Does Social Capital Moderate the Impact of Disaster on Health and Quality of Life? Causal Mediation/Sensitivity Analysis and Instrumental Variable Estimation

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Abstract

We estimated the impact of both the Great East Japan Earthquake in 2011 and the Great Kanto Earthquake in the 1920s—both of which had the highest casualties in Japan—on social capital accumulation and their relationship to self-rated health (SRH) and life satisfaction using causal mediation/sensitivity analysis and instrumental variable estimation techniques on nationwide surveys conducted in Japan.

While residents' social capital increased in the areas most devastated by the Great East Japan Earthquake, there were no significant effects on life satisfaction. However, the increase in social capital buffered the adverse impact of the quake on self-rated health.

We also examined the causal relationships between social capital and SRH and life satisfaction, using the Great Kanto Earthquake as an instrumental variable. In the first stage, the long-term impact of the Great Kanto Earthquake reduced social capital, while in the second stage, a positive causal effect of social capital on SRH and life satisfaction was observed. Based on the results of the IV estimation, it was found that the mitigating effect of SC almost eliminates the direct adverse effect of the Great East Japan Earthquake on SRH.

Keywords: Japan; Social capital; Great East Japan Earthquake; Kanto earthquake; Natural disasters; Self-rated health; Causal mediation analysis; Instrumental variable estimation

1. Introduction

The Great East Japan Earthquake in 2011 was devastating, claiming 15,848 lives with an additional 3,305 missing people. Surprisingly, however, despite the magnitude and extent of damage, some studies reported that the Great East Japan Earthquake improved life satisfaction in Japan (Yamamura et al., 2015; Ishino et al., 2011), or found no statistically significant nationwide decline in life satisfaction after the disaster (Tiefenbach and Kohlbacher, 2015).

Why is it that severe earthquake damage often does not impair the subjective health and well-being of the victims? Few papers have answered this question. In this paper, we provide an answer to this question by using the analysis method of mediation analysis. In other words, earthquakes can have a direct negative impact on subjective health, but on the other hand, earthquakes cause the accumulation of social capital, which in turn has a positive impact on subjective health, thus offsetting the direct negative impact.

Of course, this logic is based on the assumption that the accumulation of social capital leads to improved health.

The impact of social factors as well as genetic and other factors in determining health status has been

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pointed out; according to McGinnis et al. (2002), about 20% of early deaths can be explained by these environmental and social factors. Among the environmental and social factors, one of the factors that has received the most attention in recent years is social capital.

The level of social capital (SC) was found to increase in areas damaged by the Great East Japan Earthquake. During the disaster recovery phase, residents held more meetings than before the earthquake to mutually provide for survival needs and cope psychologically, and to promote interpersonal interaction. Our first aim is to perform a causal mediation/sensitivity analysis of the relationships between disaster, social capital, and happiness/self-rated health (Imai et al., 2010; Hicks and Tingly, 2011).

We show that SC increases self-reported health (SRH) and life satisfaction, but that disasters adversely affect SRH. It also shows that following the earthquake, SC levels rose; therefore, SC may have mitigated the earthquake's adverse impact on SRH.

Additionally, this paper examines the causal influence of SC on current residents' SRH and life satisfaction using data from the Kanto earthquake that occurred 80–90 years ago as instrumental variables. We argue that the areas most devastated by the 1929 Kanto Earthquake led to population decline and economic stagnation – both factors which are thought to lead to a decrease in social capital in the long run. We use this "exogenous" shock to social capital as an instrument to identify a causal effect of SC on self-rated health and happiness. Our IV analysis suggests that the relationship between SC and SRH and life satisfaction is causal and positive.

1.1 Literature Review

Social capital is defined as trust, norms of reciprocity, and networks with externalities through the minds of actors (Inaba, 2005). Although the meaning of SC varies by author, the importance of SC for both disaster preparedness and recovery has been frequently cited (Aida et al., 2013; Aghabakhshi and Gregor, 2007; Aldrich and Sawada, 2014; Aldrich, 2012; Allen, 2006; Baker and Refsgaard, 2007; Buckland and Rahman, 1999; Chen et al., 2013; Flores et al., 2014; Hurlbert et al., 2001; Islam and Walkerden, 2014; Klinenberg, 2002; Koh et al., 2008; Levac et al., 2012; Nakagawa and Shaw, 2004; Reininger et al., 2013; Shimada, 2015; Weil et al., 2011; Wind and Komproe, 2011; Yamamura, 2010; Yamamura et al., 2015) . Harada (2012) summarizes the relationship between the Great East Japan Earthquake and social capital. Also, Hikichi et al. (2017) summarize existing studies on the relationship between the Great East Japan Earthquake and social capital.

Despite this extensive research on the impact of SC on disaster preparedness and recovery from disasters, few studies have examined the impact of disasters on SC (one of the few examples is Hikichi et al. (2017)); most of them examine one component, trust. This paper attempts to bridge this gap by clarifying how the 2011 Great East Japan Earthquake affected some aspects of SC and two QOL indices (i.e., SRH and life satisfaction) based on data from two nationwide mail surveys in 2010 and 2013.

Aida et al. (2011) showed that mortality is higher in people with poor friendships.

Matsubayashi, Sawada and Ueda (2013) show that prefectures with more blood donors have lower suicide rates after a natural disaster. Also, Mohan et al. (2005) showed that regions with more social participation have significantly lower mortality rates for all causes of death.

A systematic review of the relationship between mental wellbeing and social capital (Murayama, Fujiwara and Kawachi (2012)) confirmed the positive impact of social capital in all 11 papers examined.

The lower the level of social capital (trust, social participation), the lower the health perspective. In a study using panel data (Giordano, Bjork and Lindstrom (2012)), it was observed that higher social capital was associated with a higher subsequent subjective sense of well-being.

Riumallo-Herl et al. (2014) and d'Hombres et al. (2010) show that social capital has a causal impact on subjective health perceptions in individual-level data, using a community-level social capital variable as the instrumental variables. However, it must be said that the instrumental variables used in these studies are not likely to satisfy the exclusion restriction. In this paper, we use earthquake damage from a long time ago (the Great Kanto Earthquake) as the instrumental variable, and it is highly likely that the exclusion restriction is satisfied. In addition, the inclusion of many control variables in the estimation further enhances the possibility. This paper also contributes to the context of

studies that have shown that high social capital has a positive impact on subjective health perceptions using instrumental variables.

2. Materials and Methods

2.1 Data

We examined changes in SC based on data gathered through two nationwide mail surveys on SC—defined as trust, norms of reciprocity, and networks with latent externalities (Inaba, 2005)—conducted in 2010 and 2013. These surveys clarify the level of SC in Japan, focusing on two different aspects: cognitive and structural SC. The former includes generalized trust (i.e., trust in the general public) and particularized trust (i.e., trust among particular groups of people), while the latter includes networks in terms of group participation as well as daily contact with neighbors, family members/relatives, friends/acquaintances, and colleagues. Additionally, the surveys obtained QOL indices including SRH, depression level, anxiety regarding isolation, and self-rated life satisfaction. Both surveys used two-stage stratified random sampling. In the first stage, we stratified municipalities into three categories according to population size, and one was randomly chosen from each category. In the second stage, we visited each municipality to randomly collect residents' names and addresses from resident registries of the local governments. They included residents in Japan aged 20–79 years. Survey questionnaires were sent and returned by mail. In 2010, we mailed 4,000 questionnaires across 50 municipalities, of which 1,599 were returned, and 10,000 questionnaires across 100 municipalities in 2013, of which 3,575 were returned. The response rates are about 40% and 36%, respectively. In keeping with ethical protocols, the questionnaire in the 2013 survey was checked and approved by the ethical committee of the College of Medicine of Nihon University.

2.2 Dependent variables

The dependent variables are two QOL indices, SRH and life satisfaction.

Life satisfaction was assessed by the item "Are you satisfied with your present life?" scored on a five-point scale: 1 = very satisfied, 2 = satisfied, 3 = neither, 4 = unsatisfied, and 5 = very unsatisfied. The analysis used reversed values. For SRH, respondents were asked to rate their health in general using four answer categories: 1 = very good, 2 = good, 3 = fair, and 4 = poor. Similarly, reversed values were used for the analysis.

2.3 Mediation variable

Mediation variables comprised four indexes related to SC: particularized trust, network of daily contacts, (network of) group participation, and SC (the total of the first three indexes). For more information on these social capital measures, see Inaba (2013).

Contact with neighbors was assessed by responses to the item "Please pick the most suitable answer on how you interact with your neighbors: 1 = cooperate with each other, 2 = have daily chats, 3 = have minimal contact, such as exchanging greetings, and 4 = no contact." Contacts with friends/acquaintances and colleagues were categorized by frequency of contact (1 = several times a week, 2 = at least several times a month, 3 = several times a year, 4 = once a year at most, and 5 = no contact). Each numerical value was inverted, summed, and standardized to represent "network of daily contacts."

Questions on group participation have seven answer choices (1 = more than 4 days a week, 2 = 2 or 3 days a week, 3 = once a week, 4 = 2 or 3 days a month, 5 = once a month, 6 = several times a year, and 7 = no participation). Each numerical value was inverted, summed, and standardized to represent "network as group participation."

"Social capital" comprised the standardized sum of the above three indexes.

2.4 Independent variables: Treatment variable

The treatment variable is a binary variable: 1 was assigned to an area if the Japanese government designated it as a severely damaged municipality "*Tokutei Hisai Tihou Kokyo Dantai*"; otherwise, 0 was assigned.

The criteria for this status are as follows:

(1) A municipality hit by an earthquake with an intensity of over "lower 6" on the Japanese scale.
(2) There is more than a certain number of destroyed houses.
(3) Maximum tsunami observation value is at least 2.4 meters, and flooding damage has been confirmed.

(4) Local burden on disaster restoration project cost and disaster waste disposal, etc., exceeds 5% of standard tax-revenue ratio.

That is, it is necessary to ascertain that the magnitude of the earthquake, damage of the tsunami, and the cost of damage is enormous.

Regarding the Great Kanto Earthquake, we use the total number of earthquakes in 1923 and the aftershocks that occurred between 1923 and 1939 for each municipality. Earthquake data were obtained from the Japan Meteorological Agency website. We use both the Big and Small Earthquake Index: "Big earthquakes" refer to areas hit by a huge earthquake with a seismic intensity of at least 6 and "small earthquakes" are those with a seismic intensity of 5. However, the seismic intensity scale has been altered over the last century; these changes in the definition of seismic intensity scale in Japan are shown in Table 1.

Table 1. Changes in Definitions of the Seismic Intensity Scale in Japan

1898-1936	1996-Present
0	0
1	1
2	2
3	3
4	4
5	Lower 5 Upper 5
6	Lower 6 Upper 6 7

The Great Kanto Earthquake that occurred in 1923 caused severe damage, particularly in Tokyo and Kanagawa prefectures and resulted in more than 100,000 deaths. The epicenter was in the west of Tokyo with a hypocenter in Sagami Bay, west of Kanagawa Prefecture (National Research Institute for Earth Science and Disaster Resilience(2)).

2.5 Analytic strategy

In order to conduct the causal mediation analysis, we assumed the relationships between variables as shown in Figure 1.

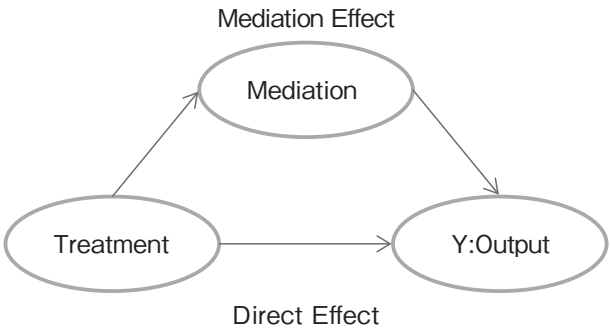

Figure 1. The relationship between variables in a causal mediation analysis.

More concretely, we estimated the following equations as a system:

$$M = \alpha_1 + \alpha_2 T + \alpha_3 X + \varepsilon_1 \quad (1)$$
$$Y = \beta_1 + \beta_2 M + \beta_3 T + \beta_4 X + \varepsilon_2 \quad (2)$$

Y is output, that is, SRH and life satisfaction. M is the mediation variable, which is social capital. T is treatment, that is, whether the municipality is designated as a severely damaged or not. If the municipality where the respondent lives in is designated *Tokutei Hisai Tihou Kokyo Dantai*, T is 1. If not, T is 0. X refers to age, gender, education, household income, marriage, occupation, duration of residence, housing, and year dummy.

Causal mediation analysis can effectively independently estimate direct and mediation effects using a quasi-Baysian Monte Carlo approximation (Imai et al., 2010; Hicks and Tingly, 2011). In order to identify the mediation effect and the direct effect, the following assumption must be satisfied:

Assumption 1: Sequential Ignorability (Imai et al., 2010)

(a) $\{Y(t,m), M(t)\} \perp T | X = x$
(b) $Y(t,m) \perp M(t) | T = t, X = x$

Where X is a vector of the observed pretreatment confounders, $0 < Pr(T = t|X = x)$ and $0 < p(M = m|T = t, X = x)$ for $t = 0$ and 1, and all x and m in support of X and M, respectively.

Assumption 1a is satisfied because earthquakes are natural incidents (natural experiments), but Assumption 1b is problematic. It requires that the correlation between ε1 and ε2 be 0. However, we cannot test this directly through observational data. Conse-

(2) https://dil.bosai.go.jp/disaster/1923kantoeq/kaisetsu.html

quently, the validity of the outcome by sensitivity analysis needs to be tested.

3. Results

3.1 Descriptive statistics

Table 2 presents the descriptive statistics of data used in this study.

In this study, we limited our analysis to individuals who lived at their current residence for more than three years, in order to match respondents' residence at the time of the Great East Japan Earthquake. In this section, all estimation was made using STATA 14, specifically "medeff," a program written by Hicks and Tingley (2011). Further, the estimation equation in this study includes the above-mentioned control variable X.

3.2 Impact of the quake on SC

Table 3 shows the impact of earthquake damage on each indicator of SC, the mediation variable. All estimates are from OLS. Numbers in parentheses are cluster-robust standard errors with municipalities (150) as clusters. Except for particularized trust, earthquake damage had a significant positive impact on three indexes of SC. Basic survival after the disaster required cooperation with neighboring residents. Residents collaborated to begin reconstruction plans and actively interacted with each other. It can be interpreted that such active exchanges are reflected in these indexes.

Solnit (2009) found that natural disasters could enhance SC, "two things matter most about these ephemeral moments—they demonstrate how deeply most of us desire connection, participation, altruism, and purposefulness" (pp. 305–306). Toya's (2014) multiple regressions based on a cross-country data set for 1970–2000 found a strong positive relationship between the frequency of natural disasters and SC in terms of trust and the quality of government, especially in OECD countries. As for the Great East Japan Earthquake, Hommerich (2012) found high levels of social trust, based on data from a mail survey in Tohoku and Kanto regions in September 2011, six months after the disaster.

3.3 Impact of earthquake damage and SC on SRH

Table 4 examines the impact of both the Great East Japan Earthquake and SC indices on SRH. All estimates are from OLS. Numbers in parentheses are cluster-robust standard errors with municipalities (150) as clusters. In Tables 4, 5, 8, 9, 10, and 11, in model 1, we use "particularized trust" as a variable for social capital, as explained in 1.4 Mediation variable. In model 2, we use "network of daily contacts" as a variable for social capital, and in model 3, we use "(network of) group participation" as a variable for social capital. Finally, in model 4, we use "SC (the total of the first three indexes) "as a variable for social capital. All four indices of SC were positively associated with SRH. Despite this, residents of severely damaged areas had lowered SRH levels. Lowered SRH from earthquake damage was relieved by 50% due to increased social capital as shown in Model 4.

3.4 Impact of earthquake damage and SC on life satisfaction

Table 5 shows the impact of earthquake damage and SC on residents' life satisfaction. All estimates are from OLS. Numbers in parentheses are cluster-robust standard errors with municipalities (150) as clusters. Earthquake damage did not directly affect life satisfaction. Simultaneously, SC improved residents' level of life satisfaction. Yamamura et al. (2015) found that the influence of SC on happiness after the earthquake increased with time. However, the earthquake damage did not directly lower the degree of happiness.

It is not clear as to why earthquake damage had no influence or even a positive influence on the degree of happiness. According to Ishino (2011), the increase in happiness is a result of people's altruistic approach after the disaster. Alternatively, the criteria for assessing SRH were not influenced by the earthquake: as the reference level for judging the degree of life satisfaction and happiness may have been lowered, self-reported life satisfaction and happiness increased. People may have appreciated simple and common aspects of life more than they did before the earthquake, lowering the reference point for judging happiness. However, this interpretation is merely inference and needs to be tested. Further, if an individual's health condition history is considered an important criterion, its reference level is to remain stable regardless of earthquake damage, providing a more objective indicator of SRH.

Table 2. Descriptive Statistics of Data from 2010 and 2013 Surveys on Social Capital

Variable	N	Mean or %	SD	Minimum	Maximum
Particularized trust	4,447	13.31	3.63	1	21
Network : daily contacts	3,815	10.88	2.87	1	19
Network : group participation	5,174	4.54	3.74	1	25
Social capital	3,547	28.46	7.35	7	56
Self-Rated Health	5,003	2.80	0.67	1	4
Happiness	4,929	3.31	1.02	1	5
Big earthquakes during 1923-1939	5,172	0.01	0.08	0	1
Small earthquakes during 1923-1939	5,172	0.14	0.74	0	7
Extent of damage of area	5,172				
severely damaged		4.2%			
not severely damaged		95.8%			
Age	5,174	52.84	15.90	20	80
Gender	5,174				
Male		45.5%			
Female		54.5%			
Education	5,134				
Junior High		10.9%			
High School		40.2%			
Tech. School		11.3%			
Tech. College		10.9%			
Univ.		23.8%			
Graduate School		2.3%			
Others		0.7%			
Household Income	5,001				
<2M		9.7%			
2-4		28.1%			
4-6		22.7%			
6-8		14.3%			
8-10		9.8%			
10-12		4.5%			
12≦		4.9%			
Marriage	4,770				
Married		78.0%			
Unmarried		22.0%			
Occupation	5,061				
Self-Employed		10.7%			
Private executive		2.6%			
Private worker		28.8%			
Public Servant		4.8%			
Part-time worker		15.5%			
Student		1.9%			
Unemployed		15.9%			
Housewife/husband		17.4%			
Others		2.5%			
Duration of Residence	5,048	25.22	18.67	0	79
Housing	5,082				
owned house		67.2%			
condominium		11.8%			
rented house		12.6%			
company-owned house		1.6%			
public housing		4.5%			
rented room		1.1%			
boarding house		0.3%			
others		0.8%			
Year Dummy	5,174				
2013		69.1%			
2010		30.9%			
Districts	150	34.48	6.31	18	49

Table 3. Impact of the Earthquake on Social Capital

	Particularized Trust	Network : Daily Contacts	Network : Group Participation	Social Capital
Severely Damaged Area	0.173 (0.116)	0.367 (0.145)**	0.187 (0.081)**	0.377 (0.122)***

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 4. Impact of the Great East Japan Earthquake and Social-Capital Indices on Self-rated Health

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	–0.035 (0.031)	–0.109 (0.042)***	–0.07 (0.03)**	–0.09 (0.041)**
Particularized trust	0.1 (0.012)***			
Network : daily contacts		0.081 (0.012)***		
Network : group participation			0.091 (0.01)***	
Social capital				0.098 (0.012)***
Observations	3,614	2,992	4,100	2,853
R-squared	0.083	0.066	0.082	0.071
Average Causal Mediated Effect (ACME)	0.016	0.029	0.019	0.035
Direct Effect	–0.035	–0.109	–0.070	–0.090
Total Effect	–0.019	–0.080	–0.051	–0.055
% of total effect mediated	–0.348	–0.356	–0.358	–0.536

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 5. Impact of the Great East Japan Earthquake and Social-Capital Indices on the Degree of Life Satisfaction

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	0.043 (0.038)	–0.011 (0.051)	0.023 (0.056)	0.009 (0.051)
Particularized trust	0.254 (0.018)***			
Network : daily contacts		0.204 (0.02)***		
Network : group participation			0.17 (0.015)***	
Social capital				0.284 (0.018)***
Observations	3,527	2,941	4,052	2,779
R-squared	0.155	0.130	0.123	0.166
Average Causal Mediated Effect (ACME)	0.043	0.073	0.028	0.102
Direct Effect	0.043	–0.011	0.023	0.009
Total Effect	0.086	0.063	0.051	0.111
% of total effect mediated	0.475	0.839	0.361	0.860

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

3.5 Sensitivity analysis

Figure 2 shows the results of checking the robustness of the effect of treatment (earthquake) through SC on SRH (indirect effect, Average Causal Mediated Effect, [ACME])[(3)]. This sensitivity analysis is performed based on Model 4, the base model in Table 4. If the correlation (ρ) of the error terms for SC and SRH is less than 0.14, the mediation effect is positive. On the other hand, if it exceeds 0.15, that mediation effect is negative. The result that the life satisfaction is the output in sensitivity analysis performed based on Model 4, the base model in Table 5, is more robust than SRH, and mediation effect is positive if ρ is 0.27 or less. The results indicate that we cannot claim that the threshold of ρ is so high. It is therefore necessary to examine the causal influence of SC on QOL: SRH and life satisfaction.

(3) This estimate was made using STATA 14, in particular "medsens," a program written by Hicks and Tingley (2011).

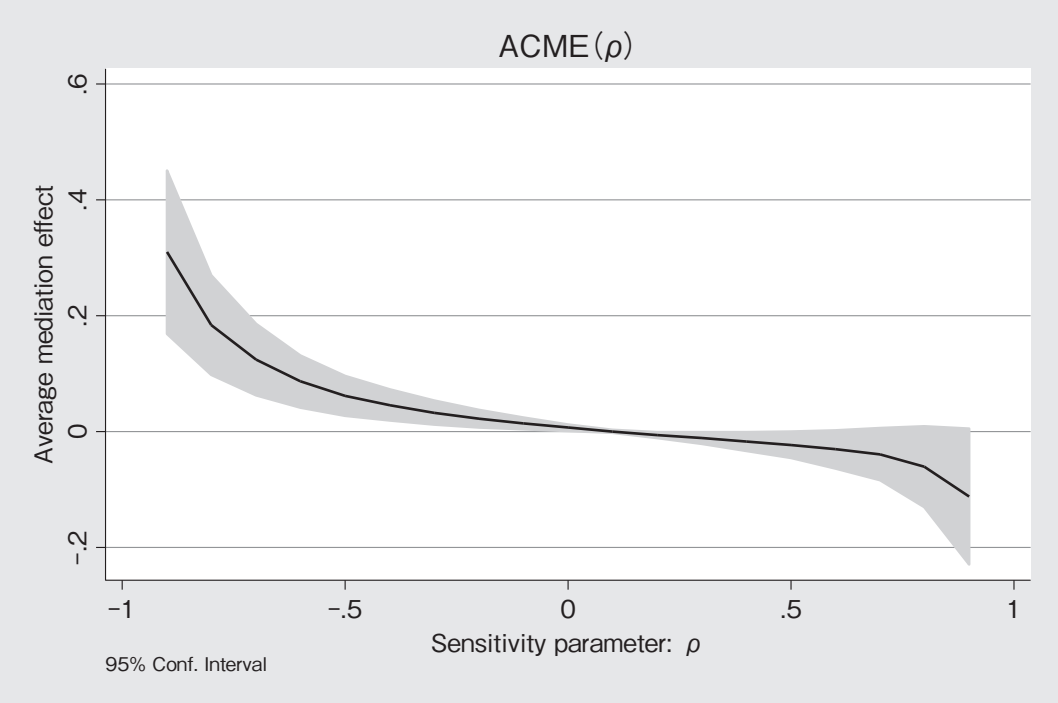

Figure 2. Sensitivity analysis for the causal effect of social capital on self-rated health.
*Rho at which ACME = 0 was 0.15. This sensitivity analysis is performed based on Model 4 in Table 4.

3.6 Instrumental variables estimation: The causal effect of SC on QOL

In our analysis, each social-capital indicator significantly influenced SRH and life satisfaction at the .01 level. However, this does not reflect a causal effect. For example, unaccounted factors may have implications for both social-capital indicators and QOL variables. Moreover, since both SC and QOL are subjective variables, a common method bias may occur.

The representative estimation method used to address such confounding problems is instrumental variable estimation. Several studies verify causal links between SC and health using instrumental variable estimation (Folland, 2007; Schultz et al., 2008; D'Hombres et al., 2010; Kim et al., 2011; Ronconi et al., 2012; Ichida et al., 2013). Kawachi et al. (2013), presents their results; Chapter 4 on causal inference in SC research is of particular interest.

In this paper, we analyze the impact of the Great Kanto Earthquake and its aftershocks that occurred in the 1920s and 1930s and in addition to the impact of the 2011 Great East Japan Earthquake to compare the role of SC in these periods. Since SC can be considered "capital" and past events influence present circumstances, though not directly, we assume that although the present generations would not have experienced direct effects of the Great Kanto Earthquake, the area would still show its effects.

Therefore, we used the Kanto Earthquake as an instrumental variable and examined the causal relationship between SC and SRH and life satisfaction. The results demonstrated a causal effect of social capital on both SRH and life satisfaction, even though the sensitivity analysis only identified an unstable causal effect.

We estimated the causal influence of SC on QOL by a two-step generalized method of moments (GMM). If the assumption of homoscedasticity in the error term holds and there is no serial correlation between samples, the GMM estimator coincides with the two-stage least squares (2SLS) estimator. However, it is impossible to assume that there is no serial correlation among individuals and there is no rational basis to assume homoscedasticity. Therefore, the two-step GMM estimation yields a more efficient and consistent estimator than the 2SLS would.

In the following estimates, we limit the age of the subjects to, at most, 70 years. This is to exclude those who directly experienced the Great Kanto Earthquake, or those who may have experienced its direct influence in early childhood.

3.6.1 First stage

There are about 2000 active faults all over Japan. After the Great East Japan Earthquake, the number of people sensitive to the risk of earthquakes has increased in Japan.

There is a huge active fault near Numazu City, and earthquakes have occurred many times in the past. For other cities that have experienced weak earthquakes, many continue to suffer population decline. While the outflow of population continues, influx does not occur, and population decline continues. These facts hinder social unity. Consequently, social capital is considered to decline as depopulation progresses.

Table 6 shows the estimation result of the first stage: Only "big earthquakes" is used as an instrumental variable, while Table 7 also includes small earthquakes as an instrumental variable. All estimates are from OLS. Numbers in parentheses are cluster-robust standard errors with municipalities (150) as clusters. The results show that the Great East Japan Earthquake had a significant positive influence, while the Great Kanto Earthquake had a significant negative influence.

The conditions immediately following earthquakes necessitate mutual assistance among residents to ensure survival. Reconstruction involves local residents to develop and execute plans, which increase opportunities for interpersonal interaction and exchange that benefits society. This raises the level of SC, specifically peoples' networks (daily contact and group participation).

However, as the reconstruction progresses, the high percentage of unfamiliar people may result in lowered indexes of trust and network density. For example, in the newly formed town, the proportion of those participating in public meetings was reported to be low (Williamson, 2002). In addition, Hanibuchi (2012) reported that as the number residents of the newly formed town grew, the more likely they were to have negative responses for SC indicators. Furthermore, with reconstruction, sections of the town are likely to be partitioned for construction, reducing walkability. Therefore, although the initial impact of the earthquake on SC will be positive, it is expected to become a negative influence.

The results of the first stage suggest that the problem of a weak correlation (Bound et al., 1995) does not occur for network involving group participation. However, the values of F-statistics were low for the others, although the coefficients of instruments were

Table 6. First Stage Analysis with Big Earthquakes Data

	Particularized Trust	Network : Daily Contacts	Network : Group Participation	Social Capital
Severely damaged area	0.206 (0.112)*	0.369 (0.146)**	0.224 (0.111)**	0.385 (0.127)***
Big earthquakes during 1923-1939	–0.057 (0.032)*	–0.091 (0.038)**	–0.157 (0.029)***	–0.07 (0.042)*
Robust F statistic (Bigearthquake)	3.378	5.763	27.940	2.982
Robust F statistic (Severelydamaged area)	1.660	8.040	4.580	10.960
observation	3,176	2,739	3,413	2,656

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 7. First Stage Analysis with Big and Small Earthquakes Data

	Particularized Trust	Network : Daily Contacts	Network : Group Participation	Social Capital
Severely damaged area	0.196 (0.113)*	0.362 (0.146)**	0.224 (0.111)**	0.376 (0.127)***
Big earthquakes during 1923-1939	–0.065 (0.033)**	–0.098 (0.038)**	–0.156 (0.03)***	–0.078 (0.043)*
Small earthquakes during 1923-1939	–0.047 (0.014)***	–0.035 (0.015)**	0.003 (0.016)	–0.038 (0.016)**
Robust F statistic (Big andsmall earthquakes)	7.995	5.007	14.120	3.834
Robust F statistic (Severelydamaged area)	1.480	7.660	4.590	10.410
observation	3,176	2,739	3,413	2,656

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

statistically significant. Therefore, the reliability of the results of particularized trust, network of daily contacts, and SC in the second stage is important.

3.6.2 Second Stage

We would like to briefly confirm the appropriateness of the instrumental variables used in this paper once again here. The Great Kanto Earthquake that occurred about 90 years ago has been affecting social capital. On the other hand, it does not affect the subjective sense of well-being and satisfaction of the present residents. This is because there is a possibility that a huge earthquake will occur anywhere in Japan. If it had an influence it would be through an economic route. We control the household income and the educational level about the economic aspect, and the result of Hansen J statistic has no problem, and it can be judged from these facts that the condition of exclusion restriction is satisfied.

Table 8 shows the estimation results at the second stage: social-capital indicators had a significant positive influence. Table 9 shows the results of including small earthquakes as an instrumental variable in addition to big earthquakes. Table 8, Table 9, Table 10, and Table 11 are estimated by two-step GMM. Hansen's (1982) J statistic can be calculated as the addition of small earthquakes as an instrumental variable that implies multiple instrumental variables. Hansen's J statistic is more than 0.2, which is satisfactory, demonstrating no issues regarding exclusion restriction.

Based on the results of table 8 - table 11, table 12 posts a recalculation of both the direct negative influence brought by the damage of the Great East Japan Earthquake and the positive mediation effect through

Table 8. Second Stage Analysis on Self-rated Health Using Big Earthquakes Data

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	–0.516 (0.424)	–0.708 (0.374)*	–0.309 (0.144)**	–0.884 (0.587)
Particularized trust	2.536 (1.375)*			
Network : daily contacts		1.737 (0.754)**		
Network : group participation			1.087 (0.239)***	
Social capital				2.26 (1.314)*

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 9. Second Stage Analysis on Life Satisfaction using Big Earthquakes Data

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	–0.174 (0.202)	–0.408 (0.234)*	–0.058 (0.104)	–0.345 (0.221)
Particularized trust	1.587 (0.487)***			
Network : daily contacts		1.395 (0.452)***		
Network : group participation			0.859 (0.164)***	
Social capital				1.338 (0.441)***

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 10. Second Stage Analysis on Self-rated Health Using Big and Small Earthquake Data

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	–0.088 (0.064)	–0.188 (0.096)*	–0.269 (0.126)**	–0.175 (0.089)*
Particularized Trust	0.398 (0.16)**			
Network : Daily Contacts		0.325 (0.229)		
Network : Group Participation			0.989 (0.24)***	
Social Capital				0.344 (0.198)*
Observations	3,176	2,739	3,413	2,656
Hansen J Statistic	0.2927	0.2573	0.1989	0.2709

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 11. Second Stage Analysis on Life Satisfaction Using Big and Small Earthquake Data

	Model 1	Model 2	Model 3	Model 4
Severely damaged area	0.048 (0.096)	–0.287 (0.178)	–0.044 (0.097)	–0.146 (0.146)
Particularized Trust	0.574 (0.29)**			
Network : Daily Contacts		1.074 (0.429)**		
Network : Group Participation			0.817 (0.204)***	
Social Capital				0.801 (0.353)
Observations	3,099	2,701	3,367	2,594
Hansen J Statistic	0.3170	0.4473	0.2277	0.3542

Note. * p < 0.1, ** p < 0.01, *** p < 0.001. For reasons of space, the coefficient values of the other explanatory variables are omitted.
The other explanatory variables are : age, gender, education, household income, marriage, occupation, duration of residence, housing, year dummy.

Table 12. The Direct and Mediation Effects of the Great East Japan Earthquake on SRH and Life satisfaction : based on Table 6. – Table 11.

		Particularized Trust	Network : Daily Contacts	Network : Group Participation	Social Capital
Table8 (SRH)	Direct Effect	–0.516	–0.708	–0.309	–0.884
	Mediation Effect	0.522	0.641	0.243	0.870
	Total	0.006	–0.067	–0.066	–0.014
Table9 (Life Satisfaction)	Direct Effect	–0.174	–0.408	–0.058	–0.345
	Mediation Effect	0.327	0.515	0.192	0.515
	Total	0.153	0.107	0.134	0.170
Table10 (SRH)	Direct Effect	–0.088	–0.188	–0.269	–0.175
	Mediation Effect	0.078	0.118	0.222	0.129
	Total	–0.010	–0.070	–0.047	–0.046
Table11 (Life Satisfaction)	Direct Effect	0.048	–0.287	–0.044	–0.146
	Mediation Effect	0.113	0.389	0.183	0.301
	Total	0.161	0.102	0.139	0.155

the rise of social capital, based on the most widely used, convenient method of Baron and Kenny (1986). As readers can see from Table12, the mediation effects are bigger than those of Direct Effects, possibly having enough influence to nearly eliminate negative effects on SRH away.

Regarding life satisfaction, the positive effect of mediation effect is very large. What this means is that if readers estimate the impact on the life satisfaction that an earthquake exerts without considering SC as an intermediate variable, the effect is likely to be biased considerably upwards .

It is empirically known that the coefficient values obtained by IV method are large in general, so these results may be observed with reservation. However, the results in Table 12 are very much strong evidence that the very powerful mediation effect does exist.

Conclusions

The causal mediation/sensitivity analysis revealed three major points:

1. The earthquake did not affect residents' levels of trust, but influenced the frequency of daily contacts and group participation.
2. The earthquake improved SC levels and lowered SRH levels. However, SC improved SRH, thereby mitigating the negative effect of the earthquake on SRH by 50%.
3. The earthquake improved SC levels but did not affect life satisfaction. However, SC improved life satisfaction.

The instrumental variable estimation revealed the two major points:

1. Contrary to the results of the causal mediation/sensitivity analysis, the effects of Kanto Earthquake on SC were negative.
2. Regarding both SRH and life satisfaction, the effects of SC were positive and statistically significant. That is, we confirmed the causal relationship between SC and SRH and life satisfaction.

Our future studies will focus on the processes by

which the level of SC is determined in the short and long terms. However, further investigation on factors that affect the SC level and how it affects QOL is needed.

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