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Effect of major disasters on geographical mobility intentions: the case of the Fukushima nuclear accident*

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Abstract

This paper uses panel data from Japan to explore how the Great East Japan Earthquake influenced the intention to leave one's place of residence by comparing the same individuals' responses before and after the earthquake. Controlling for unobserved individual fixed effects and various individual characteristics, we found that (1) people were more willing to leave their place of residence after the disaster when they lived nearer to Fukushima, (2) the effect of the disaster on intention to leave was reinforced when respondents had a small child, and (3) after dividing sample by gender, such tendencies were observed among women but not among men. From the last finding, we conclude that differences between men and women in perceived risk lead to differences in mobility intentions.

Keywords: Geographical mobility, disaster, perceived risk

JEL classification codes: Q54, J15, J61, D89

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1. Introduction

Natural disasters have been observed to occur more frequently in the last twenty years than earlier (Yamamura, 2014a). There are also cases of serious manmade disasters, such as the Chernobyl and Fukushima nuclear accidents. These accidents have led people to focus a great deal of attention on environmental issues and the security of nuclear energy (Berger, 2010). In response to this trend in public opinion, increasing numbers of studies in the field of economics have examined the influence of disasters (e.g., Anbarci et al., 2005; Eisensee and Strömberg, 2007, Kellenberg and Mobarak, 2008; Skidmore and Toya, 2002). Some researchers have explored how and the extent to which disasters have influenced subjective perception (e.g., Berger, 2010; Carroll et al., 2009; Luechinger and Saschkly, 2009). Individuals who have experienced disasters tend to estimate fatality risks from disaster higher than others do (Visucursi and Zeckhauser, 2006). Based on cross-national data, perceived risk of a nuclear accident is positively associated with having experienced technological disasters, but the perceived risk is not associated with natural disasters (Yamamura, 2012).

Given these past findings, it is plausible that experiencing the disaster caused certain people to migrate to less disaster-prone areas. That is, the perception of the risk of disasters is thought to be among the key factors determining geographical mobility after experiencing a disaster. In the case of the Fukushima accident, which occurred in 2011 following a massive earthquake and tsunami, radiation leakage drastically increased the level of the radiation dose, not only in Fukushima and its surrounding prefectures, but also in other areas of east Japan. Therefore, people were evacuated from their places of residence even if the area was not directly affected by the disaster. Further, parents feared that radiation exposure would result in serious damage to their

children, and they were consequently more likely to move (Saito, 2011: 235–271)[1]. Analyzing the effect of the Fukushima accident on an individual's intention to migrate can be regarded as a natural experiment to investigate how unexpected large-scale disasters affect population mobility. There are existing empirical analyses concerning the Great East Japan Earthquake and the Fukushima accident (e.g., Ando and Kimura, 2012; Goebel et al., 2013; Hanaoka et al., 2014; Ishino et al., 2011; Tanikawa et al., 2014; Uchida et al., 2014)[2]. In the field of regional science, many researchers have attempted to elucidate how people decide to move away from their place of residence (e.g., Belot and Ermisch, 2009; David et al., 2010; Deding and Filges, 2010; Eliasson et al., 2003; Kan, 2007; Mocetti and Porello, 2010). However, the existing research does not deal with the relation between accidents and population mobility. The present study seeks to fill this gap, using individual-level panel data to compare the willingness to leave the residential prefecture before and after the Fukushima accident, taking into account distance from Fukushima and the presence of small children.

A key finding of the estimations in this article is that people were more inclined to leave after the disaster if their place of residence was closer to Fukushima. Such a tendency was more obvious among female respondents and those with a small child.

The structure of the rest part of this paper is as follows. Section 2 presents an overview of the Fukushima accident. We then explain the data used in this paper and

[1] Students are less likely to qualify for high school if their mother were exposed to the radioactive fallout of Chernobyl's accident (Almond et al., 2007).

[2] The Great Hanshin Awaji Earthquake, which occurred in 1995, also caused tremendous damage to Japanese society. Several studies were conducted on this earthquake (e.g., Sawada and Shimizutani, 2007, 2008, 2011; Yamamura, 2014). Apart from the catastrophic disasters such as the Great Hanshin Awaji and the Great East Japan earthquakes, Japan is regarded as a country where natural disasters very frequently occur, and consequently the effects of natural disasters have been investigated relatively frequently in the Japanese context (Iwata et al., 2014; Matsubayashi et al., 2013; Yamamura, 2010).

propose testable hypotheses in section 3. Section 4 describes the method and reports the estimation results. The final section presents the conclusion.

2. Overview of the Great East Japan Earthquake

On March 11, 2011, Japan not only experienced a major natural disaster but also suffered a devastating nuclear accident. This was considered one of the most disastrous events in human history. Regarding the natural disaster, the earthquake occurred off the coast of Japan, and its magnitude scale was 9.0, making it the fourth largest earthquake recorded worldwide since 1900. The earthquake then caused a tsunami, which triggered powerful tsunami waves, pushing water to heights of more than 20 meters in some coastal areas of the northeastern coast of Japan. This was one of the largest tsunamis ever to hit Japan (Daily Yomiuri, 2011b). Approximately 16,000 people died, mainly because they could not escape the tsunami. Material stock losses of buildings and road infrastructure are estimated at 31.8 and 2.1 million tons, respectively (Tanikawa et al., 2014). Moreover, the "World Bank and Japanese government say that there's somewhere between $122 and $235 billion worth of damage to clean up" (Hammer, 2011: 28). The earthquake and tsunami caused tremendous damage in the prefectures of Iwate, Miyagi, and Fukushima, located in the northeast of Japan along the coast. However, the damage was not restricted to these prefectures[3]. The Fukushima Daiichi nuclear power generation plants faced the northeastern coast and were crippled by the disasters, leading to power outages in other prefectures, including Tokyo[4].

[3] A Japanese prefecture is almost the equivalent of a state in the United States or a province in Canada, and there are a total of 47 prefectures in Japan.
[4] The water supply was cut off in at least 1.4 million households in 16 prefectures (Daily Yomiuri, 2011a).

The nuclear plant accident also caused a nuclear leakage. The damage rating for the nuclear accident was estimated to be level 7, which was equivalent to the Chernobyl disaster, known thus far as the most serious nuclear accident in history. During the process of the nuclear accident, the Japanese government did not provide accurate information regarding the situation at the nuclear plants. This behavior inevitably intensified Japanese people's anxiety about how and the extent to which the nuclear leakage would damage their health status. People residing in the directly stricken areas, especially Fukushima Prefecture, escaped and took refuge in other areas (Daily Yomiuri, 2011c). Even in Tokyo, which is located about 250 km from Fukushima, residents feared that radioactive materials would reach them and so left Tokyo for areas further from Fukushima to reduce the risk of radiation exposure (Saito, 2011).

3. Data and Hypotheses

3.1. Data

This article used data from the "Survey of Life Satisfaction and Preferences," which was conducted to compile individual-level panel data as a part of the Global Center of Excellence Program "Human Behavior and Socioeconomic Dynamics" carried out by Osaka University. Hereafter, the data are referred to as the GCOE data. The panel survey has been conducted annually throughout Japan since 2004. It is based on random sampling, and respondents are males and females aged 20–69. The data collected include comprehensive and basic attributes such as age, sex, household income, family members, willingness to migrate, and place of residence. New samples were selected and contributed respondents to the survey for the 2004, 2006, and 2009 waves. The question concerning the key variable in the present study, willingness to migrate,

was only included in the survey questionnaire in 2009, 2010, and 2012. Therefore, the data used in this paper covered only these three years. Response rates were 71.2% (2009), 87.8% (2010), and 93.9% (2012). The numbers of observations included in the data are 6,181 (2009), 5,386 (2010), and 4,588 (2012). In total, this amounts to 16,155 observations. However, we could not obtain information of some variables used in the estimation for some respondents, reducing the sample size used in this study to 11,133.

The definitions and basic statistics of all of the variables used in this paper are shown in Table 1. The key variables of *willingness to move*, *after accident*, *closeness to Fukushima,* and *presence of child* were included to examine the hypotheses presented in the following subsection. The mean value of *willingness to move* was 0.12, suggesting that 12% of respondents were willing to leave their residential prefecture. The mean value of *presence of child* was 0.25, indicating that 25% of respondents have children under 12 years old who are regarded as primary school students or who have not yet entered primary school. The mean value of *family size,* the number of people living together, was 3.74. The mean values of *university* and *graduate school* were 0.24 and 0.02, respectively, meaning that 24% of respondents had graduated from university and 2% had completed a postgraduate degree. The mean values of *unmarried* and *divorced* were 0.14 and 0.05, respectively. This indicates that 14% of respondents were unmarried and 5% were divorced.

Table 1. Definition of variables used for estimation and basic statistics

Variable	Definition	Mean	Standard deviation
Willingness to move	Value of 1 was given if respondent was willing to move to other prefectures, otherwise 0 (%)	0.12	---
After accident	Value of 1 was given if data were collected in 2012, otherwise 0 (%)	0.29	---
Distance from Fukushima	Distance from Fukushima city (km)	477	312
Closeness to Fukushima	*Distance from Fukushima*	0.01	0.001
Presence of child	Value of 1 was given if respondent had a child under 12 years old, otherwise 0 (%)	0.25	---
Age	Respondent's age	50.8	12.6
Male	Value of 1 was given if respondent was a man, 0 if the respondent was a woman (%)	0.47	---
Home	Value of 1 was given if respondent's current residential prefecture was equivalent to their residential prefecture at age 15, otherwise 0 (%)	0.76	---
Family size	Number of people who lived together in the household	3.74	1.78
Income	Household income (millions of yen)	6.55	4.14
University	Value of 1 was given if respondent had graduated from university but had not gone to graduate school, otherwise 0 (%)	0.24	---
Graduate school	Value of 1 was given if respondent had graduated from graduate school, otherwise 0 (%)	0.02	---
Unmarried	Value of 1 is given if respondent was unmarried, otherwise 0 (%)	0.14	---
Divorced	Value of 1 is given if respondent had been divorced, otherwise 0 (%)	0.05	---
Widowed	Value of 1 is given if respondent was widowed, otherwise 0 (%)	0.03	---

Note: Standard deviation of dummy variables is not reported.

3.2. Hypotheses

Based on the government data, Figure 1 illustrates the change in the rate of those who left their residential prefecture from 2010 to 2011. Therefore, the figure

demonstrates the difference in population mobility before and after the Fukushima accident. Consistent with our expectations, we see from Figure 1 that people were more likely to leave the residential prefecture during this period when the residential prefecture was located nearer to Fukushima.

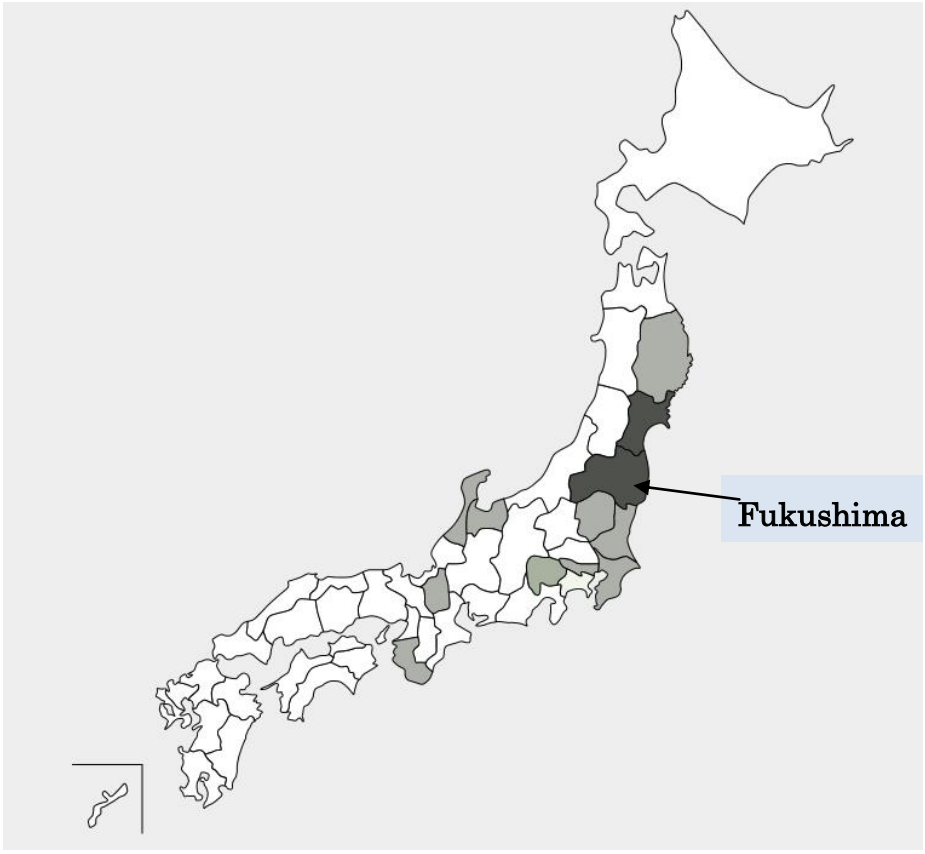

Fig 1. Map of Japan showing the change of those who leave the residential prefecture between 2010 and 2011

Note: Prefectures were darkly shaded if the difference (log of number of emigrants in 2011 minus that in 2010) was higher than 10% and lightly shaded if the difference was positive but below 10%.
Source: Website of the Statistics Bureau, Ministry of Internal Affairs and Communications:
http://www.e-stat.go.jp/SG1/estat/GL71050103.do;jsessionid=G4L3RrHY2zckFZYTZQqZhWtfLsGZC9F2ytyn415DXPvW5v6xnsCr!1767260104!737442923?_toGL71050103_&listID=000001105789&forwardFrom=GL71050101
http://www.e-stat.go.jp/SG1/estat/List.do?lid=000001073599
(Accessed on March 7, 2014)

Based on the data used in this paper, Figure 2 displays the percentage of respondents who were willing to leave the residential prefecture. Generally consistent with Figure 1, in 2012, people were more inclined to be willing to leave their place of residence when this was located nearer to Fukushima. In 2012, Fukushima residents were less likely to leave than were residents of some surrounding prefectures, possibly because significant numbers of people had already left Fukushima by 2012.

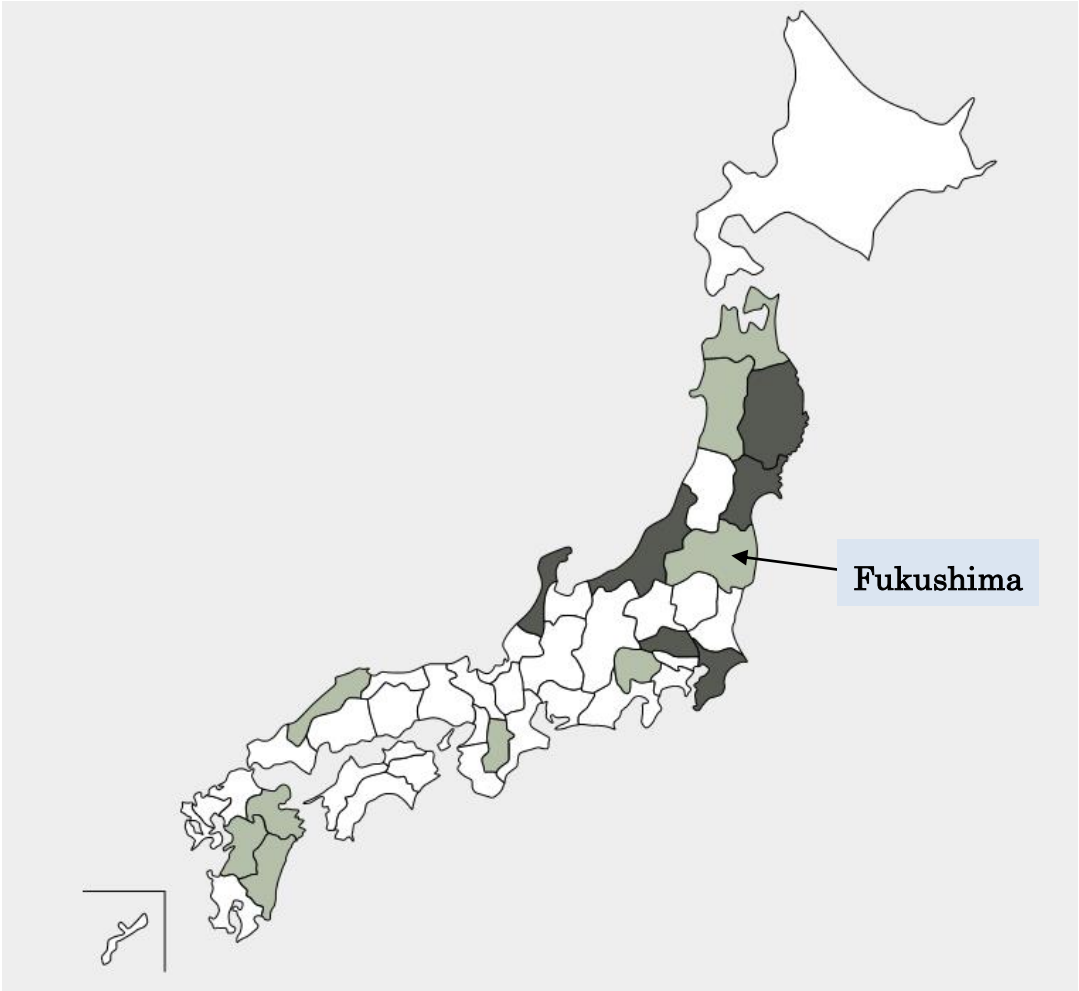

Fig 2. Map of Japan showing the rate of willingness to leave the prefecture in 2012

Note: Prefectures were darkly shaded if the percentage willing to leave was equivalent to or higher than 20%, and lightly shaded if this percentage was between 15 and 20%.
Source: GCOE data of Osaka University

Figure 3 displays the association between the percentage of residents who were willing to leave in each prefecture and the distance of the residential prefecture from Fukushima. In line with Figures 1 and 2, a cursory examination of Figure 3 reveals the negative association between willingness to leave and distance from Fukushima.

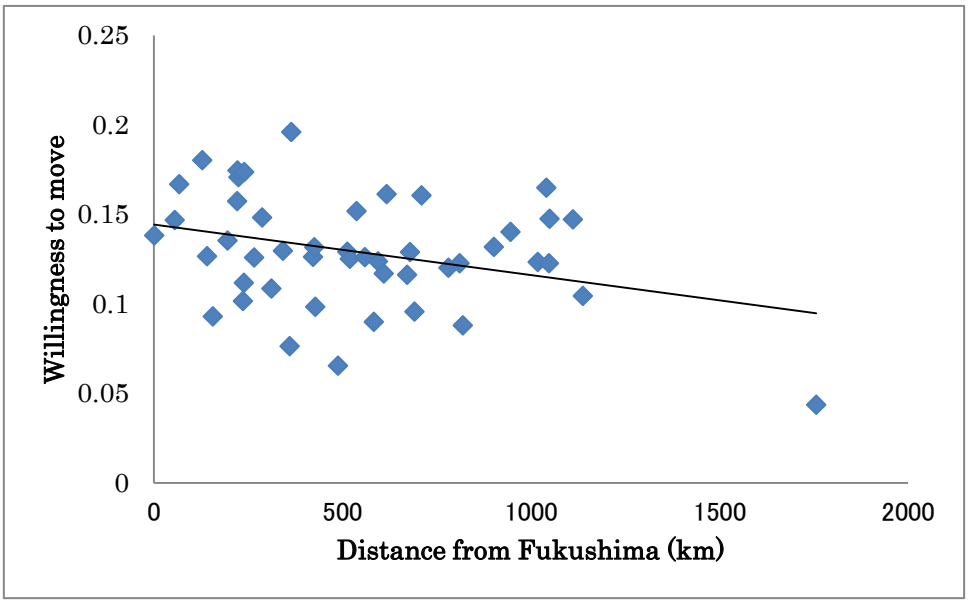

Fig 3. Relation between distance from Fukushima and willingness to leave
Source: GCOE data of Osaka University

Turning to Table 2, percentages of respondents who were willing to leave their residential prefecture were generally higher after the disaster than before the disaster. Further, respondents who lived in areas less than 300 km from Fukushima were more willing to leave than were other respondents. It can be inferred from Figures 1–3 and Table 2 that those residing in areas closer to Fukushima considered the risk of radiation exposure to be higher and were therefore willing to migrate. This is consistent with the finding of previous research that, in Japan, people have the highest level of anxiety regarding nuclear waste disposal and nuclear accidents, and this anxiety is even

greater than their fear of AIDS (Acquired Immune Deficiency Syndrome) and crime (Hinman et al., 1993)[5].

Table 2. Differences in willingness to move to other prefectures before and after the disaster

	Before the disaster (2009 and 2010)	After the disaster (2012)
Full sample	0.12	0.13
	(10,509)	(4,534)
Sub-sample		
Men	0.11	0.12
	(4,942)	(2,089)
Women	0.12	0.13
	(5,567)	(2,445)
Distance from Fukushima	0.13	0.16
< 300 km	(4,246)	(1,806)
Distance from Fukushima	0.11	0.12
≥ 300 km	(6,263)	(2,728)

Note: Numbers in parentheses are observation counts. The sample for the "before the disaster" period is the combined 2009 and 2010 samples, and the sample for the "after the disaster" period is the 2012 sample. Hence, sample size for the "before the disaster" period is about two times larger than that for the "after the disaster" period.

Taken together, these findings lead us to propose *Hypothesis 1: People are more willing to leave their place of residence after the disaster if they live closer to the area where the nuclear accident occurred.*

Empirical research has provided evidence that women are more risk averse than men in various situations (e.g., Eckel and Grossman, 2008; Jianakoplos and Bernasek, 1998)[6]. In previous work more directly relevant to this paper, MacGregor et al. (1994)

[5] A similar tendency was also observed in the United States (Hinman et al., 1993).
[6] It is widely observed in empirical work that men are generally more overly confident than are women (e.g., Barber and Odean, 2001; Beckmann and Menkhoff, 2008; Lenney,

suggested that women are more likely to perceive the transportation of radioactive waste to be risky for health than men. Consistent with this finding, in Japan after the Fukushima accident, based on interview data, Morioka (2014) found that compared with men, women expressed more concern about radiation and perceived the risk of radiation to be higher. Also consistent with these findings, Table 2 shows that women in the present study were more willing to leave the residential prefecture than were men. These findings lead us to, we postulate *Hypothesis 2: Women are more willing to leave the residential area than are men when the residential area is near Fukushima.*

Although it is widely believed among Japanese people that radiation exposure has more serious detrimental effects on the health of small children, experts' opinions on this point vary (Saito, 2011). In Fukushima primary schools, children were restricted from playing outside to reduce the risk of radiation exposure. Because of a lack of physical exercise, "an alarming trend toward obesity has been found among children in the Fukushima Prefecture, which has the highest rate of obese children in every age group between 5 and 9 years old" (Daily Yomiuri, 2012). Even outside Fukushima prefecture, parents had a motivation to move away from the place of residence for the sake of the health of their children when they lived closer to Fukushima. When households with school children leave their place of residence, their children inevitably move to new schools. Such switching of schools is observed to be costly for children (Been et al., 2011). However, if the perceived risk about the radiation exposure is sufficiently large in comparison with the cost of switching schools, parents are willing to leave the place of residence. Furthermore, such a tendency is possibly more obvious for mothers than for fathers because of gender differences in risk perception (Morioka,

1977; Lundeberg et al., 1992; Niederle and Vesterlund, 2007).

2014). Based on these arguments, we propose *Hypothesis 3: The differences between men and women in willingness to leave the place of residence is larger if they have small children.*

3.3. Econometric framework and estimation strategy

For the purpose of examining *Hypotheses 1* and *2*, the estimated function takes the following form:

$$Move_{itp} = \alpha_0 + \alpha_1\, after\ accident_t * closeness\ to\ Fukushima_p + \alpha_2\, after\ accident_t + \alpha_3\, closeness\ to\ Fukushima_p + X'_{itp} A + k_i + u_{itp},$$

where $Move_{itp}$ represents the dependent variable in individual i, year t, and prefecture p. k_i represents time-invariant individual-level fixed effects. The regression parameters are denoted by α. A is the vector of the regression parameters for the individual-level control variables that capture the influence of the respondents' various individual characteristics. The error term is denoted by u. *After accident* takes the value of 1 when observations were collected in 2012. Otherwise, the value is 0. *Closeness to Fukushima* is an inverse of the distance from Fukushima city to the capital of the prefecture in which the individual resides. If the coefficient of *after accident * closeness to Fukushima* takes a positive sign, the closer to Fukushima the respondent's residential prefecture, the more likely they were to express intention to leave after the Fukushima accident. From the *Hypothesis 1*, the absolute value of the coefficient of *after accident * closeness to Fukushima* is predicted to be larger in the women's sample than in the men's sample. There are, of course, other nuclear power plants in Japan in addition to the Fukushima plants. The Fukushima accident seems to have increased the perceived risk among people living near a nuclear power generation plant even if the plant was not the Fukushima plant. Such an effect is captured by the time-invariant

fixed effects, because no nuclear plants have been constructed after the Fukushima accident.

As for control variables, the effect of income is thought to be nonlinear. Even when migrating to another area increases the income level, there is a cost associated with migration. Accordingly, low income earners are less likely to leave their place of residence. However, the higher the initial income level, the less likely it becomes to earn more because the opportunity to gain a higher income decreases. Hence, the predicted sign of the coefficient of *income* is positive, while its square is negative. Evidence has been presented that social ties with neighbors, which can be regarded as a kind of social capital, generate benefits for residents[7]. These benefits disappear if residents move, resulting in low residential mobility (Belot and Ermisch, 2009; David et al., 2010; Kan, 2007). This indicates that individual decision making is influenced by the degree of strong ties with neighbors. The longer people have resided in an area, the stronger their social ties with neighbors, and the less willing they will be to leave the area. The coefficient of *home,* indicating those who have resided in the area from the age of 15, is predicted to have a negative sign.

To assess *Hypothesis 3,* the estimated function takes the following form:

$$move_{itp} = \beta_0 + \beta_1\, after\ accident_t * closeness\ to\ Fukushima_p * presence\ of\ child_{itp} + \beta_2\, after\ accident_t + \beta_3\, closeness\ to\ Fukushima_p + \beta_4\, presence\ of\ child_{itp} + Z'_{itp} C + m_i + e_{itp},$$

The cross term of *after accident*, *closeness to Fukushima*, and *presence of child* is the key variable for the examination of the *Hypothesis 2*. The coefficient of the cross term *after accident * closeness to Fukushima * presence of child* is expected to have a positive

[7] It has been observed that the devastating earthquake caused people to participate in community activity in Japan (Yamamura, 2014).

sign. Further, the absolute value of this coefficient is expected to be larger in the women's sample than in the men's sample. The vectors of the control variables are denoted by Z, which includes the same variable used in the model suggested earlier.

In the estimated functions above, the dependent variable is a dummy that takes the value of either 1 or 0. Hence, the probit model is used. In addition, for a check of robustness, estimations using the fixed effects model are also conducted to control the unobserved time-invariant individual fixed characteristics[8].

4. Estimation results

Table 3 reports the results where the cross term between *after accident* and *closeness to Fukushima* is not included. Tables 4 and 5 present results where the cross terms are included. Table 4 presents the results of probit models, whereas Tables 5 and 6 present the results of fixed effects models. In Tables 3–5, results based on the full sample are reported in columns (1) and (4), results based on the men's sample are shown in columns (2) and (5), and results based on the women's sample are in columns (3) and (6). Table 6 exhibits the results where the sample is divided into those residing close to Fukushima and those residing further away. Not reported in Tables 3–5 are the dummy variables for scale of residential city, occupation, and types of residence.

[8] It is appropriate to use the conditional logit model to control for fixed effects when the dependent variable is a dummy. Hence, we also conducted estimations using conditional logit. The sign and statistical significance of the key variables were almost the same as the estimation results using the fixed effect model, although the value of the coefficients was very large in the ancillary model. Therefore, reported results are considered to be robust to alternative models.

Table 3. Determinants of willingness to move

	(1) Full	(2) Men	(3) Women	(4) Full	(5) Men	(6) Women
	Probit			Fixed Effects		
After accident	0.17***	0.15***	0.19***	0.04**	0.01	0.08**
	(5.61)	(3.09)	(5.08)	(2.20)	(0.80)	(2.32)
Closeness to Fukushima	0.07*	0.16***	−0.08			
	(1.65)	(3.00)	(−1.28)			
Presence of child	−0.15***	−0.14*	−0.16**	-0.01	0.02	−0.05
	(−3.85)	(−1.89)	(−2.53)	(-0.58)	(1.15)	(−1.42)
Age	−0.02***	−0.01***	−0.01***	-0.01	0.001	−0.02
	(−9.60)	(-6.13)	(−6.44)	(-0.72)	(0.17)	(−1.22)
Male	−0.07					
	(−1.26)					
Home	−0.54***	−0.42***	−0.63***			
	(−8.88)	(−4.45)	(−9.17)			
Family	0.01	−0.003	0.01	0.001	0.002	0.001
	(0.93)	(−0.16)	(1.34)	(0.60)	(0.73)	(0.03)
Income	0.01	0.01	0.01	0.1***	0.01*	0.01*
	(0.19)	(0.29)	(0.41)	(2.73)	(1.82)	(1.96)
Income²	$-0.02*10^{-4}$	$-0.02*10^{-4}$	$-0.02*10^{-4}$	$-0.02*10^{-4}$**	$-0.02*10^{-4}$	$-0.04*10^{-4}$*
	(−0.55)	(−0.43)	(−0.36)	(−2.13)	(−1.15)	(−1.77)
University	0.08	0.11	0.05			
	(1.30)	(1.63)	(0.64)			
Graduate school	0.09	0.21*	−0.18			
	(1.00)	(1.79)	(−0.66)			
Unmarried	0.007	−0.01	0.02	−0.001	−0.01	−0.01
	(0.11)	(−0.15)	(0.33)	(−0.05)	(−0.25)	(−0.23)
Divorced	0.08	0.06	0.09	−0.03**	−0.04	−0.03
	(1.10)	(0.49)	(1.00)	(−1.97)	(−1.45)	(−1.42)
Widowed	0.02	0.40*	−0.13	−0.02	−0.01	−0.02
	(0.28)	(1.83)	(−0.96)	(−0.51)	(−0.25)	(−0.41)
Log pseudolikehood	−4,065	−1,843	−2,202			
Observations	11,133	5,343	5,790	11,133	5,343	5,790

Note: Numbers in parentheses are z-statistics calculated using robust standard errors adjusted for clusters in prefectures. *, ** and *** indicate significance at the 10, 5 and 1% levels, respectively. Numbers above the numbers in parentheses indicate marginal effects. Dummy variables for scale of residential city, occupation, and type of residence are included, but these results are not reported. In addition to the results exhibited, estimations using conditional logit models have also been conducted, resulting in effect signs and statistical significance that were almost the same as those reported in Table 3, although the value of the coefficients was very large.

In Table 3, time-invariant variables such as *closeness to Fukushima, home, male,*

and education level are completely captured by the fixed effects. Therefore, their results are reported in the probit model but not in the fixed model estimations[9]. The results of the probit model show the coefficient of *after disaster* to have a positive sign, and this coefficient was statistically significant in all estimations. Turning to the results of the fixed effects mode, results based on the full sample and the women's sample continue to indicate statistical significance and a positive sign for *after disaster*. However, as is shown in column (5), *after disaster* was not statistically significant for men, although its sign is still positive. This can be interpreted as suggesting that there was no difference in willingness to leave before and after the Fukushima accident for men, while women were more willing to leave after the accident occurred. This finding is in line with previous work suggesting that women are more likely than men to perceive radiation exposure as risky (MacGregor et al., 1994; Morioka, 2014). The significant negative coefficient for *presence of child* is observed in columns (1)–(3). This finding is consistent with the argument that changing residence and therefore school is costly for children (Been et al., 2011). However, as shown in columns (4)–(6), the effect of *presence of child* is not statistically significant after controlling for the fixed effects. *Home* exhibits the predicted negative sign, and the effect is statistically significant at the .01 level, consistent with the claim that social ties reduce the motivation to leave (Belot and Ermisch, 2009; David et al., 2010; Kan, 2007). *Income* was not statistically significant in the probit model estimations. After controlling for the fixed effects, *income* and $income^2$ have positive and negative signs, respectively, and both are statistically significant in

[9] Respondents who had left the residential prefecture during the 2009–2010 period were not followed up by the survey and are therefore excluded from the sample although they were followed up in 2012. Therefore, to conduct the fixed effects estimation, we assumed that residential prefecture did not change during the period, and hence is a time-invariant variable in the data.

the full sample and among women, a finding that is in line with the predictions.

Table 4. Effect of cross terms on willingness to move (probit model)

	(1) Full	(2) Men	(3) Women	(4) Full	(5) Men	(6) Women
*After accident * Closeness to Fukushima*	0.25*** (6.54)	0.21*** (3.23)	0.39*** (7.45)			
*After accident * Closeness to Fukushima * Presence of child*				0.48*** (7.10)	−1.14** (−2.16)	1.29*** (12.7)
After accident	0.16*** (5.48)	0.14*** (2.99)	0.18*** (4.97)	0.17*** (5.58)	0.15*** (3.11)	0.18*** (5.02)
Closeness to Fukushima	−0.02 (−0.45)	0.09 (1.63)	−0.24*** (-3.21)	0.04 (1.06)	0.17*** (3.29)	−0.20*** (−2.85)
Presence of child	−0.15*** (−3.86)	−0.13* (−1.90)	−0.16** (−2.55)	−0.15*** (−3.88)	−0.13* (−1.86)	−0.16** (−2.60)
Log pseudolikehood	−4,065	−1,842	−2,202	−4,065	−1,842	−2,201
Observations	11,133	5,343	5,786	11,133	5,343	5,786

Note: Numbers in parentheses are z-statistics calculated using robust standard errors adjusted for clusters in prefectures. *, ** and *** indicate significance at the 10, 5 and 1% levels, respectively. Numbers above the numbers in parentheses indicate marginal effects. Control variables used in estimations of Table 3 are incorporated but not reported. In addition to results exhibited, estimations using conditional logit have also been conducted, resulting in effect signs and statistical significance that were almost the same as those reported in Table 4, although the value of the coefficients was very large.

Now turning to Table 4 and focusing on the results of key variables (although other independent variables were controlled), *after accident * closeness to Fukushima* has a positive sign and is statistically significant at the .01 level. This finding is consistent with *Hypothesis 1*. Further, its marginal effect is larger in the women's sample than in the men's sample, providing corroboration for *Hypothesis 2.* As is shown in columns (4)–(6), the coefficient for *after accident * closeness to Fukushima * presence of child* has a positive sign in the full sample and in the women's sample, but it has a negative sign in the men's sample. These results are statistically significant at the .01 level. This can

be interpreted to suggest that the cost for switching schools is perceived to be sufficiently large for fathers, but not for mothers. This finding is in line with *Hypothesis 3.*

Table 5. Effect of cross terms on willingness to move (fixed effects model)

	(1) Full	(2) Men	(3) Women	(4) Full	(5) Men	(6) Women
*After accident * closeness to Fukushima*	0.02*** (4.02)	0.03** (2.45)	0.02*** (2.64)			
*After accident * closeness to Fukushima * Presence of child*				0.21*** (11.5)	−0.02 (−0.81)	0.46*** (21.4)
After accident	0.04** (2.18)	0.01 (0.78)	0.08** (2.32)	0.04** (2.18)	0.01 (0.80)	0.08** (2.31)
Closeness to Fukushima						
Presence of child	−0.01 (−0.59)	0.02 (1.14)	−0.05 (−1.42)	−0.01 (−0.60)	0.02 (1.15)	−0.05 (−1.44)
Observations	11,133	5,343	5,790	11,133	5,343	5,790

Note: Numbers in parentheses are z-statistics calculated using robust standard errors adjusted for clusters in prefectures. *, ** and *** indicate significance at the 10, 5 and 1% levels, respectively. Numbers above the numbers in parentheses indicate marginal effects. Control variables used in estimations of Table 3 are incorporated but not reported. In addition to results exhibited, estimations using conditional logit have also been conducted, resulting in effect signs and statistical significance that were almost the same as those reported in the Table 5, although the value of the coefficients was very large.

Table 5 shows that *after accident * closeness to Fukushima* continues to show a significant positive sign, even after controlling for the fixed effects, although there is a difference in this coefficient between men and women. Results indicate that the sign of *after accident * closeness to Fukushima * presence of child* is positive and statistically significant in the full sample and in the women's sample. However, in the men's sample, this coefficient is negative and not statistically significant. It seems plausible that the effect of distance from Fukushima is not linear. For checking this possibility, we investigated whether the effect of the accident was mainly observed in areas close to

Fukushima. To this end, the sample was divided and estimations were conducted. As is shown in Table 6, *after accident* has a positive sign in all columns. The coefficient for *after accident* is statistically significant in the sample of those who resided within 400 km of Fukushima, although this finding does not hold for the men's sample. Hence, the accident did not influence the willingness to leave when distance between the residential area and Fukushima was greater than 400 km. The discussion to this point, on the combined results of Tables 3–5, strongly support *Hypotheses 1–3*.

Table 6. Effect of cross terms on willingness to move (Fixed Effects model): Subsample estimation

	(1) Full	(2) Full	(3) Men	(4) Men	(5) Women	(6) Women
	Distance from Fukushima < 400	Distance from Fukushima ≥ 400	Distance from Fukushima < 400	Distance from Fukushima ≥ 400	Distance from Fukushima < 400	Distance From Fukushima ≥ 400
After accident	0.05*** (3.13)	0.03 (1.01)	0.02 (1.12)	0.01 (0.27)	0.13** (2.81)	0.05 (1.08)
Presence of child	0.003 (0.13)	−0.02 (−0.87)	0.07* (1.83)	−0.01 (−0.35)	−0.06 (−1.08)	-0.03 (-0.95)
Observations	5,175	5,958	2,570	2,773	2,605	3,185

Note: Numbers in parentheses are z-statistics calculated using robust standard errors adjusted for clusters in prefectures. *, ** and *** indicate significance at the 10, 5 and 1% levels, respectively. Numbers above the numbers in parentheses indicate marginal effects. Control variables used in estimations of Table 3 are incorporated but not reported. In addition to results exhibited, estimations using conditional logit have also been conducted, resulting in effect signs and statistical significance that were almost the same as those reported in the Table 5, although the value of the coefficients was very large.

4. Conclusion

Catastrophic events like natural disasters influence subjective perceptions such as life satisfaction (Carroll et al., 2009; Ishino et al., 2011; Luechinger and Saschkly, 2009; Uchida et al., 2014) and perception about risk (Goebel et al., 2013; Hanaoka et al., 2014). This, in turn, affects individual behavior. Therefore, disasters have an effect on the

economic condition not only through physical channels but also through psychological channels. The Great East Japan earthquake caused the Fukushima nuclear accident, resulting in a large number of evacuees and consequently a significant amount of geographical population mobility in Japan. By using individual level panel data covering time periods before and after the Fukushima accident, in this article we have attempted to explore how and the extent to which major disasters change individuals' willingness to leave their place of residence by taking into account distance from Fukushima and having of a small child.

Key findings obtained after controlling for the individual-level fixed effects are that the Fukushima accident led people to leave their place of residence if they lived near Fukushima. Such a tendency was particularly strong when respondents had a small child. Further, this tendency was observed for women but not for men when the sample was divided by gender. The effect of the Fukushima accident can be explained by the Japanese trait of exhibiting a high level of anxiety toward nuclear accidents (Hinman et al., 1993). Further, the differences in the influence of the accident on willingness to leave between men and women can be seen as consistent with previous work suggesting differences in risk perception between men and women (Eckel and Grossman, 2008; Jianakoplos and Bernasek, 1998; MacGregor et al., 1994). More specifically, the findings of this study are consistent with the claim that, after the Fukushima accident, women expressed more concern over radiation than did men (Morioka, 2014).

The focus of this study was limited to the intention to leave. Therefore, the article has not examined the influence of catastrophic events such as the Fukushima accident on actual population mobility. Furthermore, although the massive inflow of evacuees has become a critical issue in Japan (Aoki, 2012), this paper has not explored the inflow

of evacuees from Fukushima to other prefectures. Additionally, social capital such as social trust and community participation are known to be important in recovery from natural disasters (Yamamura 2010, 2014). The role of social capital after the Great East Japan earthquake is worthy of further examination. These are remaining issues to be addressed in future research.

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