The Health Effects of the Great East Japan Earthquake: A Difference-in-Differences Approach, Using the Panel Data from the Japan Study for Aging and Retirement

Michio Yuda[†] and Jinkook Lee[‡]

[October 5, 2018]

Abstract

On March 11th, 2011, the Great East Japan Earthquake (GEJE) and massive tidal waves hit the approximately 400 kilometer-length of the Pacific coasts and wreaked devastating damage to residences and communal societies. Using the three waves of panel data from the Japan Study for Aging and Retirement (JSTAR) before and after the GEJE, we examine the effect of the catastrophic natural disaster in 2011 on health, using a Difference-in-Differences (DD) model and find significant negative impact on the afflicted people's health. Considering a discontinuous decline in the copayment rate for medical care at age 70 in the Japanese public health insurance system, we further examine both the direct and indirect health effects through changing medical and long-term care utilization. We find that the GEJE disaster had a heavily negative impact on the afflicted people's health and that their medical and long-term formal care utilization after the earthquake decreased their health deterioration. We also find that a discontinuous decline in the copayment rate for medical care at age 70 in the Japanese public health insurance system increases medical and long-term care utilization, and this copayment reduction increases long-term care utilization and also has positive effects on health in the long-term.

Keywords: the Great East Japan Earthquake; difference-in-differences; health; income effect; substitution effect; health insurance; difference-in-difference-in-differences

JEL Classification Codes: I10; Q54

[†] Graduate School of Economics and Management, Tohoku University, Japan
[‡] Department of Economics & Center for Social and Economic Research, University of Southern California, United States of America

1. Introduction

On March 11th, 2011, the Great East Japan Earthquake (GEJE) and massive tidal waves induced by the earthquake hit the approximately 400 kilometer-length Pacific side of the Japanese archipelago; the Iwate, Miyagi, and Fukushima prefectures. It also wreaked devastating damage to residences and communal societies, and contributed to the nuclear accident at the Fukushima Daiichi Nuclear Power Plant. According to the Fire and Disaster Management Agency in Japan (2013), the GEJE was a 9.0 magnitude earthquake, the largest on record in Japan and the fourth largest in the world since 1900 and led to 15,373 deaths, 7,731 missing persons, 5,517 injuries, and 142,683 evacuees three months after the earthquake.

Although several empirical studies around the world have already found that the large natural disaster seriously affected health and increased medical care utilization (Kahn, 2005; Deschenes and Moretti, 2005; Frankenberg, et al, 2011; Sotomayor, 2013; and Currie and Maya, 2013), there were only handful of studies examining the health effect of the 2011 GEJE disaster[1]. Nishigori et al. (2014) uses a sample recruited from 15 hospitals and 11 clinics in the coastal area of Miyagi prefecture to explore the correlation between the impact of the GEJE and the incidence of postpartum depression. They find that exposure to the tsunami is significantly and independently associated with depression among postnatal women. Yonekura et al. (2014) uses a sample of 63 individuals to examine how the GEJE affects mental health, using salivary cortisol levels as markers of depression. They find that 22% of the sample are included in the "high depression group" after the GEJE. Tomata et al. (2015) uses monthly municipal insurer-aggregate panel data from January 2011 to January 2014 to compare the effect of the GEJE on disability prevalence. The results of their analysis of variance indicate that disability prevalence in coastal and inland disaster areas is higher than that in non-disaster areas. Sone et al. (2016) uses panel data for 2011 and 2013 for 959 individuals living in the Wakabayashi Ward in Sendai City, Ajishima City, Ishinomaki City, and Oshika City in the Miyagi prefecture to examine the longitudinal association between social isolation and psychological distress after the GEJE. They find that prevention of social isolation may be an effective public health strategy for preventing psychological distress after a natural disaster. Murakami et al. (2017) uses the same data used in Sone et al. (2016) to examine the relationship between housing type and alcohol consumption by comparing their liver functions (γ-GTP levels) at health check-ups in both 2010 and 2013. Their fixed effect

[1] On the other hand, there are already several economic studies on the effect of 2011 GEJE disaster on happiness and well-being (Yamamura, et al., 2015; Sugano, 2016; Okuyama and Inaba, 2017), risk preference (Naoi, et al., 2012; Jiang, et al., 2013; Hanaoka, et al., 2017), labor market (Higuchi, et al., 2012), and macroeconomics (Ando and Kitamura, 2012; Hosoe, 2014).

estimation result indicates that disaster victims who moved to temporary housing or rental housing are at highest risk of negative health effects due to alcohol drinking. Tsuboya et al. (2016) and Tsuboya et al. (2017) use data from the Japan Gerontological Evaluation Study, conducted in Iwanuma City in the Miyagi prefecture in 2010 and 2013, to examine the effect of the GEJE on changes in depressive symptoms and instrumental activities of daily living. Their results indicate that complete loss of a house has a significant negative effect on health indicators.

However, these previous studies have a serious identification problem. First, since the sample used in the most of the studies only consists of residences in the disaster-afflicted area, their estimates include the effect of both the GEJE disaster and other nationwide common shocks during the same period (year fixed effect) in Japan. In addition, since the sample size of the most of them is small, it is hard to interpret their results as a general effect. Moreover, since their basic statistical methods are not enough to control for unobserved heterogeneity among individuals and regions, their estimates are biased due to omitted variable and selectivity.

In this study, we focus on the 2011 GEJE disaster, a localized natural experiment, to firstly examine the effect of the catastrophic natural disaster on afflicted people's health and their demand for medical and long-term cares by using a difference-in-differences (DD) model and a comprehensive panel survey in Japan, the *Japan Study for Aging and Retirement* (JSTAR). The JSTAR has great advantages for this study. First, the study region of the JSTAR incidentally includes Sendai City, which is near the epicenter and was catastrophically damaged by the earthquake and massive tidal waves (Figure 1). Second, as the elderly populations in the afflicted area especially tend to suffer grave health damage (e.g, Frankenberg, et al., 2011), this study can estimate more detailed health effects of the disaster for the middle-aged more aged people. Third, since a natural disaster has various damaging effects, it is also important to examine the comprehensive effects rather than some specific changes. Minutely understanding the experiences of health injury and the medical provision system in the afflicted area shortly after the unexpected natural disaster would considerably underestimate the associated losses.

<Figure 1>

We find that the GEJE disaster had a heavily negative impact on the afflicted people's health and that their medical and long-term formal care utilization after the earthquake decreased their health deterioration. We also find that a discontinuous decline in the copayment rate for medical care at age 70 in the Japanese public health insurance system increases medical and long-term care utilization,

and this copayment reduction increases long-term care utilization and also has positive effects on health in the long-term.

In the next section, we discuss the details of our data. In section 3, we provide our estimation strategy and show the basic results. In section 4, we present further empirical results to consider the effect of the health insurance policy for the elderly in Japan. In section 5, we provide our conclusions.

2. Data and measurements

We use data from the JSTAR, a panel survey of the middle-aged and elderly population of Japan, which is conducted by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University, and the University of Tokyo every two years since 2007. The JSTAR is one of the *Health Retirement Study* family-surveys and collects information on the health and socioeconomic characteristics of respondents and their family members through a self-completion questionnaire and a computer-assisted personal interview[2].

The JSTAR sampled five municipalities (Adachi-Ku, Kanazawa City, Sendai City, Shirakawa City, and Takigawa City) in 2007, an additional two municipalities (Naha City and Tosu City) in 2009, and an additional three (Chofu City, Hiroshima City, and Tonbayashi City) in 2011, bringing the total to ten municipalities. Its respondents are persons aged 50 to 75 and are randomly selected from the Basic Resident Register. The JSTAR uses its sampling strategy so as to allow analysts to compare economic activities of individuals under the same circumstance. The average baseline response rates for all municipalities is 61.3% (ranging from 45.9% to 87.8%), and average retention rates in the follow-up waves is 86.1% (ranging from 69.4% to 96.4%).

Figure 1 shows the JSTAR study regions and their maximum seismic intensity scales (*Shin-do* in Japanese) of the GEJE[3]. The seismic intensity scale describes the scale of ground motion at a particular location. The maximum scale of the GEJE was 7.0 in Kurihara-City which was about 60 kilometers north of Sendai. That of Sendai ranged from 6 lower to 6 higher, which destroyed more than 30,000 houses completely and more than 100,000 houses partially, and the intensity decreases

[2] See Ichimura, Shimizutani, and Hashimoto (2009) as well as the more recent and detailed information is available on the website of the *GATEWAY TO GLOBAL AGING DATA* (https://g2aging.org/).

[3] Appendix 1 provides more detailed explanation. The maximum seismic intensity scale of the GEJE was 7.0 which is the largest scale in Japan and is about the same as Great Hanshin-Awaji Earthquake in 1995 (M 7.3) and Niigata Chuetsu earthquake in 2004 (M 6.8).

with distance from the epicenter . Since the GEJE was a localized natural disaster, we can set Sendai residents as the treatment group of the natural experiment and residents of other municipalities as the control group.

We use the three waves of the JSTAR for seven municipalities: Adachi, Kanazawa, Shirakawa, Sendai, Takigawa, Tosu and Naha. Table 1 presents the summary statistics for the study sample[4]. Health indicators in this study are subjective health, chronic disease condition, functional health condition, psychological health condition (depression symptom), and poor memory function. Subjective health is a 1-to-5 ordinal variable with 1 indicating very good self-reported health and 5 indicating very poor health and other health indicators are binary variables, and higher values represent poorer health. The mean of subjective health is 2.75 which reveals that the population is on average healthy, but 77.3 percent of the sample has more than one chronic disease. In addition, 19.7 percent and 17.8 percent of the sample have problems with their functional and psychological health conditions, respectively. 36.3 percent of the sample also has problems with memory function. Regarding care utilization, 57.8 and 39.1 percent of the sample uses outpatient care and dental care, respectively. Also, 9.6 percent have experienced hospitalization in the past 5 years. On the other hand, very few people use public long-term care services. Regarding individual characteristics, 50.5 percent are female, and the respondents have an average age of 65.1 years and 11.9 years of education. In addition, 78.5 percent are married, 10.3 percent are widowed, and 2.7 percent have dependents. Their mean gross yearly household income is 2.45 million yen and their mean amount of household financial assets is 5.03 million yen. Moreover, 53.5 percent own real estate in the form of a house and/or land.

<Table 1>

Table 1 also shows summary statistics by groups. The mean of subjective and functional health conditions for the treatment group is significantly better than those in the control group, but psychological health for the treatment group is worse than that of the controls. On the other hand, no significant differences in chronic disease and poor memory function between the two groups. Regarding care utilization, utilization rates of outpatient and dentistry for the treatment group are significantly higher. In addition, monthly usage of dentistry care for the treatment group is more than those in the control group, but inpatient and in-home formal care for the treatment group is less than those in the control group. For other characteristics, the mean values of years of education, household

[4] Detailed definitions are summarized in the Table A2 in the Appendix 2.

income and financial assets are significantly higher for the treatment group compared to those in the control group. On the other hand, the mean values of age and the ratio of real estate holder are significantly lower for the treatments than those of the controls.

Figure 2 compares the yearly proportions of health indicators by group. Because the JSTAR survey in 2011 was conducted about 6 months after the GEJE, the changes of Sendai residents from 2009 to 2011 can be regarded as being influenced by the GEJE disaster. Subjective health improves from 2007 to 2009, but worsens in 2011, with the treatment group reporting worse health compared to the control group. Chronic disease proportions also improve from 2007 to 2009. But in 2011, the proportion of the treatment group with chronic diseases exceeds that of the control group. Physical health conditions of each group remains at about the same level from 2007 to 2009, and gets worse in 2011, getting much worse with the treatment group. In 2007, the proportions of depression and poor memory function are the same level for both groups, but in 2009 and 2011, the treatment group performs much worse than the control group.

<Figure 2A-E>

3. Estimation model and Basic result

3.1 Estimation strategy

As the GEJE disaster is a localized natural disaster, we use a DD approach to examine the effect of the disaster on health. For comparison, the effect of the GEJE disaster estimated in previous studies is the average change in health and medical care utilization in the afflicted area. As we define Y_t as health status or medical care utilization in period t, it is denoted as $\mathrm{E}[Y_1 - Y_0 | Treat = 1]$, where *Treat* is an indicator variable, which equals one for the afflicted area, and zero otherwise. However, this includes the effect of both the GEJE disaster and other nationwide common shocks during the same period. To identify the true effect of the GEJE disaster, we utilize the average changes in the non-afflicted area as its counterfactual, which can be denoted as $\mathrm{E}[Y_1 - Y_0 | Treat = 0]$. Since this change only includes nationwide common shocks around the GEJE disaster, we can identify the average treatment effect of the GEJE disaster by taking the difference (*DD*): $\mathrm{DD} = \mathrm{E}[Y_1 - Y_0 | Treat = 1] - \mathrm{E}[Y_1 - Y_0 | Treat = 0]$. The key assumption for identification in the DD model is the common trend assumption, which is that the trends of health in the both groups would be similar

without treatment. As shown in Figure 2, every health indicator of the both groups except psychological health has a similar trend from 2007 to 2009 and obviously has different trends from 2009 to 2011.

Our specified DD model is:

$$Y_{it} = \alpha_0 + \alpha_1 \cdot After_t + \alpha_2 \cdot Terat_i + \alpha_3 \cdot (After_t \cdot Treat_i) + \mathbf{x_{it}\alpha_x} + \mathbf{z_{it}\alpha_z} + c_i + u_{it} \quad (1)$$

Y_{it} is an individual i's health indicators, with higher values representing worse health conditions in year t as mentioned in the previous section. $After_t$ is equal to one for the sample in 2011 representing after the GEJE and is zero otherwise. $Treat_i$ is equal to one for a Sendai resident and is zero otherwise. α_3 is a DD estimator representing the average treatment effect of the GEJE disaster on health, and α_3 is expected to be positive when the GEJE disaster has an adverse effect on health.

$\mathbf{x_{it}}$ includes individual i's socio-economic status, such as age, marital status, yearly gross household income, amount of household financial assets, indicators of having family dependents and owning real estate (housing and/or land). In addition, $\mathbf{z_{it}}$ includes local specific macro characteristics that would also affect health and care utilization, such as medical institution density, nursing care facility density, the unemployment rate, and a financial capability index. The density of medical institutions is the number of institutions per 100,000 people, and that of nursing care facilities is the number of facilities per 1000 people aged 65 and over. They capture accessibility to medical and long-term formal care services that also have good effects on health. The unemployment rate is a proxy for the economic condition because several empirical studies find that the business fluctuation also affects the population's health and medical care utilization in several developed countries (Ruhm, 2000, 2003, 2005; Gerdtham and Ruhm, 2006; and Haaland and Telle, 2015). The financial capability index, which is defined as the three-year average of the ratio of the standard financial revenue to standard financial need[5], indicates the condition of the public finances of local governments. Local governments with fiscal hardship may reduce their budget for public medical institutions by overhauling the number of staffs and medical equipment, or by not actively carrying out health promotion measures, which would have a largely negative effect on health in the area. c is an individual fixed effect and u is an error term. In addition, we take the first-difference (FD) to eliminate individual effect c (Wooldridge, 2010), and estimate Eq.(2) by ordinary least squares (OLS).

$$\Delta Y_{it} = \alpha_1 + \alpha_3(After_t \cdot Treat_i) + \Delta\mathbf{x_{it}\alpha_x} + \Delta\mathbf{z_{it}\alpha_z} + \Delta u_{it} \quad (2)$$

[5] See Doi and Ihori (2009, Ch.7) more detailed explanation.

In this model, the OLS estimators of α_1 and α_3 still represent the year effect and the average treatment effect of the GEJE disaster on health, respectively. In addition, we estimate clustered robust standard errors that allow correlated residuals within municipalities to accommodate any serial correlation (Bartland, et al., 2004). By the way, it should be noted that sample attrition problem would be serious especially in the third wave of the JSTAR because the GEJE disaster wreaked devastating damages to the Tohoku distinct. Appendix 3 provides our in advance check whether sample attrition affects the empirical results. The response rate in the follow-up survey of Sendai City in 2011 is as same as their average and increases more by 7.5 percent point than that in 2009. However, the probit estimation result suggests that Sendai respondents significantly continue to participate in the JSTAR survey. To control this adverse attrition bias, we employ the inverse weighting model[6] (Robins, et al., 1995; Wooldridge, 2002; 2007).

3.2. Empirical results

Table 2 shows the average treatment and time effects of the GEJE disaster (DD estimator) on health indicators[7]. Regardless of the combinations of independent variables, the DD estimators are positively estimated in the all models, which indicates that the GEJE disaster had an adverse effect on all health indicators. In particular, the GEJE disaster had the largest effect on memory function, and also significant negative impacts on subjective health conditions, chronic diseases, and functional health. The effect size is relatively smaller on psychological health[8].

<Table 2>

4. Further Analysis

The DD estimators indicate that the GEJE disaster had a negative impact on health in the

[6] The usual empirical results without considering sample attrition are the same as those of the inverse weighting model.

[7] We also estimate by using the 3 years balanced panel data for five municipalities and the 2 years balanced panel data for seven municipalities for robustness check. Tables A4, A5, and A6 in the appendix 4 summarizes the results that are quite similar result to Table 2.

[8] The reason may be that there is a possibility that the common trend assumption does not hold in the psychological health in the Figure 2(D).

afflicted area, but it is necessary to consider the characteristics of the Japanese public health insurance system when investigating Japanese elderly's health and medical and long-term formal care utilization patterns. Specifically, we have to consider the effect of a discontinuous decline in the copayment rate for medical care from 30 percent to 10 percent at age 70. Shigeoka (2014) and Fukushima et al. (2016) use the regression discontinuity design method and find that this discontinuous cost-sharing reduction increases the elderly's medical care utilization. Since this facing price decline is regarded as an income effect, the consumption pattern could change at age 70. For example, those aged 70 and over may not only increase medical care utilization, but also long-term formal care utilization and usage of other goods through the substitution effect; and increased usage of care services could improve the elderly's health conditions. Therefore, the DD estimators in the previous section include both the direct effect of the GEJE disaster on health and the indirect effect of an increase in care utilization due to the income and substitution effects. Separating out these effects is useful to deepen our understanding of how the utilization of medical and long-term care service contributes to the health restoration of the afflicted elderly. In addition, this indicates that the DD estimator α_3 may be underestimated and that the parameters are overestimated in previous studies (Shigeoka, 2014, and Fukushima et al., 2016). In addition, using lengthy individual panel data and DD approach enables us to firstly estimate the long-term effect of the discontinuous cost-sharing reduction at age 70, while the previous RDD studies only focus on the short-term effect.

To do so we use a difference-in-difference-in-differences (DDD) model to identify these direct and indirect effects.

$$\begin{aligned} Y_{it} &= \beta_0 + \beta_1 \cdot Treat_i + \beta_2 \cdot After_t + \beta_3 \cdot Policy_{it} \\ &+\beta_4 \cdot (Treat_i \cdot After_t) + \beta_5 \cdot (Treat_i \cdot Policy_{it}) + \beta_6 \cdot (After_t \cdot Policy_{it}) \\ &+\beta_7 \cdot (Treat_i \cdot After_t \cdot Policy_{it}) + \mathbf{x_{it}\beta_x} + \mathbf{z_{it}\beta_z} + c_i + u_{it} \quad (3) \end{aligned}$$

Policy is a policy dummy variable that equals one if an individual i is 70 years or older, and the coefficient β_3 and β_6 represent the overall policy effect in the other municipalities before and after the GEJE disaster, respectively. β_4 is the DD estimator that represents the direct effect of the GEJE disaster on health and is expected to be positive as with Eq.(1). Since β_7 is the DDD estimator that captures the policy effect after the earthquake in Sendai, it can be interpreted as the indirect effect that is due to the income or substitution effect of the discontinuous copayment reduction at age 70. Specifically, if β_7 is negatively estimated, it indicates that income and/or substitution effects reduces their health deterioration by the GEJE disaster. In addition, β_5 represents the overall policy effect in Sendai before

the GEJE disaster, which is comparable with β_7. We then estimate the following FD equation.

$$\Delta Y_{it} = \beta_2 + \beta_3 \cdot Policy_{it} + \beta_4 \cdot (Treat_i \cdot After_t) + \beta_5 \cdot (Treat_i \cdot Policy_{it})$$
$$+\beta_6 \cdot (After_t \cdot Policy_{it}) + \beta_7 \cdot (Treat_i \cdot After_t \cdot Policy_{it}) + \Delta \mathbf{x_{it}} \boldsymbol{\beta_x} + \Delta \boldsymbol{z_{it}} \boldsymbol{\beta_z} + \Delta u_{it} \quad (4)$$

In addition, we also estimate the following Eq.(5) to examine the specific effects of the disaster and how the health insurance policy affects the demand for medical and long-term care services, which is useful for the interpretation of the results.

$$\Delta C_{it} = \gamma_2 + \gamma_3 \cdot Policy_{it} + \gamma_4 \cdot (Treat_i \cdot After_t) + \gamma_5 \cdot (Treat_i \cdot Policy_{it})$$
$$+\gamma_6 \cdot (After_t \cdot Policy_{it}) + \gamma_7 \cdot (Treat_i \cdot After_t \cdot Policy_{it}) + \Delta \mathbf{x_{it}} \boldsymbol{\gamma_x} + \Delta \boldsymbol{z_{it}} \boldsymbol{\gamma_z} + \Delta e_{it} \quad (5)$$

C is a proxy for medical and long-term care utilization. Specifically, *C* is a dummy variable that equals one when individual *i* utilizes outpatient care, inpatient care, dentistry care, in-home formal care, or admission to nursing formal care. *C* also can be a count variable of the number of days per month in the above cares. If the policy variables have a significantly positive effect on medical care utilization, the income effects found in Shigeoka (2014) and Fukushima et al. (2016) exist. Conversely, the substitution effect exists if they have a significant positive effect on long-term care utilization. In addition, the DDD estimator represents the effect of an inhibitive effect of health deterioration due to the GEJE disaster, and the DD estimator therefore represents the effect of the GEJE disaster on medical and long-term care utilization. *e* is an error term.

4.1. Effects on Care Utilization

Table 3 shows the effects on the demand for medical and long-term formal care services. The results of the DD estimators indicate that utilization of inpatient and in-home formal care significantly increases after the GEJE disaster, which indicates that there is a great needs for these services aftermath the disaster. In addition, the DDD estimator of nursing formal care home admission is significantly positive, with the copayment decrease for medical care at age 70. However, in the original JSTAR data, no Sendai respondents used facility care from 2007 to 2009 but some of them using it appeared in the 2011 survey. Therefore, this result should be carefully interrupted because we cannot identify whether this increase arose before or after the GEJE disaster on the data. On the other hand, the DD estimator of outpatient utilization is significantly negative, which indicates that patients

in the afflicted area could not receive outpatient medical care just after the GEJE because most medical staff were treating hospitalized patients afflicted by the GEJE as well as the increases in inpatient and formal care. In addition, the coefficients of the policy dummy variable for outpatient, inpatient, dentistry, and in-home long-term care utilization are significantly positive. The results of medical cares are consistent with Shigeoka (2014) and Fukushima, et al. (2016) and suggest that the income effect exists. In addition, the positive effect on in-home informal care utilization indicates that the substitution effect also exists. However, the coefficients of the interaction between $After_t$ and $Policy_{it}$ for the outpatient and dental cares are significantly negative, which suggests that these income effects decrease in the long-term. On the other hand, the coefficient of in-home formal care is still significantly positive, which suggests that the substitution effect remains. That is, those aged 70 and over in Japan generally shift the demand from the medical care services to long-term care ones. In addition, Sendai residents before the GEJE have a larger income effect for outpatient, smaller income effect for inpatient, and smaller substitution effect for in-home formal care.

These characteristics of the income and substitution effects are also observed in the results on the number of days per month. However, the days for outpatient and dentistry in Sendai before the GEJE are less than those in the other municipalities. In addition, DD estimators for outpatient and dentistry are significantly negative and that for in-home formal care is significantly positive, as with their utilization. Regarding the DDD estimators, the significantly positive effect on dentistry is newly found and other effects are similar to the results of utilization.

<Table 3>

4.2. Effects on Health

Table 4 shows the effects on health, and the DD estimators are significant and positive for all health indicators, in line with the previous results in Table 2. These results still show that the GEJE disaster had a negative impact on the afflicted people's health. However, the sizes of each DD estimator, except psychological health, are larger than those obtained in Table 2. In addition, the effects of the DDD estimators except psychological health are significantly negative. These results indicate that increase in medical and long-term care utilization by the afflicted people after the earthquake has reduced their health deterioration. In terms of econometrics, this also means that DD estimators in Table 2 are underestimated because the they include both the negative direct effect of the GEJE disaster and the positive indirect effect of medical and long-term care utilization. In addition,

although the copayment decrease for medical care at age 70 have only a limited positive effect on subjective health and chronic health condition before the GEJE, it has a definitely positive impact on subjective health and chronic and functional health conditions in the long-term. In particular, it has significantly positive effects on all health indicators in Sendai before the GEJE. That is, this health policy contributes to improvement in health conditions of the Japanese elderly in the long term.

<Table 4>

5. Concluding remarks

In this paper, we use the JSTAR to examine the effect of the 2011 GEJE disaster on the health and demand for medical and long-term care of afflicted people by using a DD approach. We find that the GEJE disaster had a heavily negative impact on the afflicted people's various health conditions, and that their medical and long-term care utilization after the earthquake protected against further health deterioration. We also find that a discontinuous decline in the copayment rate for medical care at age 70 in the Japanese public health insurance system increases medical and long-term care utilization though the income and substitution effects. Especially, the copayment reduction for medical care remains to increase long-term care utilization and also has positive effects on health in the long-term.

These results imply that the government needs to organize the system to immediately provide medical and long-term care services for those afflicted by unforeseen catastrophic disasters. In addition, the existence of the substitution effect due to a decrease in the copayment rate for medical care at age 70 suggests that the government needs to design comprehensive policy reform plans for the health and long-term care systems and to ensure their financial sustainability to provide highly cost-effective services for long periods.

Our work has some limitations. First, the current JSTAR datasets does not have the actual medical and long-term care service records of the respondents. To fulfill the aforementioned policy reform design, it is necessary to employ more detailed information, such as claims data. In addition, the generalizability of our findings is confined with the representativeness of the JSTAR sample, which is representative of 10 municipalities. However, to the best of our knowledge, there is no nationally representative data with a large enough sample in affected area of the GEJE disaster with repeated observations on health and health care utilization before and after the GEJE. Finally, it may

need to consider more detailed information on patient's copayment in the afflicted area. In Miyagi prefecture including Sendai City, the central and prefectural governments temporarily covered all copayments of medical expenditures for the patients with the GEJE disaster-victim's certificate, which is provided to those with property damage. Since the JSTAR do not have the information on individual damage situation, it is unclear how this policy affects the results. However, to the extent of the changes in real estate holding in Figure A1 in Appendix 5, this effect is vanishingly small. Further analyses using other, nationally representative data would help confirm our findings.

Acknowledgment

We thank the JSTAR team of the RIETI for their support. This study was financially supported by research grants from the Japan Society for Promotion of Science (No.26780180 and No. 18K01665) and the National Institute on Aging (2 R01 AG030153). We benefited from thoughtful discussion among the seminar participants of *Japan-Singapore Academic Forum on Aging* at Singapore Management University. The authors assume responsibility for any errors.

References

Ando, Mitsuyo and Fukunari Kimura (2012) "How did the Japanese exports respond to two crises in the international production networks? The global financial crisis and the Great East Japan Earthquake," *Asian Economic Journal*, Vol.26(3), pp.261-287.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan (2004) "How Much Should We Trust Differences-In-Differences Estimates?," *Quarterly Journal of Economics*, Vol.119(1), pp.249-275.

Currie, Janet and Rossin-Slater Maya (2013) "Weathering the storm: Hurricanes and birth outcomes," *Journal of Health Economics*, Vol.32(3), pp.487-503.

Deschenes, Olivier and Enrico Moretti (2005) "Extreme weather events, mortality, and migration," *Review of Economics and Statistics*, Vol.91(4), pp.659-681.

Doi, Takero and Toshihiro Ihori (2009) *The Public Sector in Japan: Past Developments and Future Prospects*, Edward Elgar Publishing: Cheltenham.

The Fire and Disaster Management Agency in Japan (2013) *Report on the Great East Japan Earthquake in 2011*, No.128, http://www.fdma.go.jp/bn/higaihou/pdf/jishin/128.pdf (in Japanese).

Frankenberg, Elizabeth, Thomas Gillespie, Samuel Preston, Bondan Sikoki, and Duncan Thomas (2011) “Mortality, the family and the Indian ocean tsunami,” *Economic Journal*, Vol.121(554), pp.F162-182.

Fukushima, Kazuya, Sou Mizuoka, Shunsuke Yamamoto, and Toshiaki Iizuka (2016) “"Patient Cost Sharing and Medical Expenditures for the Elderly,” *Journal of Health Economics*, Vol.45, pp.115-130.

Gerdtham, Ulf-G. and Christopher J. Ruhm (2006) “Deaths rise in good economic times: Evidence from the OECD,” *Economics & Human Biology*, Vol.4(3), pp.298-316.

Haaland, Venke Furre and Kjetil Telle (2015) “Pro-cyclical mortality across socioeconomic groups and health status,” *Journal of Health Economics*, Vol.39, pp.248-258.

Hanaoka Chie, Hitoshi Shigeoka, and Yasutora Watanabe (2018) “Do risk preferences change? Evidence from the Great East Japan Earthquake,” *American Economic Journal: Applied Economics*, Vol.10(2), pp.298-330.

Higuchi, Yoshio, Tomohiko Inui, Toshiaki Hosoi, Isao Takabe, and Atsushi Kawakami (2012) “The impact of the Great East Japan Earthquake on the labor market: Need to resolve the employment mismatch in the disaster-stricken areas,” *Japan Labor Review*, Vol.9(4), pp.4-21.

Ichimura, Hidehiko, Satoshi Shimizutani, and Hideki Hashimoto (2009) “JSTAR First Results 2009 Report,” *RIETI Discussion Paper Series,* No.09-E-047, pp.1-305.

Jiang, Ying Ying, Yoshihiro Asai, and Souichiro Moridaira (2013) “On household insurance demand and loss control: Evidence from the Great East Japan Earthquake,” *International Journal of Business*, Vol.18(4), pp.332-350.

JSTAR datasets, produced by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University, and the University of Tokyo, are distributed by RIETI in Tokyo, Japan.

Kahn, Matthew E. (2005) “The death toll from natural disasters: The role of income, geography, and institutions,” *Review of Economics and Statistics*, Vol.87(2), pp.271-284.

Murakami, Aya, Yumi Sugawara, Yasutaka Tomata, Kemmyo Sugiyama, Yu Kaiho, Fumiya Tanji, and Ichiro Tsuji (2017) “Association between housing type and g-GTP increase after the Great East Japan Earthquake,” *Social Science and Medicine*, Vol.189, pp.76-85.

Naoi, Michio, Miki Seko, and Takuya Ishino (2012) “Earthquake risk in Japan: Consumers’ risk mitigation responses after the Great East Japan Earthquake,” *Journal of Economic Issue*, Vol.46(2), pp.519-529.

Nishigori, Hidekazu, Junichi Sugawara, Taku Obara, Toshie Nishigori, Kineko Sato, Takashi Sugiyama, Kunihiro Okamura, and Nobuo Yaegashi (2014) “Surveys of postpartum depression

in Miyagi, Japan, after the Great East Japan Earthquake," *Archives of Women's Mental Health*, Vol.17(6), pp.579-581.

Okuyama, Naoko and Yoji Inaba (2017) "Influence of natural disasters on social engagement and post-disaster well-being: The case of the Great East Japan Earthquake," *Japan and the World Economy*, Vol.44, pp.1-13.

Robins, James M., Andrea Rotnitzky, and Lue Ping Zhao (1995) "Analysis of semiparametric regression models for repeated outcomes in the presence of missing data," *Journal of American Statistical Association*, Vol.90(429), pp.106-121.

Ruhm, Christopher J. (2000) "Are recessions good for your health?" *Quarterly Journal of Economics*, Vol.115(2), pp.617-650.

Ruhm, Christopher J. (2003) "Good times make you sick," *Journal of Health Economics*, Vol.22(4), pp.637-658.

Ruhm, Christopher J. (2005) "Healthy living in hard times," *Journal of Health Economics*, Vol.24(4), pp.341-363.

Shigeoka, Hitoshi (2014) "The effect of patient cost sharing on utilization, health and risk protection," *American Economic Review*, Vol.104(7), pp.2152-2184.

Sone, Toshimasa, Naoki Nakaya, Yumi Sugawara, Yasutake Tomata, Takashi Watanabe, and Ichiro Tsuji (2016) "Longitudinal association between time-varying social isolation and psychological distress after the Great East Japan Earthquake," *Social Science and Medicine*, Vol.152, pp.96-101.

Sotomayor, Orlando (2013) "Fetal and infant origins of diabetes and ill health: Evidence from Puerto Rico's 1928 and 1932 hurricanes," *Economics & Human Biology*, Vol.11(3), pp.281-293.

Sugano, Saki (2016) "The well-being of elderly survivors after natural disasters: Measuring the impact of the Great East Japan Earthquake," *Japanese Economic Review*, Vol.27(2), pp.211-229.

Tomata, Yasutake, Yoshinori Suzuki, Miyuki Kawado, Hiroya Yamada, Yoshitaka Murakami, Makiko Naka Mieno, Yosuke Shibata, Toshiyuki Ojima, Shuji Hashimoto, and Ichiro Tsuji (2015) "Long-term impact of the 2011 Great East Japan Earthquake and tsunami on functional disability among older people: A 3-year longitudinal comparison of disability prevalence among Japanese municipalities," *Social Science and Medicine*, Vol.147, pp.296-299.

Tsuboya, Toru, Jun Aida, Hiroyuki Hikichi, S V Subramanian, Katsunori Kondo, Ken Osaka, and Ichiro Kawachi (2016) "Predictors of depressive symptoms following the Great East Japan earthquake: A prospective study," *Social Science and Medicine*, Vol.161, pp.47-54.

Tsuboya, Toru, Jun Aida, Hiroyuki Hikichi, S V Subramanian, Katsunori Kondo, Ken Osaka, and Ichiro Kawachi (2017) "Predictors of decline in IADL functioning among older survivors

following the Great East Japan earthquake: A prospective study," *Social Science and Medicine*, Vol.176, pp.34-41.

Wooldridge, Jeffrey M. (2002) "Inverse probability weighted M-estimators for sample selection, attrition, and stratification," *Portuguese Economic Journal*, Vol.1(2), pp.117-139.

Wooldridge, Jeffrey M. (2007) "Inverse probability weighted estimation for general missing data problems," *Journal of Econometrics*, Vol.141(2), pp.1281-1301.

Wooldridge, Jeffrey M. (2010) *Econometric Analysis of Cross Section and Panel Data*, The MIT Press: Cambridge.

Yamamura, Eiji, Yoshihiro Tsutsui, Chisako Yamane, Shoko Yamane, Nattavudh Powdthavee (2015) "Trust and happiness: Comparative study before and after the Great East Japan Earthquake," *Social Indicators Research*, Vol.123(3), pp.919-935.

Yonekura, Takashi, Kazunori Takeda, Vivek Shetty, and Masaki Yamaguchi (2014) "Relationship between salivary cortisol and depression in adolescent survivors of a major natural disaster," *Journal of Physiological Sciences*, Vol.64(4), pp.261-267.

Appendix 1. Seismic Intensity scale

Seismic intensity scale defined by the Japan Meteorological Agency (JMA) is an indicator that describes the scale of the ground motion at a particular location. It varies with the distance from the epicenter and the surface geology at each point. Table A1 summarizes the JMA's seismic intensity scale has 10 degrees: 0 (imperceptible), 1, 2, 3, 4, 5 lower (5-), 5 upper (5+), 6 lower (6-), 6 upper (6+), and 7.

<Table A1>

Appendix 2. Definition of the variables

Table A2 summarizes the definitions of the variables for our empirical analysis.

<Table A2>

Appendix 3. Probit Estimation for Checking the Attrition Bias

As mentioned in section 2, the JSTAR survey in 2011 was conduced approximately 6 months after the GEJE. However, the huge disaster may lead to sample attrition, which would influence the estimation results. We check in advance that possibility by comparing the response rates and by employing the following probit model for the respondents in 2009 survey.

$$\Pr(Cont_i = 1) = \delta_0 + \delta_1 \cdot Treat_i + \mathbf{x_i}\boldsymbol{\delta_x} + \boldsymbol{z_i}\boldsymbol{\delta_z} + \varepsilon_i$$

Where, *Cont* is a binary variable that equals one for the individual who continuously responds in the 2011 survey, and zero otherwise. If the Sendai residents more drop out of the 2011 survey than those in the other municipalities due to the GEJE disaster, δ_1 is significantly and negatively estimated.

Figure A1 summarizes the response rates in the follow-up surveys in the JSTAR by municipality. Those of Sendai are in line with the averages in each wave, which indicates sample attrition has little impact on the empirical results. In addition, Table A3 presents the estimation results. Contrary to the expectation, δ_1 is significant but positive, which indicates that Sendai residents more continuously tend to participate in the follow-up survey in 2011 than those in the other municipalities. To control the adverse attrition bias, we employ the inverse weighting model (Robins et al., 1995; Wooldridge, 2002; 2007).

<Figure A1>
<Table A3>

Appendix 4. The empirical results using the balanced panel data

Tables A4 to A6 summarize the same analysis in the paper using 3 years of balanced panel data for five municipalities and the 2 years of balanced panel data for seven municipalities as a robustness check. The results are similar to those in the text.

<Table A4>
<Table A5(i) & (ii)>

<Table A6>

Appendix 5. Yearly proportions of Real Estate Holding by Group

Figure A2 shows the yearly proportions of real estate holding by group. The proportions in the both groups decrease in 2009 and increase in 2011, and there is the insignificant difference in 2011. this effect is vanishingly small.

<Figure A2>

Table 1. Summary Statistics

Sample	All			Sendai			Other 6 municipalities			Mean difference test	
Variables	N	Mean	SD	N	Mean	SD	N	Mean	SD	Difference	SE
Health indicators											
Subjective health	11208	2.745	0.734	1867	2.693	0.738	9341	2.755	0.733	-0.062***	(0.019)
Chronic disease	10312	0.773	0.419	1630	0.777	0.416	8682	0.773	0.419	0.005	(0.011)
Functional health	12238	0.197	0.398	1963	0.162	0.369	10275	0.204	0.403	-0.042***	(0.009)
Depression	9634	0.178	0.383	1622	0.195	0.396	8012	0.175	0.380	0.020*	(0.011)
Poor memory function	9115	0.363	0.481	1564	0.363	0.481	7551	0.363	0.481	0.001	(0.013)
Care utilization											
Outpatient utilization	8254	0.578	0.494	1396	0.607	0.488	6858	0.572	0.495	0.036**	(0.014)
day	8254	1.091	2.328	1396	1.160	2.407	6858	1.077	2.312	0.084	(0.070)
Inpatient utilization	10323	0.096	0.294	1717	0.098	0.298	8606	0.095	0.293	0.003	(0.008)
day	10323	2.424	15.372	1717	1.870	12.374	8606	2.535	15.901	-0.665*	(0.344)
Dentistry utilization	12067	0.391	0.488	1925	0.465	0.499	10142	0.377	0.485	0.087***	(0.012)
day	12067	3.002	6.514	1925	3.767	6.962	10142	2.857	6.415	0.910***	(0.171)
In-home formal care utilization	14356	0.003	0.053	2448	0.002	0.045	11908	0.003	0.055	-0.001	(0.001)
day	14356	0.070	2.294	2448	0.016	0.390	11908	0.081	2.512	-0.065***	(0.024)
Nursing formal care home admission	14351	0.000	0.022	2448	0.001	0.029	11903	0.000	0.020	0.000	(0.001)
day	14351	0.426	23.826	2448	0.515	19.589	11903	0.408	24.608	0.106	(0.456)
Individual characteristics											
Female	14069	0.505	0.500	2372	0.498	0.500	11697	0.507	0.500	-0.009	(0.011)
Age	14059	65.060	7.245	2372	64.429	7.010	11687	65.189	7.285	-0.760***	(0.159)
Years of education	12653	11.940	2.425	2348	12.668	2.324	10305	11.774	2.417	0.894***	(0.054)
Married	12240	0.785	0.411	1977	0.795	0.404	10263	0.783	0.412	0.011	(0.010)
Widowed	12240	0.103	0.304	1977	0.097	0.296	10263	0.104	0.305	-0.008	(0.007)
Dependents	14356	0.027	0.212	2448	0.034	0.223	11908	0.026	891.226	0.008	(0.005)
Household income (10 thousand yen)	13929	245.764	829.426	2349	264.361	404.270	11580	241.991	0.500	22.370*	(11.754)
Household financial asset (10 thousand yen)	14112	502.966	2191.989	2411	575.084	1327.373	11701	488.106	2330.391	86.978**	(34.567)
Real estate holder	14356	0.535	0.499	2448	0.485	0.500	11908	0.545	0.209	-0.060***	(0.011)
Aggregated variables											
Medical institutions density [1]	14356	83.985	15.239	2448	90.211	0.683	11908	82.705	16.440	7.507***	(0.151)
Long-term care facility density [2]	14356	40.267	13.993	2448	44.643	5.259	11908	39.367	15.020	5.276***	(0.174)
Unemployment rate [3]	14356	4.719	1.323	2448	5.559	0.658	11908	4.546	1.358	1.013***	(0.018)
Financial capability index [4]	14356	0.766	0.309	2448	0.846	0.013	11908	0.750	0.337	0.096***	(0.003)

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively.

Sources: [1] *Survey of Medical Institutions*, the Ministry of Health, Labour, and Welfare, [2] *Survey of Institutions and Establishments for Long-term Care*, the Ministry of Health, Labour, and Welfare, [3] *Labour Force Survey*, the Ministry of Internal Affairs and Communications, and [4] *Annual Statistical Report on Local Government Finance*, the Ministry of Internal Affairs and Communications.

Table 2. Effects of the GEJE on Health

Health indicators	*After* × *Treat*	*After*	Obs. / R^2	**x**	**z**
Subjective health	0.124***	-0.031	4620	No	No
	(0.019)	(0.019)	0.001		
	0.123***	-0.032	4617	Yes	No
	(0.020)	(0.021)	0.004		
	0.103**	-0.037	4617	Yes	Yes
	(0.031)	(0.031)	0.010		
Chronic disease	0.109***	-0.094***	4263	No	No
	(0.015)	(0.015)	0.005		
	0.104***	-0.089***	4260	Yes	No
	(0.014)	(0.015)	0.010		
	0.077**	-0.091***	4260	Yes	Yes
	(0.025)	(0.024)	0.031		
Functional health	0.074***	0.027*	5341	No	No
	(0.011)	(0.011)	0.002		
	0.074***	0.028**	5338	Yes	No
	(0.010)	(0.011)	0.003		
	0.071***	0.023*	5338	Yes	Yes
	(0.012)	(0.010)	0.008		
Depression	0.028***	0.008	3448	No	No
	(0.005)	(0.005)	0.000		
	0.029***	0.008	3445	Yes	No
	(0.005)	(0.005)	0.001		
	0.045***	-0.003	3445	Yes	Yes
	(0.009)	(0.007)	0.002		
Poor memory function	0.201***	0.000	3155	No	No
	(0.046)	(0.046)	0.004		
	0.187***	0.010	3153	Yes	No
	(0.040)	(0.043)	0.010		
	0.185***	-0.015	3153	Yes	Yes
	(0.041)	(0.043)	0.043		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Table 3. Effects of the GEJE on Care Utilization by the DDD model

	Treat × After × Policy	*Treat × After*	*Treat × Policy*	*After × Policy*	*Policy*	*After*	Obs. / R^2	**x**	**z**
Utilization									
Outpatient	0.101	-0.200***	0.047*	-0.440***	0.113***	-0.022	2750	No	No
	(0.076)	(0.023)	(0.020)	(0.065)	(0.022)	(0.023)	0.072		
	0.100	-0.193***	0.045*	-0.441***	0.116***	-0.028	2749	Yes	No
	(0.082)	(0.025)	(0.021)	(0.065)	(0.022)	(0.025)	0.074		
	-0.120	-0.007	-0.002	-0.091	0.034	-0.122**	2749	Yes	Yes
	(0.086)	(0.051)	(0.044)	(0.070)	(0.026)	(0.043)	0.147		
Inpatient	0.023	0.032***	-0.036***	0.029	0.040***	-0.004	4060	No	No
	(0.025)	(0.005)	(0.002)	(0.025)	(0.006)	(0.005)	0.004		
	0.022	0.035***	-0.036***	0.033	0.038***	-0.006	4058	Yes	No
	(0.027)	(0.005)	(0.003)	(0.025)	(0.007)	(0.005)	0.006		
	0.015	0.029***	-0.032***	0.039	0.036***	-0.003	4058	Yes	Yes
	(0.025)	(0.002)	(0.006)	(0.023)	(0.006)	(0.002)	0.007		
Dentistry	0.066	-0.123***	0.016	-0.258***	0.061**	-0.066**	5222	No	No
	(0.035)	(0.020)	(0.013)	(0.029)	(0.019)	(0.020)	0.022		
	0.060	-0.121***	0.016	-0.260***	0.065**	-0.068**	5219	Yes	No
	(0.035)	(0.021)	(0.013)	(0.030)	(0.018)	(0.021)	0.023		
	-0.006	-0.050*	-0.021	-0.105**	0.014	-0.091***	5219	Yes	Yes
	(0.048)	(0.024)	(0.028)	(0.033)	(0.015)	(0.022)	0.038		
In-home formal care	0.002	0.004***	-0.004**	0.013**	0.004**	0.000	5349	No	No
	(0.004)	(0.000)	(0.001)	(0.004)	(0.001)	(0.000)	0.01		
	0.002	0.004***	-0.004**	0.012**	0.004**	0.000	5346	Yes	No
	(0.004)	(0.000)	(0.001)	(0.004)	(0.001)	(0.000)	0.009		
	0.004	0.006***	-0.005***	0.011**	0.004**	-0.001	5346	Yes	Yes
	(0.004)	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	0.010		
Nursing formal care home admission	0.017***	0.000	0.000	0.002	0.000	0.000	5348	No	No
	(0.003)	(0.000)	.	(0.003)	.	(0.000)	0.007		
	0.017***	0.000	0.000	0.002	0.000	0.000	5345	Yes	No
	(0.003)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	0.007		
	0.017***	0.000	0.000	0.003	0.000	0.000	5345	Yes	Yes
	(0.002)	(0.001)	(0.000)	(0.003)	(0.000)	(0.000)	0.009		

Number of Days									
Outpatient	0.341*	-0.339***	-0.348**	-0.808***	0.411**	-0.132***	2750	No	No
	(0.162)	(0.034)	(0.137)	(0.146)	(0.148)	(0.034)	0.011		
	0.324*	-0.322**	-0.339**	-0.790***	0.411**	-0.141***	2749	Yes	No
	(0.165)	(0.042)	(0.140)	(0.148)	(0.144)	(0.038)	0.012		
	0.243	-0.016	-0.413***	-0.597***	0.369**	-0.314***	2749	Yes	Yes
	(0.132)	(0.097)	(0.105)	(0.141)	(0.117)	(0.083)	0.015		
Inpatient	2.033	0.021	-2.953***	1.064	1.846***	0.342	4060	No	No
	(1.675)	(0.232)	(0.415)	(1.633)	(0.414)	(0.232)	0.004		
	2.037	0.061	-2.932***	1.144	1.801***	0.281	4058	Yes	No
	(1.670)	(0.302)	(0.405)	(1.614)	(0.388)	(0.277)	0.004		
	1.850	-0.815	-2.706***	1.100	1.828***	0.777*	4058	Yes	Yes
	(2.162)	(0.457)	(0.619)	(1.930)	(0.459)	(0.361)	0.005		
Dentistry	1.834***	-1.111***	-0.998***	-2.555***	0.956***	-0.760***	5222	No	No
	(0.462)	(0.143)	(0.198)	(0.381)	(0.235)	(0.143)	0.008		
	1.777***	-1.108***	-0.997***	-2.580***	0.984***	-0.767***	5219	Yes	No
	(0.432)	(0.147)	(0.190)	(0.360)	(0.248)	(0.143)	0.009		
	1.135**	-0.426	-1.495***	-0.938**	0.477*	-0.955**	5219	Yes	Yes
	(0.398)	(0.304)	(0.170)	(0.288)	(0.227)	(0.304)	0.017		
In-home formal care	-0.254	0.058***	-0.042*	0.319*	0.038	0.004	5349	No	No
	(0.132)	(0.003)	(0.022)	(0.132)	(0.022)	(0.003)	0.003		
	-0.248	0.064***	-0.046*	0.308*	0.038	0.003	5346	Yes	No
	(0.139)	(0.008)	(0.019)	(0.139)	(0.023)	(0.004)	0.004		
	-0.212	0.094**	-0.093**	0.308**	0.049*	-0.006	5346	Yes	Yes
	(0.119)	(0.031)	(0.026)	(0.125)	(0.024)	(0.020)	0.004		
Nursing formal care home admission	10.602**	0.000	0.000	1.777	0.000	0.000	5348	No	No
	(2.999)	(0.000)	.	(2.999)	.	.	0.002		
	10.846**	-0.014	-0.012	1.785	-0.034	0.033	5345	Yes	No
	(2.977)	(0.029)	(0.028)	(2.931)	(0.048)	(0.059)	0.003		
	10.800***	-0.241	-0.053	2.216	-0.168	0.188	5345	Yes	Yes
	(2.860)	(0.521)	(0.582)	(3.141)	(0.214)	(0.293)	0.004		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Table 4. Effects of the GEJE on Health by the DDD model

	Treat × After × Policy	*Treat × After*	*Treat × Policy*	*After × Policy*	*Policy*	*After*	Obs. / R^2	**x**	**z**
Subjective health	-0.149	0.128***	0.070	0.164**	0.034	-0.074***	4620	No	No
	(0.082)	(0.020)	(0.050)	(0.066)	(0.037)	(0.020)	0.008		
	-0.164*	0.132***	0.069	0.170**	0.039	-0.079**	4617	Yes	No
	(0.082)	(0.020)	(0.050)	(0.066)	(0.036)	(0.022)	0.011		
	-0.147**	0.119***	0.105**	0.103**	0.054*	-0.083**	4617	Yes	Yes
	(0.048)	(0.031)	(0.040)	(0.037)	(0.023)	(0.034)	0.014		
Chronic disease	-0.197***	0.146***	0.056**	0.108***	0.025	-0.128***	4263	No	No
	(0.032)	(0.018)	(0.021)	(0.024)	(0.017)	(0.018)	0.019		
	-0.190***	0.140***	0.056**	0.105***	0.019	-0.121***	4260	Yes	No
	(0.030)	(0.017)	(0.020)	(0.022)	(0.016)	(0.017)	0.023		
	-0.142**	0.107**	0.073	-0.009	0.069**	-0.119***	4260	Yes	Yes
	(0.047)	(0.030)	(0.042)	(0.025)	(0.024)	(0.028)	0.038		
Functional health	-0.057	0.073***	0.024	0.086**	0.010	0.008	5341	No	No
	(0.031)	(0.009)	(0.022)	(0.023)	(0.017)	(0.009)	0.010		
	-0.057	0.073***	0.024	0.087***	0.011	0.008	5338	Yes	No
	(0.031)	(0.009)	(0.023)	(0.023)	(0.016)	(0.009)	0.011		
	-0.049***	0.078***	0.032*	0.063***	0.018	0.001	5338	Yes	Yes
	(0.012)	(0.009)	(0.016)	(0.010)	(0.011)	(0.007)	0.013		
Depression	0.004	0.008	0.059***	0.018	-0.003	0.004	3448	No	No
	(0.036)	(0.009)	(0.006)	(0.029)	(0.005)	(0.009)	0.001		
	0.002	0.010	0.058***	0.019	-0.002	0.004	3445	Yes	No
	(0.036)	(0.008)	(0.007)	(0.028)	(0.004)	(0.008)	0.003		
	-0.010	0.028**	0.063***	0.034	-0.008	-0.008	3445	Yes	Yes
	(0.028)	(0.009)	(0.006)	(0.026)	(0.010)	(0.009)	0.004		
Poor memory function	-0.572**	0.459***	0.119	0.122	0.022	-0.042	3155	No	No
	(0.186)	(0.068)	(0.079)	(0.132)	(0.050)	(0.068)	0.015		
	-0.560**	0.442***	0.119	0.118	0.011	-0.027	3153	Yes	No
	(0.187)	(0.063)	(0.081)	(0.129)	(0.050)	(0.065)	0.020		
	-0.577***	0.419***	0.232***	0.051	-0.014	-0.035	3153	Yes	Yes
	(0.062)	(0.028)	(0.051)	(0.052)	(0.054)	(0.037)	0.051		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Figure 1. The JSTAR Study Regions and Their Maximum Seismic Intensity Scales of the GEJE

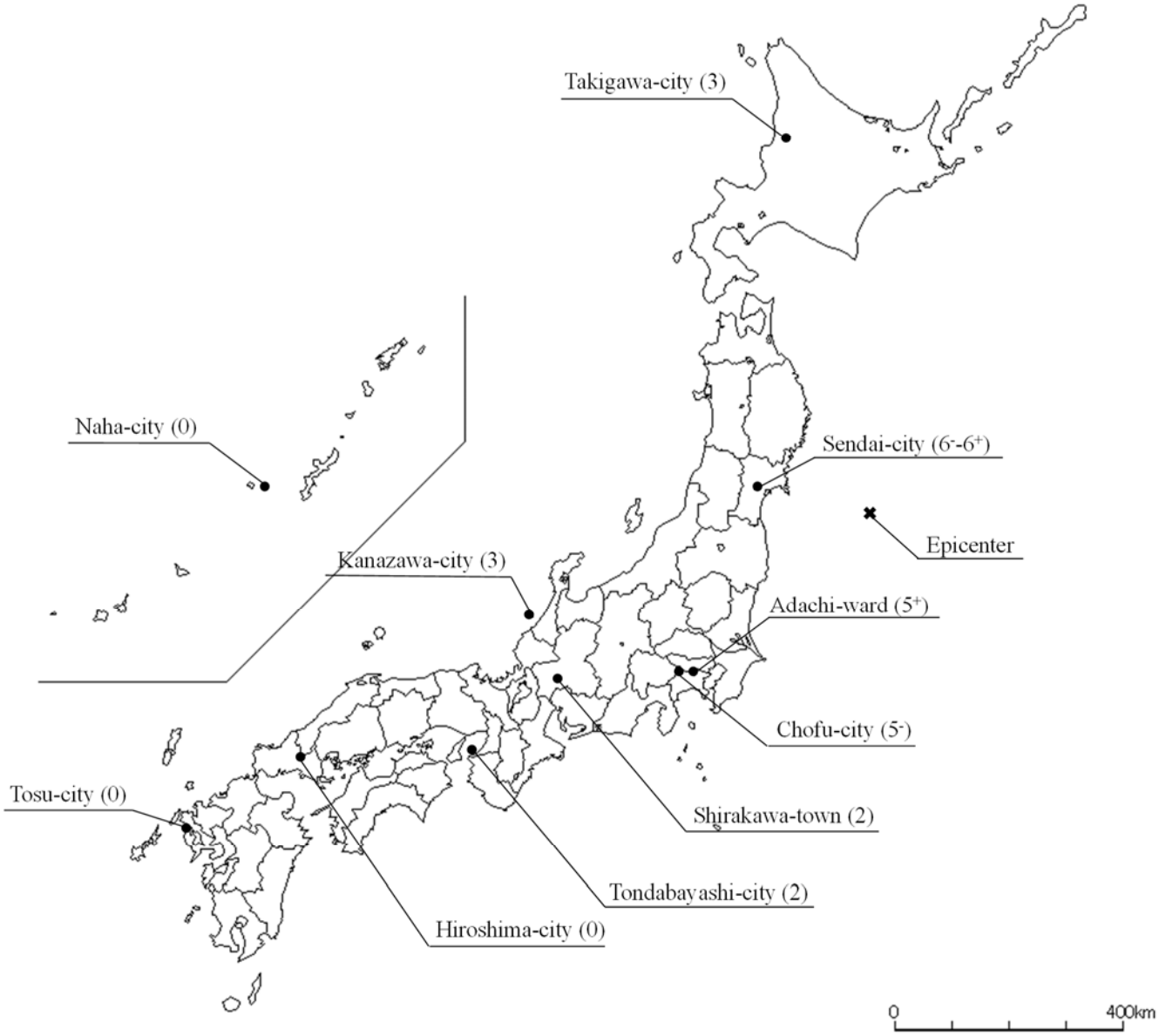
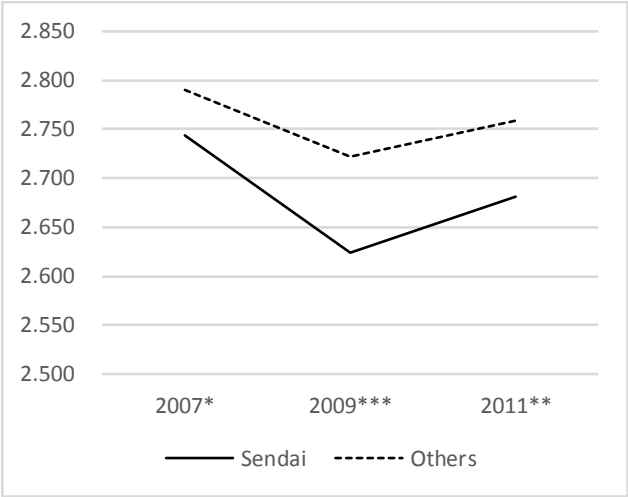
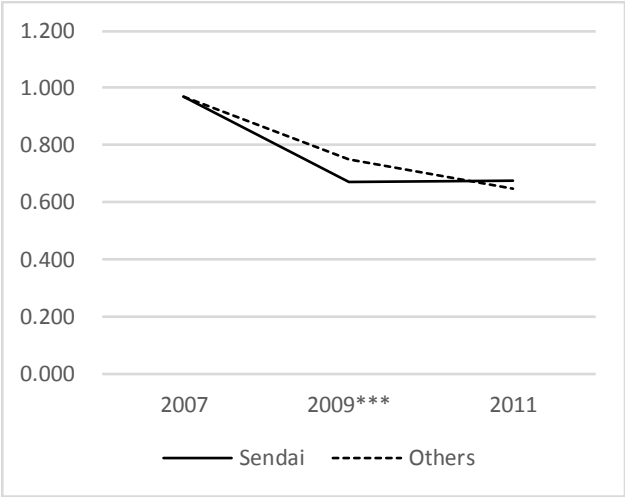


Figure 2. Yearly Proportions of Health Indicators by Groups

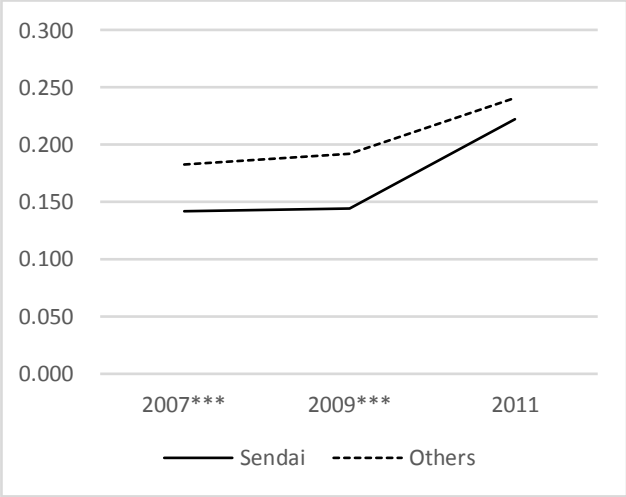
(1) Subjective health



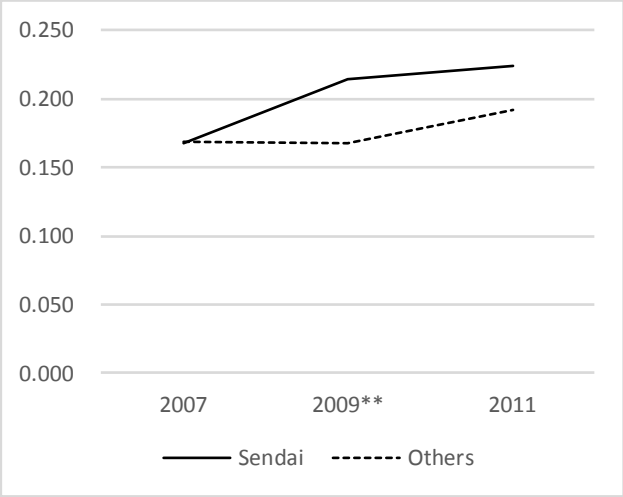
(2) Chronic disease



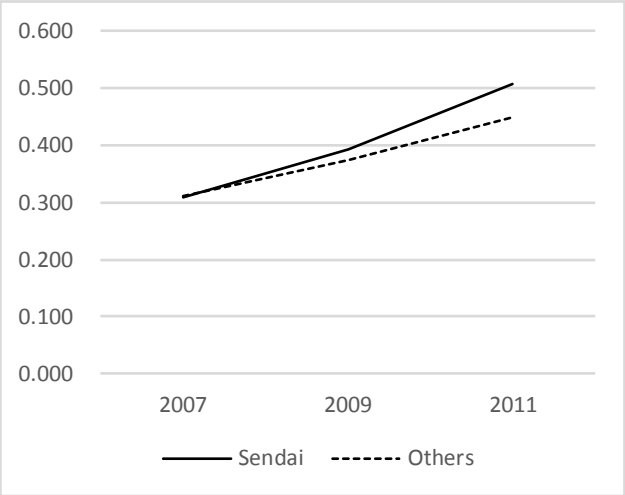
(3) Functional health



(4) Depression



(5) Poor memory function



Notes: ***, **, and * represent statistical significance in the mean differences by year at the 1, 5, and 10 percent levels, respectively.

Table A1. Seismic Intensity, Human Perception and Reaction and Indoor and Outdoor Situations

Seismic intensity	Human perception and reaction	Indoor situation	Outdoor 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.	Electric wires swing slightly.
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.	Electric wires swing significantly. Those driving vehicles may notice the tremor.
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.	In some cases, windows may break and fall. People notice electricity poles moving. Roads may sustain damage.
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.	Windows may break and fall, unreinforced concrete-block walls may collapse, poorly installed vending machines may topple over, automobiles may stop due to the difficulty of continued movement.
6 Lower	It is difficult to remain standing.	Many unsecured furniture moves and may topple over. Doors may become wedged shut.	Wall tiles and windows may sustain damage and fall.
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.	Wall tiles and windows are more likely to break and fall. Most unreinforced concrete-block walls collapse.

7		Most unsecured furniture moves and topples over, or may even be thrown through the air.	Wall tiles and windows are even more likely to break and fall. Reinforced concrete-block walls may collapse.

Source: The website of the Japan Meteorological Agency: http://www.jma.go.jp/jma/en/Activities/inttable.html (Accessed May 7, 2018).

Table A2. Definition of the Variables

Variables	Definition
Health indicators	
Subjective health	The respondent's subjective self-reported health status; = 0 for very good; 1 good, 2 fair, 3 poor, and 4 very poor.
Chronic disease	=1 if the respondent with more than one chronic diseases; 0 otherwise.
Functional health	=1 if the respondent with more than one functional limitations for daily activities; 0 otherwise
Depression	=1 if the respondent with the CES-D score of 16 and more; 0 otherwise.
Poor memory function	=1 if the respondents cannot answer the memory test; 0 otherwise.
Care utilization	
Outpatient utilization	=1 if the respondent uses outpatient healthcare services.
day	The number of days of outpatient utilization
Inpatient utilization	=1 if the respondent uses inpatient healthcare services.
day	The number of days of medical admission
Dentistry utilization	=1 if the respondent uses dentistry services.
day	The number of days of dentistry utilization
In-home formal care utilization	=1 if the respondent uses in-home formal care services.
day	The number of days of in-home formal care utilization
Nursing formal home admission	=1 if the respondent uses nursing formal care services.
day	The number of days of nursing care facility
Individual characteristics	
Female	=1 if female; 0 otherwise
Age	The respondent's age
Years of education	The respondent's years of education
Married	=1 if married; 0 otherwise
Widowed	=1 if widowed; 0 otherwise
Dependents	=1 if having the dependent(s)
Household income	Gross yearly marital income (million yen)
Household financial asset	The amount of martial financial assets (million yen)
Real estate holder	=1 if householder and/or landholder; 0 otherwise
Aggregated variables	
Medical institutions density	The number of medical institutions per 100,000 people (municipal level)
Long-term care facility density	The number of long-term care facilities per 1,000 people aged 65 and over (municipal level)
Unemployment rate	Regional unemployment rate (prefectural level)
Financial capability index	Municipal financial capability index (municipal level)

Note: The chronic diseases include heart disease, high blood pressure, hyperlipemia, cerebral accident, cerebrovascular accident, diabetes, chronic lung disease, asthma, liver disease, ulcer or other stomach disorder, joint disorder, broken hip, osteoporosis, eye disease, ear disorder, bladder disorder, Parkinson’s disease, depression or emotional disorder, dementia,

skin disorder, and cancer. Functional limitations of daily activities include (1) Walk 100 meters, (2) Sit in a chair for two hours continuously, (3) Get up from a chair after sitting continuously for a long time, (4) Climb up several flights of stairs without using the handrail, (5) Climb up one flight of stairs without using the handrail, (6) Squat or kneel, (7) Raise your hands above your shoulders, (8) Push or pull a large object such as a living-room chair or sofa, (9) Lift and carry an object weighing 5kg or more, such as a bag of rice, and (10) Pick up a small object such as a one-yen coin from a desktop with your fingers.

Table A3. Results of Probit Estimation for Checking Attenuation Bias

	Coef/ SE	Coef/ SE
Treat (=1 if Sendai residents)	0.190**	0.176***
	(0.091)	(0.056)
Female	-0.033	0.009
	(0.075)	(0.069)
Age	0.006	0.006
	(0.006)	(0.005)
Years of education	0.011	0.046**
	(0.030)	(0.018)
Married	-0.235*	-0.278**
	(0.126)	(0.116)
Widowed	-0.158	-0.161
	(0.173)	(0.155)
Household income	0.067***	0.067***
	(0.014)	(0.013)
Householder & Landholder	0.148	0.086
	(0.144)	(0.135)
Household financial asset	0.004	0.003
	(0.009)	(0.008)
Dependents	-0.009	0.033
	(0.084)	(0.085)
Medical institution density		-1.062***
		(0.121)
Nursing care facility density		0.347***
		(0.089)
Unemployment rate		-0.052
		(0.069)
Financial capability index		-0.167***
		(0.027)
Constant	0.871	3.995***
	(0.699)	(0.559)
Log likelihood	-871.907	-849.002
Observations	3797	3797
x	Yes	Yes
z	No	Yes

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust

standard errors allowing for correlated residuals within prefectures are in parentheses.

Table A4. Effects of the GEJE on Health by the DD model with Balanced Panel Datasets

Health indicators	Sample	*DD*	*T*	N/ R^2	**x**	**z**
Subjective health	3 years balanced panel	0.129***	-0.036	4113	No	No
	(5 municipalities)	(0.022)	(0.022)	0.001		
		0.127***	-0.037	4110	Yes	No
		(0.024)	(0.024)	0.005		
		0.080**	-0.013	4110	Yes	Yes
		(0.021)	(0.027)	0.013		
	2 years balanced panel	0.128***	-0.035	4475	No	No
	(7 municipalities)	(0.019)	(0.019)	0.001		
		0.126***	-0.035	4472	Yes	No
		(0.021)	(0.021)	0.004		
		0.100**	-0.037	4472	Yes	Yes
		(0.032)	(0.033)	0.011		
Chronic disease	3 years balanced panel	0.097***	-0.082***	3845	No	No
	(5 municipalities)	(0.014)	(0.014)	0.004		
		0.093***	-0.077***	3842	Yes	No
		(0.013)	(0.013)	0.009		
		0.052***	-0.058***	3842	Yes	Yes
		(0.009)	(0.011)	0.037		
	2 years balanced panel	0.106***	-0.090***	4154	No	No
	(7 municipalities)	(0.015)	(0.015)	0.004		
		0.101***	-0.086***	4151	Yes	No
		(0.014)	(0.014)	0.010		
		0.075**	-0.088**	4151	Yes	Yes
		(0.025)	(0.025)	0.031		
Functional health	3 years balanced panel	0.071***	0.030*	4695	No	No
	(5 municipalities)	(0.012)	(0.012)	0.002		
		0.072***	0.031*	4692	Yes	No
		(0.011)	(0.012)	0.003		
		0.056***	0.043***	4692	Yes	Yes
		(0.005)	(0.006)	0.011		
	2 years balanced panel	0.073***	0.029**	5173	No	No
	(7 municipalities)	(0.011)	(0.011)	0.002		
		0.072***	0.030**	5170	Yes	No
		(0.009)	(0.011)	0.003		
		0.070***	0.024*	5170	Yes	Yes
		(0.012)	(0.011)	0.007		

Depression	3 years balanced panel	0.028***	0.008	3082	No	No
	(5 municipalities)	(0.005)	(0.005)	0.000		
		0.029***	0.008	3079	Yes	No
		(0.005)	(0.005)	0.002		
		0.049***	-0.009	3079	Yes	Yes
		(0.007)	(0.006)	0.003		
	2 years balanced panel	0.030***	0.006	3347	No	No
	(7 municipalities)	(0.005)	(0.005)	0.000		
		0.031***	0.006	3344	Yes	No
		(0.005)	(0.005)	0.001		
		0.046***	-0.005	3344	Yes	Yes
		(0.009)	(0.008)	0.002		
Poor memory function	3 years balanced panel	0.187**	0.014	2904	No	No
	(5 municipalities)	(0.050)	(0.050)	0.004		
		0.170**	0.025	2902	Yes	No
		(0.043)	(0.047)	0.010		
		0.078**	0.108**	2902	Yes	Yes
		(0.028)	(0.037)	0.072		
	2 years balanced panel	0.196***	0.005	3074	No	No
	(7 municipalities)	(0.047)	(0.047)	0.004		
		0.182***	0.014	3072	Yes	No
		(0.041)	(0.044)	0.009		
		0.186***	-0.014	3072	Yes	Yes
		(0.043)	(0.045)	0.042		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Table A5. Effects of the GEJE on Care Utilization by the DDD model with Balanced Panel Datasets

(i) Effects on Utilization

Utilization	Sample	*Treat × After × Policy*	*Treat × After*	*Treat × Policy*	*After × Policy*	*Policy*	*After*	Obs. / R^2	**x**	**z**
Outpatient										
	3 yrs BP	0.139*	-0.205***	0.054**	-0.480***	0.108***	-0.017	2459	No	No
		(0.062)	(0.024)	(0.018)	(0.047)	(0.023)	(0.024)	0.082		
		0.139	-0.199***	0.052**	-0.483***	0.113***	-0.023	2458	Yes	No
		(0.070)	(0.026)	(0.018)	(0.043)	(0.024)	(0.027)	0.084		
		-0.163	0.016	0.049	-0.090	0.026	-0.154*	2458	Yes	Yes
		(0.138)	(0.068)	(0.082)	(0.088)	(0.033)	(0.068)	0.162		
	2 yrs BP	0.088	-0.194***	0.054**	-0.440***	0.119***	-0.028	2641	No	No
		(0.075)	(0.023)	(0.018)	(0.063)	(0.022)	(0.023)	0.073		
		0.088	-0.186***	0.052**	-0.441***	0.122***	-0.034	2640	Yes	No
		(0.081)	(0.026)	(0.018)	(0.063)	(0.023)	(0.027)	0.075		
		-0.127	-0.005	0.005	-0.093	0.036	-0.124**	2640	Yes	Yes
		(0.084)	(0.052)	(0.044)	(0.065)	(0.026)	(0.044)	0.148		
Inpatient										
	3 yrs BP	0.021	0.032***	-0.017***	0.018	0.034***	-0.004	3613	No	No
		(0.028)	(0.005)	(0.003)	(0.026)	(0.006)	(0.005)	0.003		
		0.020	0.034***	-0.018***	0.019	0.034***	-0.006	3611	Yes	No
		(0.030)	(0.006)	(0.004)	(0.024)	(0.007)	(0.005)	0.004		
		-0.001	0.033**	-0.002	0.030	0.029**	-0.010	3611	Yes	Yes
		(0.033)	(0.008)	(0.009)	(0.027)	(0.006)	(0.006)	0.004		
	2 yrs BP	0.005	0.031***	-0.017***	0.035	0.033***	-0.003	3896	No	No
		(0.025)	(0.005)	(0.003)	(0.024)	(0.005)	(0.005)	0.004		
		0.004	0.034***	-0.017***	0.038	0.032***	-0.006	3894	Yes	No
		(0.027)	(0.005)	(0.004)	(0.025)	(0.006)	(0.005)	0.006		
		-0.004	0.028***	-0.013*	0.045*	0.030***	-0.002	3894	Yes	Yes
		(0.026)	(0.003)	(0.007)	(0.023)	(0.006)	(0.002)	0.007		
Dentistry										
	3 yrs BP	0.077*	-0.122***	0.027	-0.272***	0.053*	-0.068**	4591	No	No
		(0.035)	(0.022)	(0.013)	(0.020)	(0.020)	(0.022)	0.024		
		0.071	-0.119***	0.027	-0.274***	0.057**	-0.070**	4588	Yes	No
		(0.035)	(0.024)	(0.013)	(0.021)	(0.020)	(0.024)	0.025		
		-0.023	-0.044	0.001	-0.101*	0.005	-0.099**	4588	Yes	Yes

	(0.055)	(0.024)	(0.033)	(0.037)	(0.017)	(0.026)	0.040		
2 yrs BP	0.048	-0.115***	0.027*	-0.249***	0.059**	-0.074**	5061	No	No
	(0.035)	(0.021)	(0.013)	(0.028)	(0.020)	(0.021)	0.021		
	0.041	-0.112***	0.027*	-0.249***	0.063**	-0.076**	5058	Yes	No
	(0.035)	(0.022)	(0.013)	(0.029)	(0.019)	(0.022)	0.022		
	-0.018	-0.045	-0.011	-0.102**	0.013	-0.097***	5058	Yes	Yes
	(0.049)	(0.024)	(0.029)	(0.034)	(0.018)	(0.022)	0.037		
In-home formal care									
3 yrs BP	0.002	0.004***	-0.004*	0.012*	0.004*	0.000*	4697	No	No
	(0.005)	(0.000)	(0.002)	(0.005)	(0.002)	(0.000)	0.009		
	0.004	0.005***	-0.004*	0.011*	0.004*	0.000	4694	Yes	No
	(0.005)	(0.000)	(0.002)	(0.005)	(0.002)	(0.000)	0.008		
	0.006	0.006***	-0.006**	0.010*	0.005**	0.000	4694	Yes	Yes
	(0.005)	(0.001)	(0.002)	(0.004)	(0.002)	(0.001)	0.010		
2 yrs BP	0.002	0.004***	-0.004*	0.013**	0.004*	0.000***	5177	No	No
	(0.004)	(0.000)	(0.002)	(0.004)	(0.002)	(0.000)	0.009		
	0.003	0.004***	-0.004**	0.011**	0.004**	0.000	5174	Yes	No
	(0.004)	(0.000)	(0.002)	(0.004)	(0.002)	(0.000)	0.009		
	0.004	0.006***	-0.006***	0.011**	0.005**	-0.001	5174	Yes	Yes
	(0.004)	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	0.010		
Nursing formal care home admission									
3 yrs BP	0.015***	0.000	0.000	0.004	0.000	0.000	4696	No	No
	(0.002)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	0.009		
	0.015***	0.000	0.000	0.004	0.000	0.000	4693	Yes	No
	(0.002)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	0.01		
	0.016***	0.000	-0.001**	0.005*	0.000	0.000	4693	Yes	Yes
	(0.002)	(0.001)	(0.000)	(0.002)	(0.000)	(0.000)	0.011		
2 yrs BP	0.017***	0.000	0.000	0.002	0.000	0.000	5176	No	No
	(0.003)	.	(0.000)	(0.003)	(0.000)	.	0.007		
	0.017***	0.000	0.000*	0.002	0.000	0.000	5173	Yes	No
	(0.003)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	0.007		
	0.018***	0.000	0.000	0.003	0.000	0.000	5173	Yes	Yes
	(0.002)	(0.001)	(0.001)	(0.003)	(0.000)	(0.000)	0.009		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

(ii) Effects on the Number of Days per Month

Day	Sample	*Treat × After × Policy*	*Treat × After*	*Treat × Policy*	*After × Policy*	*Policy*	*After*	Obs. / R^2	**x**	**z**
Outpatient										
	3 yrs BP	0.340*	-0.352***	-0.239	-0.908***	0.403*	-0.119**	2459	No	No
		(0.124)	(0.038)	(0.144)	(0.114)	(0.158)	(0.038)	0.012		
		0.312*	-0.335***	-0.229	-0.886***	0.409*	-0.130**	2458	Yes	No
		(0.137)	(0.046)	(0.148)	(0.116)	(0.156)	(0.042)	0.014		
		0.167	-0.010	-0.232*	-0.691**	0.357**	-0.342**	2458	Yes	Yes
		(0.178)	(0.118)	(0.103)	(0.160)	(0.119)	(0.113)	0.017		
	2 yrs BP	0.231	-0.336***	-0.239	-0.814***	0.419**	-0.135**	2641	No	No
		(0.160)	(0.037)	(0.139)	(0.145)	(0.151)	(0.037)	0.011		
		0.215	-0.316***	-0.232	-0.796***	0.422**	-0.146**	2640	Yes	No
		(0.164)	(0.044)	(0.143)	(0.147)	(0.149)	(0.040)	0.012		
		0.132	-0.012	-0.303**	-0.602***	0.376**	-0.318***	2640	Yes	Yes
		(0.131)	(0.096)	(0.104)	(0.148)	(0.125)	(0.084)	0.015		
Inpatient										
	3 yrs BP	1.351	0.154	-2.739***	1.436	1.943***	0.209	3613	No	No
		(1.986)	(0.195)	(0.434)	(1.998)	(0.381)	(0.195)	0.004		
		1.256	0.214	-2.743***	1.496	1.973***	0.152	3611	Yes	No
		(1.969)	(0.254)	(0.425)	(1.962)	(0.339)	(0.237)	0.004		
		0.156	-0.169	-1.810**	1.883	1.783**	0.068	3611	Yes	Yes
		(2.027)	(0.280)	(0.443)	(2.025)	(0.438)	(0.226)	0.006		
	2 yrs BP	1.824	0.018	-2.739***	1.100	1.807***	0.346	3896	No	No
		(1.679)	(0.240)	(0.419)	(1.629)	(0.414)	(0.240)	0.004		
		1.857	0.049	-2.730***	1.165	1.780***	0.293	3894	Yes	No
		(1.683)	(0.312)	(0.407)	(1.613)	(0.383)	(0.286)	0.004		
		1.671	-0.811	-2.504***	1.123	1.805***	0.779*	3894	Yes	Yes
		(2.167)	(0.463)	(0.633)	(1.924)	(0.462)	(0.358)	0.005		
Dentistry										
	3 yrs BP	2.288**	-1.112***	-1.266***	-2.748***	0.964**	-0.759***	4591	No	No
		(0.554)	(0.141)	(0.254)	(0.505)	(0.299)	(0.141)	0.009		
		2.200**	-1.068***	-1.269***	-2.775***	1.021**	-0.799***	4588	Yes	No
		(0.506)	(0.150)	(0.236)	(0.474)	(0.317)	(0.149)	0.01		
		1.381*	-0.340	-1.639***	-1.147*	0.579	-1.092*	4588	Yes	Yes
		(0.600)	(0.361)	(0.328)	(0.435)	(0.312)	(0.397)	0.017		
	2 yrs BP	2.011***	-1.020***	-1.266***	-2.563***	1.056***	-0.851***	5061	No	No

	(0.485)	(0.136)	(0.245)	(0.431)	(0.284)	(0.136)	0.008		
	1.942***	-1.003***	-1.263***	-2.580***	1.087**	-0.870***	5058	Yes	No
	(0.450)	(0.140)	(0.230)	(0.411)	(0.298)	(0.139)	0.008		
	1.388**	-0.373	-1.775***	-1.029**	0.596*	-1.020**	5058	Yes	Yes
	(0.405)	(0.295)	(0.202)	(0.361)	(0.306)	(0.298)	0.016		
In-home formal care									
3 yrs BP	-0.244	0.058***	-0.045	0.309	0.041	0.005	4697	No	No
	(0.166)	(0.004)	(0.024)	(0.166)	(0.024)	(0.004)	0.003		
	-0.232	0.065***	-0.051*	0.298	0.039	0.003	4694	Yes	No
	(0.176)	(0.010)	(0.021)	(0.176)	(0.025)	(0.005)	0.003		
	-0.202	0.096*	-0.090**	0.296	0.051	-0.011	4694	Yes	Yes
	(0.154)	(0.043)	(0.032)	(0.160)	(0.025)	(0.029)	0.004		
2 yrs BP	-0.251	0.058***	-0.045*	0.316*	0.041	0.004	5177	No	No
	(0.133)	(0.004)	(0.023)	(0.133)	(0.023)	(0.004)	0.003		
	-0.245	0.064***	-0.049*	0.305*	0.041	0.003	5174	Yes	No
	(0.139)	(0.008)	(0.020)	(0.140)	(0.024)	(0.004)	0.004		
	-0.207	0.094**	-0.098***	0.304*	0.053*	-0.005	5174	Yes	Yes
	(0.118)	(0.031)	(0.026)	(0.126)	(0.024)	(0.020)	0.004		
Nursing formal care home admission									
3 yrs BP	8.502**	0.000	0.000	3.877	0.000	0.000	4696	No	No
	(3.033)	(0.000)	.	(3.033)	.	(0.000)	0.004		
	8.785**	-0.002	-0.042	3.897	-0.021	0.025	4693	Yes	No
	(2.917)	(0.037)	(0.041)	(2.895)	(0.038)	(0.080)	0.005		
	10.056**	-0.464	-1.840**	4.367	0.234	0.957	4693	Yes	Yes
	(2.835)	(0.683)	(0.648)	(3.175)	(0.349)	(0.483)	0.006		
2 yrs BP	10.602**	0.000***	0.000	1.777	0.000	0.000***	5176	No	No
	(3.000)	(0.000)	(0.000)	(3.000)	(0.000)	(0.000)	0.002		
	10.876**	-0.009	-0.037	1.784	-0.028	0.029	5173	Yes	No
	(2.978)	(0.025)	(0.033)	(2.935)	(0.044)	(0.056)	0.003		
	10.864**	-0.259	-0.104	2.208	-0.162	0.206	5173	Yes	Yes
	(2.861)	(0.534)	(0.582)	(3.145)	(0.216)	(0.302)	0.004		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Table A6. Effects of the GEJE on Health by the DDD model with Balanced Panel Datasets

Health	Sample	*Treat × After × Policy*	*Treat × After*	*Treat × Policy*	*After × Policy*	*Policy*	*After*	Obs. / R^2	**x**	**z**
Subjective health										
	3 yrs BP	-0.155	0.127***	0.067	0.199*	0.008	-0.073**	4113	No	No
		(0.091)	(0.021)	(0.054)	(0.075)	(0.040)	(0.021)	0.009		
		-0.173	0.131***	0.067	0.207*	0.011	-0.077**	4110	Yes	No
		(0.092)	(0.022)	(0.055)	(0.076)	(0.040)	(0.024)	0.013		
		-0.114*	0.095**	0.069	0.120**	0.037	-0.055	4110	Yes	Yes
		(0.050)	(0.021)	(0.040)	(0.043)	(0.021)	(0.028)	0.017		
	2 yrs BP	-0.146	0.127***	0.067	0.190**	0.008	-0.074***	4475	No	No
		(0.082)	(0.019)	(0.052)	(0.068)	(0.040)	(0.019)	0.008		
		-0.162*	0.131***	0.068	0.196**	0.012	-0.078**	4472	Yes	No
		(0.083)	(0.019)	(0.053)	(0.068)	(0.040)	(0.021)	0.012		
		-0.142**	0.113**	0.103*	0.124**	0.030	-0.080*	4472	Yes	Yes
		(0.055)	(0.031)	(0.046)	(0.043)	(0.028)	(0.034)	0.015		
Chronic disease										
	3 yrs BP	-0.208***	0.131***	0.063**	0.128***	0.009	-0.112***	3845	No	No
		(0.034)	(0.016)	(0.021)	(0.019)	(0.014)	(0.016)	0.019		
		-0.201***	0.124***	0.062**	0.126***	0.003	-0.106***	3842	Yes	No
		(0.032)	(0.015)	(0.021)	(0.018)	(0.013)	(0.015)	0.023		
		-0.108*	0.080***	0.043	-0.010	0.067*	-0.084***	3842	Yes	Yes
		(0.045)	(0.011)	(0.044)	(0.031)	(0.030)	(0.012)	0.043		
	2 yrs BP	-0.199***	0.142***	0.063**	0.109***	0.020	-0.124***	4154	No	No
		(0.031)	(0.017)	(0.021)	(0.024)	(0.016)	(0.017)	0.018		
		-0.193***	0.135***	0.063**	0.106***	0.014	-0.117***	4151	Yes	No
		(0.030)	(0.017)	(0.020)	(0.023)	(0.016)	(0.017)	0.022		
		-0.146**	0.104**	0.079	-0.006	0.065**	-0.116***	4151	Yes	Yes
		(0.047)	(0.030)	(0.042)	(0.025)	(0.024)	(0.028)	0.037		
Functional health										
	3 yrs BP	-0.076*	0.071***	0.036	0.092**	0.011	0.010	4695	No	No
		(0.032)	(0.011)	(0.024)	(0.022)	(0.019)	(0.011)	0.010		
		-0.077*	0.072***	0.036	0.096***	0.011	0.009	4692	Yes	No
		(0.032)	(0.010)	(0.025)	(0.020)	(0.019)	(0.011)	0.012		
		-0.043**	0.065***	0.020	0.064***	0.025	0.019*	4692	Yes	Yes
		(0.009)	(0.006)	(0.019)	(0.011)	(0.019)	(0.008)	0.016		
	2 yrs BP	-0.068**	0.073***	0.036	0.082***	0.013	0.008	5173	No	No

		(0.028)	(0.010)	(0.023)	(0.020)	(0.019)	(0.010)	0.010		
		-0.068*	0.073***	0.035	0.083***	0.014	0.008	5170	Yes	No
		(0.029)	(0.009)	(0.024)	(0.019)	(0.018)	(0.009)	0.011		
		-0.060***	0.077***	0.043*	0.059***	0.022	0.001	5170	Yes	Yes
		(0.012)	(0.008)	(0.021)	(0.008)	(0.017)	(0.007)	0.013		
Depression										
	3 yrs BP	-0.010	0.007	0.070***	0.028	-0.010	0.006	3082	No	No
		(0.044)	(0.010)	(0.011)	(0.035)	(0.009)	(0.010)	0.002		
		-0.014	0.009	0.070***	0.029	-0.008	0.004	3079	Yes	No
		(0.044)	(0.008)	(0.013)	(0.035)	(0.009)	(0.009)	0.003		
		-0.035	0.033**	0.084***	0.043	-0.017	-0.015	3079	Yes	Yes
		(0.031)	(0.009)	(0.004)	(0.029)	(0.013)	(0.008)	0.005		
	2 yrs BP	-0.009	0.010	0.070***	0.024	-0.008	0.003	3347	No	No
		(0.040)	(0.009)	(0.011)	(0.032)	(0.009)	(0.009)	0.002		
		-0.011	0.011	0.069***	0.025	-0.006	0.002	3344	Yes	No
		(0.039)	(0.008)	(0.012)	(0.032)	(0.009)	(0.008)	0.003		
		-0.023	0.029**	0.075***	0.039	-0.013	-0.010	3344	Yes	Yes
		(0.029)	(0.009)	(0.007)	(0.028)	(0.012)	(0.009)	0.004		
Poor memory function										
	3 yrs BP	-0.637**	0.448***	0.132	0.183	0.013	-0.031	2904	No	No
		(0.217)	(0.072)	(0.086)	(0.157)	(0.054)	(0.072)	0.022		
		-0.624**	0.430***	0.132	0.178	0.002	-0.016	2902	Yes	No
		(0.219)	(0.068)	(0.089)	(0.154)	(0.055)	(0.070)	0.026		
		-0.545***	0.356***	0.114	0.122	0.001	0.058	2902	Yes	Yes
		(0.115)	(0.047)	(0.060)	(0.096)	(0.050)	(0.044)	0.078		
	2 yrs BP	-0.578**	0.452***	0.132	0.121	0.017	-0.035	3074	No	No
		(0.190)	(0.068)	(0.084)	(0.136)	(0.052)	(0.068)	0.015		
		-0.566**	0.435***	0.132	0.117	0.006	-0.021	3072	Yes	No
		(0.192)	(0.064)	(0.085)	(0.133)	(0.053)	(0.066)	0.019		
		-0.591***	0.420***	0.243***	0.059	-0.019	-0.035	3072	Yes	Yes
		(0.066)	(0.030)	(0.054)	(0.053)	(0.056)	(0.039)	0.050		

Note: ***, **, and * represent statistical significance at the 1, 5, and 10 percent levels, respectively. Clustering robust standard errors allowing for correlated residuals within prefectures are in parentheses.

Figure A1. Response Rates in the Follow-up Surveys in the JSTAR

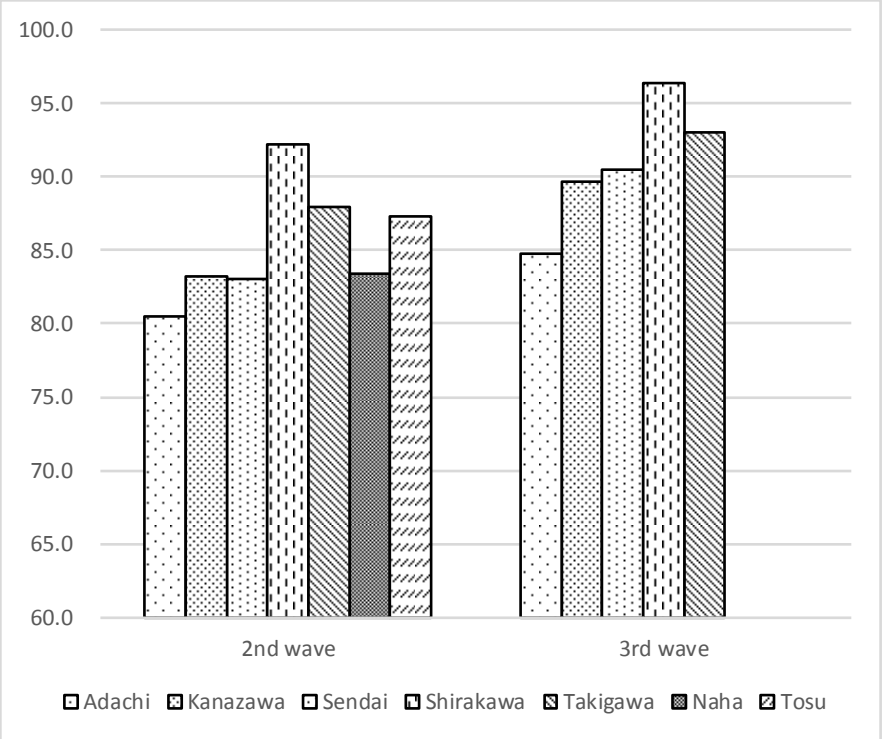


Figure A2. Yearly proportions of Real Estate Holding by Group