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Earthquake Risk Information and Risk Aversive Behavior: Evidence from a Survey of Residents in Tokyo Metropolitan Area

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【Abstract】This paper analyzes the relationship between provision of earthquake risk information and residents' willingness to pay (WTP) for disaster risk reduction by the Contingent Valuation Method (CVM), using questionnaire survey data on the purchase of earthquake insurance in the Tokyo Metropolitan Area, Japan. Degree of disaster risk aversion and subjective probability of loss are estimated as parameters of expected utility function in a discrete choice model. The results suggest that when more precise and specific earthquake risk information is provided, residents of vulnerable houses are willing to pay more for disaster risk reduction, with larger subjective probability of loss, while those in safe houses are willing to pay slightly less, with a larger degree of risk aversion.

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1. Introduction

The Great East Japan Earthquake, which hit the northeast region of Japan on March 11, 2011, claimed about 20 thousand lives, caused the asset loss of 16.9 trillion yen (about 200 billion US dollars, largest ever in the world), and also had a great impact on disaster management policy in Japan. However, Japan is still facing the great danger of other earthquakes. For example, an earthquake expected in the Tokyo Metropolitan Area, which has a 70% probability of occurrence within 30 years, may cause the asset loss of 112 trillion yen (about 1.4 trillion US dollars). The large amount of non-earthquake-resistant buildings and densely populated districts of wooden buildings, widespread in the central part of cities, are major issues for disaster reduction policy. The low ratio of earthquake insurance policyholders to households (21.5% as of the end of March 2008, Non-Life Insurance Rating Organization of Japan) is another significant issue.

On the other hand, project-based disaster reduction policies such as urban redevelopment projects usually require long-term processes of consensus building, and moreover, the government faces financial difficulties to support them, causing the delay of effective disaster reduction measures in the cities.

Under these circumstances, the development of hazard maps and disclosure of earthquake risk information have recently become popular policies adopted by the government[1]. These policies aim to induce residents to prepare for disasters by providing them with objective risk information. However, it seems unlikely that residents can make rational decisions which reflect objective risk[2].

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1 Since March 2005 the Headquarters for Earthquake Research Promotion of the central government has released 'Probabilistic Seismic Hazard Maps,' which show the occurrence probability of earthquakes with a given seismic intensity at a fairly disaggregated geographical level (1km x 1km grid cells) throughout Japan, on the website (http://www.j-shis.bosai.go.jp/). Recently local governments have also been proactive in providing their residents with such risk information as hazard maps and estimations of damage by natural disasters. (see Nakagawa(2003))

2 For example the ratio of earthquake insurance policyholders to households usually increases when the earthquake causes huge damages somewhere in Japan. The rate of increase was 28.6% in FY 1994, 28.9% in FY 1995 (The great Hanshin-Awaji Earthquake occurred in January 1995; Japan's FY turns over in April of each year), and 8.6% in FY

In order to make these policies work effectively, it is important to understand residents' risk perception mechanisms, especially the relationship between available risk information and residents' risk aversive behavior.

Residents are generally considered to have difficulty to prepare themselves in an economically rational manner because they don't have direct experiences of, or enough information about, low-frequency, large-scale disasters such as major earthquakes. Residents' risk perception toward disasters often amounts to a vague feeling of uneasiness. So the preparedness level for those disasters (risk aversive behavior) is considered to be greatly influenced by (1) individual attitudes toward avoiding uncertainty (degree of risk aversion) and (2) individual subjective prediction of loss (subjective probability of loss), which are affected by personal preferences as well as external information sources such as sensational news in the media.

Based on the above recognition, this paper empirically examines residents' disaster risk aversive behavior. More specifically this paper estimates the degree of risk aversion and the subjective probability of loss as parameters of expected utility function in a discrete choice model and analyzes the relationship between provision of earthquake risk information and willingness to pay (WTP) for disaster risk reduction using the Contingent Valuation Method (CVM).

The unique methodological contribution of this study is the construction of individual data which includes the correspondence relationship between the subjective probability of loss and the objective probability of loss. An internet survey on the purchase of virtual earthquake insurance was conducted to construct this dataset.

The results of analysis suggest that when earthquake risk information, such as hazard maps and probability of asset loss, is provided and made more specific to each resident, those in vulnerable houses are willing to pay more for disaster risk reduction while those in safe houses are willing to

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2005 (Niigata Prefecture Chuetsu Earthquake occurred in October 2004), while the average rate of increase from FY 1991 to FY 2008 was 7.5%. These behaviors were far from rational decisions which reflected their own objective earthquake risks.

pay slightly less than before. As an explanation for these changes in risk aversive behaviors, it is suggested that residents of vulnerable houses have larger subjective probability of loss while those in safe houses have a larger degree of risk aversion as well as slightly smaller subjective probability of loss.

This implies that the disclosure of earthquake risk information, especially the provision of specific risk information such as the probability of asset loss for each resident, can effectively induce the residents living in non-earthquake-resistant houses or other high-risk houses located in densely populated districts of wooden buildings to make more investments in disaster risk reduction.

This paper is organized as follows. Section 2 reviews the previous studies of disaster risk information and people's risk aversive behaviors. Section 3 presents the empirical specifications of this study. Section 4 describes the questionnaire survey using CVM. Section 5 reports the estimated results and interpretations. Section 6 concludes by discussing the policy implications for disaster risk reduction.

2. Previous studies

There are not so many studies which address the relationship between the provision of disaster risk information and residents' disaster risk investments. One of the difficulties of this kind of study is that residents' risk aversive behavior (or WTP for risk reduction) is not directly affected by the objective risk but is affected by the degree of disaster risk aversion and the subjective probability of loss involving the residents' risk perception biases (see Figure 1). Some related studies have been conducted in the fields of civil engineering, economics, and psychology.

<Figure 1>

Among the studies in the fields of economics and civil engineering, Matsuda et al. (2005), Kaoru (1998), Willis and Asgary (1997), and others have tried to estimate risk premium and WTP using CVM questionnaire surveys. However, since these studies are based on data without the correspondence information of each resident's subjective and objective probability of loss (or some of them are based on data of the virtual objective probability of loss), it is impossible for them to analyze "risk perception bias" in detail.

Moreover, in order to induce residents to take proper action for disaster risk reduction, it is thought that the provision of "general risk information for an entire city," such as a hazard map, is not sufficient, but rather the provision of easily understandable "specific risk information on individual house" is needed (Nakagawa (2003)). However, the correspondence between provided information level and WTP for disaster risk reduction is also not yet empirically clarified in the previous studies.

There are also literatures such as Brookshire et al.(1985) and Nakagawa et al.(2009) which estimated the depreciation ratio of the hedonic housing price (or land price) caused by the earthquake risk and calculated the WTP for earthquake risk reduction (or risk premium) based on this ratio. However, since the housing price (or land price) reflects people's comprehensive judgment on the multiple disaster risks as well as various neighborhood environment factors, those studies have difficulties to analyze the impact of specific disaster risk such as earthquake risk on the housing price (or land price). Moreover, they had another difficulty to examine the magnitude of people's "risk perception bias" since the analysis is only based on the objective risk data.

On the other hand, in the field of psychology, there are studies such as Slovic (1997), Lichtenstein et al. (1978), Kunreuther et al. (1978), Ganderton et al. (2000) which tested whether the expected utility theory in the field of economics is adequate to explain people's risk aversive behavior. These studies indicated the existence of "risk perception bias" which usually makes the subjective probability of loss larger than the objective probability of loss in the low frequency events.

In this case low frequency natural disasters such as earthquakes tend to be considered as higher frequency events than they are in reality. As for this risk perception bias, it is indicated by Viscusi (1998) and other related studies that the subjective probability of loss is recognized based on the person's "experience" and cannot be easily changed. To adjust people's subjective probability of loss closer to the objective probability of loss, the accuracy of information and the mutual trust between provider and recipient of the information are considered to be the key elements, according to these studies.

But since most of these studies were conducted in the laboratory without considering people's social conditions and based mainly on qualitative analysis, they have not succeeded in quantifying the degree of disaster risk aversion in real social situations.

This study examines residents' WTP for disaster risk reduction when "the specific risk information on actually existing houses" is provided, and tries to quantify the changes in degree of risk aversion and subjective probability of loss (or risk perception bias) according to the level of information quantity and specificity.

3. Model

The analytical model for this study follows Matsuda et al.(2005). We use the discrete choice model of Hanemann et al. (1984, 1991) to explain purchase or non-purchase of the disaster risk avoidance option (e.g. earthquake insurance), and estimate the degree of relative risk aversion γ and the subjective probability of loss p as parameters of the indirect utility function. Then we calculate the WTP for disaster risk reduction and the risk premium ρ based on the estimation results of γ and p. We analyze the impact of provision of information on resident's disaster risk aversive behavior by comparing the magnitude of these estimates among the subsamples with the different information levels.

First, we assume the resident behaves in accordance with the expected utility maximization hypothesis and we use the measurable von Neumann-Morgenstern (VNM) utility function. If the resident's expected utility is EV_1 in the case of purchase of risk avoidance option and EV_0 in the case of non-purchase, each expected utility can be written as follows.

$$EV_1 = p\,V_{11} + (1 - p)\,V_{01} \qquad (1)$$

$$EV_0 = p\,V_{10} + (1 - p)\,V_{00} \qquad (2)$$

Here for the sake of simplicity we assume 4 cases: $s = 1$ when the resident suffers loss due to disasters and $s = 0$ when no loss, as well as $a = 1$ when the resident purchases the risk avoidance option and $a = 0$ when non-purchase. The indirect utility V_{sa} is described according to the above mentioned 4 cases.

Next, we consider the expected utility difference (EUD) between the purchase of risk avoidance options and non-purchase of them, and introduce the following random utility model which consists of the fixed term ΔEV and the stochastic error term ε which is supposed to be normally distributed with variance σ.

$$\text{(Fixed term)} \qquad \Delta EV = EV_1 - EV_0$$

$$= p\,(V_{11} - V_{10}) + (1 - p)\,(V_{01} - V_{00}) \qquad (3)$$

$$\text{(Stochastic error term)} \qquad \varepsilon \sim N\,(0,\ \sigma^2) \qquad (4)$$

Then, we suppose that the utility function exhibits Constant Relative Risk Aversion (CRRA). CRRA function can be written as follows.

$$V(y; \gamma) = y^{1-\gamma} / (1 - \gamma) \qquad \text{for } \gamma \neq 1 \qquad (5)$$

$$V(y) = \ln y \qquad \text{for} \quad \gamma = 1 \qquad (6)$$

$V(y)$: indirect utility $\qquad$ y : household wealth

We also suppose that the cost of purchasing risk avoidance option is c, the resident's wealth at the normal situation is y_0, the loss of resident's wealth due to disasters in the case of purchase of risk avoidance option is l_1, and the loss of resident's wealth due to disasters in the case of non-purchase of risk avoidance is l_0. Then the equation (3) can be rewritten as follows.

$$\Delta EV = [\, p\, \{(y_0 - c - l_1)^{1-\gamma} - (y_0 - l_0)^{1-\gamma}\}$$
$$+ (1 - p)\, \{(y_0 - c)^{1-\gamma} - y_0^{1-\gamma}\}] / (1 - \gamma) \qquad (7)$$

In addition, in order to examine the detailed structure of the degree of relative risk aversion γ, we also conduct the empirical analysis on the assumption that γ is the function of resident's attribute vector X.

$$\gamma\,(X) = X'\,\alpha \qquad \alpha : \text{coefficient vector} \qquad (8)$$

On the other hand, the probability of purchase of risk avoidance option and that of non-purchase is respectively given as follows based on the normal distribution of error term ε.

$$\Pr(a = 1 \mid y) = \Pi_1 = 1 - \Phi(-\Delta EV / \sigma) \qquad (9)$$

$$\Pr(a = 0 \mid y) = \Pi_0 = \Phi(-\Delta EV / \sigma) \qquad (10)$$

Π_a: probability in the case of a, $\quad$ Φ : probability distribution function of standard normal distribution

Based on this, we introduce the two-stage binomial discrete choice model. The questions with 2 alternatives (purchase or non-purchase of the risk avoidance option) are asked in 2 stages. Let 1 represent purchase and 0 non-purchase in the first stage and the second stage; then the set of alternatives consists of 4 elements {a = 11, a = 10, a = 01, a = 00}. In this case, the log-likelihood function can be formulated as follows. (see Hanemann et al. (1991)).

$$\begin{aligned} \ln L &= \Sigma_i \Sigma_a d^i_a \ln \Pi^i_a \\ &= \Sigma_i \{d^i_{11} \ln(1 - \Phi(-\Delta EV_U / \sigma)) \\ &\quad + d^i_{10} \ln(\Phi(-\Delta EV_U / \sigma) - \Phi(-\Delta EV_1 / \sigma)) \\ &\quad + d^i_{01} \ln(\Phi(-\Delta EV_1 / \sigma) - \Phi(-\Delta EV_L / \sigma)) \\ &\quad + d^i_{00} \ln(\Phi(-\Delta EV_L / \sigma))\} \end{aligned} \tag{11}$$

d_a: 1 in the case of a, 0 otherwise, ΔEV_1: EUD in the first stage, ΔEV_U: EUD in the second stage after purchase in the first stage, ΔEV_L: EUD in the second stage after non-purchase in the first stage, i: household number

Based on equations (7) and (11), we estimate the parameters (γ, p, σ) by the maximum likelihood method, using the data from the questions with 2 alternatives in 2 stages about purchase or non-purchase of disaster risk avoidance options.

Finally, using the estimated parameters $\hat{\gamma}$, $\hat{p}$, we calculate the WTP for disaster risk reduction and the risk premium ρ of a representative resident (see Figure 2). The calculation is conducted by the following equation, where y^E is the expected resident's wealth including subjective loss by the disaster, and y^* is the certainty equivalent.

$$WTP = y_0 - y^* \tag{12}$$

$$\rho = y^E - y^* = (y_0 - \hat{p}\, l_0) - y^* \tag{13}$$

$$y^* = V^{-1}(\hat{p}\, V(y_0 - l_0; \hat{\gamma}) + (1 - \hat{p})\, V(y_0; \hat{\gamma})\, ; \hat{\gamma}) \tag{14}$$

<Figure 2>

4. Questionnaire survey on purchase of earthquake insurance

4.1 Methodology of survey

In this study we carried out the following CVM questionnaire survey via Internet (see Table 1). We selected the Tokyo Metropolitan area as a target area since detailed earthquake risk indicators for each district have been developed by the Tokyo Metropolitan Government. We used earthquake insurance as a resident's earthquake risk avoidance option and asked the question whether to purchase the hypothetical earthquake insurance under the condition that a certain level of earthquake risk information was given.

<Table 1>

In this study, the "earthquake risk" a resident faces is defined as the "objective probability of loss", which is obtained as a product of "probability of earthquake occurrence" and the "ratio of asset loss to resident's risk asset in case the earthquake occurs". "Risk asset" is defined as the amount of a resident's housing assets exposed to earthquake risk, and it consists of the building asset value (excluding the land value) and the value of home contents. Risk asset also means the amount of asset the earthquake insurance can cover.

"Expected loss of asset by earthquake" is regarded as the "objective loss" which is obtained as a product of "risk asset" and "earthquake risk". (See Figure 3)

<Figure 3>

We assume that the "earthquake insurance payment" covers up to 50% of the risk asset and is decided according to the damage level[3]. We asked the residents whether they would like to purchase the earthquake insurance for the hypothetical "annual insurance cost"[4]. Then we asked those who answered "yes" the second question, whether they would like to purchase the same insurance for twice as much as the cost of the first question, and asked those who answered "no" the alternative second question, whether they would like to purchase the same insurance for half as much as the cost of the first question (the questions with 2 alternatives in 2 stages).

In this survey we provided each resident with 2 kinds of information just before the questions about the purchase of earthquake insurance: the "earthquake risk information" and the information on "amount of risk assets"

As for the "earthquake risk information", we divided the total sample of 1,000 into three equal subsamples, and provided one of the following three levels of earthquake risk information to the residents in the respective subsample (see Table 2).

- Level 1: No earthquake risk information available
- Level 2: Earthquake risk information easily obtained in daily life such as hazard maps ((1) and (2) were provided.)
- Level 3: Earthquake risk information which requires some expertise or cost to obtain, but which can clearly identify the objective risk of individual housing ((1) - (6) were all provided.)

As for the information on "amount of risk assets", we provided all residents with the precise calculation result of each resident's amount of risk assets.

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[3] This is the same as the payment rule of the current Japanese earthquake insurance.

[4] The hypothetical annual insurance cost was determined by multiplying the earthquake insurance payment by any one of the five levels of insurance rates. We set the insurance rate of 0.06%, 0.1%, 0.2%, 0.4%, and 0.6% based on the result of preliminary questionnaire survey in a small group, and randomly used one of them. Meanwhile, the actual earthquake insurance rates in the Tokyo Metropolitan Area are 0.169% for non-wooden houses and 0.313% for wooden houses.

<Table 2>

In this survey, by taking advantage of the internet-based questionnaire, we automatically calculated each resident's "earthquake risk (objective probability of loss)" and "amount of risk assets" based on the resident's housing attributes (address (district or street), building structure, year of original construction, gross floor area of house, purchase price of house, family structure) input by each respondent[5], and displayed them on the survey sheets (or controlled the amount of information displayed).

Therefore, it became possible to determine the WTP by asking the resident the questions in the realistic situation where the actual house may be affected by an earthquake. In addition, since the "amount of risk assets" was standardized and presented on the survey sheets (the resident usually doesn't know this precisely, resulting in considerable variation of resident's prediction and unreliable WTP estimation), it became possible to develop accurate individual data of the correspondence relationship between each resident's risk perception and WTP for disaster risk reduction, and also the correspondence relationship between the objective probability of loss and the subjective probability of loss. (See Figure 4, 5, 6 for the survey sheets)

5 The "probability of earthquake occurrence" was read from the 1 km mesh data of PSHM using the typical latitude and longitude of the district (chō-me) where the resident is living, and the "probability of total collapse and half collapse" was calculated using the damage function based on the building damage data from the 1995 Great Hanshin-Awaji Earthquake in Kobe (Murao and Yamazaki(2000)) and the data on each resident's housing attributes such as building structure and year of original construction. The "Potential earthquake damage level for the district" was derived from the Comprehensive Hazard Map corresponding to the district where the resident was living.

The "amount of risk assets" was calculated by adding the value of home contents to the value of building asset. The value of home contents was determined from the data on standard value of home contents corresponding to the family structure (age, number of family members, etc.) developed by Nissay Dowa General Insurance Co., Ltd.. The value of building asset was calculated using the average construction unit cost of wooden or non-wooden structures in the Tokyo Metropolitan Area based on the Annual Report on Building Statistics, the gross floor area of the house, and also the age of the house in order to take into account age degradation. (See Kawawaki (2009) for a more detailed numerical calculation.)

<Figure 4>

<Figure 5>

<Figure 6>

In the meantime however, it is pointed out that CVM involves various biases associated with stated preference data and its estimation. Moreover, in the Internet survey, there is a question as to whether the monitors in the research company adequately represent general consumers.

In this survey the demographic composition of respective three subsamples such as age and gender is adjusted as close as possible to that of the census result of the Tokyo metropolitan area, and the sample size ratio among municipalities is also confirmed to be not much different from the real population distribution among municipalities. However, meticulous attention to bias is required for the proper interpretation of this survey result.

4.2 Results of survey

The descriptive statistics of the survey result are shown in Table 3. As for the ratio of building types, wooden detached housing was 40.0%, non-wooden detached housing was 9.9%, non-wooden multifamily housing such as condominiums was 49.1%, and wooden apartment housing was 1.0%. The average purchase price of a house was 46,860 thousand yen, the average construction year was 1990, the average number of family members was 2.9, and the average age of head of household was 48.5 years old. The average amount of gross asset (including liabilities) was 56,460 thousand yen (the median was 40,000 thousand yen) since all of the respondents were homeowners.

In addition, the average objective “probability of earthquake occurrence” of the districts where the residents were living was 15.5% (the earthquake with ground motions equal to or larger than JMA seismic intensity 6^- within 30 years was assumed), and the average "ratio of asset loss to resident's risk asset" in case of earthquake was 16.5% (the earthquake with ground motions equal to JMA seismic intensity 6^+ was assumed)[6].

<Table 3>

The average earthquake insurance cost presented in the first stage was 34.2 thousand yen (the median was 23.4 thousand yen), and based on this, 53.7% of the residents answered “yes” to purchase the insurance.

In the second stage 31.3% of the residents who answered “yes” in the first stage answered “yes” again to purchase the same insurance for the twice as much as the previous cost. On the other hand 46.2% of the residents who answered “no” in the first stage answered “no” again to purchase the same insurance for the half as much as the previous cost (see Figure 7).

<Figure 7>

5. Estimation results

We estimated the two-stage binomial discrete choice model by the maximum likelihood method. The descriptive statistics of the variables used for the estimation[7] are shown in Table 4, the

[6] Since the damage level was assessed as ‘total collapse’ when the asset loss was more than 50% and ‘half collapse’ when the asset loss was from 20% to 50%, we used the intermediate value of asset loss of 75% for ‘total collapse’ and 35% for ‘half collapse’ to calculate the “ratio of asset loss to resident’s risk asset”.

[7] Since we have built the model with the stock concept such that the resident’s utility level is a function of the

estimation results of whole sample models are shown in Table 5, 6, and the estimation result of segmentation models is shown in Table 7.

<Table 4>

5.1 Estimation results of whole sample model

In the estimation result of the whole sample model, the degree of relative risk aversion was estimated to 0.399 and the subjective probability of loss was estimated to 0.00184. Both of them were significant at 1% level. (see Table 5)

The positive degree of relative risk aversion means resident's risk-averse preference, which is consistent with the theory[8]. The estimated subjective probability of loss was larger than the average of the objective probability of loss among residents which was 0.00082.[9] This is likely to be due to the bias in risk perception of low frequency events, which is also consistent with the risk perception theory. This indicates that it is not the residents' underestimation of earthquake risk which causes the low ratio of earthquake insurance policyholders to households.[10]

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amount of gross asset (see Section 3), the income which comes from the flow concept is not included in the explanatory variables. So we tested the effect of not including the income variable in the model by comparing the estimation results with and without the income variable using an expenditure function model. We found that the effect of not including the income variable was primarily reflected in a little larger coefficient of "wealth" variable and not so much reflected in the coefficients of "resident attributes" variables.

[8] Since most of the degree of relative risk aversion estimated by previous studies were 1.0 or larger (concerning the demand for risky assets such as shares, Friend and Blume (1975) etc), the estimation result of this study seems to be a little smaller. But when we used the objective probability of loss as a value of subjective probability of loss instead, the estimation result of degree of relative risk aversion became 1.647. It is considered that compared with the model assuming people's precise risk perception the estimation result of this study was smaller due to the effect of risk perception bias.

[9] The PSHM showed the probability of earthquake occurrence within 30 years. We converted the probability within 30 years (p(30)) into the probability within one year (p(1)) using the equation ($p(1) = 1 - \exp(1/30 \ln(1 - p(30)))$) assuming that the probability of earthquake occurrence follows a Poisson distribution.

[10] Fujimi and Tatano (2006) has demonstrated that the "ambiguity" inherent in the earthquake insurance contract made it difficult for residents to purchase the earthquake insurance even if they had earthquake risk information and

Another whole sample model including resident's attributes which affect relative risk aversion is shown in Table 6.

The residents who were carrying the earthquake insurance had a larger degree of risk aversion, and the residents who had greatly raised awareness of disaster prevention after the Hanshin-Awaji Earthquake also had a larger degree of risk aversion.

<Table 5>

<Table 6>

However, the residents who had experienced natural disasters didn't always have a larger degree of risk aversion. This suggests that earthquake risk and other natural disaster risks are considered to be different types of risks in terms of residents' risk perception.

The residents who thought that earthquake countermeasures taken by the government were more important than those taken by residents themselves had a higher degree of risk aversion than the residents who thought the reverse. This is the opposite result to our initial expectation that those residents who think that earthquake countermeasures taken by the government are more important would not be risk averse and would not invest in their own disaster risk reduction, as they would expect a government bail-out after a disaster (the moral hazard). In reality, those residents have a higher priority for safety and behave more risk aversively by themselves.

In addition, those who were 60 years old or over had a lower degree of risk aversion than others, and men had a higher degree of risk aversion than women. The reason for these differences may be that the elderly are not so much interested in the risk avoidance option for long-term housing asset holdings, and that men are more deeply involved in the management of housing asset than women.

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found the purchase of the insurance is advantageous to them on an actuarial basis.

5.2 Estimation results of Segmentation Model

This time, to analyze the effect of provision of risk information on the vulnerable houses and safe houses respectively, we divided the whole sample into two subsamples of different vulnerabilities (larger or smaller than the average of objective probability of loss), and also divided each of them into three subsamples of different information levels. Then we estimated the parameters using those divided subsamples (see Table 7).

The estimation result shows that the degree of relative risk aversion was not significant in the vulnerable houses. The residents in the vulnerable houses had risk-neutral preference and did not change their preferences according to the risk information level. On the other hand, the degree of relative risk aversion was larger and significant at 1% level in the safe houses. The residents in safe houses had risk-averse preferences. Moreover, the degree of risk aversion became larger at information levels 2 and 3. The provision of risk information might increase the degree of risk aversion of the residents in safe houses[11].

However, when we look at the estimate value closely, we can find it became largest at information level 2.[12] It is assumed that when only the hazard maps were presented, the mere existence of danger was communicated to the residents, resulting in the increase of risk aversion of the residents in safe houses. But when the specific probabilities of loss to each resident were presented, the low earthquake risk of the safe houses became explicit and the uncertainty was reduced, resulting in the decrease of risk aversion of the residents in safe houses.[13]

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[11] In a similar finding, Viscusi et al. (1999) reported that non-smokers tended to take information about risk for smoking more seriously than smokers did.

[12] To confirm whether there are statistically significant differences between the estimate values of relative risk aversion, we tested it based on the variance of estimator. We found significant differences at 5% level only between the information level 1 and 2 (the effect of provision of hazard map information) in the safe houses.

[13] From this, the information level and the degree of risk aversion were not in a simple proportional relationship.

<Table 7>

Next, regarding the subjective probability of loss, it increased as the information level increased, and became largest at information level 3 in the vulnerable houses[14]. The provision of risk information increased the subjective probability of loss of the residents in the vulnerable houses. However, the gap between subjective probability of loss and objective probability of loss (bias in risk perception) became also larger as the information level became higher, and this contradicts the theory. One of the possible explanations for this is that the information on large earthquake risk had a larger impact on the residents' risk perception than the real impact on asset loss, since it is difficult for them to understand the hazard map and the probability of loss precisely and respond correctly according to the real risk level. The other possible explanation is that in this survey the information of each district's earthquake risk was also provided in addition to each house's objective probability of loss, and it became clearer that a lot of vulnerable houses were located in the dangerous districts[15] as the information level became higher.

On the other hand, there was no major change in the subjective probability of loss in the safe houses even though it became slightly smaller when some information was provided. However, the

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There are various types of risk information such as hazard maps, probability of loss, video image of damages, and so on. The degree of risk aversion is considered to be affected by the types of information or the way of providing information. Hershey et al. (1982) demonstrated that, based on the data in the laboratory and the review of previous studies, the way information is presented will make people focus attention on different aspects of things and change their preferences. (This is called "context effect".) It seems that in this study the presentation of the hazard map shifted the residents' interest on the aspect of existence of the risk while the presentation of the specific information on probability of loss shifted the residents' interest on the aspect of level of the risk. However, there are not sufficient previous studies on this matter. Future research is necessary to understand this phenomenon in detail.

[14] To confirm whether there are statistically significant differences between the estimate values of subjective probability of loss, we tested it based on the variance of estimator. We found significant differences at 5% level only between the information levels 1 and 3 (the effect of provision of specific probability information) in the vulnerable houses.

[15] 35.1% of vulnerable houses were located in the district of potential damage level 3-5 of the Comprehensive Hazard Map, while 23.8% of safe houses were located in the district of potential damage level 3-5.

risk perception bias in the safe houses was much larger than that in the vulnerable houses. This suggests that the residents in safe houses had not only risk-averse preference but also a tendency to estimate their probability of loss excessively. The subjective probability of loss was more than three times as much as the objective probability of loss, even though the specific information on the objective probability of loss was provided for the residents in safe houses. With these facts it is noted that changing residents risk perception is not an easy thing. [16]

5.3 Willingness to pay and risk premium

Using the estimation results of the degree of relative risk aversion and the subjective probability of loss obtained by the above model, we calculated the WTP and the risk premium of a representative resident (see Table 8). We used the gross asset of 40 million yen (median of the sample) and the risk asset of 23.64 million yen (median of the sample) for a representative resident.

According to the calculation result, the WTP for earthquake risk reduction was 50,900 yen per year when whole sample was used, and as for the breakdown of WTP, 43,500 yen per year was for subjective loss and 7,400 yen per year was for risk premium. (The WTP for earthquake insurance was 23,200 yen per year since we assumed the earthquake insurance which would cover up to 50% of residents' risk assets in this study.)

On the other hand, the objective loss was 19,300 yen per year. (We calculated this using the objective probability of loss and risk asset of a representative resident. See Fig. 3.) The gap between the WTP and the objective loss amounted to 31,600 yen. This gap includes the overestimation of

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[16] One possible explanation for this is that it was difficult for residents to understand the earthquake risk presented in the long-term probability and to reflect it on risk avoidance behavior such as purchase of earthquake insurance. The other possibility is that there still existed uncertain events which might cause the unexpected loss such that the consequent fire might break out after the earthquake or some unknown active faults might move. For example, the Great East Japan Earthquake caused unexpected large scale of tsunami wave and also caused unexpected Fukushima Daiichi Nuclear Power Plant accident.

earthquake risk associated with the risk perception bias. If the model does not take into account the risk perception bias, the calculation result of risk premium may capture this "superficial risk premium" resulting in the overestimation of risk premium (see Figure 8).

<Table 8>

<Figure 8>

The provision of risk information resulted in a great increase of WTP in vulnerable houses (54.6→88.2 thousand yen) and a slight decrease of WTP in safe houses (50.4→45.4 thousand yen). The decrease of WTP in safe houses was not as large as the increase of WTP in vulnerable houses. This suggests that the provision of risk information made residents in safe houses more risk averse.

6. Conclusion

This paper analyzed the relationship between provision of earthquake risk information and residents’ WTP for disaster risk reduction by the Contingent Valuation Method, using questionnaire survey data on the purchase earthquake insurance in the Tokyo Metropolitan Area, Japan.

The results suggested that when more precise and specific earthquake risk information is provided, residents of vulnerable houses are willing to pay more for disaster risk reduction, while those in safe houses are willing to pay slightly less than before.

As an explanation for these changes in risk aversive behaviors, it was suggested that residents of vulnerable houses had larger subjective probability of loss while those in safe houses had a larger degree of risk aversion as well as slightly smaller subjective probability of loss. (See Table 9)

<Table 9>

In addition, there was a bias in residents' risk perception. The subjective probability of loss was more than twice as much as the objective probability of loss. These biases were quite large in both vulnerable houses and safe houses at all information levels. It didn't seem to be easy to change residents' risk perception.

Figure 9 shows the changes of WTP of a representative resident for earthquake insurance according to the risk information level. In the case of no information (information level 1) there was not a large gap between WTP of vulnerable houses and that of safe houses; however, when more information was provided (information levels 2 and 3), the gap between them became larger.

At information level 3, the WTP of vulnerable houses went up to a level which was higher than the real earthquake insurance cost of a representative wooden house in Tokyo. This implies that the disclosure of earthquake risk information can induce residents' purchase of earthquake insurance who are living in the high-risk houses located in densely populated districts of wooden buildings.

However, it should be noted that the "specific risk information" for each residence is needed to induce this behavior and that what kind of risk information is provided makes a difference in the degree of risk aversion. Especially the provision of "general risk information," such as a hazard map for the entire Tokyo metropolitan area, just increases the degree of risk aversion of the residents in safe houses who are originally behaving risk aversively, and does not increase WTP of the residents in vulnerable houses sufficiently.

<Figure 9>

On the other hand, at information levels 2 and 3, the WTP of safe houses went slightly down to the level which was close to the real earthquake insurance cost of a representative non-wooden house in Tokyo. This means some residents in safe houses such as newly built condominiums may stop purchasing insurance once they come to know their houses are safe enough.

The increase of earthquake insurance holders in vulnerable houses and the decrease of those in safe houses will cause an imbalance between revenue and expenditures in the earthquake insurance business. The current earthquake insurance rate is the same in each prefecture in Japan. This rate needs to be more segmented reflecting earthquake risk of each building and district. The equalization of earthquake insurance cost per risk is necessary.

Kunreuther (2008) explained that insurance premiums should be based on risk to provide signals to individuals as to the hazards they face and to encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes[17]. Integrated disaster risk management, such as the combination of disclosure of risk information and the improvement of the earthquake insurance system, will be necessary.

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[17] There is a concern for some residents in vulnerable houses who will be faced with large premium increases if insurers adhere to the risk-based premiums policy. In this case Kunreuther (2008) insists that any special treatment given to residents in vulnerable houses (for example, low income homeowners) should come from general public funding and not through insurance premium subsidies.

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Tables and Figures

Table 1. Outline of the survey

Date	20 August 2008～1 September 2008
Respondents	Male and female, aged 20 years or over, who have their own houses
Number of sample	1,000 (Component ratio of sex and age followed the census result in Tokyo)
Method	Internet survey ("Goo Research", a research company, was entrusted to conduct the survey)

Table 2. Provided earthquake risk information

	Earthquake risk information	Note		
(1)	Distribution map of earthquake occurrence probability for the entire Tokyo metropolitan area[1]	Earthquakes of Japan Meteorological Agency (JMA) seismic intensity scale ≥ 6⁻ in the district within the next 30 years	Level 2 information	Level 3 information
(2)	Distribution map of potential earthquake damage level for the entire Tokyo metropolitan area[2]	5-level index of potential building damage in the district due to earthquake shocks and consequent fires	Level 2 information	Level 3 information
(3)	Probability of earthquake occurrence for the district where the resident is living[1]	Earthquakes of JMA seismic intensity scale ≥ 6⁻ in the district within the next 30 years		Level 3 information
(4)	Probability of total collapse and half collapse of the house where the resident is living in the case of earthquake[3]	The earthquake with the ground motion level of JMA seismic intensity scale 6⁺ assumed		Level 3 information
(5)	Potential earthquake damage level for the district where the resident is living[2]	5-level index of potential building damage in the district due to earthquake shocks and consequent fires		Level 3 information
(6)	Ranking of potential earthquake damage level for the district where the resident is living among all of the districts in Tokyo metropolitan area[2]	Ranking of the district from 1 to 5099 among all of the 5099 districts in Tokyo metropolitan area		Level 3 information

Source: [1]The Probabilistic Seismic Hazard Map (PSHM), [2]The Survey on Regional Earthquake Risk: The Comprehensive Hazard Map, [3]Murao and Yamazaki (2000)

Table 3. Descriptive statistics of resident's attributes

Variables	Mean	S.D.	Median
Purchase price of the house (in 10 thousand yen)	4686	4670	4000
Year of home purchase	1993	13.94	1998
Year of home building	1990	15.03	1995
Gross floor area of the house (in square meter)	91.03	52.04	80
Number of family members	2.94	1.15	3
Age of head of household	48.46	11.54	50
Amount of gross asset(including liabilities) (in 10 thousand yen)	5646	5452	4000
Objective probability of earthquake occurrence (%)	15.53	8.42	11.9
Objective ratio of asset loss to resident's risk asset (%)	16.52	13.63	12.6
Potential damage level by earthquake for the district (1:lowest～5:highest)	2.06	1	2
Ranking of potential damage level by earthquake for the district (1～5099)	2180	1348	2041

Table 4. Descriptive statistics of variables

Variables	Description	Mean	S.D.	Median
Purchase of insurance	Purchase of insurance (first stage) (=1 if purchase)	0.537	0.499	1
	Purchase of insurance(second stage; twice as much as insurance cost provided) (=1 if purchase) Number of observations: 537	0.313	0.464	0
	Purchase of insurance(second stage; half as much as insuranace cost provided) (=1 if purchase) Number of observations: 463	0.538	0.499	1
Insurance cost provided (c)	Insurance cost provided (first stage) (in 10 thousand yen)	3.422	3.362	2.34
	Insurance cost provided (second stage; twice as much as insurance cost provided) (in 10 thousand yen)	6.843	6.724	4.68
	Insurance cost provided (second stage; half as much as insurance cost provided) (in 10 thousand yen)	1.711	1.681	1.17
Wealth (y_0)	Amount of gross asset (in 10 thousand yen) ※Largest value of the band is employed	7046	6104	4999
Risk asset (l_0)	Amount of asset covered by earthquake insurance (in 10 thousand yen) (Present value of building assets and home contents)	2603	1427	2364
Resident attributes (X)	Carrying earthquake insurance (=1 if yes)	0.417	0.493	0
	Awareness of disaster prevention raised after Hanshin-Awaji earthquake (=1 if raised very much)	0.271	0.445	0
	Having experience of natural disasters (=1 if yes)	0.067	0.25	0
	The thought whether responsible actors for earthquake disaster prevention are governments or residents including a respondent himself (=1 if governments)	0.472	0.499	0
	Age (=1 if 60 years old or over)	0.251	0.434	0
	Sex (=1 if male)	0.494	0.500	0

※To avoid the case the amount of asset becomes negative when the resident suffered loss, the largest value of each band(～499, 500～999, 1000～1999, 2000～2999, 3000～4999, 5000～9999, 10000～19999, 20000～; in 10 thousand yen) was employed.

Table 5. Estimation result of whole sample model

Relative risk aversion（γ）	0.399	***
	(16.16)	
Subjective probability of loss（p）	0.00184	***
	(23.12)	
Subjective probability of loss / Objective probability of loss	2.25	
Standard deviation（σ）	0.143	***
	(4.55)	
Log likelihood（L）	-1780.63	
Number of observations（N）	1000	

Table 6. Estimation result of whole sample model with resident's attributes

Relative risk aversion (γ(X))		
Constant	0.341	***
	(11.84)	
Carrying earthquake insurance （1,0）	0.0387	***
	(6.98)	
Awareness of disaster prevention raised very much after Hanshin-Awaji earthquake （1,0）	0.0315	***
	(5.87)	
Having experience of natural disasters （1,0）	0.0102	
	(1.37)	
Thought that responsible actors for earthquake disaster prevention are governments （1,0）	0.0205	***
	(3.71)	
Age(60 years old or over) （1,0）	-0.0262	***
	(-4.03)	
Sex(male) （1,0）	0.0310	***
	(5.41)	
Subjective probability of loss(within a year)（p）	0.00167	***
	(23.66)	
Standard deviation（σ）	0.152	***
	(4.02)	
Log likelihood （L）	-1747.86	
Number of observations （N）	1000	

Notes: Numbers in parentheses are t-values. *** indicates the 1% level of significance.

Table 7. Estimation results of segmentation model

Sample of vulnerable houses
[Sample whose objective probability of loss is larger than average]

	Information level 1		Information level 2		Information level 3	
Relative risk aversion（γ）	0.163		-0.127		0.00863	
	(1.64)		(-1.15)		(0.06)	
Subjective probability of loss（p）	0.00217	***	0.00282	***	0.00372	***
	(5.35)		(7.18)		(6.30)	
Subjective probability of loss / Objective probability of loss	1.34		1.58		2.01	
Standard deviation（σ）	0.76		9.13		3.66	
	(1.17)		(1.07)		(0.82)	
Log likelihood（L）	-156.02		-174.33		-180.08	
Number of observations（N）	93		100		98	

Sample of safe houses
[Sample whose objective probability of loss is smaller than average]

	Information level 1		Information level 2		Information level 3	
Relative risk aversion（γ）	0.336	***	0.583	***	0.463	***
	(4.51)		(10.39)		(6.12)	
Subjective probability of loss（p）	0.00187	***	0.00148	***	0.00160	***
	(8.83)		(8.58)		(11.82)	
Subjective probability of loss / Objective probability of loss	4.16		3.39		3.70	
Standard deviation（σ）	0.231		0.0308	**	0.0864	
	(1.56)		(1.99)		(1.51)	
Log likelihood（L）	-409.73		-407.08		-426.96	
Number of observations（N）	234		234		241	

Notes: Numbers in parentheses are t-values. ***, ** and * indicates the significance level of 1%, 5% and 10% respectively. Subjective probability/Objective probability is calculated by dividing estimate of subjective probability of loss by average of objective probability of concerning samples.

Table 8. WTP of a representative resident for earthquake risk reduction

(Thousand yen per year)

	Information level 1	Information level 2	Information level 3	Whole sample
WTP of whole sample	50.5	51.5	50.7	50.9
・Subjective loss	44.4	43.3	43.7	43.5
・Risk premium	6.0	8.3	6.9	7.4
WTP of vulnerable houses	54.6	63.6	88.2	69.1
・Subjective loss	51.3	66.7	87.9	69.5
・Risk premium	3.3	-3.1	0.3	-0.4
WTP of safe houses	50.4	44.2	45.4	46.2
・Subjective loss	44.2	35.0	37.8	38.1
・Risk premium	6.2	9.2	7.6	8.1

Table 9. The effect of provision of earthquake risk information

	Risk preference	Subjective probability of loss	WTP for disaster risk reduction
Vulnerable houses	Stay risk neutral	Become much larger	Increase greatly
Safe houses	Become more risk averse	No big change (Slightly smaller)	Decrease slightly

Figure 1. Provision of risk information and change in WTP

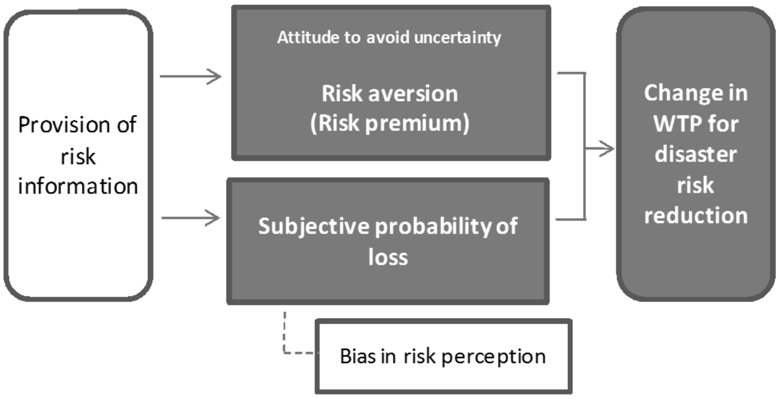


Figure 2. VNM utility function and risk premium

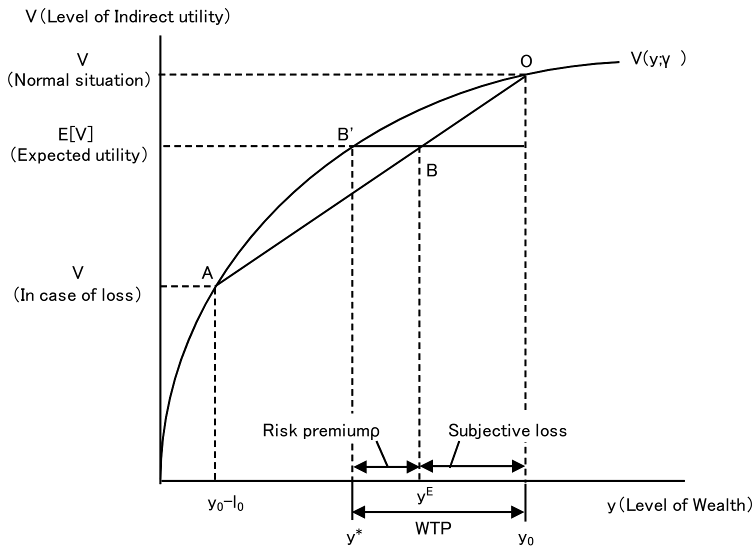


Figure 3. Evaluation of earthquake risk

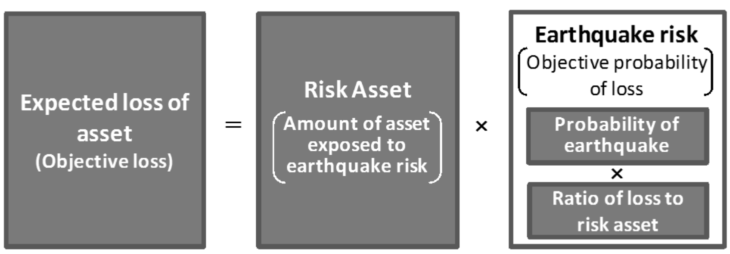


Figure 4. A part of the survey sheet (Questionnaire on purchase of earthquake insurance)

From the information you provided, the estimated standard amount of your housing asset for which you can purchase the earthquake insurance is following.
Here the earthquake insurance is assumed to cover the total amount of building asset (not including land) and the value of home contents at market value. If the house is a condominium, the value of properietary area of the building is covered by the insurance.

Amount of your housing asset for which you can purchase the earthquake insurance	* (4161) 10 thousand yen

Now you are presumed to be able to purchase the earthquake insurance which covers up to 50% of 'amount of your housing asset (amount of *)' according to the damage level in case your house and/or home contents are damaged by an earthquake.
Your case is as follows:

Insurance cost you have to pay every year: (2.08) 10 thousand yen
Maximum insurance you receive when you suffer a damage:
(2081) 10 thousand yen

Based on the above-mentioned presumption, please answer the following questions.

Here the earthquake risk information of each respondent is provided

Question 8. Would you like to purchase this insurance which covers maximum (2081) 10 thousand yen of your asset for (2.08) 10 thousand yen per year?
You are presumed to live in the same house in the future as you live in now and also presumed not to carry an earthquake insurance policy now.

○ Yes
○ No

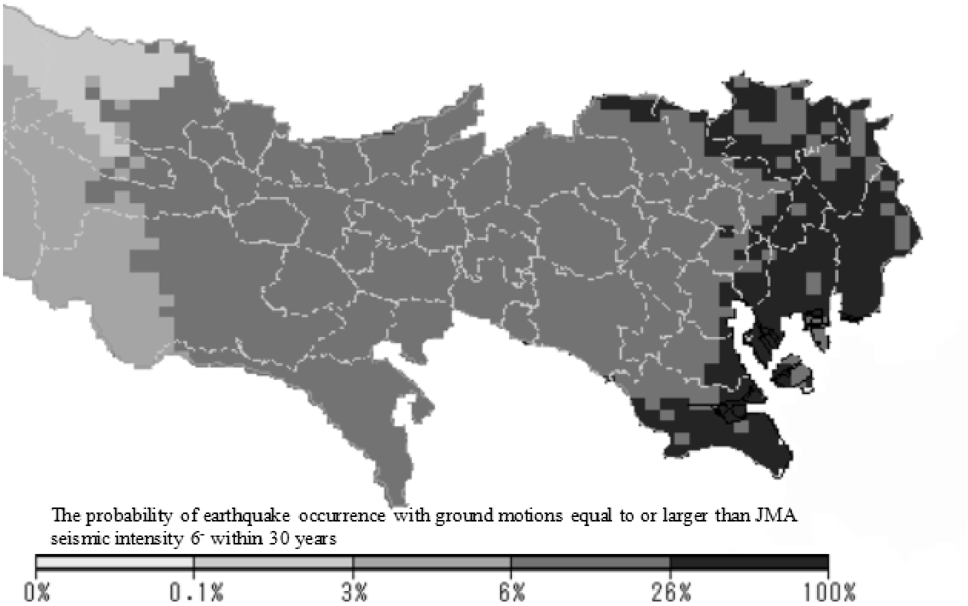
Question 9.(10.) Then would you like to purchase this insurance for twice(half) as much as the cost of Question 8. ?

○ Yes
○ No

Figure 5. A part of the survey sheet (The earthquake disaster risk information (1))

(1) Probabilistic Seismic Hazard Map (PSHM) (The Headquarters for Earthquake Research Promotion, Government of Japan, April 2008)

This PSHM shows the probability of earthquake occurrence with ground motions equal to or larger than the Japanese Meteorological Agency(JMA) seismic intensity 6- in the Tokyo metropolitan area within 30 years. All of the probable earthquakes which may hit the area are taken into account to calculate the probability. (For reference: 30-years is roughly equal to the pay-back period of commonly-used housing loan or the life-span of buildings)



According to the PSHM, the district '(**1 chome**) (**Kami-Kitazawa**) (**Setagaya-ku**) Tokyo' where you live will suffer the earthquake with the following probability.

The probability of earthquake occurrence with ground mothions equal to or larger than JMA seismic intensity 6- within 30 years	(**11.1**)%

Note: The probability was read from the PSHM using the typical latitude and longitude of the district

If this earthquake hits the district where you live, your house, a (**condominium of non-wooden structure**) built in (**2006**), will suffer a following damage according to the scientific investigation data by Murao and Yamazaki(2000).

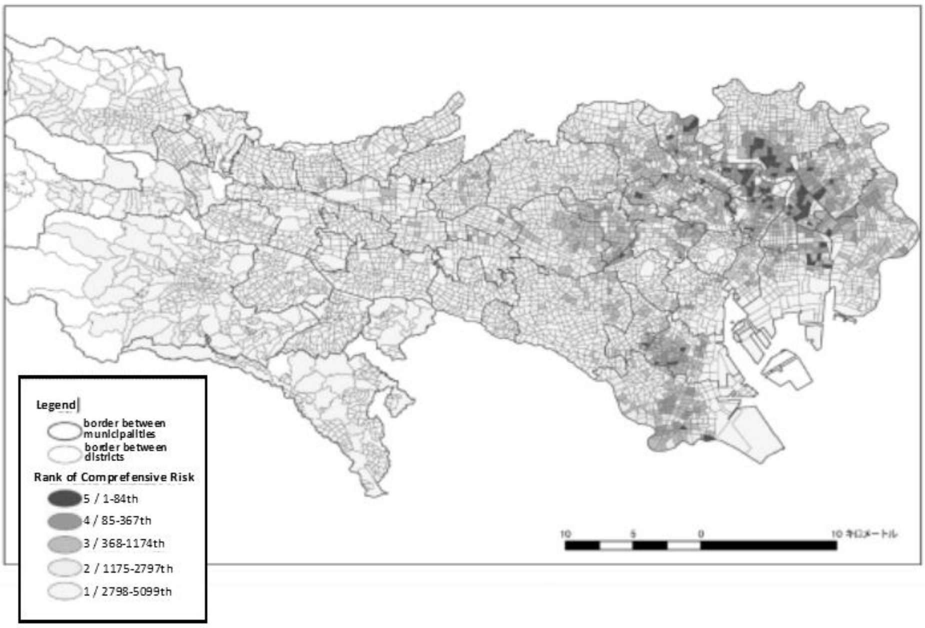
Probability of total collapse	about (**3**)%
Probability of half collapse or more severe damage	about (**15**)%

Notes: The probability was calculated based on data on building damage by the Great Hanshin-Awaji Earthquake (1995) in Kobe. The ground motion level was assumed to be JMA seismic intensity 6+. Aging degradation of the building after 1995 was not considered.

Figure 6. A part of the survey sheet (The earthquake disaster risk information (2))

(2) The Survey on Regional Earthquake Risk: The Comprehensive Hazard Map (The Bureau of Urban Development, Tokyo Metropolitan Government, February 2008)

This map shows the comparative vulnerability of districts with 5-rank index (from rank 1 (safest) to rank 5 (most vulnerable)) based on the expected amount of damaged buildings and the possible fire breakout and spreading in case of earthquake in the Tokyo Metropolitan Area.



According to the Comprehensive Hazard Map, the district '(**1 chome**) (**Kami-Kitazawa**) (**Setagaya-ku**) Tokyo' where you live has the following risk.

Comprefensive risk (combination of building damage risk and fire risk)	Rank (2)
(2542)th-most vulnerable among all of the 5099 districts in the Tokyo Metropolitan Area	

(Note: 5-rank index from rank 1 (safest) to rank 5 (most vulnerable))

Figure 7. Flow chart of the purchase of earthquake insurance

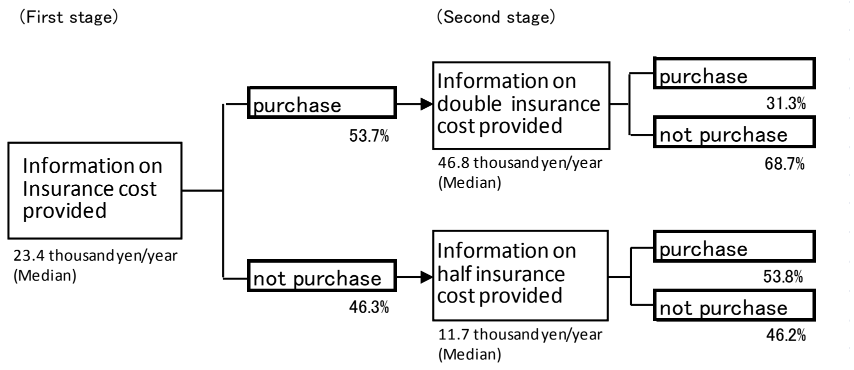


Figure 8. Relation between WTP and risk premium

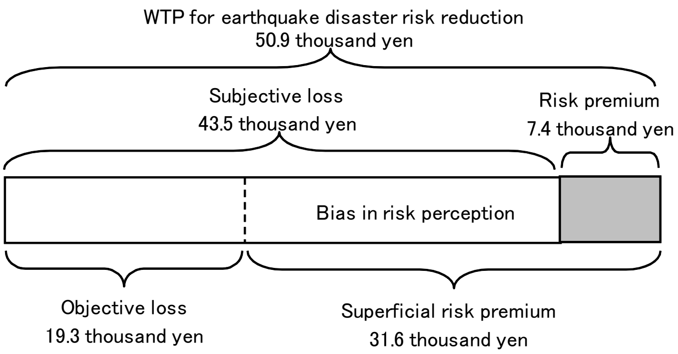


Figure 9. Changes of WTP for earthquake insurance according to the risk information level