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ORIGINAL PAPER

Social capital as a shield against anxiety among displaced residents from Fukushima

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Abstract The March 2011 meltdowns at the Fukushima nuclear power plants in Japan resulted in an increased risk of psychological distress among affected residents. We conducted original surveys of Futaba residents, a town in Fukushima where all of the residents were forced to evacuate from their homes due to radioactive contamination, obtaining 585 responses (a response rate of about 20%). Using this original data set, we investigate the role of social capital in maintaining mental health among the residents. First, we found the level of stress captured by the Kessler index (K6) to be unusually high compared both with people across Japan and with those who were displaced because of the earthquake and/or tsunami (but not the nuclear catastrophe). However, having high levels of social capital—captured by the number of neighbors from Futaba after displacement, participation in volunteer work after displacement, and participation in tea parties after displacement—plays an important role in reducing anxiety and distress among Futaba residents. Finally, we provide concrete recommendations for policy makers and NGOs to increase resilience among affected residents by strengthening social ties.

Keywords Social capital · Mental health · Fukushima · Nuclear disasters · Great East Japan Earthquake

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Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

1 Introduction

AQ2 More than 6 years have passed since the 11 March 2011 Great East Japan Earthquake and the resulting tsunami and nuclear reactor meltdowns. The compound disaster claimed some 18,500 lives and destroyed thousands of homes and businesses along the coast of the Tohoku region causing more than $250 billion in losses (National Police Agency of Japan 2015; Cabinet office of the Government of Japan 2011). Some 120,000 people remain displaced from their homes in Fukushima prefecture because of radioactive fallout from the Fukushima Daiichi nuclear plant; thousands of others remain in temporary shelters in non-irradiated areas awaiting permanent shelter (*Mainichi Shinbun* 8 March 2015). Evacuees from the disaster face various challenges such as uncertainty about their livelihoods and health, a loss of normalcy, and the evacuation of their homes and towns.

Comparative epidemiological research has shown that disasters negatively affect the mental health of survivors (Deeg et al. 2005; Reininger et al. 2013; Fergusson et al. 2014). Previous studies reported that the risk prevalence of post-traumatic stress disorder (PTSD) is higher after manmade or technological disasters than natural disasters (Neria et al. 2008). A study of Chernobyl-affected residents suggested that perceived exposure to high levels of radiation seriously impacted the mental health of residents (Bromet 2012). Initial surveys of the evacuees from Fukushima prefecture after the 2011 Tohoku disaster found increased stress and higher levels of psychological distress (Yasumura et al. 2012; Yabe et al. 2014; Niwa 2014; Oe et al. 2016).

On the other hand, research has illuminated how social capital serves as a key factor for improving disaster preparedness and building resilience to crisis (Aldrich 2012). Studies of disasters have shown that deeper reservoirs of social ties improve disaster survival, physical and mental health (Aida et al. 2013; Greene 2015; Aldrich and Sawada 2015; Gaston et al. 2016). However, few empirical studies examined the role of social capital in maintaining mental health during and after disasters, especially among residents affected by nuclear catastrophe. One study in Miyagi prefecture showed that high levels of social cohesion before the disaster were associated with a lower risk of post-traumatic disorder after the disaster (Hikichi et al. 2016). That study focused on the role of social cohesion before the disaster but did not explore the role of social capital after it. To our knowledge, there have been no studies focusing on the role of social capital after the disaster in maintaining mental health among evacuees from Fukushima.

To bridge these gaps in the literature, we measure and analyze the levels of social capital and mental health of 585 displaced residents from the town of Futaba in Fukushima Prefecture through original survey research. We uncover two important findings. First, the average level of mental stress among displaced Futaba residents is unusually high compared with all Japanese citizens. Their psychological distress scores are high compared even to individuals displaced in areas of Tohoku because of the earthquake and tsunami but not by the nuclear catastrophe. Second, high levels of social capital captured by the number of neighbors from Futaba after displacement, participation in volunteer work after displacement, and participation in tea parties after displacement act as a shield against unusually poor mental health.

This paper makes several contributions to the literature. First, it is the first paper to quantitatively investigate the nexus between mental health and social capital among the displaced population from Fukushima and demonstrate a positive association with social ties. Next, we demonstrate that the influence of a nuclear power plant accident on mental health can be more serious than that of other natural disasters under Great East Japan

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Earthquake. The results bring important policy implications for disaster managers, vulnerable communities, and decision makers as different toolkits are necessary to improve mental health in a nuclear crisis. With social capital as a shield against psychological distress, we also suggest that decision makers implement evacuation plans which ensure—as much as possible—continuity among social networks through techniques such as keeping evacuees from the same original community together in temporary shelters. Disaster managers should support local community activities such as volunteer work opportunities and social activities. Finally, we find that income consistently correlates positively with mental health, and suggest that disaster managers focus on providing jobs, not just compensation, to evacuees.

2 Methods

2.1 Data collection and measurement of mental health and social capital

Futaba town, which (pre-disaster) had some 7000 residents split among some 2900 households, remains one of the towns most affected by the nuclear power plant accident after the Great East Japan Earthquake on March 11, 2011, as it sits some 4 km (2.5 miles) from the Fukushima Daiichi reactor. After the meltdowns at Tokyo Electric Power Company (TEPCO) reactors, the central government set up an exclusion zone around the area to prohibit entry to the region. All Futaba residents were forced to evacuate from the town to locations across Japan and, as of summer of 2017, continue to live as displaced residents. A date for their return has not been released by the government or TEPCO, the power utility responsible for the Fukushima nuclear power plants.

With support of the Futaba's City Hall, we distributed a survey to all households of the town with the monthly Futaba town newsletter by mail on July 3, 2013. We received 585 answers by August 22, 2013, for a response rate of about 20% of all the household heads. While a response rate of 20% is not necessarily low compared to other general Japan surveys which do not provide incentives, the rate is not as high as other post-disaster surveys. As such, we employed 2010 census data to explore the determinants of survey participation. According to the estimation results of our survey participation regression model based on the combined 2010 census data and our data, older residents, male residents, and residents of certain settlements were more likely to complete our questionnaire (results available upon request). To handle potential sample selection bias arising from endogenous survey participation, we combine our data with 2010 census data for validation and adopted Heckman's correction method (Heckman 1979).

The questionnaire asks about general demographic characteristics such as age, sex, family composition before and after the disaster, living place before and after the disaster, income before and after the disaster, and educational achievement. Also, we included various measures of social capital before and after the disaster along with the K6 questions (Kessler et al. 2002) to measure their state of mental health (the distributed questionnaire is available upon request). For each question in the K6 battery, respondents selected an answer on a scale from 0 to 4. The total score for the six questions is summarized as the K6 score of the respondent; higher scores indicate more propensity for mental health problems. In the Japanese context, experts developed a Japanese language version of K6 and demonstrated screening performances equivalent to the original (Furukawa et al. 2008).

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

To capture levels of social capital, we included various measures based on past research for network, trust, and civic participation frameworks as shown in Tables 1 and 2 (Cabinet Office of the Government of Japan 2003). Table 1 presents questions we used to capture social capital levels. In addition to participation measures, such as participation in volunteer activities and tea parties, we ask about the number of Futaba neighbors after displacement to measures levels of social ties continuing from their pre-disaster community. We ask about the number of Futaba neighbors after displacement who knew each other before the disaster and the number of Futaba neighbor after displacement who did not know each other. Table 2 presents social capital-related measures we use to derive a factor variable "trust perception" that we will explain detail in the analysis section. To capture trust perception, we go beyond standard *attitudinal* measures of trust and social capital—such as those from the General Social Survey (GSS)—to include *behavioral* measures such as "Do you leave the door unlocked when you go out? (Anderson et al. 2004)." Descriptive statistics of all the variables used in our analysis are shown in Table 6 in "Appendix 1."

We analyze the impact of bonding social capital—the connections between people who are quite similar—after displacement in individual level on mental health (Aldrich 2012). Capturing bonding social capital is more appropriate than capturing bridging or linking social capital—which involve cross-group or vertical ties—in our setting. Our survey participants all come from one small town in Fukushima, which makes it difficult to observe variations in bridging and linking social capital in the pre-disaster community. Also, we can investigate the role of bonding social capital by exploiting a serendipitous situation arising from exogenous displacement. As past research has demonstrated, crises regularly activate bonding ties more than other forms of social connection (Beggs et al. 1996).

2.2 Analysis

We begin by looking at psychological distress captured by K6 scores. We compare the distribution of K6 scores among Futaba residents with those from across Japan, residents in

Table 1 Social capital proxies

Variable	Question in the questionnaire	Answer
Number of Futaba unknown neighbors	Number of Futaba neighbors after displacement who did not know each other before the disaster	Category 1. Over 20 2. 10 to 19 3. 6 to 9 4. 3 to 5 5. 1 to 2 6. None (For analysis, interval regression is used for constructing continuous variable. Explanation of interval regression is available in "Appendix 2")
Number of Futaba known neighbors	Number of Futaba neighbors after the disaster who knew each other before the disaster	
Participation in volunteer activities	# Hours participating in volunteer work per week	Numerical: hour/week (For analysis, a dummy variable for 0< is employed)
Participation in tea party	# Hours joining tea party or other activities per week	Numerical: hour/week (For analysis, a dummy variable for 0< is employed)

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Table 2 Social capital proxies for deriving a factor (trust to neighbors and general people)

Variable	Question in the questionnaire	Answer
General trust	Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?	Category (ordered) 4: People can be trusted 3: People can be trusted more often than not 2: You cannot be too careful more often than not 1: You cannot be too careful
Mutual help	Talking of neighborly ties, how often does household head give something to neighbors or help neighbors, or get something from neighbors or get help from neighbors?	Category (ordered) 4: So often 3: Moderately 2: Not so often 1: None
Fairness	Do you think most people try to be fair?	Category 1: Yes 2: No 3: Don't know
Self-trustworthiness	Do you think you are trustworthy?	Category 1: Yes 2: No 3: Don't know
Trust in neighbors	Neighbors will help me when I am in trouble	Category (ordered) 5: Strongly agree 4: Agree 3: Can't tell 2: Don't agree 1: Don't agree at all
Leaves door open	Do you leave the door open when you go out?	Category 1: Yes 2: No 3: Don't know
Borrows from neighbors	Do you often lend or borrow money or things to or from your friends?	Category 1: Yes 2: No 3: Don't know

other disaster-affected areas, and evacuees in other disaster-affected areas, using age and gender distribution to validate the findings.

Second, we investigate the relationship between social capital and mental health using a two-step empirical procedure. First, we conduct a factor analysis to derive a factor from variables shown in Table 2, which are general trust, mutual help, fairness, self-trustworthiness, trust in neighbors, leaves doors open, and borrows from neighbors. General trust follows the General Social Survey (GSS) measure asking "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?" Respondents selected an answer from four choices: (4) people can be trusted, (3) people can be trusted more often than not, (2) you cannot be too careful more often than not, and (1) you cannot be too careful. Mutual help indicates the frequency of mutual help with neighbors.

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Our survey measures fairness through a dummy variable for those who think that people generally try to be fair. We capture self-trustworthiness with a dummy variable for those who agree that others think that they are trustworthy. Trust in neighbors indicates the agreement level (from 1 to 5) with the sentence "Neighbors will help me when I am in trouble." We also included a dummy variable for those who leave the door open when they go out and for those who sometimes borrow or lend money or goods from or to others. The proxies used for deriving a factor measure trust and trusting behavior within the community and trust in general after displacement. Therefore, we name this factor as "trust perception."

Second, using the derived factor "trust perception," we test an intervening model as shown in Fig. 1. Following Mackinnon et al. (2002) and Shrout and Bolger (2002), we use the following estimation models.

$$I = \beta_{I0} + \boldsymbol{S}\beta_{IS} + \varepsilon_I \tag{1}$$

$$P = \beta_{P0} + \boldsymbol{S}\beta_{PS} + \alpha_{PI} I + \varepsilon_P \tag{2}$$

where P represents K6 score. I represents the intervening variable "trust perception." $\boldsymbol{S}$ is a set of social capital proxies: the number of Futaba neighbors after displacement who knew each other before the disaster, the number of Futaba neighbors after displacement who they did not know each other, a dummy variable for those who participate in volunteer activities after displacement, and a dummy variable for those who participate in tea parties after displacement. We first test the significance of β_{IS} using the specification (1) and the significance of α_{PI} using the specification (2). We also check the insignificance of β_{PS} using specification (2) to make sure that there is no direct impact of social capital on K6 score and then we test the significance of $\beta_{IS} \times \alpha_{PI}$ using Sobel (1982), Aroian et al. (1995) and Goodman (1960) tests. In addition, we estimate the reduced-form version of the model (2) to quantify determinants of mental health other than social capital proxies and use control variables to manage potential confounding factors.

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2.3 Limitation

As we have cross-sectional study with a response rate of about 20%, we recognize the potential for two biases in our estimation: sample selection bias arising from endogenous participation in our survey and endogeneity bias arising from endogenous social capital due to each evacuee's relocation choice. To mitigate the former, we adopted a Heckman correction model using observed characteristics in the 2010 Census such as sex and age categories of each respondent and non-respondent. Though we adjust demographic characteristics using the Heckman correction model, we recognize that demographic characteristics are not the only driving factor in the decision of responding. Those worse off and

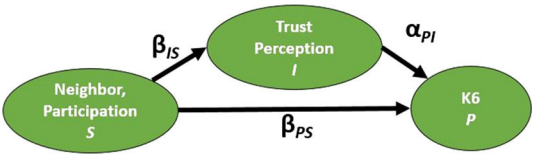

Fig. 1 Intervening model. S represents social capital variables, I is the intervening variable trust perception, and P indicates K6, the mental health proxy

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

less connected can be less likely to respond, which could result in underestimating the effect.

As to the latter bias, we estimated the model with administrative unit fixed effects to eliminate endogeneity bias due to time-invariant unobserved heterogeneity across local government levels. Furthermore, we also note that the possibility of common method bias as a limitation to our study as both explanatory variables and outcome variable are based on self-reported answers (Podsakoff et al. 2003).

3 Results

The average level of psychological distress among Futaba residents is unusually high compared with those from across Japan as shown in Fig. 2. The age- and gender-stratified comparison of K6 score also validates our finding (age- and gender-stratified comparisons are not presented here but are available upon request). The Japanese data used for comparison come from the Comprehensive Survey of Living Conditions conducted by Japanese ministry of Health, Labor and Welfare in 2013 which we use because it is one of the most large-scale, random surveys covering all the population of Japan.

AQ6 Furthermore, the average level of psychological distress among Futaba residents is high even when compared with other disaster-affected areas such as the Wakabayashi district of Sendai, Ogatsu and Oshika districts of Ishinomaki, Yamada, Oduchi, and Rikuzentakata that were seriously damaged by the earthquake and tsunami (but not the nuclear plant AQ7 meltdowns) as shown in Fig. 3. The data on disaster-affected areas come from *Higashi Nihon Daishinsai hisaisya no kenkōjō taitō ni kansuru chōsa* [Exploration of health status of disaster-affected residents by the Great East Japan Earthquake] conducted in 2011 by Hayashi et al. These data were chosen for comparison since it is one of the largest scale survey data targeting residents in seriously damaged areas and the city-, town-, or district-level distribution of K6 score was available.

However, we recognize the limitation of the comparison shown in Fig. 3; namely, our survey respondents consist of only evacuees while the supplemental data do not reflect evacuees' mental health. This is because the data reflect the answers of those who did not need to evacuate though the areas were seriously damaged. Therefore, we conducted a further comparison of the K6 distribution of Futaba residents using data which reflect the AQ8 mental health of evacuees in another disaster-affected area as shown in Fig. 4. The data used for comparison here are from *Ōkyū kasetsu jūtaku Nyūkyosha kenkō chōsa* (Health

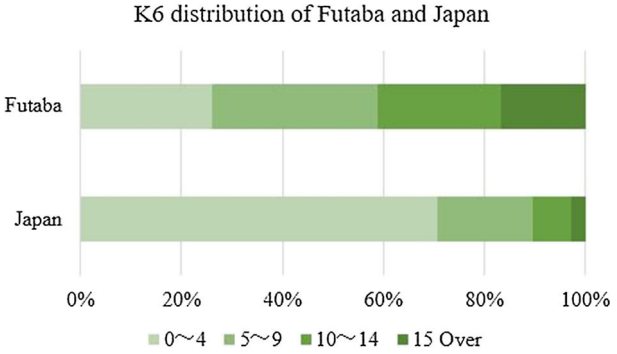

Fig. 2 K6 distribution of Futaba and Japan. *Notes* Futaba data are from author surveys and Japan data are from *Kokumin seikatsu kiso chōsa 2013* [Comprehensive Survey of Living Conditions 2013]

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

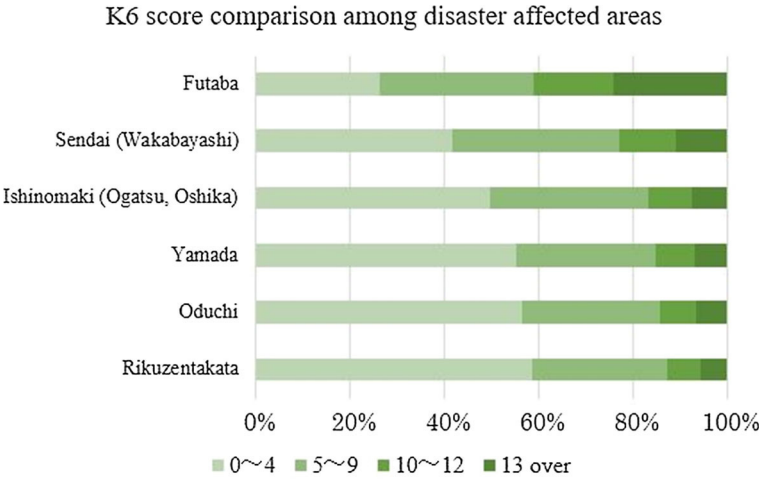

Fig. 3 K6 score comparison among disaster-affected areas. *Notes* Futaba data are from author surveys and data from Sendai and Ishinomaki are from *Higashinihon daishinsai hisaisha no kenkōjōtai nikansuru chōsa kenkyū, 2011* [The study about health of Great East Japan disaster-affected people, 2011] by Hayashi et al. (2012)

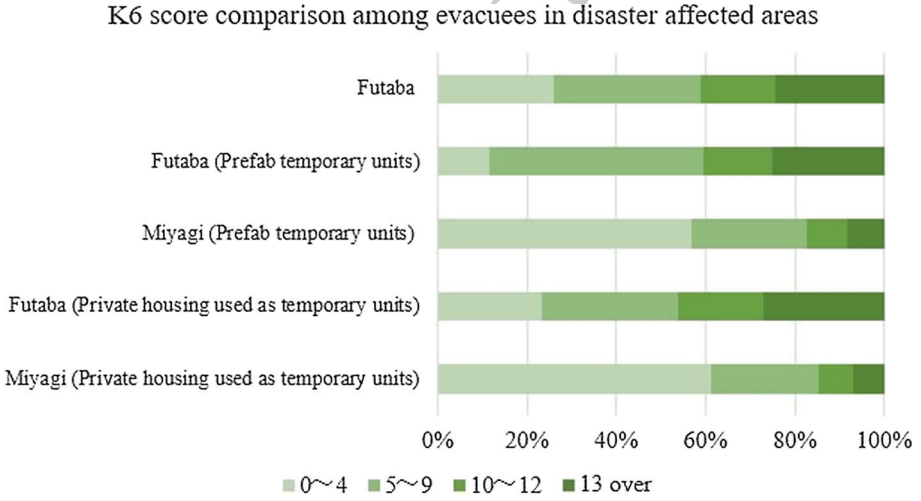

Fig. 4 K6 score distribution among evacuees in disaster-affected areas. *Notes* Futaba data are from author survey. Miyagi data (prefab temporary units) are from *Ōkyū kasetsujūtaku (Prefab) Nyūkyosha kenkō chōsa* [Health survey of prefab temporary units' residents] in 2013 by Miyagi prefectural government. Miyagi (private housing used as temporary units) is from *Minkan chintai kariage jutaku tō nyūkyosha kenkō chōsa* [Health survey of residents in private housing used as temporary units] in 2013 by Miyagi prefectural government

222 survey of prefabricated temporary shelter residents) and *Minkan chintai kariage jutaku tō*
223 *nyūkyosha kenkō chōsa* (Health survey of residents in private housing used as temporary
224 units) conducted in Miyagi prefecture in 2013 by the prefectural government. We used

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

these data as they reflect the status of those who live in temporary units in Miyagi, that is, the mental health status of disaster evacuees.

Figure 4 shows that Futaba residents have high K6 scores even when compared with evacuees in other disaster-affected areas. Gender- and age-stratified comparison of percentage of K6 score over 13 among evacuees (not presented but available upon request) shows that K6 scores are especially high among elderly Futaba evacuees (over 60s) compared to evacuees in other disaster-affected areas. This comparison shows that displacement caused by the nuclear accident led to more serious mental health problems than displacement caused by other natural disasters.

Next, we find that levels of social capital as captured by post-disaster number of Futaba known and unknown neighbors, participation in volunteer activities, and participation in tea parties can improve mental health through a factor we deem *trust perception*. We demonstrate this through a two-step empirical analysis. First, we derived the intervening variable trust perception by conducting a factor analysis of general trust, trust in neighbors, frequency of mutual help with neighbors, self-evaluation of trustworthiness, and evaluation of fairness of society. As the first factor with the largest eigenvalue highly correlates with these five variables as we can see in Table 3, we label this factor *trust perception*. Then, we used this factor in an intervening variable model as shown in Fig. 1.

The estimated results of model (1) of β_{IS} and (2) of β_{PS} and α_{PI} of Fig. 1 with Heckman correction and administrative unit fixed effects are displayed in Table 4 which shows that the four social capital variables (number of Futaba known and unknown neighbors after displacement, participation in volunteer activities, and participation in tea parties) significantly and positively correlate with the factor trust perception, thereby demonstrating the significance of β_{IS} in model (1). Also, the estimation results of model (2) show that trust perception is significantly negatively correlated with K6 scores (α_{PI}) while the four social capital proxies captured by estimated β_{PS} are largely insignificant, which is consistent with the intervening model. The Sobel, Aroian, and Goodman tests show the significance of $\beta_{IS} \times \alpha_{PI}$ in Table 5 and validate our intervening variable model. It should be noted that the inverse mills ratio of all the estimation results is insignificant which means that sample selection bias is not a serious obstacle.

Table 3 Factor loadings result to derive the intervening variable, "trust perception"

Variable	Factor 1 (trust perception)	Uniqueness
General trust	0.3376	0.886
Mutual help	0.5957	0.6452
Trust in neighbors	0.6918	0.5214
Leaves door open (yes)	#	0.9808
Borrows from neighbors (yes)	#	0.9845
People are fair (yes)	0.4562	0.7919
Self-trustworthiness (yes)	0.5033	0.7467
KMO measure = 0.63		

Shows that factor loadings are smaller than 0.3 in absolute value. We retained only the first factor because the eigenvalues associated with the remaining factors are smaller than 1 following Kaiser's criterion (Kaiser 1960). KMO measure represents Kaiser–Meyer–Olkin measure of sampling adequacy (Kaiser 1974) which shows that the derived factor is meaningful at acceptable level

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Table 4 Regression results of Heckman selection model (1) and (2) with administrative unit fixed effects

	[1] Dependent variable: trust perception			[2] Dependent variable: K6		
	(a)	(b)	(c)	(d)	(e)	(f)
Factor *I* (trust perception)				−0.903***	−0.799**	−0.830**
				(0.333)	(0.320)	(0.331)
No. of Futaba unknown neighbor	0.0203***	0.0186***	0.0152**	0.103**	0.0795	0.0727
	(0.00645)	(0.00692)	(0.00651)	(0.0508)	(0.0518)	(0.0501)
No. of Futaba known neighbor	0.0256***	0.0261***	0.0292***	0.0277	0.0193	0.0378
	(0.00718)	(0.00735)	(0.00701)	(0.0563)	(0.0550)	(0.0543)
Volunteer participation dummy	0.211**	0.237**	0.201*	−0.178	−0.730	−1.400*
	(0.104)	(0.105)	(0.107)	(0.812)	(0.776)	(0.813)
Tea party participation dummy	0.304***	0.284***	0.440***	−0.936	−0.748	−0.0395
	(0.0879)	(0.0893)	(0.0935)	(0.688)	(0.670)	(0.740)
Constant	−0.375**	−0.788*	−1.180**	10.16***	3.818	4.111
	(0.171)	(0.444)	(0.460)	(1.345)	(3.093)	(3.352)
Inverse mills ratio for the Heckman correction	0.0164	0.191	0.210	−0.389	0.292	0.516
	(0.0847)	(0.152)	(0.144)	(0.653)	(1.006)	(0.973)
Control variables	FE	FE + short set	FE + long set	FE	FE + short set	FE + long set
N	5691	5684	5678	5671	5665	5660
Wald test statistics of a null hypothesis that all coefficients except the constant term are zero	142.35	189.24	307.83	100.88	212.53	275.94
p value for the null hypothesis	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000

Standard error in parentheses. Interval regression is used for constructing continuous variable for number of Futaba neighbors (known and unknown). We also report a Wald test statistics of a null hypothesis that all coefficients in the regression model except the constant term are zero. Our results reject the null hypothesis strongly. Explanation of interval regression is available in "Appendix 2." Omitted control variables from all the columns are prefecture fixed effects (except for Fukushima prefecture) and city fixed effects in Fukushima prefecture. We adopted a Heckman correction model using observed characteristics in the 2010 Census such as sex and age categories of each respondent and non-respondent. In addition, omitted control variables on (b) and (e) are house type, education, gender, income level and income level before the disaster dummies, and age. In addition to those, on (c) and (f), general trust before the disaster, mutual help before the disaster, trust in neighbors before the disaster, leaves door open before the disaster, borrows from neighbors dummies before the disaster, people are fair dummies before the disaster, self-trustworthiness dummies before the disaster, volunteer participation dummies before the disaster, and tea party participation dummies before the disaster are included. Those coefficients are not reported in the table but are available from the corresponding author upon request

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

Journal : Small 11069 Dispatch : 19-6-2017 Pages : 17
Article No. : 2971 LE TYPESET
MS Code : NHAZ-D-16-01378 CP DISK

Table 5 Joint significance test for regression results of Heckman selection model with administrative unit fixed effects

	β_{IS}	α_{PI}	$\beta_{IS}\ \alpha_{PI}$	Sobel test		Aroian test		Goodman test	
				Score	p value	Score	p value	Score	p value
No. of Futaba unknown neighbor									
Test of (a) and (d) of Table 4	0.0203***	−0.903***	−0.0183	−2.054	0.0399	−1.997	0.0458	−2.117	0.0343
Test of (b) and (e) of Table 4	0.0186***	−0.799**	−0.0149	−1.829	0.0673	−1.765	0.0776	−1.901	0.0573
Test of (c) and (f) of Table 4	0.0152**	−0.830**	−0.0126	−1.709	0.0875	−1.640	0.1009	−1.787	0.0740
No. of Futaba known neighbor									
Test of (a) and (d) of Table 4	0.0256***	−0.903***	−0.0231	−2.158	0.0309	−2.107	0.0352	−2.214	0.0268
Test of (b) and (e) of Table 4	0.0261***	−0.799**	−0.0209	−2.042	0.0411	−1.990	0.0466	−2.099	0.0358
Test of (c) and (f) of Table 4	0.0292***	−0.830**	−0.0242	−2.148	0.0317	−2.104	0.0354	−2.195	0.0281
Volunteer participation dummy									
Test of (a) and (d) of Table 4	0.211**	−0.903***	−0.1905	−1.624	0.1042	−1.558	0.1192	−1.700	0.0891
Test of (b) and (e) of Table 4	0.237**	−0.799**	−0.1894	−1.674	0.0941	−1.605	0.1085	−1.754	0.0795
Test of (c) and (f) of Table 4	0.201*	−0.830**	−0.1668	−1.503	0.1327	−1.432	0.1521	−1.586	0.1126
Tea party participation dummy									
Test of (a) and (d) of Table 4	0.304***	−0.903***	0.2745	−2.134	0.0328	−2.081	0.0375	−2.191	0.0284
Test of (b) and (e) of Table 4	0.284***	−0.799**	0.2565	−2.589	0.0096	−2.574	0.0100	−2.604	0.0092
Test of (c) and (f) of Table 4	0.440***	−0.830**	0.3652	−2.213	0.0269	−2.175	0.0296	−2.253	0.0243

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

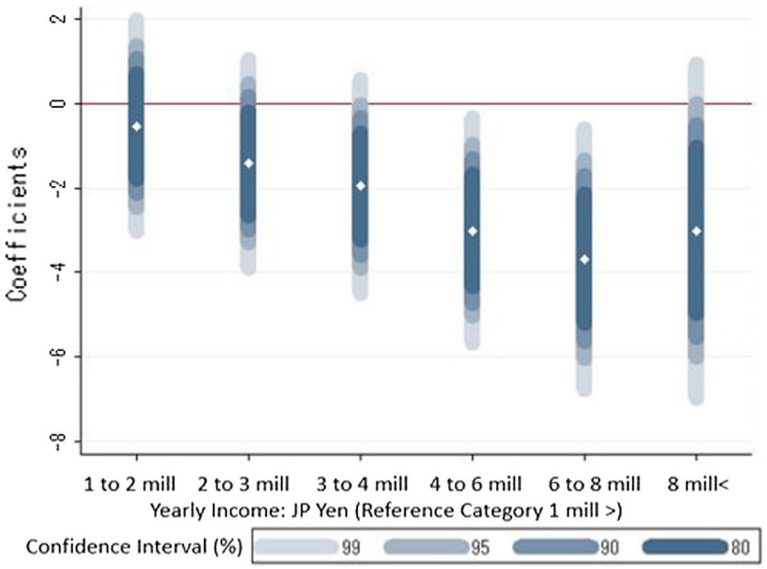

Fig. 5 K6 regression on wealth

In addition to social capital measures, the income of the residents is strongly associated with mental health. To quantify the overall effects of income on mental health, Fig. 5 displays the estimation results of a reduced-form version of the model. Futaba residents have received various types of monetary compensation from TEPCO, but these subsidies are not included in our analysis.

4 Discussion

Several takeaways come from these empirical results. First, the K6 scores of ex-Futaba residents indicate the high possibility of severe mental distress caused by the nuclear disaster; residents may be experiencing PTSD, anxiety, and depression because of direct and indirect costs.[1] Causes of distress include rapid evacuation, uncertainty about the future, and potential radiation impact on their health and livelihoods. There are a substantial number of residents who described these concerns in open-ended sections of our survey. Also, many evacuees feel betrayed by the government and the Tokyo Electric Power Company because of the collapse of the safety myth about nuclear power. As a result, specialized mental health care should be provided for those who were affected by nuclear disaster; decision makers and NGOs may need different toolkits for handling these kinds of natural–technological (*natech*) disasters (Arata et al. 2000).

[1] As larger amounts of damage correlate with higher distress among Futaba residents (Iwasaki and Sawada 2016), we can strengthen and externally validate the claim that disasters damage mental health of affected residents. However, as our results only examine the case of Futaba residents, it is only suggestive that nuclear catastrophe led to more serious damages to mental health than other natural disasters. For external validation, further comparisons with studies under other nuclear disaster settings are necessary. As to internal validity, those worse off are less likely to respond, which could result in underestimating the serious mental health situation of the Futaba residents.

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Second, our results show that social capital positively correlates with mental health through the intervening factor trust perception.[2] This association between social capital and mental health corresponds with a theory by Cohen et al. (2000) in which social networks can improve mental health through positive affective states. Furthermore, local governments across Tohoku have created various policies and activities to maintain social networks among disaster-affected residents to create better mental health. For example, in Saitama prefecture, to where many evacuated residents from Fukushima have moved, local communities provide various opportunities for disaster-affected residents to gather and have tea parties through programs such as the *Saigai-Tsunagari Café* (post-disaster social connection café), *F-café-juju*, and the *Oshaberi-salon* (NPO hands-on Saitama 2013). Our study provides the first quantitative evidence of the potential efficacy of these social capital strengthening activities after the disaster. These activities should be expanded, and NGOs and other organizations should work to attract shut-in, introverted residents who avoid joining activities.

Our results also show that disaster-affected residents who participate in volunteer work improve their psychological well-being. From the anthropological perspective, some disaster-affected residents faced an emotional debt because of the support they received. One scholar theorized that residents can restore their dignity by presenting "counter-gifts" to others (Uchio 2013).

The *Ibasho-café*, a program setup in the tsunami-affected city of Ofunato to provide a place for disaster-affected residents to gather and allow elderly residents to take leadership roles, similarly builds on the role of engagement and civic participation (Kiyota et al. 2015; Aldrich and Kiyota 2017). Our analysis suggests that volunteer work and bottom up social activities should be supported and expanded in disaster-affected areas. Governments tend to focus on infrastructure reconstruction; the Japanese government budgeted 26.3 trillion yen ($310 billion) for reconstruction rehabilitation for 5 years after the Great East Japan Earthquake with the largest portion (about 38%) for infrastructure reconstruction (Reconstruction Agency 2015a, b). Our results suggest that focusing on strengthening social capital and social ties is important in revitalizing disaster-affected areas.

Further, we show that having more neighbors from Futaba town can improve mental health. This result supports various policies by Japanese local governments which distribute temporary and permanent shelter spaces according to residents' original neighborhoods (Aldrich and Meyer 2015). Our study provides empirical support for the effectiveness of these group-relocation activities (Aldrich 2012), and we suggest that decision makers work to evacuate residents in ways which keep social networks intact.

Finally, income and livelihood conditions influence mental health. This is consistent with various empirical studies of mental health which argue for the importance of economic resources in maintaining mental health (Keleher and Armstrong 2006). Authorities should promote public policies which provide jobs and income—and not just compensation—for evacuees and internally displaced people following disaster.

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[2] As our results only examine Futaba residents, our claim that social capital can be a shield against deterioration of mental health cannot have external validity. For external validation, further comparisons with other nuclear disaster settings will be necessary. As to internal validity, those worse off and less connected are less likely to respond, which could result in underestimating the effect of the social capital on mental health among Futaba residents.

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Appendix 1: Descriptive statistics

See Table 6.

Table 6 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
Age (in years)	575	62.967	14.388	24	94
Gender dummies					
Male	585	0.774	0.418	0	1
Female	585	0.210	0.408	0	1
No answer	585	0.015	0.123	0	1
House type dummies					
Kasetsu (temporary prefab) units	585	0.103	0.304	0	1
Relative's house	585	0.053	0.224	0	1
Kariage (private housing used as temporary) units	585	0.603	0.490	0	1
House bought	585	0.106	0.308	0	1
Rental housing	585	0.055	0.228	0	1
Nursing home	585	0.015	0.123	0	1
Kisai high school	585	0.017	0.130	0	1
Employer's provision	585	0.032	0.177	0	1
No answer	585	0.016	0.123	0	1
Income dummies (in yen)					
Less than 1 million	585	0.159	0.366	0	1
1 million to 2 million	585	0.174	0.380	0	1
2 million to 3 million	585	0.171	0.377	0	1
3 million to 4 million	585	0.144	0.351	0	1
4 million to 6 million	585	0.126	0.333	0	1
6 million to 8 million	585	0.091	0.287	0	1
More than 8 million	585	0.046	0.210	0	1
No answer	585	0.089	0.285	0	1
Health condition dummies					
Much better	585	0.007	0.082	0	1
Better	585	0.032	0.177	0	1
No change	585	0.268	0.443	0	1
Worse	585	0.480	0.500	0	1
Much worse	585	0.109	0.312	0	1
No answer	585	0.103	0.304	0	1
K6 measure	524	8.656	6.014	0	24
No. of Futaba unknown neighbor	583	3.702	6.043	0	22
No. of Futaba known neighbor	583	3.513	5.452	0	28
Tea party dummies					
0 h/week	585	0.421	0.494	0	1
More than 0 h/week	585	0.195	0.396	0	1
No answer	585	0.385	0.487	0	1

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

Table 6 continued

Variable	Obs	Mean	SD	Min	Max
Volunteer dummies					
0 h/week	585	0.451	0.498	0	1
More than 0 h/week	585	0.123	0.329	0	1
No answer	585	0.426	0.495	0	1
General trust (after disaster)	571	2.317	0.852	1	4
Mutual help (after disaster)	574	1.911	0.853	1	4
Trust in neighbors (after disaster)	564	2.465	1.197	1	5
Leaves door open dummies					
Yes	585	0.050	0.217	0	1
No	585	0.909	0.287	0	1
Don't know	585	0.014	0.116	0	1
No answer	585	0.027	0.163	0	1
Borrows from neighbors dummies					
Yes	585	0.027	0.163	0	1
No	585	0.909	0.287	0	1
Don't know	585	0.024	0.153	0	1
No answer	585	0.039	0.195	0	1
People are fair dummies					
Yes	585	0.306	0.461	0	1
No	585	0.159	0.366	0	1
Don't know	585	0.472	0.500	0	1
No answer	585	0.063	0.244	0	1
Self-trustworthiness dummies					
Yes	585	0.243	0.429	0	1
No	585	0.080	0.272	0	1
Don't know	585	0.638	0.481	0	1
No answer	585	0.039	0.195	0	1

Kasetsu housing refers to temporary shelters provided by government, while *kariage* housing refers to cash compensation for housing rentals. Income variables do not include any compensation. Health condition: We ask, "How is the household head's health compared to his or her health before the disaster?"

Appendix 2: Interval regression of number of unknown and known Futaba neighbors

These variables are treated as continuous variables, but they were originally structured as ordered categories. However, to better understand the estimation results, we constructed a continuous variable using interval regression. For the estimation, in addition to the category number of unknown and known Futaba neighbors, gender dummies, age, house type dummies, current prefecture dummies, and residential block in Futaba dummies were employed. After the estimation, the numbers were rounded. Furthermore, upper and lower bounds were adjusted according to the original categories. Estimation results of interval regression are not reported here but are available upon request.

Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

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Journal : Small 11069 | Dispatch : 19-6-2017 | Pages : 17
Article No. : 2971 | LE | TYPESET
MS Code : NHAZ-D-16-01378 | CP | DISK

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