any.

To shed light on this research question, we test whether experiencing the Great East Japan Earthquake alters risk preferences of individuals. We exploit the unique panel dataset that track the change in risk preference of the same individuals before and after the Earthquake, unlike previous studies that use cross-sectional data that are collected only after the negative shocks have occurred.

We find that people who experienced larger intensity of the Earthquake become more risk tolerant and that the findings are all driven by men. We also show that this increased risk tolerance among men remains at after-Earthquake level for at least two years after the Earthquake. Furthermore, we find the suggestive evidence that men who live in hardest-hit locations become engaged more in gambling and drinking.

This study may be especially important since natural disasters are becoming increasingly prevalent all over the world. In fact, most of the past studies predominately examined the cases in developing countries. Our results show that risk preferences of people in Japan—a developed country—are also affected by a large negative shock.

There are some limitations of our paper. First, we can only examine the effect of the Earthquake on limited number of risk-taking behaviors such as gambling. Second, we cannot fully understand the mechanism on how experiencing the high intensity of the Earthquake alters individuals' risk preferences. The intensity measures of the Earthquake we use indeed capture the degree of shock physically felt by each individual, and thus it can plausibly affect people's risk preferences. However, it is impossible to identify whether our results are driven by the emotional responses or other channels such as learning in which individuals updated probability of a large disaster after experiencing the Earthquake. These questions are beyond the scope of our paper but clearly remain as an avenue for the future research.

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Appendix A: JMA seismic intensity scale

Various seismic intensity scales are used in different countries to measure the degree of shaking at a specific location. JMA seismic intensity scale is used in Japan and is computed using the acceleration data for each monitoring station. After adjusting the raw digital acceleration data to the adjusted acceleration (a gal), JMA seismic intensity scale (I) can be obtained by $I = 2\log_{10}a + 0.94$. Thus, the measure can basically be considered as the logarithm of the acceleration. In other words, increase of JMA intensity scale corresponds to exponential increase in acceleration.[44]

JMA's description on JMA seismic intensity for human perception and reaction as well as indoor situation is as follows.

Seismic intensity	**Human perception and reaction**	**Indoor situation**
0	Imperceptible to people, but recorded by seismometers.	-
1	Felt slightly by some people keeping quiet in buildings.	-
2	Felt by many people keeping quiet in buildings. Some people may be awoken.	Hanging objects such as lamps swing slightly.
3	Felt by most people in buildings. Felt by some people walking. Many people are awoken.	Dishes in cupboards may rattle.
4	Most people are startled. Felt by most people walking. Most people are awoken.	Hanging objects such as lamps swing significantly, and dishes in cupboards rattle. Unstable ornaments may fall.
5 Lower	Many people are frightened and feel the need to hold onto something stable.	Hanging objects such as lamps swing violently. Dishes in cupboards and items on bookshelves may fall. Many unstable ornaments fall. Unsecured furniture may move, and unstable furniture may topple over.

[44] For detail, see an announcement describing the seismic intensity by JMA http://www.mext.go.jp/b_menu/hakusho/nc/k19960215001/k19960215001.html

5 Upper	Many people find it hard to move; walking is difficult without holding onto something stable.	Dishes in cupboards and items on bookshelves are more likely to fall. TVs may fall from their stands, and unsecured furniture may topple over.
6 Lower	It is difficult to remain standing.	Many unsecured furniture moves and may topple over. Doors may become wedged shut.
6 Upper	It is impossible to remain standing or move without crawling. People may be thrown through the air.	Most unsecured furniture moves, and is more likely to topple over.
7		Most unsecured furniture moves and topples over, or may even be thrown through the air.

Source: Japan Meteroligal Agency http://www.jma.go.jp/jma/en/Activities/inttable.html

Appendix B: Survey questions on variables used in this study

Following are survey questions used in the study.

1. Risk Preferences

Suppose that there is a "speed lottery" with a 50% chance of winning 100,000 JPY. If you win, you get the prize right away. If you lose, you get nothing. How much would you spend to buy a ticket for this lottery? Choose Option "A" if you would buy it at that price, and choose Option "B" if you would not buy the ticket at that price. **(X ONE Box For EACH Row)**

Price of the "speed lottery" ticket		Which ONE do you prefer? **(X ONE Box For EACH Row)**	
		Option "A" (buy the "speed lottery" ticket)	Option "B" (DO NOT buy the "speed lottery" ticket)
10 JPY	(USD 0.1)	1 □	2 □
2,000 JPY	(USD 20)	1 □	2 □
4,000 JPY	(USD 40)	1 □	2 □
8,000 JPY	(USD 80)	1 □	2 □
15,000 JPY	(USD 150)	1 □	2 □
25,000 JPY	(USD 250)	1 □	2 □
35,000 JPY	(USD 350)	1 □	2 □
50,000 JPY	(USD 500)	1 □	2 □

Note: The exchange rate of JPY100 = USD1 is used.

2. Gambling

Do you gamble in lotteries or at casinos or bet on sporting events or horse races? **(X ONE Box)**

1 □ Don't gamble at all
2 □ Used to gamble, but quit gambling now
3 □ Hardly gamble
4 □ Several times a year or so
5 □ Once a month or so
6 □ Once a week or so
7 □ Almost everyday

3. Drinking

Do you drink alcoholic beverages? **(X ONE Box)**

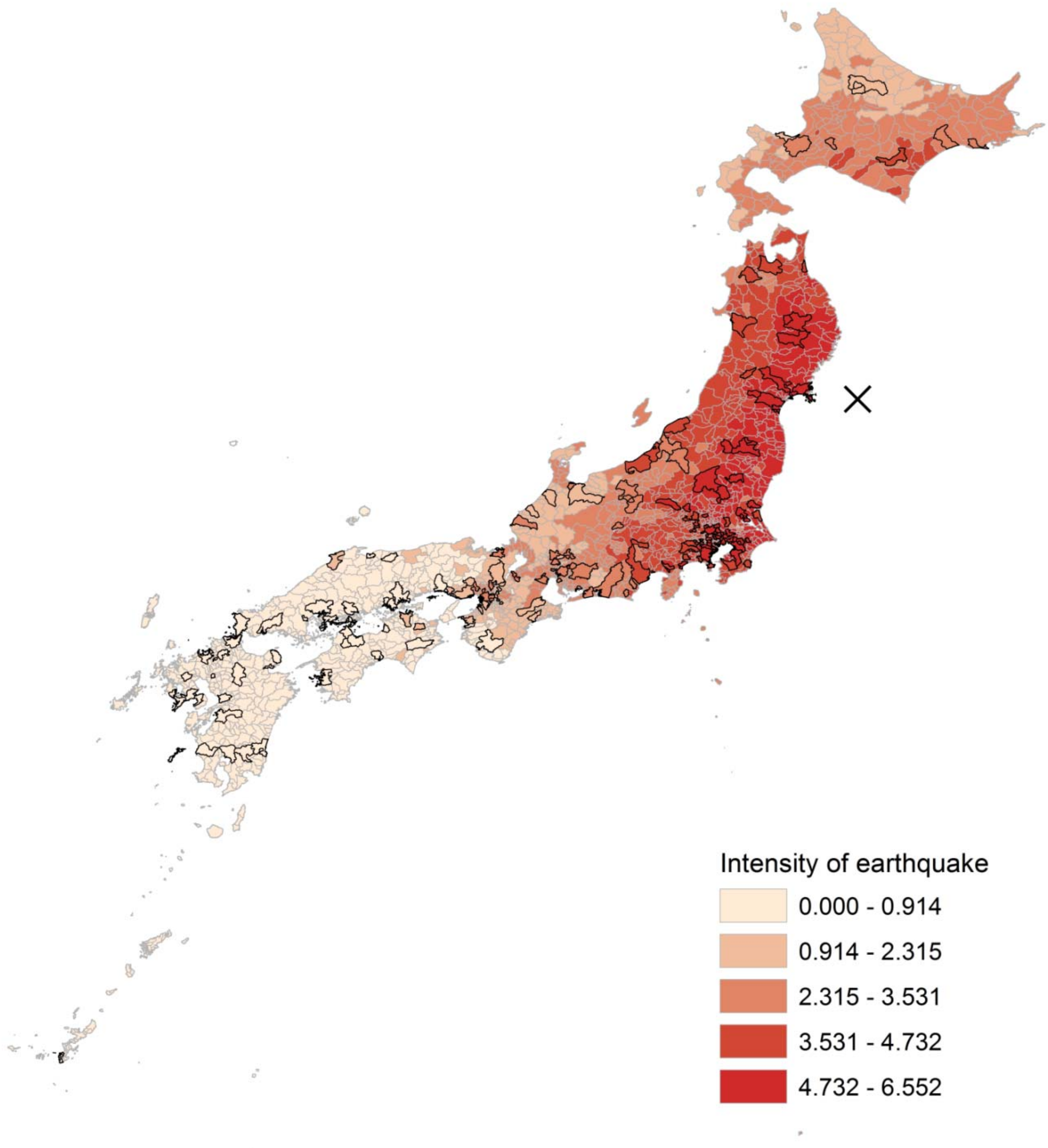
1 □ Don't drink at all
2 □ Hardly drink (a few times a month or less)
3 □ Drink sometimes (a few times a week)
4 □ A can of beer (12 oz.) or its equivalent a day, almost everyday
5 □ 3 cans of beer (12 oz. x 3) or its equivalent a day, almost everyday
6 □ 5 or more cans of beer (12 oz. x 5) or its equivalent a day, almost everyday

4. Smoking

Do you smoke? **(X ONE Box)**

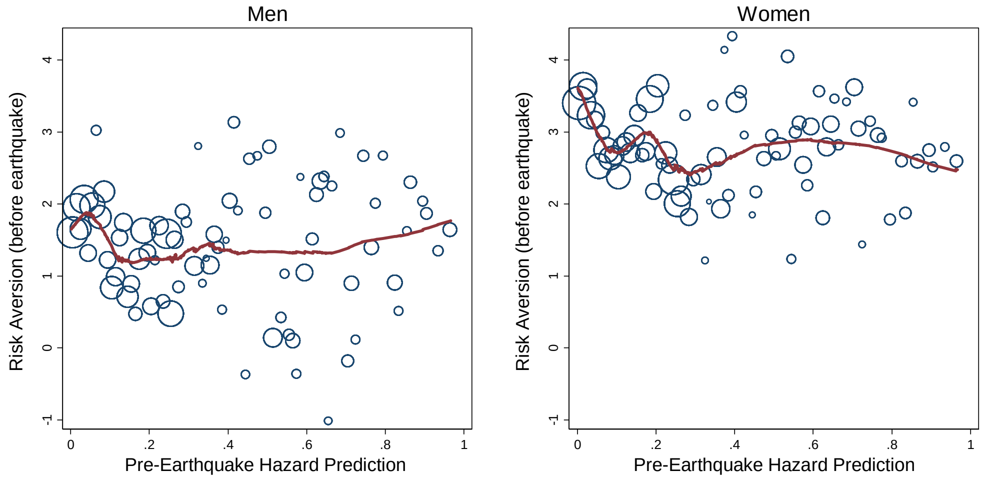
1 □ Never smoked
2 □ Hardly smoke
3 □ Occasionally smoke
4 □ I smoke about 1 to 5 cigarettes a day
5 □ I smoke about 6 to 10 cigarettes a day
6 □ I smoke about 11 to 20 cigarettes a day
7 □ I smoke about 21 to 30 cigarettes a day
8 □ I smoke about 31 to 40 cigarettes a day
9 □ I smoke 41 cigarettes or more a day
10 □ I used to smoke, but I quit

Figure 1. Seismic Intensity of the Great East Japan Earthquake



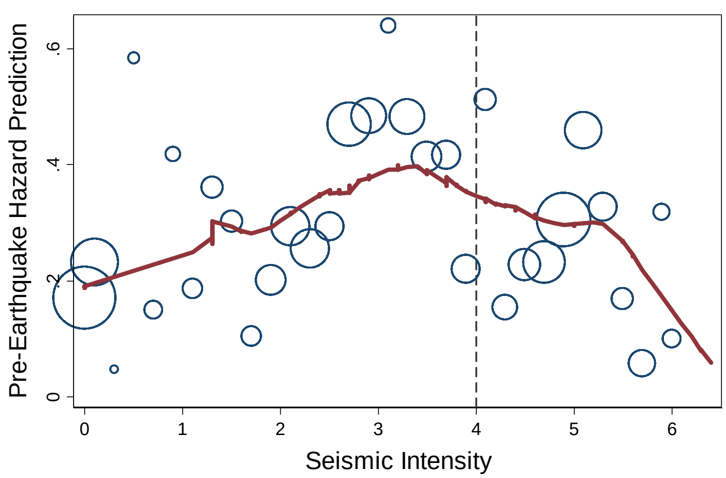
Note: The epicenter of the Great East Japan Earthquake (38.322°N 142.369°E) is marked with the cross sign. There are total of 1,724 municipalities in Japan (as of April 1, 2011), and 226 municipalities in our survey are boxed with black line. The intensity of earthquake comes from seismic intensity of the Earthquake (*Shindo* in Japanese), which is a metric of the strength of earthquake at a specific location. It is constructed by Japanese Meteorological Association. See main text and Appendix Table A6 for details.

Figure 2. Risk Preferences and Earthquake Hazard Prediction Before the Earthquake



Note: The line is *lowess* curve with a bandwidth of 0.3. Pre-Earthquake hazard prediction on *x*-axis is the probability of experiencing a large earthquake in the next 30 years (see Appendix Table A6 for details). Risk aversion on *y*-axis is logit-converted transformed price. See main text for construction of the variable.

Figure 3. Pre-Earthquake Hazard Prediction and Intensity of the Earthquake

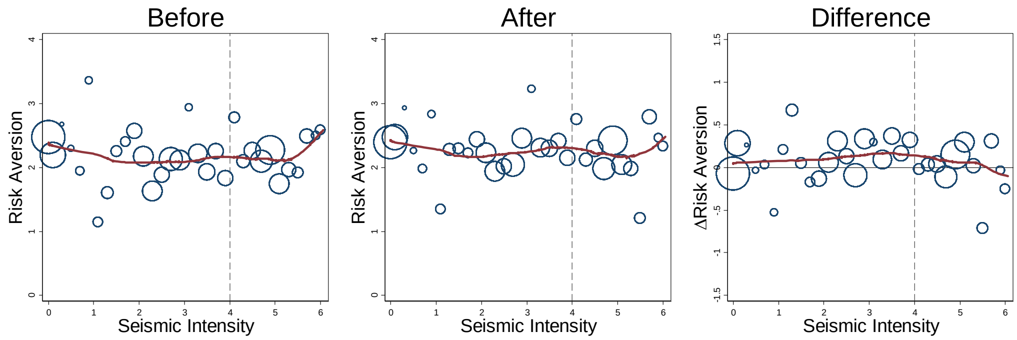


Note: Each dot represents the mean of observations within each bin of 0.2, and the size of the dot reflects the number of the observations in each bin. The line is *lowess* curve with a bandwidth of 0.5. Pre-Earthquake hazard prediction on *y*-axis is the probability of experiencing a large earthquake in the next 30 years, and it is the same measure as the *y*-axis in Figure 2. The seismic intensity of the Earthquake (*Shindo* in Japanese) on *x*-axis is a metric of the strength of earthquake at a specific location. See Appendix Table A6 for details.

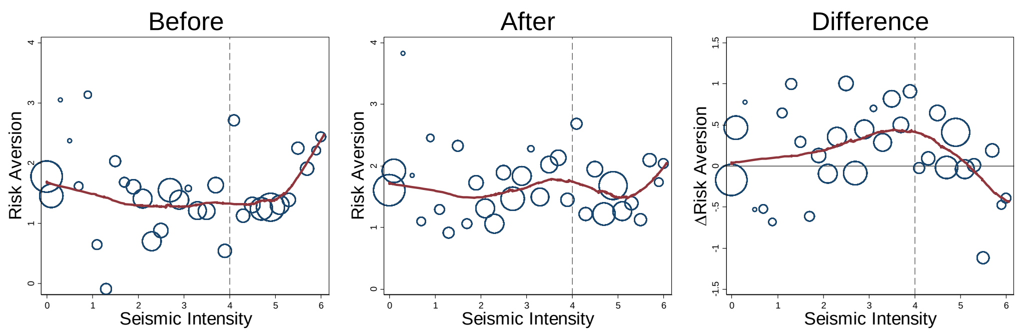
Figure 4. Risk Preferences Before and After the Earthquake

Outcome: Risk Preferences

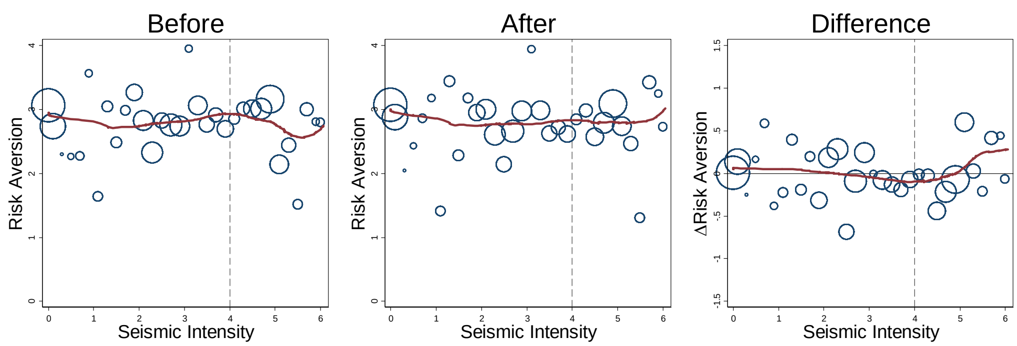
(A) Full Sample



(B) Men



(C) Women

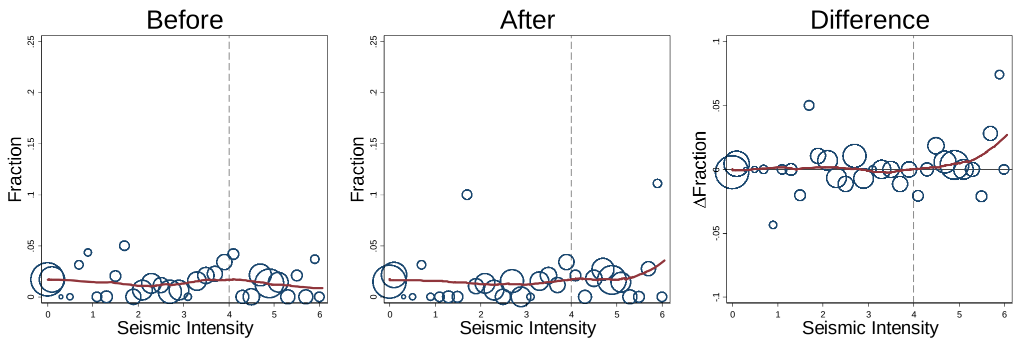


Note: The data come from the JHPS. The risk aversion on *y*-axis is the log-converted transformed price. See the main text for construction of the variable. The seismic intensity of the Earthquake (*Shindo* in Japanese) on *x*-axis is a metric of the strength of earthquake at a specific location. Each dot represents the mean of observations within each bin of 0.2, and the size of the dot reflects the number of the observations in each bin. The solid fitted line is *lowess* curve with the bandwidth of 0.5. The vertical dotted lines correspond to the seismic intensity of four. Total number of individuals is 3,221, and that of municipalities is 226.

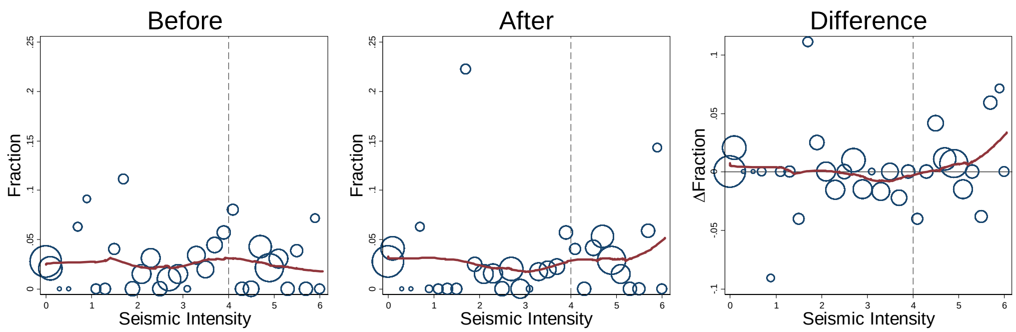
Figure 5. Drinking Behavior Before and After the Earthquake

Outcome: Fraction of 5 cans of beer (12 oz. per can) or its equivalent a day, almost everyday

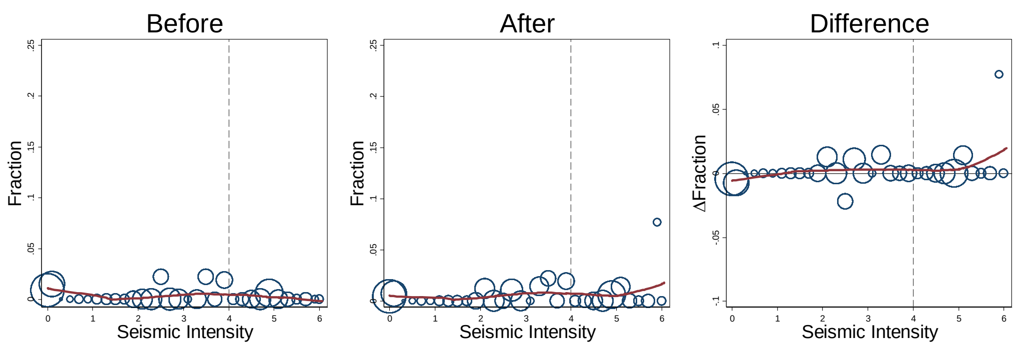
(A) Full Sample



(B) Men



(C) Women



Note: The data come from the JHPS. The *y*-axis is the fraction of people who report drinking 5 cans of beer (12 oz. per can) or its equivalent a day, almost every day. The seismic intensity of the Earthquake (*Shindo* in Japanese) on *x*-axis is a metric of the strength of earthquake at a specific location. Each dot represents the mean of observations within each bin of 0.2, and the size of the dot reflects the number of the observations in each bin. The solid fitted line is *lowess* curve with the bandwidth of 0.5. The vertical dotted lines correspond to the seismic intensity of four. Total number of individuals is 3,221, and that of municipalities is 226.

Table 1. Summary Statistics

Variables	N	Mean	SD	Min	Max
A. Individual-Level Variables (before earthquake)					
Risk Preferences					
Risk aversion measure 1 (transformed price)	3,221	0.8070	0.2149	0	0.9998
Risk aversion measure 2 (absolute risk aversion)	3,221	0.0019	0.0004	0	0.0020
Behaviors					
Gambling (once or more a week)	3,221	0.09	0.29	0	1
Drinking (5 or more cans of beer, almost everyday)	3,221	0.01	0.12	0	1
Smoking (more than 30 cigarettes per day)	3,221	0.01	0.11	0	1
Individual Characteristics					
Age (in years)	3,221	52.1	12.6	22	78
Male	3,221	0.47	0.50	0	1
Agriculture and fisheries industries	3,221	0.02	0.15	0	1
Annual household income (in million JPY)	3,221	6.35	3.75	1.0	20
House ownership	3,204	0.88	0.33	0	1
High School graduation or less	3,204	0.55	0.50	0	1
Married	3,171	0.82	0.38	0	1
Asset (in million JPY)	2,983	13.5	17.4	2.5	100
B. Municipality-Level Variables					
X (seismic intensity)	226	2.83	1.94	0	6.06
Distance from earthquake epicenter	226	627.5	334.2	93.8	1932.3
Radiation (μSv/h)	226	0.10	0.24	0	2.40

Note: See Appendix Table A6 for construction of each municipality-level variables. Note that number of observations for asset, house ownership, education, and marital status differs slightly due to missing values.

Table 2(a). Results on Risk Preferences

Outcome: Risk Aversion Measure 1 (Logit-converted Transformed Price)

	Full Sample			Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
X	0.043	0.040	0.007	0.127**	0.119**	0.069	-0.032	-0.030	-0.049
	(0.036)	(0.035)	(0.027)	(0.064)	(0.060)	(0.044)	(0.042)	(0.038)	(0.030)
X * 1[X ≥ 4]	-0.041			-0.115**			0.024		
	(0.030)			(0.052)			(0.033)		
X * 1[X ≥ 4.5]		-0.042			-0.117**			0.025	
		(0.029)			(0.049)			(0.031)	
X * 1[X ≥ 5]			-0.013			-0.119**			0.088***
			(0.031)			(0.047)			(0.030)
Constant	0.035	0.036	0.077	0.014	0.016	0.068	0.054	0.054	0.087
	(0.083)	(0.082)	(0.078)	(0.139)	(0.137)	(0.130)	(0.097)	(0.096)	(0.090)
Individual FE	×	×	×	×	×	×	×	×	×
Mean of Δrisk aversion	0.089	0.089	0.089	0.184	0.184	0.184	0.005	0.005	0.005
Mean of risk aversion (before)	2.168	2.168	2.168	1.429	1.429	1.429	2.823	2.823	2.823
N of individuals	3,221	3,221	3,221	1,514	1,514	1,514	1,707	1,707	1,707
R-squared	0.001	0.001	0.000	0.003	0.003	0.004	0.000	0.000	0.004

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01.Standard errors clustered at the municipality are reported in parentheses.

Table 2(b). Results on Risk Preferences

Outcome: Risk Aversion Measure 2 (Logit-converted Absolute Risk Aversion)

	Full Sample			Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
X	0.086*	0.071	-0.001	0.222***	0.191**	0.077	-0.033	-0.035	-0.072
	(0.051)	(0.049)	(0.039)	(0.082)	(0.076)	(0.057)	(0.071)	(0.065)	(0.051)
X * 1[X ≥ 4]	-0.075*			-0.183***			0.020		
	(0.041)			(0.065)			(0.055)		
X * 1[X ≥ 4.5]		-0.065			-0.166***			0.024	
		(0.040)			(0.061)			(0.051)	
X * 1[X ≥ 5]			0.021			-0.088			0.124**
			(0.042)			(0.057)			(0.051)
Constant	-0.014	0.000	0.095	-0.118	-0.092	0.047	0.073	0.078	0.136
	(0.120)	(0.119)	(0.114)	(0.179)	(0.177)	(0.169)	(0.171)	(0.168)	(0.158)
Individual FE	×	×	×	×	×	×	×	×	×
Mean of Δrisk aversion	0.105	0.105	0.105	0.210	0.210	0.210	0.012	0.012	0.012
Mean of risk aversion (before)	5.564	5.564	5.564	4.548	4.548	4.548	6.466	6.466	6.466
N of individuals	3,221	3,221	3,221	1,514	1,514	1,514	1,707	1,707	1,707
R-squared	0.001	0.001	0.000	0.005	0.005	0.002	0.000	0.000	0.003

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses.

Table 3. Robustness Checks for Results on Risk Preferences (Men only)

Outcome: Risk Aversion Measure 1 (Logit-converted Transformed Price)

	Men							
				Changes in Income Bracket				
Additional Control Variables	Baseline	Industry dummy	Income	ΔIncome = 0	ΔIncome > 0	ΔIncome < 0	Asset	House Ownership Dummy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
X	0.127**	0.128**	0.127**	0.272***	-0.015	-0.027	0.128**	0.126*
	(0.064)	(0.064)	(0.064)	(0.087)	(0.123)	(0.148)	(0.064)	(0.064)
X * 1[X ≥ 4]	-0.115**	-0.116**	-0.116**	-0.204***	0.030	-0.078	-0.117**	-0.113**
	(0.052)	(0.052)	(0.052)	(0.071)	(0.095)	(0.115)	(0.052)	(0.052)
Constant	0.014	0.008	0.011	-0.160	0.356	0.977**	0.000	0.019
	(0.139)	(0.140)	(0.139)	(0.195)	(0.401)	(0.452)	(0.142)	(0.145)
Individual FE	×	×	×	×	×	×	×	×
Work in agriculture and fisheries		×	×	×	×	×	×	×
Income			×	–	×	×	×	×
Asset							×	×
House ownership								×
Mean of Δrisk aversion	0.184	0.184	0.184	0.255	0.023	0.180	0.184	0.184
Mean of risk aversion (before)	1.429	1.429	1.429	1.463	1.364	1.413	1.429	1.429
N of individuals	1,514	1,514	1,514	810	344	360	1,514	1,514
R-squared	0.003	0.003	0.003	0.013	0.008	0.029	0.004	0.011

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses.

Table 4. Heterogeneous Effects on Risk Preferences (Men only)

Outcome: Risk Aversion Measure 1 (Logit-converted Transformed Price)

	Men					
	Age		Educational Attainment		Marital Status	
	Age < 52	Age ≥ 52	High School graduation or less	More than High School graduation	Married	Unmarried
	(1)	(2)	(3)	(4)	(5)	(6)
X	0.022	0.212**	0.259***	-0.047	0.120*	0.169
	(0.108)	(0.088)	(0.093)	(0.109)	(0.065)	(0.232)
X * 1[X ≥ 4]	-0.040	-0.174**	-0.187**	-0.023	-0.077	-0.305
	(0.082)	(0.067)	(0.074)	(0.087)	(0.053)	(0.187)
Constant	0.094	-0.060	-0.125	0.217	-0.052	0.353
	(0.247)	(0.213)	(0.207)	(0.237)	(0.160)	(0.419)
Individual FE	×	×	×	×	×	×
Income	×	×	×	×	×	×
Mean of Δrisk aversion	0.087	0.268	0.315	0.040	0.165	0.267
Mean of risk aversion (before)	1.096	1.714	1.672	1.176	1.431	1.403
N of individuals	699	815	782	724	1,245	249
R-squared	0.002	0.008	0.010	0.002	0.002	0.027

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Men whose marital status changed are 0.99% of the sample and we drop them in Columns (5)–(6).

Table 5. Results on Risk Preferences: Panel vs. Cross Section

Outcome: Risk Aversion Measure 1 (Logit-converted Transformed Price)

	Men			Women		
	Panel	Cross Section		Panel	Cross Section	
	BEFORE and AFTER earthquake	AFTER earthquake only		BEFORE and AFTER earthquake	AFTER earthquake only	
	(1)	(2)	(3)	(4)	(5)	(6)
X	0.127**	-0.003	0.012	-0.032	-0.060	-0.047
	(0.064)	(0.061)	(0.059)	(0.042)	(0.047)	(0.046)
X * 1[X ≥ 4]	-0.115**	-0.008	-0.005	0.024	0.038	0.042
	(0.052)	(0.049)	(0.047)	(0.033)	(0.041)	(0.039)
Constant	0.014	1.637***	1.472	0.054	2.935***	4.346***
	(0.139)	(0.141)	(1.167)	(0.097)	(0.097)	(0.816)
Individual FE	×	—	—	×	—	—
Covariates	—		×	—		×
N of individuals	1,514	1,514	1,514	1,707	1,707	1,707
R-squared	0.003	0.000	0.047	0.000	0.001	0.036

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Covariates in Columns (3) and (6) are age, age squared, and income.

Table 6. Persistent Effects on Risk Preferences

Outcome: Risk Aversion Measure 1 (Logit-converted Transformed Price)

	Full Sample	Men	Women
	(1)	(2)	(3)
Initial Impact (2012-2011)			
X * 1[Year = 2012]	0.047	0.103	-0.003
	(0.039)	(0.071)	(0.046)
X * 1[X ≥ 4] *1[Year = 2012]	-0.040	-0.093*	0.008
	(0.032)	(0.056)	(0.036)
Further Change (2013-2011)			
X * 1[Year = 2013]	0.060	0.058	0.057
	(0.044)	(0.069)	(0.049)
X * 1[X ≥ 4] *1[Year = 2013]	-0.068**	-0.093*	-0.043
	(0.033)	(0.055)	(0.039)
Constant	0.027	0.033	0.022
	(0.091)	(0.160)	(0.107)
H_0: X * 1[X ≥ 4] *1[Year = 2012]	F(1, 225)	F(1, 221)	F(1, 225)
= X * 1[X ≥ 4] *1[Year = 2013]	= 0.64	= 0.00	= 1.36
	[0.42]	[0.99]	[0.24]
Individual FE	×	×	×
Year FE	×	×	×
Income	×	×	×
N of individuals	2,803	1,331	1,472
R-squared	0.001	0.003	0.001

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality-year are reported in parentheses. P-values for F-statistics are reported in brackets.

Table 7. Results on Behaviors

Outcomes	Full Sample			Men			Women		
	Gambling	Drinking	Smoking	Gambling	Drinking	Smoking	Gambling	Drinking	Smoking
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
X	-0.011**	-0.000	0.000	-0.017**	-0.004	0.001	-0.006	0.003	-0.000
	(0.005)	(0.001)	(0.002)	(0.007)	(0.002)	(0.004)	(0.005)	(0.002)	(0.000)
X * 1[X ≥ 4]	0.009***	0.001	-0.001	0.013***	0.004*	-0.002	0.005	-0.001	0.000
	(0.003)	(0.001)	(0.001)	(0.005)	(0.002)	(0.003)	(0.004)	(0.001)	(0.000)
Constant	0.025**	0.000	0.005	0.045**	0.006	0.010	0.009	-0.005	0.002
	(0.011)	(0.003)	(0.004)	(0.018)	(0.005)	(0.009)	(0.009)	(0.005)	(0.002)
Individual FE	×	×	×	×	×	×	×	×	×
Income	×	×	×	×	×	×	×	×	×
Mean of Δoutcome	0.008	0.002	0.005	0.018	0.003	0.011	-0.001	0.001	0.001
Mean of outcome (before)	0.089	0.014	0.012	0.145	0.024	0.024	0.040	0.005	0.002
N of individuals	3,221	3,221	3,221	1,514	1,514	1,514	1,707	1,707	1,707
R-squared	0.003	0.001	0.000	0.005	0.002	0.000	0.002	0.002	0.001

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. A gambling dummy takes one if the person is engaged in gambling once or more a week. A drinking dummy takes one if the person drinks 5 or more cans of beer (12 oz. per can) or its equivalent a day for almost every day. A smoking dummy takes one if the person smokes more than 30 cigarettes per day.

Table 8. Radiation

Outcome: Risk Preference Measure 1 (Logit-converted Transformed Price)

	Men		Women	
	(1)	(2)	(3)	(4)
X	0.127**	0.126**	-0.032	-0.032
	(0.064)	(0.064)	(0.042)	(0.042)
X * 1[X ≥ 4]	-0.116**	-0.119**	0.025	0.015
	(0.052)	(0.053)	(0.033)	(0.034)
Radiation		0.169		0.422**
		(0.318)		(0.202)
Constant	0.017	0.008	0.056	0.032
	(0.139)	(0.140)	(0.097)	(0.098)
Individual FE	×	×	×	×
Income	×	×	×	×
N of individuals	1,514	1,514	1,707	1,707
R-squared	0.003	0.003	0.000	0.002

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Radiation is measured in μSv/h. See Appendix A6 for the details of these variables. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses.

Appendix Figures and Tables

Table A1. Risk Aversion Measures

1. Risk aversion category, price of the lottery tickets, and risk aversion measures

	<- Less risk averse							More risk averse ->	
Risk aversion category	1	2	3	4	5	6	7	8	9
Price of the lottery tickets (JPY)	~50,000	50,000~35,000	35,000~25,000	25,000~15,000	15,000~8,000	8,000~4,000	4,000~2,000	2,000~10	10~
Raw Values									
Transformed Price	~0	0~0.30	0.30~0.50	0.50~0.70	0.70~0.84	0.84~0.92	0.92~0.96	0.96~0.99	0.99~
Absolute Risk Aversion	~0	0~1.100	1.100~1.600	1.600~1.879	1.879~1.969	1.969~1.993	1.993~1.998	1.998~2.000	2.000~
Logit-Converted Values									
Transformed Price	~-9.21	-9.21~-0.85	-0.85~0	0~0.85	0.85~1.66	1.66~2.44	2.44~3.18	3.18~8.51	8.51~
Absolute Risk Aversion	~-2.94	-2.94~0.20	0.20~1.39	1.39~2.74	2.74~4.18	4.18~5.66	5.66~7.09	7.09~16.49	16.49~

Note: Raw values of absolute risk aversion are multiplied by 1000. The raw values of zero (applied to the price of the lottery ticket 50,000) are replaced by 0.0001 to use logit transformation. See main text for the construction of each risk aversion parameter based on the price of the lottery tickets.

2. Transition Matrix of Risk Aversion Category Before and After the Earthquake (Men only)

A. X ≥ 4

		After: <- Less risk averse								More risk averse ->	
		1	2	3	4	5	6	7	8	9	Total
Before (Less risk averse ->)	1	1	4	1	2	3	0	1	0	1	13
	2	5	13	6	2	4	2	1	1	0	34
	3	3	6	11	8	9	2	3	0	0	42
	4	2	1	7	14	19	13	2	1	1	60
	5	0	1	7	23	44	26	17	4	0	122
	6	1	1	2	10	26	14	31	8	1	94
	7	1	0	2	0	20	24	36	14	5	102
	8	1	0	1	1	6	4	17	13	3	46
(<- More risk)	9	0	0	0	0	1	5	3	1	11	21
Total		14	26	37	60	132	90	111	42	22	534

B. X < 4

		After: <- Less risk averse								More risk averse ->	
		1	2	3	4	5	6	7	8	9	Total
Before (Less risk averse ->)	1	4	5	4	6	5	1	2	0	0	27
	2	9	10	10	10	7	3	2	1	1	53
	3	4	12	22	20	11	8	6	4	0	87
	4	2	5	17	32	34	24	4	3	0	121
	5	0	3	10	34	91	47	37	7	3	232
	6	1	6	4	7	51	55	39	7	6	176
	7	1	1	3	6	29	43	60	30	7	180
	8	0	0	1	3	8	8	16	25	5	66
(<- More risk)	9	0	1	1	3	3	6	0	8	16	38
Total		21	43	72	121	239	195	166	85	38	980

Table A2. The Validity of Risk Aversion Measures

1. Using the 2011 survey (before the Earthquake)

Outcomes	Gambling	Drinking	Smoking
	(1)	(2)	(3)
Risk aversion measure 1	-0.010***	-0.002*	-0.002**
	(0.002)	(0.001)	(0.001)
Constant	0.111***	0.018***	0.017***
	(0.007)	(0.003)	(0.003)
N of individuals	3,221	3,221	3,221
R-squared	0.009	0.002	0.002

2. Using the 2012 survey (after the Earthquake)

Outcomes	Gambling	Drinking	Smoking
	(1)	(2)	(3)
Risk aversion measure 1	-0.014***	-0.002**	-0.001
	(0.002)	(0.001)	(0.001)
Constant	0.129***	0.021***	0.021***
	(0.008)	(0.004)	(0.004)
N of individuals	3,221	3,221	3,221
R-squared	0.016	0.003	0.001

Note: Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Risk Aversion Measure 1 is the logit-converted transformed price. See main text for construction of the variable. A gambling dummy takes one if the person is engaged in gambling once or more a week. A drinking dummy takes one if the person drinks 5 or more cans of beer (12 oz. per can) or its equivalent a day for almost every day. A smoking dummy takes one if the person smokes more than 30 cigarettes per day.

Table A3. Alternative Measure of Earthquake (Men only)

Outcome: Risk Preference Measure 1 (Logit-converted Transformed Price)

	Men			
	Intensity Measure			
	Baseline	Alternative Measure 1	Alternative Measure 2	Alternative Measure 3
Method of constructing an intensity measure	Weighted Average of Three Closest Points	Weighted Average of Two Closest Points	Simple Average of Three Closest Points	The closest point
	(1)	(2)	(3)	(4)
Intensity Measure	0.127**	0.115*	0.118*	0.111*
	(0.064)	(0.065)	(0.061)	(0.065)
Intensity Measure * 1[Intensity Measure ≥ 4]	-0.115**	-0.102*	-0.109**	-0.097*
	(0.052)	(0.053)	(0.050)	(0.052)
Constant	0.014	0.032	0.025	0.038
	(0.139)	(0.139)	(0.137)	(0.139)
Individual FE	×	×	×	×
Mean of Δrisk aversion	0.184	0.184	0.184	0.184
Mean of risk aversion (before)	1.429	1.429	1.429	1.429
N of individuals	1,514	1,514	1,514	1,514
R-squared	0.003	0.002	0.003	0.002

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses.

Table A4. Persistent Effects of Radiation

Outcome: Risk Preference Measure 1 (Logit-converted Transformed Price)

	Full Sample	Men	Women
	(1)	(2)	(3)
Initial Impact (2012-2011)			
Shindo * 1[Year = 2012]	0.047	0.103	-0.002
	(0.039)	(0.071)	(0.046)
Shindo * 1[Year = 2012] * 1[Shindo ≥ 4]	-0.048	-0.098*	-0.004
	(0.033)	(0.057)	(0.036)
Radiation * 1[Year = 2012]	0.416	0.290	0.526**
	(0.302)	(0.420)	(0.225)
Further Change (2013-2011)			
Shindo * 1[Year = 2013]	0.060	0.058	0.057
	(0.044)	(0.069)	(0.050)
Shindo * 1[Year = 2013] * 1[Shindo ≥ 4]	-0.072**	-0.092*	-0.053
	(0.034)	(0.055)	(0.040)
Radiation * 1[Year = 2013]	0.207	-0.076	0.464
	(0.235)	(0.277)	(0.300)
Constant	0.002	0.015	-0.009
	(0.093)	(0.162)	(0.108)
H_0: X * 1[X ≥ 4] *1[Year = 2012]	F(1, 225)	F(1, 221)	F(1, 225)
= X * 1[X ≥ 4] *1[Year = 2013]	= 0.45	= 0.02	= 1.29
	[0.50]	[0.90]	[0.26]
H_0: Radiation *1[Year = 2012]	F(1, 225)	F(1, 221)	F(1, 225)
= Radiation *1[Year = 2013]	= 1.13	= 0.99	= 0.05
	[0.29]	[0.32]	[0.82]
Individual FE	×	×	×
Year FE	×	×	×
Income	×	×	×
N of individuals	2,803	1,331	1,472
R-squared	0.002	0.003	0.003

Note: X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Radiation is measured in μSv/h. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality-year are reported in parentheses. P-values for F-statistics are reported in brackets.

Table A5(a). Attrition

Outcome	Attrition				
	(1)	(2)	(3)	(4)	(5)
X	-0.002	-0.008*	-0.008*	-0.005	-0.003
	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)
X * 1[X ≥ 4]		0.006*	0.005	0.003	0.002
		(0.003)	(0.003)	(0.004)	(0.004)
X * Male				-0.008	-0.009
				(0.008)	(0.008)
X * 1[X ≥ 4] * Male				0.007	0.007
				(0.007)	(0.006)
Constant	0.082***	0.089***	0.278***	0.073***	0.274***
	(0.009)	(0.010)	(0.076)	(0.013)	(0.076)
Male			×	×	×
Covariates			×		×
N of individuals	3,484	3,484	3,484	3,484	3,484
R-squared	0.000	0.001	0.007	0.004	0.007

Note: Outcome is the dummy that takes one if the person who drops from the sample in 2012 (after the earthquake). The attrition rate is 7.5 percent (263 out of 3,484 respondents). X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Covariates in Columns (3) and (5) are age, age squared, and income.

Table A5(b). Multiple Switch

Outcome	Multiple Switch				
	(1)	(2)	(3)	(4)	(5)
X	-0.001	-0.001	-0.002	-0.001	-0.001
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
X * 1[X ≥ 4]		0.001	0.001	-0.001	-0.000
		(0.002)	(0.001)	(0.002)	(0.002)
X * Male				-0.001	-0.001
				(0.004)	(0.004)
X * 1[X ≥ 4] * Male				0.003	0.003
				(0.003)	(0.003)
Constant	0.034***	0.034***	0.082***	0.030***	0.082***
	(0.004)	(0.004)	(0.027)	(0.006)	(0.027)
Male			×	×	×
Covariates			×		×
N of individuals	3,419	3,419	3,419	3,419	3,419
N of observations	6,838	6,838	6,838	6,838	6,838
R-squared	0.000	0.000	0.016	0.002	0.016

Note: Outcome is the dummy that takes one if the person exhibits multiple switches in either in 2011 (before) or 2012 (after). The rate of multiple switches is 5.8 percent (198 out of 3,419 respondents; 104 in 2011 only, 77 in 2012 only, and 17 in both 2011 and 2012). X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Covariates in Columns (3) and (5) are age, age squared, and income.

Table A5(c). Migration

Outcome	Migration				
	(1)	(2)	(3)	(4)	(5)
X	0.004	-0.002	-0.001	-0.002	-0.001
	(0.007)	(0.010)	(0.009)	(0.011)	(0.011)
X * 1[X ≥ 4]		0.006	0.005	0.007	0.006
		(0.008)	(0.008)	(0.008)	(0.008)
X * Male				0.000	-0.001
				(0.006)	(0.006)
X * 1[X ≥ 4] * Male				-0.003	-0.002
				(0.004)	(0.004)
Constant	0.031	0.038*	0.189***	0.041	0.188***
	(0.020)	(0.023)	(0.067)	(0.026)	(0.067)
Male			×	×	×
Covariates			×		×
N of individuals	3,368	3,368	3,368	3,368	3,368
R-squared	0.002	0.003	0.009	0.004	0.010

Note: Outcome is the dummy that takes one if the person who moved municipalities between surveys in 2011 and 2012. The migration rate is 4.4 percent (147 out of 3,368 respondents). X is the seismic intensity of the Earthquake (*Shindo* in Japanese), a metric of the strength of earthquake at a specific location. Significance level *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors clustered at the municipality are reported in parentheses. Covariates in Columns (3) and (5) are age, age squared, and income.

Table A6. Source of data and variable lists

1. Intensity of the Earthquake

   Detail: http://www.kyoshin.bosai.go.jp/kyoshin/quake/

   Accessed: 12:32pm CST, Sep 13, 2013

   Data on seismic intensity of the Earthquake is obtained from Earthquake and Volcano Data Center, National Research Institute for Earth Science and Disaster Prevention (NIED), Japan. The Center maintains strong-motion seismograph network (K-NET, Kik-net) that includes more than 1,700 observation stations distributed every 20km uniformly covering Japan. The seismic intensity data as well as the geocode information of each observation stations for all major earthquakes in Japan are collected.

2. Radiation

   Detail: https://mapdb.jaea.go.jp/mapdb/portals/60/

   Accessed: 3:55pm CST, March 11, 2014

   Data on radiation is collected by the Airborne Monitoring Survey by the Ministry of Education, Culture, Sports, Science and Technology, Japan. The data was collected by airplane flight with altitudes between 150-300m above ground. The flight paths had width of 5km at most and covers almost all the municipalities in Japan. The air dose rate of radiation (μSv/h) is adjusted to reflect the number at the height of 1m above the ground. This is the only radiation survey that covered all the municipalities across Japan after the Earthquake and the following accident at the Fukushima Daiichi Nuclear Power Plant. The survey was conducted during the period of June 22, 2011 and May 31, 2012. Most of the affected municipalities are surveyed in 2011, while some of the less or almost non-affected areas such Mie, Shiga, Kyoto, Hyogo Shimane, Tottori, and Hokkaido are measured after March 2012.

3. Pre-Earthquake Hazard Prediction

   Detail: http://www.j-shis.bosai.go.jp/download

   Accessed: 12:54pm CST, March 12, 2014

   Earthquake Prediction based on the 2010 report of the National Seismic Hazard Maps for Japan by the Headquarters for Earthquake Research Promotion of the Ministry of Education, Culture, Sports, Science and Technology, Japan. The report presents detailed prediction on the probability of earthquake occurrence at 250m-mesh code level. The prediction combines earthquake occurrence models, seismic source models, and subsurface structure model to calculate the predicted probability of different intensity level at each mesh code level.