



RIETI Discussion Paper Series 15-E-069

The Well-Being of Elderly Survivors after Natural Disasters: Measuring the impact of the Great East Japan Earthquake

SUGANO Saki
Kobe University



Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
<http://www.rieti.go.jp/en/>

**The Well-Being of Elderly Survivors after Natural Disasters:
Measuring the impact of the Great East Japan Earthquake**

SUGANO Saki *

Kobe University

Abstract

The Great East Japan Earthquake of March 11, 2011 had a devastating impact on the northeastern part of Japan. In a 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 elderly survivors affected by the earthquake and tsunami. The results show that the subjective well-being of female survivors in their 60s and of those who had high financial assets significantly dropped. However, people in the other age and gender brackets did not exhibit a significant diminishment in their life satisfaction in the aftermath of the earthquake. These latter results may be due partially to the early economic recovery experienced in the surveyed city six months after the earthquake.

Keywords: Great East Japan Earthquake, Elderly, Subjective well-being

JEL Classification: I31, Q54.

RIETI Discussion Papers Series aims at widely disseminating research results in the form of professional papers, thereby stimulating lively discussion. The views expressed in the papers are solely those of the author(s), and neither represent those of the organization to which the author(s) belong(s) nor the Research Institute of Economy, Trade and Industry.

* Graduate School of Economics, Kobe University, 2-1 Rokkodai-cho, Nada-ku, Kobe, Hyogo Prefecture, JAPAN 657-8501
E-mail: sugano@econ.kobe-u.ac.jp,

This study is conducted as a part of the Project “Toward a Comprehensive Resolution of the Social Security Problem: A new economics of aging” undertaken at the Research Institute of Economy, Trade and Industry (RIETI), Japan. This research uses the micro data “Japanese Study of Aging and Retirement (JSTAR)” (Very High) which was conducted by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University and the University of Tokyo. I especially thank Yasuyuki Sawada and John Strauss for the excellent comments and encouragement. I am grateful for comments made by Daniel Benjamin, Robert Dekle, Richard Easterlin, Hideki Hashimoto, Hidehiko Ichimura, Jinkook Lee, Fumio Ohtake, Albert Park, Masahiro Shoji, and participants that attended the RIETI-JER Workshop. Financial support Grant-in-Aid for JSPS Fellows from the Japan Society for the Promotion of Science is gratefully acknowledged.

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 (M_w) 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, expenditure 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 actual data also shows the economic recovery in some perspective about half a year after the earthquake. Graph 1 shows changes in department store sales compared to the same month of the previous year across Japan and specifically Sendai city, one of the biggest cities closest to the epicenter of the earthquake. Two months after the earthquake, Sendai city experienced a huge increase in sales compared to both last year and to the sales average of the whole country in the same year. There are two reasons that may explain this. First, people in the damaged area needed to buy new goods to replace damaged ones. Second, many of them received an insurance payout from a private insurance company and monetary aid from the government. By July 2011, the insurers had paid out about 70% of the estimated total benefit, that is, they had paid one trillion, eight hundred billion yen (about eighteen billion US dollars) out of two trillion, seven hundred billion yen (about twenty billion US dollars) (Financial Service Agency, The Japanese Government). The employment situation also recovered early in some areas. In Miyagi prefecture, the jobs-to-applicants ratio steadily increased after the earthquake (Graph 2). In Sendai city, which is in this prefecture, the ratio was close to one after six months, because Sendai is the biggest city in northeastern Japan and the center of reconstruction after the earthquake. We have to note that the ratio covering inland cities in Miyagi prefecture rose earlier than the ratio spanning the coastal area including Ishinomaki city in Graph 2.

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. Fatalities and damage were particularly concentrated along the coastal areas of Sendai city, while the further inland areas of the city were relatively less affected.

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 prefectures¹. 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.

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 whether the respondent lives in Sendai city or not 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 the two probit models, there are no significant coefficients for the Sendai dummy and also city equals Sendai dummy. As also evident in Table 1,

¹ Sendai city is about 95 km away from Fukushima Daiichi Nuclear Power Plant, and Sendai city officially announced that radiation levels were low enough for safe human exposure.

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 statistics². The economic variables of interest in this study are labor status and expenditure level. JSTAR includes four expenditure measures: total monthly expenditures except for payment for housing and durable goods, expenditure of food, expenditures of dining out, and expenditure 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 expenditure of food and dining out with the question: “In a typical month, about how much did you spend on food/dining out?” Note that how respondents interpret the phrase “typical month” may introduce measurement errors in the expenditure 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 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 expenditure levels instead of income to assess a person’s overall economic condition for two key reasons. One, income is often volatile while expenditure 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 expenditure variables to assess the economic condition of respondents is quite reasonable. The labor variables examined include 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, we changed these to “life satisfaction = 5 – answer number”. Thus if a respondent answered “1. Satisfied”, the life satisfaction variable is

² It is well understood that surveyed economic data has a problem of measurement error. We dropped some outliers in economic variables, including expenditure amounts and hourly wage rates that may lead to biased results. For the purpose of reducing this potential bias, expenditure and wage figures higher than the 95 percentile of our sample are considered to be outliers and eliminated.

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. We 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

We 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:

$$Y_{ijt} = \alpha + \beta_1 \text{After}_{ijt} + \beta_2 \text{Sendai}_{ijt} + \beta_3 \text{After}_{ijt} \times \text{Sendai}_{ijt} + \gamma X_{ijt} + u_i + \varepsilon_{it}$$

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. X_{ijt} 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, third wave of JSTAR survey did not collect ADL in 7 cities from second 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. 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: self-reported health, IADL, and CESD. Self-reported health is measured using a scale ranging from 1 (Poor) to 5 (Excellent).

When we look at the impact of earthquake on health status by age gender group in Table 6, 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 third wave, which is consistent with the result of sample selection bias check in Table 2.

Can CESD sufficiently capture respondents mental condition? When we take a look at the detailed CESD questions, Table 7 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 Expenditure

With these key material effects identified, we now turn to the economic impact of the natural disaster on people in Sendai city. Table 8 shows the results for the expenditure variables. Spending amount per person is calculated as divided by the root of number of family members³. 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' spending 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 expenditure levels as much as possible because their assets and income levels likely plummeted after the disaster. As Table 8 indicates, such a predicted reduction occurred in total monthly expenditures.

However the results indicate that survivors overall paid more on food expenditure 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 accident, and the destruction of fisheries and agriculture throughout northeastern part 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 expenditure 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 expenditure levels generally remained the same before and after the earthquake.

4.4 Labor status

The results on employment in Table 9 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

³ The reason why we divide expenditure level by the root of the number of household members is because there is an economy of scale in household spending. When the number of household members doubles, for example from two to four, the expenditure does not increase by double but increases by the root of the number of the household members.

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.

$$Y_{ijt} = \alpha + \beta_1 \text{After}_{ijt} + \beta_2 \text{Sendai}_{ijt} + \beta_3 \text{After}_{ijt} \times \text{Sendai}_{ijt} + \beta_4 \mathbf{Z} + \beta_5 \text{After}_{ijt} \times \mathbf{Z} + \beta_6 \text{Sendai}_{ijt} \times \mathbf{Z} + \beta_7 \text{After}_{ijt} \times \text{Sendai}_{ijt} \times \mathbf{Z} + \gamma \mathbf{X}_{ijt} + u_i + \varepsilon_{it}$$

\mathbf{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 assets⁴ is higher than median in city. The coefficient β_7 captures the different effects on subgroup \mathbf{Z} . Table 10 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. This might indicate the loss aversion reacting to the earthquake damage. Other socio-economic status variables are not shown to have any significant different effects on subjective well-being.

5. Conclusion

The 2011 Great East Japan Earthquake and resulting tsunami killed thousands of people and caused enormous damage to buildings and infrastructure in the northeastern 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' expenditure, labor situation, life satisfaction and health. This study helps to build a bridge in natural disaster research between economics and psychology. The results show, with the exception of females aged 60s, the psychological well-being of survivors did not change compared 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

⁴ Income and assets are imputed by Harmonized JSTAR Stata Code. <http://www.g2aging.org>

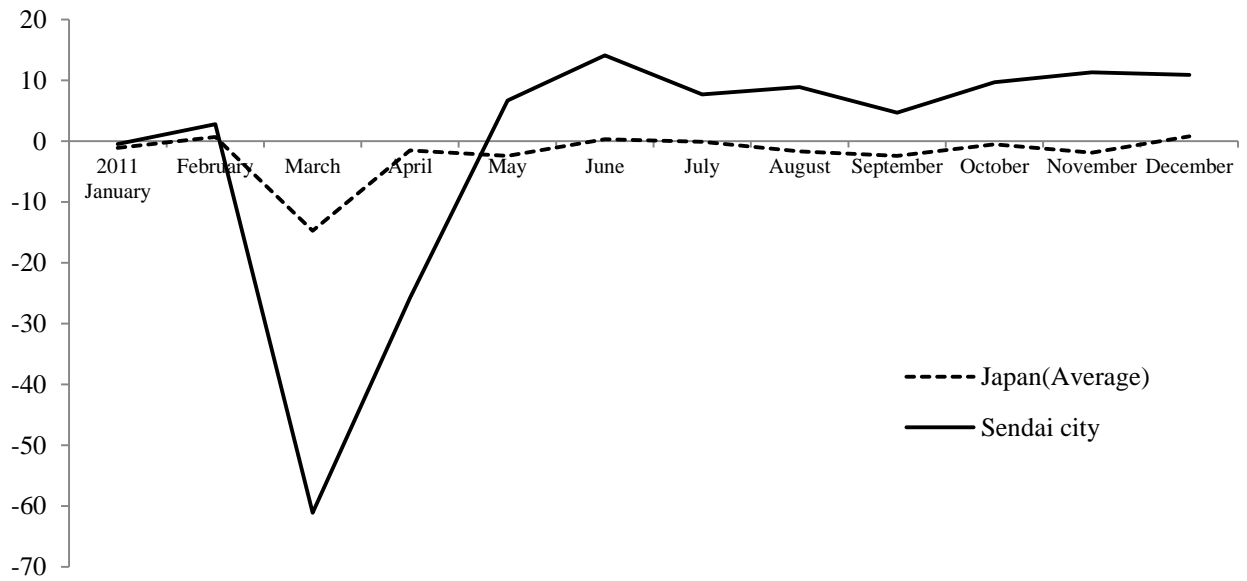
expenditures. In addition, owing to the reconstruction effort, the labor market also showed signs of recovery during the period that the survey was conducted. We found that working Sendai residents generally did not reduce their working hours and experienced increases in their wages after the earthquake. Thus survivors in the Sendai area were financially able to maintain or increase their expenditure, 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 damaged areas. In addition, since Sendai city is large and extends from coastal areas to further inland, the level of damage as well as recovery speed is thought to vary throughout the city. We should note that the results might be underestimated or not be able to capture all the difficulties of survivor's life in the aftermath of the earthquake.

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.

REFERENCES

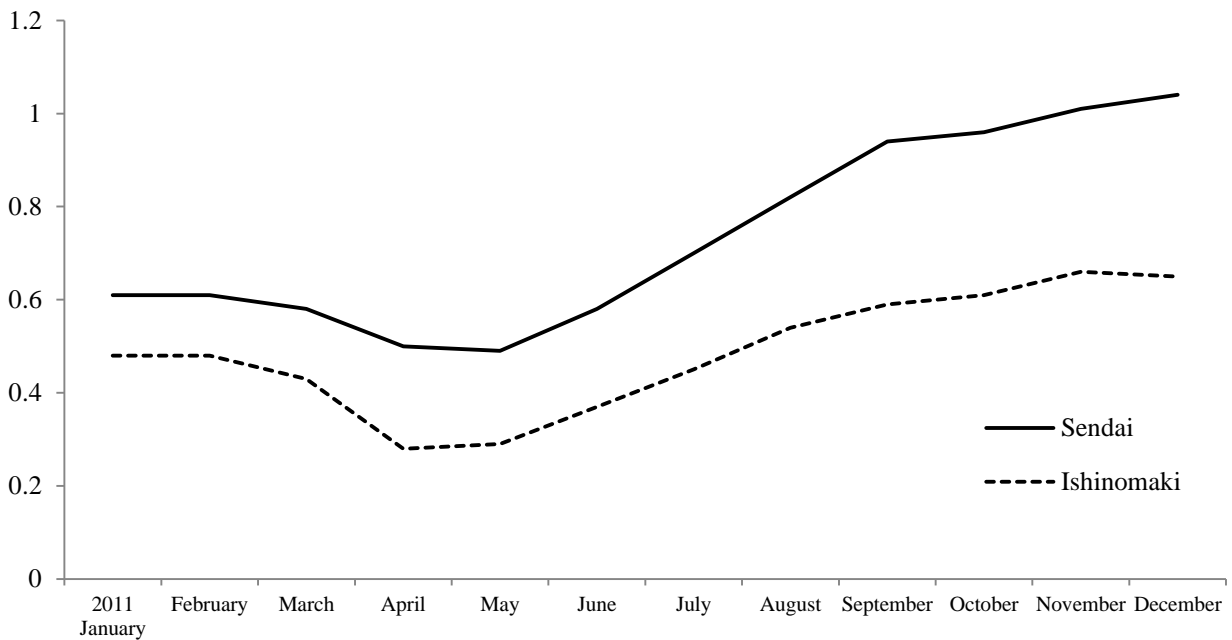
- Belasen A, and Polachek S. (2008) "How Hurricanes Affect Wages and Employment in Local Labor Markets", *The American Economic Review*, 98(2): 49-53.
- Easterlin, R. (2006) "Life Cycle Happiness and Its Sources: Intersections of Psychology, Economics, and Demography", *Journal of Economic Psychology*, 27(4) :463-482.
- Frankenberg, E., Friedman, J., Gillespie, T., Ingwersen, N., Pynoos, R., Rifai, IU., Sikoki, B., Steinberg, A., Sumantri, C., Suriastini, W., and Thomas, D. (2008) "Mental health in Sumatra after the tsunami." *American Journal of Public Health*, Sep; 98(9):1671-7.
- Frankenberg, E., Gillespie, T., Preston, S., Sikoki, B., and Thomas, D. (2011)"Morality, the Family and the Indian Ocean Tsunami", *The Economic Journal*, 121.
- Hanaoka, C., Shigeoka, H., & Watanabe, Y. (2014). "Do Risk Preferences Change? Evidence from Panel Data Before and After the Great East Japan Earthquake". Evidence from Panel Data Before and after the Great East Japan Earthquake (April 15, 2014).
- Ishino, T., Kamesaka, A., Murai, T., & Ogaki, M. (2012). "Effects of the Great East Japan Earthquake on subjective well-being". *Behavioral Economics(Kodokeizaigaku)*, 5(0), 269-272.
- Kimball, M., Levy, H., Ohtake, F., & Tsutsui, Y. (2006). "Unhappiness after hurricane Katrina". National Bureau of Economic Research No. w12062.
- Matsubayashi, T., Sawada, Y., and Ueda, M. (2013) "Natural Disasters and Suicide: Evidence from Japan", *Social Science and Medicine*, 82: 126-133.
- Metcalf, R., Powdthavee, N., and Dolan, P. (2011) "Destruction and distress: Using a Quasi-Experiment to Show the Effects of the September 11 Attacks on Mental Well-Being in the United Kingdom" *The Economic Journal*, 121.
- Nishio, A., Akazawa, K., Shibuya, F., Abe, R., Nushida, H., Ueno, Y., et al. (2009). "Influence on the suicide rate two years after a devastating disaster: a report from the 1995 Great Hanshin-Awaji Earthquake", *Psychiatry and Clinical Neurosciences*, 63(2): 247-250.
- Ohtake, F., & Yamada, K. (2013). "Appraising the unhappiness due to the Great East Japan Earthquake: Evidence from weekly panel data on subjective well-being". ISER Discussion Paper, No. 876. Institute of Social and Economic Research, Osaka University.
- Rehdanz, K., Welsch, H., Narita, D., & Okubo, T. (2013). "Well-being effects of a major negative externality: The case of Fukushima". Kiel Working Paper, No. 1855.
- Romanov, D., Zussman, A., and Zussman, N. (2012), "Does Terrorism Demoralize? Evidence from Israel". *Economica*, 79(313): 183-198.
- Skoufias, E. (2003). "Economic crises and natural disasters: coping strategies and policy implications", *World Development*, vol. 31(7), pp. 1087–102.
- Uchida, Y., Takahashi, Y., & Kawahara, K. (2014). "Changes in hedonic and eudaimonic well-being after a severe nationwide disaster: The case of the great east Japan earthquake". *Journal of Happiness Studies*, 15(1), 207-221.
- Yamamura, E., Tsutsui, Y., Yamane, C., Yamane, S., & Powdthavee, N. (2014). "Trust and Happiness: Comparative Study Before and After the Great East Japan Earthquake". *Social Indicators Research*, 1-17.

Graph 1. Changes in department store sales volume across Japan and Sendai city in 2011 compared to the previous year 2010



(Data source: Japan Department Stores Association)

Graph 2. The jobs-to-applicants ratio in Miyagi prefecture in 2011



(Data source: Miyagi Labour Bureau)

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



Table 1. JSTAR sample size by wave and city

Surveyed City	2 wave (2009)	3 wave (2011)
1. Sendai	603	475
2. Kanazawa	707	549
3. Takikawa	455	384
4. Shirakawa	697	637
5. Adachi	590	430
6. Naha	922	587
7. Tosu	645	510

Table 2. Selection bias check

Dependent variable = 1 if the respondent answer in wave 2 but do not answer in wave 3		
	(1)	(2)
	Probit	Probit
Sendai dummy	-0.03 (0.064)	
City = Sendai (City reference group is Kanazawa city.)		-0.01 (0.079)
City = Takikawa		-0.24*** (0.090)
City = Shirakawa		-0.64*** (0.094)
City = Adachi		0.18** (0.078)
City = Naha		0.37*** (0.070)
City = Tosu		-0.01 (0.076)
Age	-0.06 (0.060)	-0.06 (0.061)
Age square	0.00 (0.000)	0.00 (0.000)
Married dummy	-0.14** (0.056)	-0.08 (0.057)
Junior high school or less dummy	0.05 (0.199)	0.29 (0.206)
high school dummy	-0.01 (0.199)	0.13 (0.206)
university dummy	-0.06 (0.202)	0.02 (0.209)
IADL	0.08** (0.032)	0.06* (0.033)
log of household income	0.06** (0.027)	0.08*** (0.028)
pension dummy	-0.02 (0.066)	-0.01 (0.067)
Constant	0.63 (1.965)	-0.00 (2.021)
Observations	6,376	6,376
R-squared		

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

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 expenditure	5658	38338	19073.92	0	150000
Dining out expenditure	3408	9492.7	14043.59	0	212132
Monthly expenditure	5017	109372.7	71532.91	0	2121320
Durable goods expenditure	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

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

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

Dependent Variable: Life satisfaction (1-4)				
	Male			
	Total	50s	60s	70s
After×Sendai	-0.003 (0.063)	-0.209 (0.146)	-0.026 (0.087)	0.076 (0.087)
After	0.068 (0.124)	-0.054 (0.253)	0.271 (0.171)	-0.046 (0.194)
Constant	-2.046 (4.689)	-6.252 (17.517)	1.857 (9.535)	-0.971 (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
	Female			
	Total	50s	60s	70s
After×Sendai	-0.049 (0.056)	-0.01 (0.131)	-0.114* (0.067)	0.14 -0.099
After	0.191 (0.117)	0.447* (0.265)	0.047 (0.158)	0.138 -0.185
Constant	0.819 (4.680)	17.760 (17.160)	-9.926 (9.805)	-5.352 (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 dummy.

Table 6. The causal effects on health variables by age and gender: Fixed effects estimation

Dependent Variable: Self-Reported Health									
	Total	Male				Female			
		Total	50s	60s	70s	Total	50s	60s	70s
After×Sendai	0.02	0.08	0.15	0.09	0.04	-0.05	-0.07	0.01	-0.18
	(0.058)	(0.084)	(0.174)	(0.115)	(0.140)	(0.080)	(0.171)	(0.110)	(0.135)
Observations	6,068	2,940	758	1,397	1,092	3,128	763	1,427	1,211
Dependent Variable: IADLA									
	Total	Male				Female			
		Total	50s	60s	70s	Total	50s	60s	70s
After×Sendai	-0.00	0.06	0.09*	0.04	0.05	-0.07*	-0.03	-0.01	-0.18**
	(0.028)	(0.040)	(0.052)	(0.050)	(0.079)	(0.039)	(0.042)	(0.044)	(0.086)
Observations	7,540	3,756	929	1,776	1,438	3,784	885	1,738	1,489
Dependent Variable: CESD20									
	Total	Male				Female			
		Total	50s	60s	70s	Total	50s	60s	70s
After×Sendai	0.62	0.65	0.78	-0.12	0.91	0.63	1.28	0.25	0.36
	(0.433)	(0.601)	(1.261)	(0.828)	(0.971)	(0.623)	(1.290)	(0.820)	(1.177)
Observations	6,068	2,940	758	1,397	1,092	3,128	763	1,427	1,211

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

Note: Control variables include after dummy, age, age squared, married dummy.

Table 7. The causal effect on detailed CESD: Fixed effects estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Bothered by things	Poor appetite	Could not shake off blues	Felt as good as others	Trouble keeping mind on task	Felt depressed	Everything was an effort	Felt hopeful	Life was failure	Felt fearful
After×Sendai	0.039 (0.048)	-0.001 (0.030)	-0.006 (0.035)	-0.030 (0.101)	-0.039 (0.041)	0.034 (0.046)	0.048 (0.045)	0.077 (0.089)	0.013 (0.043)	0.052 (0.045)
Observations	5,964	6,015	5,969	5,851	5,944	5,957	5,960	5,745	5,932	5,914
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
VARIABLES	Sleep was restless	Was happy	Talked less than usual	Felt lonely	People were unfriendly	Enjoyed life	crying	Felt sad	Felt people disliked me	Could not get going
After×Sendai	0.176*** (0.049)	-0.094 (0.070)	0.02 (0.047)	0.009 (0.047)	0.006 (0.029)	0.038 (0.068)	0.073* (0.041)	0.086** (0.043)	0 (0.032)	0.001 (0.050)
Observations	5,966	5,807	5,929	5,929	5,943	5,823	5,942	5,927	5,957	5,969

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

Note: Control variables include After.

Table 8. The causal effect on expenditure

Dependent Variable:	Monthly expenditure		Food expenditure		Dine-out expenditure		Durable goods expenditure	
	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***
	(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 9. The causal effect on employment: Fixed effects estimation

	Dependent Variable: Work hour per Week			
	Total	Male	Male 50s	Female
After×Sendai	0.93 (1.149)	2.31* (1.378)	4.05** (2.031)	-1.54 (2.050)
After	-5.13** (2.067)	-6.89*** (2.518)	-1.12 (3.477)	-2.52 (3.582)
Constant	-158.12** (75.325)	-169.63* (91.566)	159.44 (227.493)	-138.31 (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

	Dependent Variable: Hourly Wage			
	Total	Male	Male 60s	Female
After×Sendai	191.76* (102.313)	146.18 (139.875)	302.68* (177.803)	248.10* (147.767)
After	-259.92 (188.951)	-174.01 (257.686)	-401.69 (350.823)	-362.61 (273.169)
Constant	-6,906.24 (6,871.699)	-3,884.81 (9,336.281)	-9,901.67 (19,559.757)	-9,711.89 (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 10. Pre-disaster conditions and the impact on subjective well-being

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

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