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Key factors on migration assuming disaster risk of a megathrust earthquake:

A case study in the Pacific coastal area of Japan

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Abstract: Seismologists anticipate the occurrence of a massive earthquake with a hypocenter near Japan's Pacific coast within decades. This study was conducted in October 2015 among 6000 subjects residing in Kochi and Kanagawa Prefectures in Japan, and it investigated ways that residents of the coastal areas perceive the relative safety of urban versus rural areas and the effects of such views on people's desire to relocate to a non-coastal area. This study revealed that the evaluation of safety and resilience to the areas were different and that the extent to which the evaluation affects migration for disaster prevention is extremely small.

1. INTRODUCTION

1.1 Japan, land of earthquakes

This paper presents the statistical results of a large-scale social survey on factors influencing the perceptions of individuals regarding the relative safety of urban versus rural areas for recovery in the event of a huge earthquake disaster and other findings of a study that considered whether such views directly contribute to the possibility of migration for disaster prevention purposes.

An island country situated at the very east of East Asia, Japan is widely known as a land of frequent earthquakes. According to one Cabinet Office report (Cabinet Office Government of Japan, 2017), the hypocenters of approximately 20% of major earthquakes of magnitude six and over occurring worldwide have been situated either in Japan or its immediate vicinity, and the historical record demonstrates that Japan has suffered damage from large-scale earthquakes to an extent essentially unequalled in any other corner of the globe.

The Great East Japan Earthquake of March 2011 (magnitude 9.0; *Figure 1*) remains particularly vivid in the country's memory, along with the Kumamoto Earthquake (magnitude 7; *Figure 2*) of April 2016. The number of fatalities and missing persons after the Great East Japan Earthquake totalled about 20,000 people, and large numbers of evacuees are still living in temporary housing. Since immediately after that earthquake, the author has made repeated visits to Sendai, one of the cities struck by the disaster, to document the implementation process of policies for the rehabilitation of farmland damageds by the tsunami (Makiyama & Yamashita, 2015).

Figure 1. Damage to A Large Embankment (Photo by Ryohei Yamashita on June 2011)

Figure 2. A Collapsed Wall at Kumamoto Castle (Photo by Kimihide Yamamoto on Aug. 2016)

Figure 3. Farmland Laid to Waste by The Tsunami (Photo by Ryohei Yamashita on Nov. 2011)

Fatalities from the Kumamoto Earthquake exceeded 100 people, and as with the areas hit by the Great East Japan Earthquake, the process of reconstruction and recovery is still underway. In addition to having substantial social and economic impacts, the earthquake set off major landslides in areas including the Aso region, which is a World Agricultural Heritage site. Even for Japan, this is an area with a long and eventful history of damage from major earthquakes—indeed, the list of such events is so long and numerous that it would be difficult to number and describe them all.

Each time areas have been hit, they have steadfastly confronted the task of reconstruction and recovery from the ravages suffered during the earthquakes, aided by the generous support of the entire country and the wider world beyond. In the process, a body of practical on-site knowledge (both explicit and tacit) has been built up alongside scholarly understandings on disaster planning.

In this context, “resilience” refers to the power of adaptability displayed by disaster-affected communities in their recovery. A higher degree of attention began to be paid to post-disaster resilience during the reconstruction and recovery process that followed the March 2007 Noto Earthquake (magnitude 7.0) in Ishikawa Prefecture, and long-term surveys were conducted to assess the local residents’ awareness of matters such as disaster prevention and tsunami escape response (Aoki & Hayashi, 2009; Hayashi & Aoki, 2016).

Whether triggered by the occurrence of earthquakes or by the perceived risk of future earthquakes, migrations are a factor exerting profound and ongoing influence on the development of social resources, and their social impact is highly significant from the perspectives of disaster prevention and regional development planning. In the context of the relationship between earthquake risk and migration, this study examined differences between urban and rural areas in residents’ cognition of the safety of their residential spaces.

1.2 Megathrust earthquake risk in the near future in Japan

We can be confident that the ongoing risk of large-scale earthquakes and their attendant tsunamis in the Japan vicinity will remain high in the future. Of all the various future possibilities, particular public attention has focused on the prospect of a series of Nankai "megathrust" earthquakes with hypocenters in the Tonankai-Nankai offshore areas. The principal brunt of such an event is predicted to be borne by Japan's Pacific coast, along which the country's urban functions are concentrated. The phrase "Nankai megathrust earthquakes" is not an official term, so there is also a criticism of lowering disaster prevention consciousness in an area corresponding to the edge of the range of damage estimation. However, as it is common practice today to be described in government debates and documents, that name will also be used in this paper.

Because earthquakes are by nature impossible to accurately predict, the debate on the likely scale and extent of damage of the anticipated Nankai megathrust earthquakes has produced a mass of conflicting opinions. Thus, the various local governments in the areas expected to be affected are lacking in definitive information, and many elements of local disaster planning have been inadequate. However, among the predictive datasets released by the national government in 2012, the surface intensity map presented in *Figure 4* shows that most of the Pacific coast—including the bulk of Japan's major urban centers—is forecast to experience high-level tremors causing significant damage.

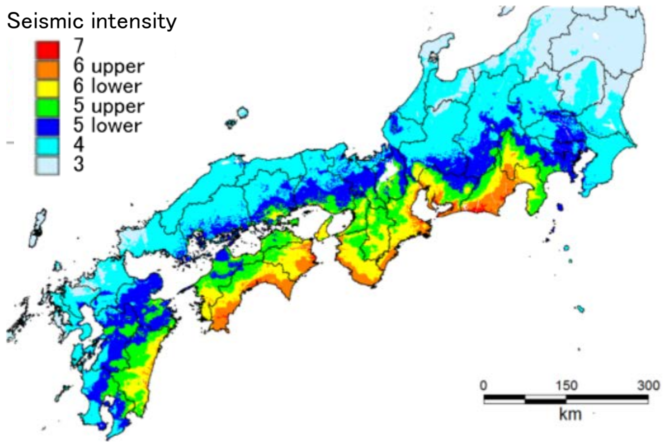


Figure 4. Example Forecast of Surface Seismic Intensity Distribution.
Source: Cabinet Office Government of Japan, 2017

The policy term "pre-disaster prevention" has become common in Japan in recent years, and regional planning for the coming earthquake is promoted based on this precautionary principle (T. Hori, 2017). Thus, preparing for the impact of a potential massive earthquake in the Nankai Trough area is important not only for coastal areas, but also for the inland zones, where migration is expected to occur as earthquake victims scramble to reach safer ground.

2. RESEARCH DESIGN

2.1 Literature review

It has long been known that experiences of earthquake damage and the perceived risk of future earthquake damage have a major impact on individuals' decisions to relocate from vulnerable areas. For example, research focusing on areas affected by the Great East Japan Earthquake demonstrated significant population movement (Koike, 2013), for which possible causative factors include drastic changes in the labor environment due to the disaster (Higuchi et al., 2012), and changes in individuals' patterns of behavior in daily life (Uchida, Takahashi, & Kawahara, 2011). Outside of Japan, multiple reports have documented trends in population migration occurring in the aftermath of Hurricane Katrina, which struck the United States in 2005. Most of the existing literature on migrations related to earthquake risk or damage has tended to account for evidence of population movements by focusing on individual socioeconomic contexts and disparities in regional development; however, the diversity of regional characteristics and the complexity of the factors at play make a single overarching explanation difficult to achieve (M. Hori, Schafer, & Bowman, 2009). In France, researchers have attempted to construct a conceptual model to predict how population movements might be impacted by coastal residents' cognitive awareness of increased disaster risk related to climate change (Quinn et al., 2018). Studies have demonstrated how regional attachment has both positive and negative influences on risk perception (Ruiz & Hernandez, 2014), such that those who have a strong attachment to an area are particularly reluctant to leave even in a case of disaster (Bonaiuto et al., 2016). Boheim & Taylor (2002) examined the economic costs associated with migration to a new area, and (Clark & Huang, 2003) proposed relationships between migration behaviors and personal attributes such as securing housing based on family composition and income level.

Although the above-mentioned studies have greatly increased our understanding of disaster-related migrations, limited research has investigated influences on migration accruing from perceptions of the relative benefits of urban or rural characteristics in the case of disasters. Since metropolitan areas are widely considered to be more vulnerable than rural zones to the depredations of huge earthquakes, it is important to identify the factors influencing people's understanding of the differences between these two types of settlements (Kita, 2017; Kosugi, Baba, & Tanaka, 2017). After the Great East Japan Earthquake, a number of people were expected to move from urban areas to rural areas, but in fact it was not so many. This showed that Japan's problem of population leveling due to population movement between urban and rural villages did not become a driving force even for a huge earthquake. However, there is a possibility that the experience had some influence on the next generation.

On the other hand, one study empirically showed that the transfer rate from the Tsunami damaged area increased by more than 30% after the Great East Japan Earthquake in March 2011 (Thiri, 2017), and another found that disparities in income and assets had a strong influence on individuals' decisions to stay or to move immediately after the disaster (Hashimoto & Kawawaki, 2015).

Taking previous findings into consideration, the question of what kinds of migration can be predicted to occur when the risks posed by the Nankai megathrust earthquakes begin receiving regular mass-media coverage is an issue of profound interest. Although statistical predictions of population movements using cohort analysis have been undertaken in the past, such studies did not consider the intentions of the people subjected to such analysis (Chen, Maki, & Hayashi, 2010). Renewed analysis of the current situation is all the more significant in the aftermath of the Great East Japan Earthquake.

2.2 Research approach

Studies based on detailed social surveys have indicated that whether to migrate in the event of a disaster is not determined on the basis of the disaster's physical or ecological severity, but rather on how the experience was handled psychologically (Jansen, Hoekstra, & Boumeester, 2017). Accordingly, it is important to examine the factors impacting migration as a means of mitigating risks related to disasters in Japan, where additional Nankai megathrust earthquakes are predicted to occur in the future.

Based on the above issues, this paper analyzes the characteristics of potential migration intentions in the case of a massive earthquake in the Nankai Trough area. The study aims to verify the validity of the working hypothesis that "a global view of the region is formed by elements such as individual attributes, living region characteristics and disaster risk recognition factors, and regional view and relocation intention are related." Through testing this hypothesis of intention formation, we attempted to glean the actual state of migration intentions in the case of a huge earthquake disaster.

For the purposes of this research, the "regional view" incorporates the concepts of safety and toughness against disaster risk, whereby "safety" denotes robustness against the risk that the earthquake will threaten stable daily life, and "toughness" refers to the resilience of the region, meaning the speed and extent of restoration from extremely unstable conditions accruing from earthquake damage to the physical and social stability of daily life.

These two concepts are particularly important due to the uncertainty of the conditions that will signal the predicted huge earthquake. For example, it remains unclear whether the massive earthquake will be preceded by any warning signs from seismologists or if it will be experienced more suddenly; it is uncertain whether the risk level will be accurately calculated from forecasting reports such as damage simulations, and the length and severity of the aftershocks also remain unknown.

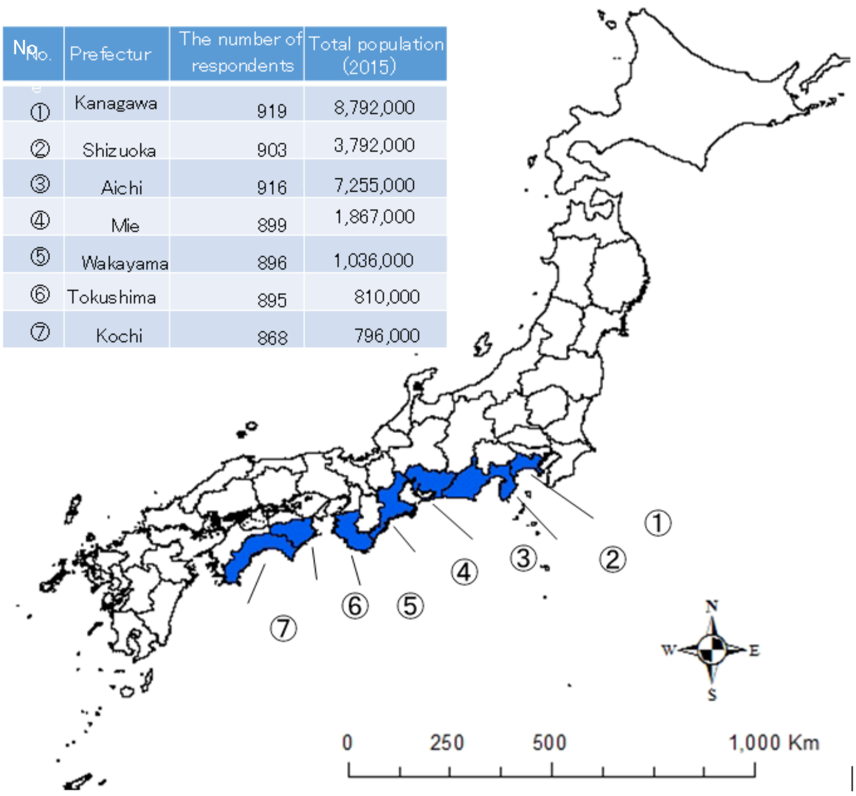
The purpose of this research is to clarify the impact of disaster risk on migration intentions within the context of a regional study in a wide area; however, the environment will vary depending on the disaster situation. Therefore, this study aims to extract characteristics of potential migrants and the conditions impacting their movement by considering regional views of safety and toughness.

3. DATA COLLECTION

A questionnaire survey was conducted in October 2015 using the online survey method, whereby emails were sent to participants and replied to online, making use of linked services provided by specialized agencies. The online survey method has become a mainstream tool for carrying out large-scale social surveys in recent years. Making use of user-registration ID, it is possible to initially check and filter out respondents replying multiple times, and regular screenings also prevent the intake of invalid answers, thus excluding from the totalization those participants whose responses exhibit frequent changes in indices such as occupation and age, gender, home-place, etc., which should be easily determinable on an objective basis.

In addition, systems have been independently developed to exclude frivolous responses, such as those filled out in too short a time or filled out repeatedly using the same number to reply to multi-choice questions. Such developments have increasingly enhanced the credibility of data gathered in this manner over recent years.

The survey respondents were residents of seven prefectures considered liable to be affected by the Nankai megathrust earthquakes, namely Kanagawa Prefecture, Shizuoka Prefecture, Aichi Prefecture, Mie Prefecture, Wakayama Prefecture, Tokushima Prefecture and Kochi Prefecture. The respondents' age range was set at 20 years and over. Responses were recovered on an averaged basis per prefecture in order to prevent imbalances arising between the prefectures. The total number of replies was 6295 and the resulting figures are presented in *Figure 5*.



No.	Prefectur	The number of respondents	Total population (2015)
①	Kanagawa	919	8,792,000
②	Shizuoka	903	3,792,000
③	Aichi	916	7,255,000
④	Mie	899	1,867,000
⑤	Wakayama	896	1,036,000
⑥	Tokushima	895	810,000
⑦	Kochi	868	796,000

Figure 5. The Seven Prefectures Covered in The Survey (Shaded Area) and Number of Responses from Each Prefecture

Table 1. The items and their details concerned with this analysis

No.	Question	decision branch
①	Do you think a huge earthquake will occur off the Pacific Ocean (around the Kanto off the coast of Shikoku) in the future?	"1. Absolutely occur"; "2. I do not know"; "3. Absolutely not occur"
②	To what extent do you think a huge earthquake would affect the area and the living environment in which you currently live?	"1. It would be so enormous that you would have to evacuate and move away for a long time"; "2. Little damage would occur"; "3. I cannot believe that damage would occur to me"; "4. I do not know"
③	If a disaster such as a huge earthquake happened while you were away from home, could you become a returning refugee?	"1. There is a fairly high probability"; "2. There might be a chance"; "3. It will not become absolute"
④	In general, do you think you would feel safer in urban or rural areas amid the social disorder caused by the huge earthquake, the occurrence of damage, and/or the possibility of security deterioration?	"1. Urban area"; "2. Rural area"; "3. I cannot say either way"
⑤	Generally, in case of long-term social upheavals due to a huge earthquake, do you think that recovery and reconstruction of a safe and secure life would be more rapid in urban areas or rural areas?	"1. Urban area"; "2. Rural area"; "3. I cannot say either way"
⑥	Would you consider changing your residence for the purpose of protecting your safety and property due to the risk of a huge earthquake?	"1. Have specifically considered (already actually moved for disaster prevention purposes)"; "2. Might consider it"; "3. Would not consider at all"

The main data entry items requested information on respondents' age, gender, occupation, family composition, household income and postal code on the condition that use of such information would be limited to research purposes. Apart from these basic entry items, several other questions were posed, as shown in *Table 1*.

4. DATA ANALYSIS

4.1 Overview of the respondents

a) *Table 2* presents a breakdown of the total 6,295 sample responses by gender and age. Female respondents were more numerous among the younger cohorts respondents, whereas males predominating predominated among the older respondents. Extreme polarizations in opinion between the

generations were not in evidence. In addition, as seen in *Figure 6*, people living in two-generational families formed the core and most numerous groups of respondents. The income distribution also shows a good balance from below- to above- the national average (*Figure 7*).

Table 2. Age and Gender Distribution of Respondents

Age ＼ Sex	Male	Female	Total
Under 29	193	737	930 (14.8%)
30 ~ 39	496	1,072	1,568 (24.9%)
40 ~ 49	791	874	1,665 (26.4%)

50 ~ 59	758	503	1,261 (20.0%)
Over 60	607	264	871 (13.8%)
Total	2,845	3,506	6,295 (100%)

The sample numbers were sufficient to meet the analysis criteria in all categories even when responses such as “other” and “no answer” were excluded. Judged in an overall manner, it can be concluded that the recovered samples form a satisfactory group for analysis.

For the purposes of the analysis, the population density of respondents’ area of residence was allocated by municipality, and the entire sample was graded into five ranked categories (less favored area, rural area, intermediate area, urban fringe area, city area). In addition, samples with the responses “other” in *Figure 6* and “no answer” in *Figure 7* were excluded. *Table 3* presents the total respondent numbers for each area category.

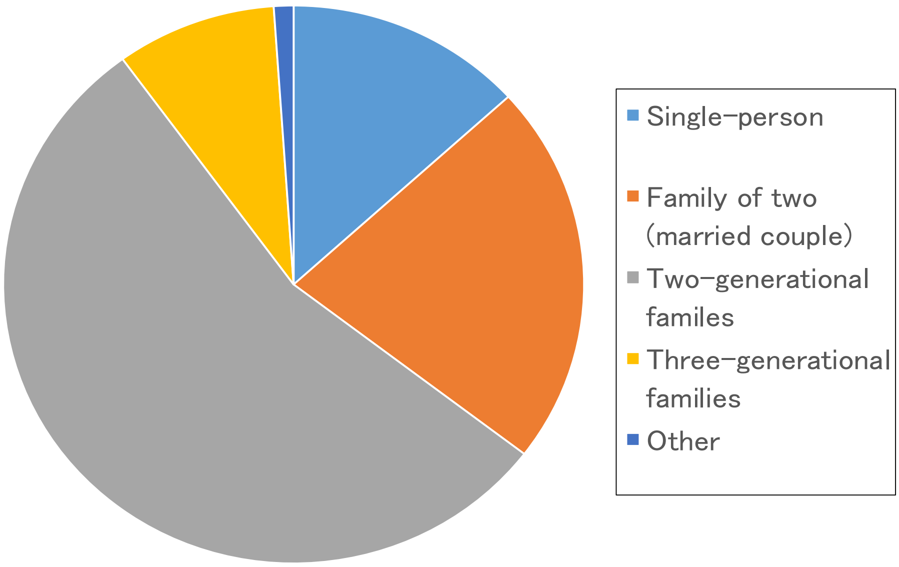


Figure 6. Family Composition of Respondents

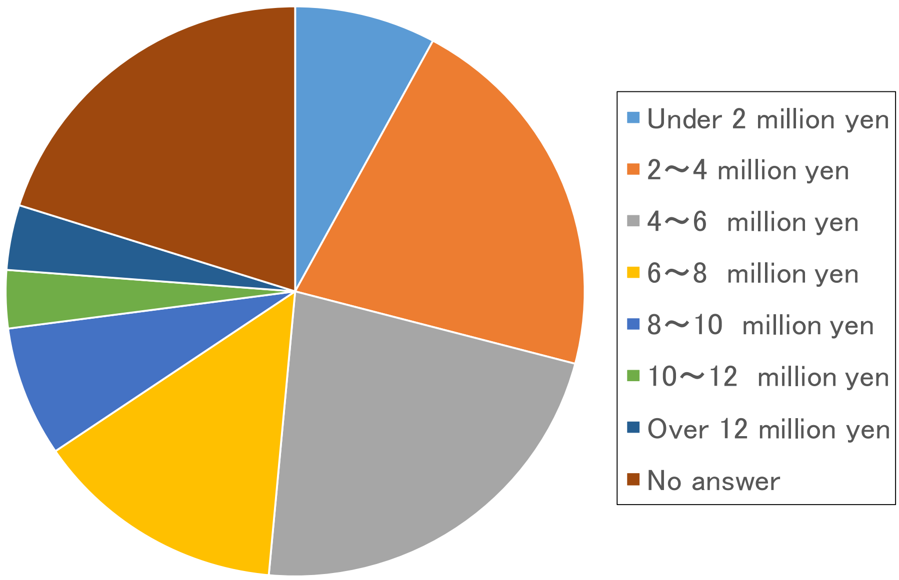


Figure 7. Household Income Distribution of Respondents

4.2 Analysis framework

Taking the respondents' individual attributes, current living environments and notions regarding the occurrence and resulting damage of large-scale earthquakes as dependent variables, the influence of differences in perception of the relative safety and resilience of urban vs. rural areas against the dependent variables of the respondents' individual attributes, current living environments and notions regarding the occurrence and resulting damage of large-scale earthquakes were statistically analysed.

Individual attributes are comprised of the age and genders given in *Table 3*.

Table 3. Sample Numbers with Excluded Samples Not Counted

Area Category	Range of population density (/ km2)	Age ＼ Sex	Under 29	30 ~ 39	40 ~ 49	50 ~ 59	Over 60	Total
Less favored area	0 ~ 382.9	Male	21	82	128	111	101	935 (18.8%)
		Female	96	167	133	61	35	
Rural area	382.9 ~ 1026.51	Male	26	82	131	135	115	1,002 (20.1%)
		Female	102	160	130	74	47	
Intermediate area	1026.51 ~	Male	33	86	121	116	99	1,033 (20.7%)
	1506.61	Female	134	168	148	92	36	
Urban fringe area	1506.61~ 3303.60	Male	34	76	150	122	93	976 (19.6%)
City area	3303.60	Female	106	164	132	70	29	
	~	Male	38	84	141	142	94	1,036 (20.8%)
		Female	102	181	139	77	38	
Total			692 (13.9 %)	1250 (25.1 %)	1353 (27.1 %)	1000 (20.1 %)	687 (13.8 %)	4982 (100%)

Note: n=1219, log-likelihood −1398.25. *** 1% significant

Cognitions of the occurrence of a large-scale earthquake were ranked in three categories ("inevitable," "don't know," and "will never happen"), and responses were solicited on this basis. Four answer choices measured the harm respondents imagined suffering in the event of a large-scale earthquake ("enough to make moving or long-term evacuation inevitable," "enough to cause a little damage," "can't imagine any harm coming to me," and "don't know").

Figure 7 presents results for questions on respondents' current living environments on the basis of household incomes, along with the possibility of having difficulty commuting home in the event of a large-scale earthquake, for which three responses were solicited ("quite high possibility of this happening," "it could possibly happen," and "it won't happen").

Answers regarding safety and resilience in the event of a large-scale earthquake were solicited for three graded categories ("urban area," "don't know," and "rural area"). Because coastal fishing villages are more vulnerable to tsunamis, such areas were intentionally contrasted with the city and assigned to the category "rural area."

In addition to the above items, the respondents' imagined possibility of migrating in the event of a large-scale earthquake was ranked into three categories ("would think about it definitely," "would think about it a bit," and "wouldn't think about it").

5. ANALYSIS OF FINDINGS

Table 4 presents the distribution of the responses for all samples on cognitions of the safety and resilience against harm and damage of different areas in the case of a large-scale earthquake. A point of significant interest is the marked discrepancy between urban and rural areas in participants' evaluations of safety versus risk and of resilience against harm and damage.

Table 4. Notions of Regional Safety and Resilience to Damage in Case of Large-Scale Earthquakes

	Safer	More resilient
City area	905 (18.2%)	2,695 (54.1%)
Not sure	1,801 (36.1%)	1,218 (24.4%)
Rural area	2,276 (45.7%)	1,069 (21.5%)

Table 5 and *Table 6* present the results of the multiple regression analyzes that were performed using these indices as objective variables against each of the dependent variables listed above (individual attributes, current living environments and notions regarding the occurrence and resulting damage of large-scale earthquakes). The dependent variables were selected by the stepwise variable selection method. As a result, the following trends became clear:

Firstly, there appears to be greater potential for 1) r young women, and 2) people living in areas with a high population density, to have difficulty getting home in the event of a large-scale earthquake. However, 3) the risk of a large-scale earthquake was perceived as low, and the less likely individuals were to think of themselves as being at any real risk of harm from an earthquake, the more likely they were to respond that urban areas are safer than rural areas in the event of a large-scale earthquake.

Table 5. Result of Multiple Regression Analysis on The Regional View of Safety

Objective Variable	Safe area for huge earthquake (1. City, 2. Don't know, 3. Rural)				
	coefficient	SE	t-value	p-value	95% CI
Constant term	2.426	0.47			
Gender (1. M, 0. F)	0.082	0.022	3.688	0.000	0.038 ~ 0.125
Age (5 grades)	0.048	0.009	5.366	0.000	0.030 ~ 0.066
Cognition of huge earthquake occurrence (3 grades)	-0.028	0.012	-2.331	0.020	-0.052 ~ -0.004
Damage assumption (4 grades)	-0.049	0.010	-4.931	0.000	-0.069 ~ -0.030
Household income (4 grades)					

Objective Variable	Safe area for huge earthquake (1. City, 2. Don't know, 3. Rural)				
	coefficient	SE	t-value	p-value	95% CI
Possibility to be a stranded commuter (3 grades)	0.045	0.017	2.724	0.006	0.013 ~ 0.077
Population density of living area (5 grades)	-0.093	0.007	-12.595	0.000	-0.108 ~ -0.079

Table 6. Result of Multiple Regression Analysis on The Regional View of Resilience

Objective Variable	Safe area for huge earthquake (1. City, 2. Don't know, 3. Rural)				
	coefficient	SE	t-value	p-value	95% CI
Constant term	1.580	0.045			
Gender (1. M, 0. F)	0.187	0.023	8.317	0.000	0.232 ~ 0.995
Age (5 grades)					
Cognition of huge earthquake occurrence (3 grades)					
Damage assumption (4 grades)	0.050	0.010	4.824	0.000	0.030 ~ 0.071
Household income (4 grades)					
Possibility of being a stranded commuter (3 grades)	0.050	0.018	2.834	0.005	0.015 ~ 0.085
Population density of living area (5 grades)	-0.060	0.008	-7.549	0.000	-0.076 ~ -0.045

In addition, 4) for women 5) living in areas with a high population density, the more likely individuals are to consider themselves at risk of major harm from an earthquake and to have difficulty getting home in the event of a large-scale earthquake, the more likely they are to respond that an urban area will recover from a large-scale earthquake more rapidly than a rural area. These tendencies hint at the current situation of the population structure, as younger women are steadily departing rural areas for cities.

Next, we analysed how these cognitions related to the intention to migrate in preparation against the risk of a large-scale earthquake. Correlations were made on the basis of the relationships examined in *Table 5 and Table 6* to assess the possibility of individuals' migrating through the agency of factors such as risk information and the occurrence of foreshocks.

Table 7 presents the distribution of data indicating the possibility of migrating in preparation against the risk of a large-scale earthquake. The study found that the proportion of individuals considering migrating due to the risk of a large-scale earthquake (including both those who had already migrated in recent years and those considering such a move to some extent) was approximately 30%, and their current location of residence did not impact the volition to migrate. Given the uneven distribution of the Japanese population, this proportion can be judged to be very substantial indeed. *Table 8* presents the results of correlations between this finding and the cognitions on safety and resilience discussed above, showing that there is almost no noticeable correlation between these factors.

Table 7. Opinion Distribution of Possibility of Migration Considering The Risk of A Large-Scale Earthquake

Think realistically	314 (6.3%)
	【 L.A. (53), R.A. (56), I.A. (84), U.A. (65), C.A. (56) 】
Think faintly	1,346 (27.0%)
	【 L.A. (248), R.A. (259), I.A. (288), U.A. (260), C.A. (291) 】
Can't transfer	3,322 (66.7%)
	【 L.A. (634), R.A. (687), I.A. (661), U.A. (651), C.A. (689) 】

Table 8. Correlation of The Possibility of Migration in Preparation Against The Risk of A Large-Scale Earthquake and of Cognition of An Area's Safety and Resilience

Explanatory variable	coefficient	SE	t-value	p-value	95% CI
Safety	.003	.011	.288	.773	-0.019 ~ 0.026
Resilience	-0.020	0.011	-1.841	.066	-0.040 ~ 0.001

6. DISCUSSION

This study's findings indicate that the proportion of people currently considering a migration due to perceptions of the high risk of a large-scale earthquake is negligible. Even if I include those considering such a move "to some extent," were included, the total yields a figure of only approximately 30%. In addition, whereas trends in thinking on the safety and resilience of local communities can be explained to some extent from the current living environment and individual attributes and awareness of the risk of a large-scale earthquake, these factors have no bearing on whether an individual will migrate. Thus, it is difficult to predict where people will migrate from and to when directly confronted with the risk of an earthquake on the basis of current surveys such as this one.

However, as shown in *Table 4*, since cognitions of an area's safety before the disclosure of risk differs entirely from perceptions of an area's resilience after the disclosure of risk. It is possible that variations in assumed migration patterns may be conjectured on the basis of whether the period before the disclosure of risk is longer or shorter.

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