The Well-Being of Elderly Survivors after Natural Disasters:

Measuring the Impact of the Great East Japan Earthquake

Saki Sugano

University of Tokyo

Abstract

The Great East Japan Earthquake and resulting tsunami of March 11, 2011 had a devastating impact on the northeastern part of Japan. In the quasi-experimental situation, using panel data collected six months after the earthquake from the Japanese Study of Aging and Retirement (JSTAR), this study examines the causal effects of the disaster on both the economic and psychological well-being of survivors affected by the earthquake and tsunami. The results show that the subjective well-being of female in their 60s survivors significantly dropped. However people in the other age and gender brackets did not exhibit significant diminishment in their life satisfaction in the aftermath of the earthquake. Survivors experienced increases in work hours and wages on average, while reducing their total monthly expenditures and increasing their durable goods expenditure. Since Japan is a developed country with many more resources at its disposal, its ability to launch an early economic recovery may have served as an important buffer protecting the subjective well-being of the survivors.

I especially thank Yasuyuki Sawada and John Strauss for the excellent comments and encouragement. I am grateful for comments made by Hiroko Akiyama, Daniel Benjamin, Robert Dekle, Richard Easterlin, Hideki Hashimoto, Hidehiko Ichimura, Jinkook Lee, Fumio Ohtake, Albert Park, Masahiro Shoji. Financial support from the Japan Society for the Promotion of Science is gratefully acknowledged. This research uses the micro data "Japanese Study of Aging and Retirement (JSTAR)" (Very High) from Research Institute of Economy, Trade and Industry (RIETI), Japan.

1. Introduction

On Friday, March 11, 2011, the Great East Japan Earthquake occurred and triggered a tsunami that hit northeastern Japan. This megathrust earthquake was the most powerful earthquake to have hit Japan on record in terms of the moment magnitude (Mw) 9.0. The powerful tsunami generated by the earthquake had wave heights of at least 3 meters and sometimes more than 20 meters. It damaged and destroyed areas along the coast. 15,885 people died and 6,148 were injured, and 2,626 people are still missing today, according to the National Police Agency. 90% of the deaths from the natural disaster were due to drowning in the tsunami. 52.98% of those who died were female and 64.4% of total deaths included people aged 60 and older. This massive earthquake brought unexpected exogenous shock to people in Japan, causing both destruction of physical capital and psychological damage. This paper aims to explore in more detail how people's lives and well-being have been affected by the earthquake.

This research is the first paper to explore the impact of the Great East Japan Earthquake on elderly people, by looking at a wide range of variables, including subjective well-being, health, consumption and labor status. Using panel data from Japanese Study of Aging and Retirement

(JSTAR) allows us to examine the causal impact of the earthquake in a quasi-natural experimental setting. JSTAR stands as the best dataset to attempt this goal because JSTAR surveyed both areas most damaged by the earthquake and areas not as significantly damaged, both before and after the earthquake, making it a powerful quasi-natural experimental setting.

This study aims to explore several aspects of survivor well-being in the aftermath of the earthquake with the following objectives. First, by studying both the economic and psychological factors, we want to gain a more thorough understanding of survivors of natural disasters. There are few quantitative analyses that estimate a disaster's economic and psychological impact in the same study. The current study may bridge some gaps between economics and other research areas, especially psychology and public health. The rich panel data set used here allows us to investigate the causal effects of the earthquake within multiple domains. Second, this paper examines the vulnerability of elderly survivors. Although Frankenberg et al. (2011) showed that the elderly had higher mortality rates in the Indian Ocean tsunami, their study did not focus on investigating the condition of the elderly who survived. The present study shows how shocks to mental and physical

health vary across age groups, pre-disaster physical capital such as income and assets, and social capital such as relationships with family.

There is a large body of research on how people have been affected by and respond to natural disasters. This area of study continues to grow as the frequency of natural disasters is increasing. Several studies have provided important evidence on the effects of natural disasters on human populations. It is well known that the groups most vulnerable to natural disasters are elderly people and poor people. Frankenberg et al., (2011) using panel data from the Study of Tsunami Aftermath and Recovery (STAR), examined tsunami mortality and its correlation with sex, age, and socio-economic status. They found that among the over 130,000 deaths in the 2004 Indian Ocean Tsunami, children, the elderly, and women had higher mortality rates than men in the prime age range of 15-44. Older women were shown to be the most vulnerable group by sex and age. They are physically weak and are less able to run and evacuate from dangerous areas. This implies that physical strength, swimming ability, and stamina play a role in surviving natural disasters. Even if the elderly people survive, they can be still more exposed to physical and economic hardship because they are more likely to contract diseases and less likely to have an opportunity to work, and

more likely to live without family. In developing countries, poorer people also suffer more from natural disasters because they don't have sufficient access to credit markets nor disaster insurance. Even more, when all members of a group are affected, informal risk-coping strategies break down (Skoufias, 2003).

People are not only damaged economically but also psychologically in the aftermath of natural disasters. Frankenberg et al. (2008) indicates that survivors from coastal Aceh and North Sumatra, Indonesia, which were areas damaged by the Indian Ocean Tsunami in 2004, experienced Post Traumatic Stress Reactions (PTSR). Population-representative interview surveys were conducted both before and after the tsunami and included residents from heavily damaged and indirectly damaged areas. They found the highest PTSR scores for respondents from heavily damaged areas, with scores declining over time. Survivors of Hurricane Katrina reported significant drops in happiness levels, lasting over two or three weeks (Kimball et al., 2006). A review of the literature produced a few studies that examined the effect of the Great East Earthquake on people's subjective well-being. Uchida et al., (2011) reported that after the earthquake, young people aged 20s and 30s in Japan have no change in their happiness level. However, their samples are limited to

the area without Ibaraki prefecture and Tohoku regions that were directly hit by the earthquake, and thus it could not capture the impact on the earthquake survivors' happiness. Another study showed a mix of increases and decreases in subjective well-being after the earthquake (Ishino et al., 2012; Rehdanz et al., 2013; Yamamura et al., 2014). Hanaoka et al., (2014) specifically explored changes in attitudes toward risk in the aftermath of the earthquake, and found that males who experienced the earthquake where there was greater seismic intensity become more risk tolerant As well as natural disasters, terrorist attacks are also used as a quasi-experimental situation and can function as an exogenous variable to estimate the causal effects of the shock. Terrorist attacks also generate enormous psychological stress. Metcalfe et al. (2011) reported that the 9/11 terrorist attack in the United States significantly decreased the subjective well-being of people in Britain. This effect persisted over the following two months, October and November, but in December their well-being showed to have rebounded. Romanov et al. (2010) studied the effect of terrorism on the happiness of Israelis, and found no immediate or delayed effect on the happiness of Jewish Israelis, but adverse affects on the happiness of Arab citizens of Israel. Thus a traumatic event may affect the subjective

well-being of people differently between different countries or within subgroups in the same country.

There is little research with micro data to examine the causal impact of natural disasters on local economies. Belasen and Polachek (2008), using a generalized Difference-in-Difference approach, estimated the causal impact of hurricanes on the labor market in Florida. They found that the average wage rate of the workers in a Florida county rose over 4 percent within the first four months of being hit by a major hurricane compared to counties that were not directly hit. Historically speaking, even in the wake of such catastrophic events like the atomic bombing of Hiroshima or the Hanshin-Awaji earthquake, the economy eventually recovers and nations continue to develop.

The remainder of this paper is organized as follows. Section 2 introduces the data and explains the quasi-natural experiment setting. Section 3 discusses the estimation strategy and section 4 discusses the results, with a summary and possible directions for future research included in section 5.

2. Data

This paper uses two waves of panel data from JSTAR. Since 2007, city level representative surveys have been conducted every two years with the same respondents interviewed in each wave. The first wave in 2007 covered Sendai city in Miyagi Prefecture, Adachi-ku in Tokyo, Sirakawa-cho in Gifu Prefecture, Kanazawa city in Ishikawa Prefecture, and Takikawa city in Hokkaido. JSTAR added two more cities, Naha city in Okinawa prefecture and Tosu city in Saga prefecture, in 2009 and then three more cities, Hiroshima city in Hiroshima prefecture, Chofu city in Tokyo, and Tondabayashi in Osaka, in 2011. The 2011 wave was conducted in September and October, about six months after the Great East Japan Earthquake. Thus by happenstance, JSTAR collected data in Sendai City both before and after the earthquake. Sendai City is located in the most directly damaged area, with about 1,000 deaths and more than 30,000 houses and buildings totally destroyed. Thus the natural disaster is able to function as an exogenous variable in the

present study. We use JSTAR data that was collected in the second and third waves, as it corresponds to the time intervals before and after the earthquake.

The map shows the epicenter of the earthquake, the three directly damaged prefectures, and the seven cities that were included in both the second and third waves of JSTAR's survey, namely Sendai, Kanazawa, Takikawa, Shirakawa, Adachi-ku, Naha, and Tosu. Among the seven cities, Sendai City is the only city in both the second and third waves of the survey that was in one of the more severely affected prefectures.

Using the rich panel dataset, this study analyzes the causal impact of the natural disaster using a Difference-In-Difference approach. We designate Sendai City respondents as the treatment group since they were harmed by the earthquake, and other city respondents as the control group. For these designations to suitably serve in identifying the earthquake effect, we need to assume that direct damage from the earthquake was primarily limited to the area of the treatment group. It is reasonable to assume this because almost all the deaths and buildings destroyed by the earthquake were in that area.

Table 1 shows the sample sizes of each city in JSTAR. The sample size of Sendai City is 603 for 2009 and 475 for 2011. The age distributions of Sendai City respondents aged 50 and over are: 50-59 years old at 27.2%, 60-69 years old 44.4%, and 70 years old and over at 28.3%. A concern about sample selection bias may be raised, regarding whether the number of respondents in Sendai dropped disproportionately due to the earthquake. We address this question as follows. The dependent variable is the dummy variable, which takes a value of one if the respondent participated in the second wave but quit the survey during the third wave. The independent variables are: the Sendai dummy or each city dummy regarding whether the respondent lives in the city or not, age, age squared, three education dummies (junior high school or less dummy, high school dummy, and university dummy), marital status dummy, log of household income, a household pension dummy that indicates whether a respondent or/and a spouse receives a public pension, and IADL, which indicate health status. Table 1 shows that in OLS and probit model, there are no significant coefficients for the Sendai dummy and also Sendai City dummy. As also evident in Table 1, the drop-off rate in Sendai City is no different from other cities. Thus no attenuation bias for Sendai City was detected.

Table 3 shows the summary statistics[1]. The economic variables of interest in this study are labor status and consumption level. JSTAR includes four consumption and expenditure measures: total monthly expenditures except for payment for housing and durable goods, consumption of food, expenditures on dining out, and consumption of durable goods. Information on total monthly expenditures was obtained through the question: "What was the amount of your typical monthly expenditures, excluding housing costs (rent, housing loan payments, etc.) and the purchase of durable goods (television sets, refrigerators, etc.)?" JSTAR asks about consumption of food and dining out with the question: "In a typical month, about how much did you spend on food/dining out (except for payment for house and purchase of durable goods)?" Note that how respondents interpret the phrase "typical month" may introduce measurement errors in the consumption variables. Without a more specific definition available, we assume that the "typical month" referred to in the question is construed by respondents to mean the month after the earthquake. Since the survey was conducted six months after the earthquake and people were

[1] It is well understood that surveyed economic data has a problem of measurement error. We dropped some outliers in economic variables, including consumption amounts and hourly wage rates that may lead to biased results. For the purpose of reducing this potential bias, consumption and wage figures higher than the 95 percentile of our sample are considered to be outliers and eliminated.

busy becoming accustomed to their new lives at the time, it is not unrealistic to consider "a typical month" as a month after the earthquake. Economists often prefer to look at consumption levels instead of income to assess a person's overall economic condition for two key reasons. One, income is often volatile while consumption level is considered to remain more stable over time and thus can better capture normal economic conditions. Second, income has more measurement errors since people sometimes do not answer, or provide untrue answers. Therefore using consumption variables to assess the economic condition of respondents is quite reasonable. The labor variables examined include whether the respondent is employed full time or part time, number of work hours per week, and hourly wage rate.

Regarding the psychological variables used in the present study, while there is no single definition for well-being, researchers from different disciplines use the concept of well-being to tell us how people perceive how well their lives are going (Centers for Disease Control and Prevention). It generally includes the absence of negative emotions, the presence of positive emotions, life satisfaction, fulfillment and positive functioning and economic well-being.

The variable used to measure subjective well-being in the current study is life satisfaction, which was investigated through the JSTAR survey question "Are you satisfied or unsatisfied with your current life?" The respondents could select one of four choices: 1. Satisfied, 2. Fairly satisfied, 3. Somewhat unsatisfied, and 4. Unsatisfied. To convert the responses into the level of life satisfaction variable, I changed these to "life satisfaction = 5 – answer number". Thus if a respondent answered 1, Satisfied, the life satisfaction variable is calculated as 5-1 = 4 and thus put 4 points. If the respondent answers 4, Unsatisfied, it is indicated as 5-4 = 1 and put 1 point. Thus Subjective well-being point takes from 1 to 4 and higher points indicate better.

In addition to life satisfaction as the measure of subjective well-being, the other psychological variable used in the current study is CESD score. The CESD is a widely-used 20 multiple choice questionnaire to measure depression. The 20 questions ask how much of the time over the week prior to the interview did the respondent feel different emotions such as feeling depressed, feeling that everything was an effort, and feeling happy. The respondents could select a value along a four-point scale for each of the 20 questions: "1. Rarely", " 2. Some days (1-2 days)", " 3. Occasionally (3-4 days) ", "4. Most of the time (5-7 days)". For the negative

questions, the answers are scored as 0 for "1. Rarely", 1 for " 2. Some days (1-2 days)", 2 for " 3. Occasionally (3-4 days) ", and 3 for "4. Most of the time (5-7 days)". For the positive questions, the scoring is reversed. Thus the higher the score, the more negative the respondent felt during the past week. CESD is calculated for all respondents who answered at least one of the questions. CESD adds the scores of these 20 items for a total score ranging from 0 to 60. I drop those who select the same number to all 20 questions since these answers are irrational. A higher CESD score indicates greater depressive symptoms.

3. Empirical Strategy

I used the following difference-in-differences (DID) approach to examine the causal effect of the 2011 Great East Japan Earthquake on subjective well-being and health:

$$Y_{int} = \alpha + \beta_1 After_{ijt} + \beta_2 Sendai_{it} + \beta_3 After_{ijt} * Sendai_{it} + \gamma X_{ijt} + u_{ij} + \epsilon_{ijt}$$

Let Y_{ijt} be the variable of interest for respondent *i* in city *j* at wave *t*. The dummy variable 'After' takes on the value of 1 if the respondent was interviewed after the earthquake and 0 otherwise.

The dummy variable 'Sendai' equals 1 for the respondents in Sendai city and 0 otherwise. is other socio economic variables. u_i is an individual fixed effect and is assumed to be uncorrelated with the timing and place of the disaster. Since the earthquake suddenly occurred in the east part of Japan, the coefficient, β_3, of the interaction term *After*Sendai* captures the causal effect of the earthquake, or in other words, the treatment effect. If there was no earthquake or if the earthquake had no significant impact on the treatment group compared to the control group, the coefficient β_3 would be statistically the same as zero and thus indicate no significant differences in the outcome variables before and after the earthquake. Control variables are basically age, age squared, and marital status. Then as a health variable, we add IADL (Difficulty of instrumental activities of daily living) score and it takes 0 (No) to 5 (Most), with a higher score indicating a worse health status. There are other measures to capture health status, such as self-reported health and ADL (Difficulty of activities of daily living). Since self-reported health is a subjective score, it is not advisable to use it as an independent variable to measure a dependent variable which is itself subjective. As for ADL, 3rd wave of JSTAR survey did not collect ADL in 7 cities from 2nd wave. Thus we don't use ADL, but instead IADL. To capture the economic condition of the respondent,

we next add log of household income and pension dummy. Pension dummy takes 1 if a respondent and/or a spouse receive a public pension.

In order to identify the earthquake effect, it is necessary to assume that the direct damage of the earthquake was primarily limited to Sendai city. This is consistent with the fact that almost all deaths and buildings destroyed due to the earthquake occurred in that area. Ohtake & Yamada (2013) found a large geographical heterogeneity between the disaster area and non-disaster areas in what the authors termed "mental cost." It is reasonable to assume that well-being of survivors who live in very damaged areas is fairly different from those in non-damaged areas.

4. Results

4.1 Subjective Well-Being

Did the East Japan earthquake in 2011 cause measurable psychological damage to survivors? Table 4 shows the results from estimating a DID model using OLS, FE, RE and ordered logit on the subjective well-being of people in Sendai City. Table 6 displays the results

estimated with potential explanatory variables for life satisfaction. The interaction coefficient between *Sendai* dummy and *After* dummy is negative in FE and RE, but not significant. Lower IADL, which indicates a better health condition, is correlated to higher life satisfaction. Higher income is also and receiving a public pension also correlate with higher life satisfaction. Thus this stable income appears to play an important role in sustaining the subjective well-being of the elderly during the days and weeks after the disaster.

When we see the results by age gender group in Table 5, life satisfaction levels of females in their 60s showed an additional dip that is correlated to the interaction term. This indicates that this group experienced further distress as a result of the earthquake. Even though the immediate distress caused by the earthquake was enormous for those directly affected, the elderly seemed not to be affected or seemed to have been able to overcome it after six months.

4.2 Health

We see the concern about health status of elderly survivors after the earthquake. There are three variables to capture the health status (both physical and mental health) in JSTAR: CESD,

self-reported health, and IADL. Self-reported health is measured using a scale ranging from 1.(Poor) to 5 (Excellent). Table 6 shows that, overall, there is no significant change in the CESD levels of survivors in Sendai City. Although CESD scores are strongly correlated with self-reported general health, we are not able to say that there is causality between self-reported health and CESD because CESD and self-reported health interact with one another.

When we look at the impact of earthquake on health status by age gender group in Table 7, males in their 50s significantly experienced a deterioration in their IADL level after the earthquake, while females, especially in their 70s, overall seemed to have experienced an improvement in IADL after the earthquake. This may capture the sample selection bias that people who are not in good health are more likely to quit participating in JSTAR in the 3rd wave, which is consistent with the result of selection bias.

Can CESD sufficiently capture respondents mental condition? When we take a look at the detailed CESD questions, Table 8 shows significant psychological damage for people in Sendai City in the aftermath of the earthquake. First, people reported difficulties in sleeping

during the previous week. Second, people reported feeling like crying more often and third, people felt sad more often. Although these detailed mental symptoms are not captured by CESD or subjective well-being, elderly survivors are still suffering in the aftermath of the earthquake.

4.3 Consumption

With these key material effects identified, we now turn to the economic impact of the natural disaster on people in Sendai City. Table 9 shows the results for the consumption variables. Consumption amount per person is calculated as divided by the root of number of family members[2]. The estimates were generated by applying a DID approach on OLS and Fixed Effect. One might anticipate that since many earthquake survivors lost their goods, and even durable goods might have been severely damaged by the huge disaster, the survivors' consumption behavior would change to more modest levels compared to their behavior prior to the disaster and compared to people in other areas who did not experience such material loss. One may expect survivors to try to cut down their consumption levels as much as possible because

[2] The reason why we divide consumption level by the root of the number of household members is because there is an economy of scale in household consumption. When the number of household members doubles, for example from two to four, the consumption does not increase by double but increases by the root of the number of the household members.

their assets and income levels likely plummeted after to the disaster. As Table 4 indicates, such a predicted reduction occurred in total monthly expenditures.

However the results indicate that survivors overall paid more on food consumption and durable goods after the earthquake. The increase in the expenditure on food might have been prompted by the inflation in the price of food. A shortage of many goods overwhelmed Japan during that time, due to multiple factors, including the loss of electricity to fuel industries after the Fukushima Daiichi nuclear power plant failure, and the destruction of fisheries and agriculture throughout many areas of Japan. This corresponding to the findings in Abe et al., (2014) that the price index based on scanner data shows significant increase in commodity prices following the disaster in eastern Japan. The increase in consumption of durable goods has a ready explanation: as durable goods were damaged by the earthquake, people needed to replace them with new ones. Dining out consumption levels generally remained the same before and after the earthquake.

4.4 Labor status

The results on employment in Table 10 suggest that people in Sendai significantly increased their weekly work hours. This likely reflects the need to reconstruct damaged infrastructure in Sendai, which stimulated the city's economy. Following this, hourly wage rates also increased after the earthquake in Sendai City. This resulting recovery in the labor market is consistent with the outcomes reported on the aftermath of the hurricane disasters in Florida (Belasen & Polachek, 2008).

4.5 Heterogeneity and pre-disaster conditions

In general, the difference-in-difference estimation shows that subjective well-being did not change in Sendai City. However the impact may vary depending on the socio-economic status of survivors before the earthquake. A respondent who lives alone may perhaps be more affected than a respondent who lives with family. Or people who are in better economic situations may experience less impact from a disaster than people who have less income or fewer assets. To investigate for these possible different impacts, I estimate with the following equation.

$$
\begin{aligned}
y_{ijt} =& \alpha + \beta_1 After_{ijt} + \beta_2 Sendai_{ijt} + \beta_3 After * Sendai_{ijt} + \beta_4 Z_{ijt} \\
&+ \beta_5 After * Z_{ijt} + \beta_6 Sendai * Z_{ijt} + \beta_7 After * Sendai * Z_{ijt} \\
&+ \beta_8 X + u_j + v_t + \epsilon_{ijt}
\end{aligned}
$$

Z indicates each pre-disaster socio-economic status in a dummy variable: whether a respondent lives alone, whether a respondent works, whether household has a public pension and whether income/housing assets/financial assets[3] is higher than median in city. The coefficient captures the different effects on subgroup Z. Table 11 shows the results. People with higher financial assets before the earthquake than median in the same city reported a significantly greater negative effect on their subjective well-being, compared to people who have less financial assets. However other socio-economic status variables are not shown to have any significant different effects on subjective well-being.

5. Conclusion

[3] Income and assets are imputed by Harmonized JSTAR Stata Code. http://www.g2aging.org

The 2011 Great East Japan Earthquake and resulting tsunami killed thousands of people and caused enormous damage to buildings and infrastructure in the Tohoku area. This study investigated how older adult survivors were coping economically and psychologically in the aftermath of this natural disaster. JSTAR panel data enabled us to do so through looking at survivors' consumption, assets, labor situation, life satisfaction and depression levels. This study helps to build a bridge in natural disaster research between economics and psychology. The results show, with the exception of females aged 65 or less, the psychological well-being of survivors rebounded to pre-natural disaster levels. One reason why the life satisfaction of many survivors does not appear to have been affected by the earthquake can be explained by economics. Early economic recovery efforts in Sendai City likely played a role in the recovery of survivor's psychological well-being as well. The analysis also found that many survivors paid more on food and durable goods, although they cut their total monthly expenditures. In addition, owing to the reconstruction effort, the labor market also showed signs of recovery during the period that the survey was conducted. We found that working Sendai residents generally did not reduce their working hours and experienced increases in their wages after the earthquake. Thus survivors in

the Sendai area were financially able to maintain or increase their consumption, which may have prevented people from experiencing a deterioration in their life satisfaction and mental health. This degree of economic recovery appears to be locally concentrated in Sendai City, rather than more widely and equally distributed in other areas of Japan.

For future research, we need to more carefully explore each individual survivor's situation. With more precise information we could more specifically investigate the relationship between the material damage suffered by survivors and their subsequent economic condition and psychological well-being. Nonetheless, at this stage we can note that compared to Indonesia in the 2004 Indian Ocean Tsunami study, Japan is a developed country with many more economic resources at its disposal. Thus the early economic recovery may have served as an important buffer protecting the subjective well-being of the survivors.

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Map. JSTAR 2nd and 3rd wave surveyed city and earthquake damaged area

Table 1. Sample size by wave and city

	1 wave	2 wave	3 wave
Surveyed City	2007	2009	2011
1. Sendai	908	603	475
2. Kanazawa	1,011	707	549
3. Takikawa	570	455	384
4. Shirakawa	806	697	637
5. Adachi	869	590	430
6. Naha		922	587
7. Tosu		645	510
8. Hiroshima			1,099
9. Chofu			566
10. Tondabayashi			517

Table 2. Selection bias check

Dependent variable = 1 if the respondent answer in wave 2 but do not answer in wave 3				
VARIABLES	OLS	OLS	Probit	Probit
Sendai dummy	-0.00		-0.02	
	(0.012)		(0.065)	
City = Sendai		0.00		0.00
		(0.015)		(0.081)
City = Kanazawa		-0.04**		-0.23**
		(0.015)		(0.092)
City = Takigawa		-0.09***		-0.68***
		(0.014)		(0.098)
City = Shirakawa		0.04***		0.20**
		(0.015)		(0.080)
City = Adachi		0.09***		0.38***
		(0.014)		(0.073)
City = Naha		-0.00		-0.03
		(0.014)		(0.079)
Constant	0.98**	0.92**	1.65	1.18
	(0.409)	(0.407)	(2.136)	(2.207)
Observations	5,977	5,977	5,977	5,977
R-squared	0.011	0.038		

Notes. Control variables include age, age-squared, married dummy, Junior high school of less dummy, high school dummy, university dummy, IADL, log of household income, pension dummy. City reference group is Tosu city.

Table 3. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Male dummy	8191	0.5	0.5	0	1
Age	8188	65.57	7.25	50	80
Age square	8188	4351.9	947.07	2500	6400
Junior school or less dummy	8191	0.31	0.46	0	1
High school dummy	8191	0.42	0.49	0	1
University and above dummy	8191	0.24	0.43	0	1
Married dummy	8191	0.77	0.42	0	1
Log of household income	6797	14.97	0.84	9.61	20.51
Household pension dummy	8170	0.69	0.46	0	1
Life satisfaction	7455	3.13	0.79	1	4
IADL	7558	0.156	0.65	0	5
Self-reported health	8084	3.45	1.04	1	5
CESD	6078	11.71	7.05	0	57
Food consumption	5658	38338	19073.92	0	150000
Dining out consumption	3408	9492.7	14043.59	0	212132
Monthly expenditure	5017	109372.7	71532.91	0	2121320
Durable goods consumption	7218	67880.51	142762.6	0	3700000
Hours of work per week	3492	37.16	15.91	0	70
Wage rate per hour	3356	1406.84	946.57	0	7000
Full time dummy	7857	0.21	0.4	0	1
Part time dummy	7857	0.17	0.37	0	1

Table 4　The causal effect on subjective wel-being (Total)

	(1)	(2)	(3)	(4)
	Dependent Variable: Life satisfaction (1-4)			
VARIABLES	OLS	Fixed Effects	Random Effects	Ordered Logit
After×Sendai	0.022	-0.026	-0.005	0.046
	(0.056)	(0.042)	(0.039)	(0.145)
After	0.035*	0.123	0.028*	0.071
	(0.021)	(0.085)	(0.016)	(0.053)
Sendai	-0.010		-0.008	0.011
	(0.037)		(0.039)	(0.097)
Married	0.147***	-0.001	0.160***	0.377***
	(0.026)	(0.145)	(0.030)	(0.066)
Age	0.091***	0.146*	0.104***	0.218***
	(0.028)	(0.077)	(0.030)	(0.071)
Age square	-0.001***	-0.001***	-0.001***	-0.001**
	(0.000)	(0.001)	(0.000)	(0.001)
Junior high school	0.057		0.088	0.104
	(0.085)		(0.116)	(0.225)
High school	0.038		0.068	0.064
	(0.085)		(0.116)	(0.225)
University	0.074		0.122	0.146
	(0.086)		(0.117)	(0.228)
IADLA	-0.175***	-0.057	-0.159***	-0.416***
	(0.016)	(0.041)	(0.023)	(0.043)
Log of income	0.093***	0.004	0.064***	0.225***
	(0.012)	(0.019)	(0.013)	(0.032)
Pension dummy	0.097***	0.012	0.072**	0.217***
	(0.031)	(0.053)	(0.033)	(0.080)
Constant	-1.953**	-0.699	-2.001**	
	(0.916)	(3.313)	(1.014)	
Observations	6,266	6,266	6,266	6,266
R-squared	0.075	0.010		
Number of id		3,972	3,972	

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 5　The causal effect on subjective well-being (by age and gender)

	(1)	(2)	(3)	(4)
	Male			
	Total	50s	60s	70s
VARIABLES	FE	FE	FE	FE
After×Sendai	-0.003	-0.209	-0.026	0.076
	(0.063)	(0.146)	(0.087)	(0.087)
After	0.068	-0.054	0.271	-0.046
	(0.124)	(0.253)	(0.171)	(0.194)
Constant	-2.046	-6.252	1.857	-0.971
	(4.689)	(17.517)	(9.535)	(15.482)
Observations	3,212	776	1,546	1,213
R-squared	0.014	0.048	0.011	0.022
Number of id	2,008	501	941	745

	(5)	(6)	(7)	(8)
	Female			
	Total	50s	60s	70s
VARIABLES	FE	FE	FE	FE
After×Sendai	-0.049	-0.01	-0.114*	0.14
	(0.056)	(0.131)	(0.067)	-0.099
After	0.191	0.447*	0.047	0.138
	(0.117)	(0.265)	(0.158)	-0.185
Constant	0.819	17.760	-9.926	-5.352
	(4.680)	(17.160)	(9.805)	(15.681)
Observations	3,054	723	1,436	1,168
R-squared	0.015	0.056	0.027	0.010
Number of id	1,964	467	894	753

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Control variable include Age, Age square, Married dummy, IADLA, log of household income, pension

Table 6. The causal effect on health

	(1)	(2)	(3)
	Total	Total	Total
	Self-Reported Health	IADL	CESD20
	FE	FE	FE
After×Sendai	0.02	-0.00	0.62
	(0.058)	(0.028)	(0.433)
After	-0.19*	0.09*	0.63
	(0.107)	(0.053)	(0.836)
Constant	-5.53	3.48*	82.53***
	(3.969)	(1.975)	(30.877)
Observations	8,071	7,540	6,068
R-squared	0.004	0.004	0.008
Number of id	4,576	4,388	3,905

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7 Coefficient of interaction term of health variables (by age and gender)

	(1)	(2)	(3)	(4)
	Male			
	Total	50s	60s	70s
Outcome Variables	FE	FE	FE	FE
Self-reported health	0.08	0.15	0.09	0.04
	(0.084)	(0.174)	(0.115)	(0.140)
IADL	0.06	0.09*	0.04	0.05
	(0.040)	(0.052)	(0.050)	(0.079)
CESD	0.65	0.78	-0.12	0.91
	(0.601)	(1.261)	(0.828)	(0.971)

	(5)	(6)	(7)	(8)
	Female			
	Total	50s	60s	70s
Outcome Variables	FE	FE	FE	FE
Self-reported health	-0.05	-0.07	0.01	-0.18
	(0.080)	(0.171)	(0.110)	(0.135)
IADL	-0.07*	-0.03	-0.01	-0.18**
	(0.039)	(0.042)	(0.044)	(0.086)
CESD	0.63	1.28	0.25	0.36
	(0.623)	(1.290)	(0.820)	(1.177)

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Control variables include age, age squared, and married dummy

Table 8. The causal effect on detailed CESD

VARIABLES	(1) Bothered by things	(2) Poor appetite	(3) Could not shake off blues	(4) Felt as good as others	(5) Trouble keeping mind on task	(6) Felt depressed	(7) Everything was an effort	(8) Felt hopeful	(9) Life was failure	(10) Felt fearful
	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
After×Sendai	0.0393	-0.000644	-0.00643	-0.0301	-0.0385	0.0336	0.0478	0.0766	0.0131	0.0522
	(0.0482)	(0.0298)	(0.0347)	(0.101)	(0.0409)	(0.0456)	(0.0447)	(0.0889)	(0.0433)	(0.0447)
After	0.0252	0.0259*	0	0.0105	0.00621	-0.00448	0.0522***	0.0702**	0.0227	0.0125
	(0.0195)	(0.0138)	(0.0153)	(0.0395)	(0.0173)	(0.0183)	(0.0181)	(0.0315)	(0.0170)	(0.0151)
Constant	0.339***	0.138***	0.174***	0.979***	0.271***	0.343***	0.372***	0.877***	0.301***	0.199***
	(0.00825)	(0.00574)	(0.00640)	(0.0169)	(0.00728)	(0.00777)	(0.00769)	(0.0136)	(0.00726)	(0.00661)
Observations	5,964	6,015	5,969	5,851	5,944	5,957	5,960	5,745	5,932	5,914
R-squared	0.002	0.002	0.000	0.000	0.000	0.000	0.007	0.004	0.001	0.002
Number of id	3,870	3,882	3,869	3,827	3,862	3,863	3,869	3,779	3,858	3,848

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 8. The causal effect on detailed CESD (cont.)

VARIABLES	(11) Sleep was restless	(12) Was happy	(13) Talked less than usual	(14) Felt lonely	(15) People were unfriendly	(16) Enjoyed life	(17) crying	(18) Felt sad	(19) Felt people disliked me	(20) Could not get going
	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
After×Sendai	0.176***	-0.0941	0.0208	0.00865	0.00640	0.0380	0.0734*	0.0858**	0.000641	0.00176
	(0.0490)	(0.0697)	(0.0466)	(0.0467)	(0.0291)	(0.0682)	(0.0411)	(0.0428)	(0.0319)	(0.0499)
After	-0.104***	0.0404	0.00565	0.00791	0.00337	0.0366	0.0231	0.0221	0.0123	0.0335*
	(0.0198)	(0.0281)	(0.0190)	(0.0186)	(0.0133)	(0.0289)	(0.0150)	(0.0173)	(0.0108)	(0.0186)
Constant	0.523***	1.217***	0.316***	0.360***	0.139***	1.297***	0.197***	0.280***	0.127***	0.398***
	(0.00837)	(0.0120)	(0.00803)	(0.00788)	(0.00553)	(0.0122)	(0.00647)	(0.00734)	(0.00471)	(0.00798)
Observations	5,966	5,807	5,929	5,929	5,943	5,823	5,942	5,927	5,957	5,969
R-squared	0.014	0.001	0.000	0.000	0.000	0.001	0.004	0.004	0.001	0.002
Number of id	3,870	3,800	3,855	3,856	3,857	3,805	3,857	3,855	3,860	3,866

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 9. The causal effect on consumption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Monthly expenditure		Food consumption		Dine-out consumption		Durable goods expenditure	
VARIABLES	OLS	FE	OLS	FE	OLS	FE	OLS	FE
After×Sendai	-9,708.88*	-8,475.87**	3,658.61***	3,643.87***	280.93	1,363.97	30,642.99***	30,287.95**
	(5,328.715)	(4,200.559)	(1,368.430)	(1,227.284)	(1,256.452)	(950.479)	(9,741.809)	(13,347.496)
After	5,494.76**	2,371.86	-1,811.04***	-1,654.04	455.41	2,512.82	24,725.29***	11,981.08
	(2,160.752)	(8,941.132)	(540.961)	(2,094.370)	(538.176)	(2,119.266)	(3,653.633)	(21,988.366)
Sendai	27,678.21***		77.01		-909.45		-1,353.64	
	(3,644.106)		(929.731)		(858.194)		(6,582.229)	
Constant	-188,605.01**	-147,496.21	-101,185.29***	-38,500.71	17,983.58	194,584.86**	-229,784.66	-201,459.33
	(81,964.511)	(306,828.962)	(20,628.859)	(74,063.793)	(20,318.817)	(81,537.922)	(140,250.331)	(800,554.758)
Observations	5,016	5,016	5,657	5,657	3,408	3,408	7,217	7,217
R-squared	0.071	0.008	0.071	0.007	0.014	0.014	0.018	0.026
Number of id		3,312		3,598		2,448		4,326

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Control variables include age, age square, married dummy, education dummies.

Table 10. The causal effect on employment: Hours of Work per Week and Hourly Wage

	(1)	(2)	(3)	(4)
	FE	FE	FE	FE
	Work hour per Week			
VARIABLES	Total	Male	Male 50s	Female
After×Sendai	0.93	2.31*	4.05**	-1.54
	(1.149)	(1.378)	(2.031)	(2.050)
After	-5.13**	-6.89***	-1.12	-2.52
	(2.067)	(2.518)	(3.477)	(3.582)
Constant	-158.12**	-169.63*	159.44	-138.31
	(75.325)	(91.566)	(227.493)	(130.783)
Observations	3,488	2,103	816	1,385
R-squared	0.019	0.038	0.027	0.006
Number of id	2,234	1,327	499	907

	(5)	(6)	(7)	(8)
	FE	FE	FE	FE
	Hourly Wage			
VARIABLES	Total	Male	Male 60s	Female
After×Sendai	191.76*	146.18	302.68*	248.10*
	(102.313)	(139.875)	(177.803)	(147.767)
After	-259.92	-174.01	-401.69	-362.61
	(188.951)	(257.686)	(350.823)	(273.169)
Constant	-6,906.24	-3,884.81	-9,901.67	-9,711.89
	(6,871.699)	(9,336.281)	(19,559.757)	(10,000.667)
Observations	3,352	1,949	1,027	1,403
R-squared	0.007	0.009	0.028	0.020
Number of id	2,214	1,280	652	934

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Control variables include age, age square, married dummy.

Table 11. Pre-disaster conditions and the impact on subjective well-being

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: SWB (Life Satisfaction)					
Z	Single	Work	Pension	High income	High housing asset	High financial asset
VARIABLES	FE: Total	FE: Total	FE: Total	FE: Total	FE: Total	FE: Total
After×Sendai	-0.025	-0.004	-0.044	0.050	-0.008	0.128*
	(0.040)	(0.051)	(0.088)	(0.059)	(0.074)	(0.067)
After×Sendai×Z	0.162	-0.008	0.052	-0.148	-0.044	-0.263***
	(0.137)	(0.080)	(0.098)	(0.094)	(0.210)	(0.093)
After	0.157**	0.128*	0.144*	0.123	0.147*	0.176**
	(0.074)	(0.077)	(0.084)	(0.086)	(0.077)	(0.076)
Z	0.142*	0.019	0.056	0.023	0.024	0.025
	(0.079)	(0.045)	(0.051)	(0.036)	(0.032)	(0.030)
After×Z	0.023	0.060*	0.007	0.003	0.006	-0.021
	(0.050)	(0.035)	(0.048)	(0.041)	(0.047)	(0.038)
Sendai×Z	-0.549***	-0.012	-0.109	-0.005	0.032	0.055
	(0.176)	(0.125)	(0.111)	(0.093)	(0.183)	(0.078)
Constant	-0.118	1.702	-0.736	-1.534	-0.304	-0.066
	(2.847)	(2.989)	(3.343)	(3.266)	(2.883)	(2.829)
Observations	7,440	7,408	7,421	6,429	7,440	7,440
R-squared	0.014	0.012	0.012	0.012	0.012	0.015
Number of id	4,364	4,353	4,361	4,051	4,364	4,364

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Appendix: 20 items on the CESD

1	Feeling uneasy about things you would usually not be concerned about
2	Poor appetite
3	Feeling depressed and unable to dispel the gloom despite encouragement from family and friends
4	Feeling capable of doing what an average person can do
5	Unable to concentrate on what you are doing
6	Feeling depressed
7	Feeling troublesome to do something you would usually do effortlessly
8	Feeling optimistic about the future
9	Feeling that your life has been a failure
10	Feeling fearful
11	Poor sleep
12	Feeling happy
13	Talking less than usual
14	Feeling lonely
15	Feeling that people are unfriendly
16	Feeling fun
17	Crying or feeling like crying
18	Feeling sad
19	Feeling that people dislike you
20	Feeling low on energy and finding everything takes effort

Appendix: Question on consumption

[Total monthly expenditure]

What was the amount of your typical monthly expenditures, excluding housing costs (rent, housing loan payments, etc.) and the purchase of durable goods (television sets, refrigerators, etc.)?

[Food consumption]

"In the past 12-month period, how much did you spend on food (excluding eating out) per month on average?"

[Dine out consumption]

In the past 12-month period, did you often eat out, and if you did, how much did you spend on eating out in a typical month?

[Durable goods expenditure]

Does the amount of overall expenditures you just mentioned include all of the items listed here? If not, please include all of them. Also, please make sure that housing costs (rent, housing loan payments, etc.) and the purchase of durable goods (television sets, refrigerators, etc.) are excluded. How would that change the amount?