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An Empirical Analysis of Individual Heterogeneity Effect on Ambiguity Aversion

Toshio FUJIMI* and Hirokazu TATANO

*Graduate School of Science and Technology, Kumamoto University

Synopsis

This paper empirically investigates the influence of the ambiguity on the decision to buy hypothetical earthquake insurance and the relationship with individual characteristics based on MEU model using questionnaire data. For that purpose, we develop the econometric model consistent with theoretical model derived from axioms. The main results of this paper are summarized as follows. First, respondent's preferences to the insurance with 1, 5, and 10% appraisal risk are generally inconsistent with expected utility theory. Second, respondents demanded more than 20% reduction in premium to offset each appraisal risk. Third, the ambiguity premium is larger in men who purchase earthquake insurance, have never received insurance payment, and distrust insurance companies than each correspondents, and increases with age, education level.

Keywords: ambiguity, earthquake insurance, appraisal risk, maximin expected utility

1. Introduction

Decisions in the real world are often made under uncertainty. Two types of uncertainties exist. One is essentially random and called "risk". The second type of uncertainty arises from imprecise, unreliable, or incomplete information and/or other factors that prohibit the precise quantification of risk. Referred to as ambiguity, this uncertainty leads to the nondeterministic nature of subjective risks. Camerer and Weber (1992) present a good thought experiment to understand how ambiguity influences decision. Suppose that you have to bet on one of two coins. You win if it turns head. Coin A was tossed 1000 times and turned head 500 times. Coin B was tossed twice and turned head once. You may choose coin A even though you believe both coins are fair. This is because the knowledge of coin A is more ambiguous and a kind of risk. This tendency is called "ambiguity aversion"

Ambiguity aversion is originally pointed out by Ellsberg (1986) and its robustness is confirmed through a great number of empirical analyses. Furthermore, it is getting known that ambiguity disturbs rational decisions in the various fields in a real-world setting such as medical, insurance, management, or finance. Therefore, polices of reducing or vanishing the ambiguity are required. For that purpose, it is important to know that how personal characteristics affect the ambiguity effect. Econometric approach is useful to get such kind of implication. In this approach, decision model of representative household in the relevant population is estimated. While studies focusing on the homogeneous group such as students or professionals in the theoretical and experimental literature, there are few empirical studies focusing on the effect of ambiguity on decision making outside the laboratory. The aim of this paper is to show how personal characteristics affect the decision under ambiguity.

Economists have only recently begun to develop econometric model to investigate whether and how ambiguity effect varies with observed characteristics of the respondents, such as age and income. Cameron (2005) extends the empirical risk literature and allow for ambiguity about mean, future global temperatures using a single variable mean-variance approach. She applies the model to a convenience sample of college students and shows that ambiguity affects the willingness to pay (WTP) for climate-change mitigation programs. Riddel et al. (2006) use a survey-based study of nuclear waste disposal to examine housing-location decisions when mortality and morbidity risks are uncertain. Both studies show that the size of perceived ambiguity affects WTP.

However, these econometric models are not based on generalized expected utility model derived from axioms and are somewhat ad hoc as Riddle et al. (2006) admits. Therefore, it is unclear theoretical interpretation of variance of future global temperature or mortality risk defined as ambiguity in these models. This drawback makes it impossible to link obtained results from these models with previous theoretical literature.

One of the largest contributions of this paper is to develop the econometric model consistent with theoretical model in order to investigate whether and how personal characteristics influence the ambiguity effects on decisions. Our econometric model is based on Maximin Expected Utility (MEU) model developed by Gilboa and Schmeidler (1989). Consistency with theoretical model clarifies implications of estimated parameters. In our model, the parameter representing the size of ambiguity and ambiguity attitude is specified from the theoretical point of view.

Cameron (2005) and Riddel et al. (2006) have not analyzed how personal characteristics influence the size of perceived ambiguity or ambiguity attitude while they have shown that the size of perceived ambiguity affects WTP for mitigation policy. Our model can examine it by regressing the ambiguity parameter on personal characteristics.

The paper is structured as follows. We start with a brief description of previous studies of ambiguity and generalize expected utility models that can deal with ambiguity in Section 2. Section 3 explains the household survey data on hypothetical earthquake insurance with appraisal risk. Section 4 develop econometric model consistent with MEU model and Section 5 presents the estimated results. Section 6 derives the implications from the results. Section 7 concludes.

2. Ambiguity and General Expected Utility Model

2.1 Ambiguity

Ambiguity is originally pointed out by Ellsberg (1961) as a counterexample of Subjective Expected Utility (SEU) developed by Savage (1954). SEU is capable of quite wide application. If one's preference satisfies the several plausible axioms, he can construct a unique subjective probability distribution under Knightian uncertainty and follow expected utility theory by using it. Thus Savage (1954) argued that the distinction between risk and uncertainty is not essential. However, Ellsberg has shown that SEU can not explain observed decisions under some sort of uncertainty by presenting the following thought experiment. Suppose that you have to choose from an urn that contains 30 red balls and 60 balls in some combination of black and yellow. There are four lotteries: X, Y, X' and Y'. X is the lottery that you can earn $100 if a red ball is drawn otherwise $0. Y is the lottery that you can earn $100 if a black ball is drawn otherwise $0. X' is the lottery that you can earn $100 if a red or yellow ball is drawn otherwise $0. Y' is the lottery that you can earn $100 if a black or yellow ball is drawn otherwise $0. You have to choose between X and Y and also choose between X' and Y'. You may choose X and Y' respectively. Simple calculation shows that SEU can not describe these decisions by using any subjective probability distributions. Tendency in these decisions is called "ambiguity aversion" because objective probability distributions in both X and Y' are know while those are unknown in X' and Y. A great number of subsequent studies empirically examined the existence and extent of ambiguity aversion is the similar settings. Robustness of existence of ambiguity aversion is generally recognized (Becker and Brownson, 1964; Slovic and Tversky, 1974; MacCrimmon and Larson, 1979; Einhorn and Hogarth, 1986; Kahn and Sarin, 1988; Curely and Yates, 1989 etc).

Not all researchers have used the same definition of ambiguity. Ellsberg (1961, p.657) defined that ambiguity is “the quality depending on the amount, type, reliability and ‘unanimity’ of information.” Einhorn and Hogarth (1986) and Hogarth and Kunreuther (1995) defined ambiguity as intermediate state between complete lack of knowledge and risk in which a probability distribution is specified. Fellner (1961), Frisch and Baron (1988) and Camerer (1995) defined that ambiguity is uncertainty about probability, created by missing information that is relevant and could be known. In any definitions, the key concept is that ambiguity is the situation where a subjective probability distribution can not be uniquely determined due to the lack of information.

2.2 Formulating ambiguity

There are mainly three approaches to formulate the ambiguity. First is to express ambiguity as the second order probability distribution. The second order probability distribution means the probability distribution of probability distribution. One example is the normal probability distribution with mean and variance that are random variables. Segal (1987) and Klibanoff, Marinacci and Mukerji (2005) deal with the ambiguity in this framework. Second is to formulate ambiguity as multiple subjective probability distributions that decision maker perceives. This approach permits it by relaxing "independence axiom" while SEU requires a unique subjective probability distribution. In this frame works, Gilboa and Schmeidler (1989) developed Maxmin Expected Utility model (MEU) and Ghirardato et al. (2004) constructed alpha- Maxmin Expected Utility (alpha-MEU). Third is to express ambiguity by using "Capacity" instead of probability. Capacity is probability measure that relaxing additivity. For an ambiguity averse decision maker, ambiguity is described as convexity of capacity. In Ellsberg's example, it means

$$p(black \cup yellow) \geq p(black) + p(yellow) \quad .$$

The probability of drawing a black or yellow ball is clear because we know the sum of black and yellow balls. The event of drawing a black ball and the event of drawing a yellow ball are ambiguous because we do not know the number of black balls and yellow balls separately. Therefore, the convexity of capacity represents that the ambiguity averse decision maker put more weight on the former than the latter, which avoid Ellsberg's paradox. In this framework, Schmeidler (1989) developed Choquet Expected Utility (CEU) model. In this paper, MEU is applied.

2.3 Maxmin expected utility model

Maxmin expected utility model is constructed in the framework of Anscombe and Aumann (1963). Let S be a set of states and let Σ be an algebra of S and let X be a set of outcomes. Denote an act by $f : S \rightarrow X$ and denote by F the set of acts. Both SEU and MEU satisfies the following five axioms.

[A.1] (1) For all $f, g \in F$, $f \geq g$ or $g \geq f$.
(2) For all $f, g, h \in F$, if $f \geq g$ or $g \geq$ h then $f \geq$ h.

[A2] $f, g \in F$, $x \in X$, $\lambda \in$ (0,1], $f \geq g \Leftrightarrow \lambda f$+(1-$\lambda$)$x \geq \lambda g$+(1-$\lambda$)$x$.

[A3] For all $f, g, h \in F$, if $f > g$, g>h then $\lambda, \mu \in$ (0,1] exist such that λf+(1-λ)$h > g$ and $g > \mu f$+(1-μ)h.

[A4] If $f(s) \geq g(s)$ for all $f, g \in F$ and $s \in S$, then $f \geq g$.

[A5] There exist $f, g \in F$ such that $f > g$.

In addition, SEU holds if the following axiom [A6] is satisfied and MEU holds if [A7] is satisfied.

[A6] For all $f, g \in F$ such that $f \sim g$ and all $\lambda \in$ (0,1], λf+(1-λ)$g \sim g$.

[A7] For all $f, g \in F$ such that $f \sim g$ and all $\lambda \in$ (0,1], λf+(1-λ)$g \geq g$.

[SEU] $f \geq g \Leftrightarrow$

$$\int_S u(f(s))dP(s) \geq \int_S u(g(s))dP(s)$$

[MEU] $f \geq g \Leftrightarrow$

$$\min_{P \in C} \int_S u(f(s))dP(s) \geq \min_{P \in C} \int_S u(g(s))dP(s)$$

where $P : \Sigma \rightarrow [0,1]$ is a subjective probability distribution and C is the closed convex set of probability distributions.

3. Ambiguity of appraisal risk in earthquake insurance.

In this paper, we focus on the ambiguity of appraisal risk in earthquake insurance in order to examine whether and how personal characteristics affect the perception of ambiguity. The penetration rate of earthquake insurance is low in Japan (only 18% households buy the earthquake insurance in 2005). One of main reason is that many households feel insurance cost expensive. It becomes a matter why insurers set high premiums and households feel it expensive.

Insurers set high premium because earthquake risk has the property of low-frequency and high impact. They have to pay reinsurance fee or high interest of CAT bond since they cannot cover an enormous loss from earthquake by themselves. Lack of information due to low frequency of earthquake cause ambiguity in earthquake risk and prevents insurers from getting precious estimation of occurrence probability and damage size. Kunreuther et al. (1993, 1995) show that insurance premium for ambiguous risk is higher than for unambiguous one by the survey of actuaries, insurers and reinsurers.

It is generally thought that households feel earthquake insurance expensive because of their underestimation of earthquake risk. However, many questionnaire surveys suggest that it is not true. In our survey described fully in section 4, 75% respondents think that earthquake of seven-point Japanese intensity scale (intensity of the Great Hanshin Earthquake) occurs with more than 10% probability in 25 years. Insurance cost in the survey area is actuarially fair in the case that the probability of over half collapse of their house is more than 12% in 25 years. However, only 30% of households purchase the earthquake insurance. Mazda, Tatano and Okada (2005) shows only 18% respondents buy the earthquake insurance even though 64% of them consider that over half collapse occurs in 25 years due to earthquake. Non-Life Insurance Rating Organization of Japan (2003) shows that 61% of respondents who have no intention to buy earthquake insurance believe great earthquake causing a severe damage in your house or town will occur in 20 years. In short, many households do not buy earthquake insurance even though perceive earthquake risk high enough that insurance premium is actuarially cheap.

These results imply that important reasons exists other than insurance cost or perceived earthquake risk. This paper focuses on the ambiguity of appraisal risk in earthquake insurance. The amount of insurance payment is supposed to be determined after damage occurs by earthquake. However, in fact, a household faces uncertainty of insurance appraisal because it does not have enough knowledge for understanding appraisal criteria written in the contract and has to entrust insurer with it's appraisal of damage. Thus, the household faces the risk that it gets less amount of insurance payment than it expected at the time of contract because the insurance appraisal is unexpectedly strict. In this paper, we call this "appraisal risk."

Ambiguity of appraisal risk may become more important in earthquake insurance than other insurances such as car or accident insurance. Earthquake insurance payment is extremely low frequent in comparison with other insurances such as mobile, fire or accident insurance. For the car or accident insurance, we have a lot of chances to know insurance payment cases in various accidents. On the other hand, earthquake insurance payment is quite rare so that we can not have enough information to even roughly grasps the amount of it. As a result, many households overestimate appraisal risk due to ambiguity and hesitate to buy earthquake insurance.

4. Survey data

Questionnaires were sent out by mail to 3,000 households in Joyo city, Kyoto in the middle of January, 2006. Samples are randomly selected from the NTT telephone book. 681 responses have been collected (the response rate is 23.4%). The questionnaires are structured as follows. First, the hypothetic situation is presented. Then the willingness to pay for full covered insurance and for probabilistic insurance are asked.

(H) Imagine that you have a house worth 10 million yen and the other asset (e.g. cash, stocks, or land) worth 20 million yen. Assume that earthquake with a seismic intensity 7 on the Japanese scale will occur with probability of 5% in 25 years (or, 0.205% per year). If such earthquake happens, your house will be half destroyed (¥5 million loss) with 50% probability and completely destroyed (¥10 million loss) with 50% probability.

Table1 Comparison between sample and population means

	sample mean	population mean
Age of head of household	63	55^{*1}
Income (thousand yen)	6,040	$6{,}620^{*1}$
Number of household members	2.99	2.81^{*2}
Ratio of house owner	0.97	0.81^{*2}
Penetration ratio of earthquake insurance	0.17	0.15^{*3}

Table2 Variables of personal characteristics

Variables	Description	Mean
Age	Age (in yeas)	62.0
Female	Dummy; 1 if respondent is female	0.088
Married	Dummy; 1 if respondent is married	0.945
Childe	Dummy; 1 if respondent has a childe (under 10 years old)	0.077
Education	Dummy; 1 if respondent graduated an university or graduate school	0.379
Unemployment	Dummy; 1 if respondent is unemployed	0.279
Self-employment	Dummy; 1 if respondent is self-employed	0.103
Civil servant	Dummy; 1 if respondent is a civil servant	0.073
Experience	Dummy; 1 if respondent has experienced a economic loss from earthquake	0.074
Purchase	Dummy; 1 if respondent has purchased an earthquake insurance	0.311
NeverPaid	Dummy; 1 if respondent has never received any insurance payment	0.337
Trust	Dummy; 1 if respondent trusts insurance companies	0.454

(A). What is the most you would be willing to pay for an insurance policy that will cover all damages due to earthquake?

(B) Imagine that you have been offered a different policy that is identical to the previous one expect that there is **about** α % appraisal risk. That is, there is a possibility with about α % that your claim will not be paid in case of half collapse and only half of your claim will be paid in case of complete collapse. This risk is caused by the adjuster's too strict appraisal of the damage. What is most you would be willing to pay for probabilistic earthquake insurance?

In this paper, the insurance described in question (A) is called "full-cover insurance" and the insurance described in question (B) is called "probabilistic insurance." In the probabilistic insurance, α % is presented to the respondents as a kind of mean probability of the ambiguous appraisal risk. This is called "reference risk." The word of "about" is written with larger and bold font in the actual questionnaire in order to emphasize the ambiguity of appraisal risk. It is up to the respondents how large they perceive the range of appraisal risk. Einhorn and Hogarth (1985, 1986) originally expressed ambiguity in this way. Mauro and Maffioletti (1996, 2004) examine whether responses differ or not in the different ways of expressing ambiguity: the way mentioned above, the range (e.g. $\alpha \sim \beta$ %) and the several probabilities (e.g. α %, β %, γ %). They obtain the result that no statistical differences appear among them.

Necessarily, this survey is hypothetical. It is impossible to have real incentives paid to the respondents. One could devise similar experiments for real money. In earthquake insurance setting, however, the probability and loss of the relevant event have to be considerably lower and larger than the lottery choice in experiment respectively. Therefore, the stake would have to be affordably low, which makes the experiment completely different from the earthquake insurance setting we want to consider. Hence, we believe that in this domain, thought experiments for large sums can be more instructive than real experiments for pennies. Fortunately, there is evidence indicating that there is no difference in response for respondents with and without real payments. Beattie and Loomes (1997) designed an experiment to investigate the relevance of real incentives in decision problems and concluded that "in simple pairwise choices, incentives appear to make very little difference to performance." Further evidence is presented by, among others, Grether and Plott (1979), and Conlisk (1989), and is surveyed in Camerer (1995). Binswanger (1981) reports absence of significant difference in his analytical results between individuals participating in an experiment with real money or only playing a hypothetical game. Similarly, Camerer and Hogarth (1999) compare 74 experiments and conclude that financial versus hypothetical incentives in experiment occasionally improve performance although often do not.

5. Model

To examine the influence of ambiguity of insurance payment, we analyze the data based on both the Expected Utility (EU) model and Maxmin Expected Utility (MEU) model. EU is most widely used to model decision making under uncertainty. However it can not represent observed individual choice under ambiguity. MEU is the generalized expected utility model to deal with the ambiguity developed by Gilboa and Schmeidler (1989). we explain EU first, then describe MEU.

5. 1 Expected Utility Model

In the full covered insurance setting above, a decision maker has the prospect

$$\Pi = (1-\pi_1-\pi_2, W+Y;\ \pi_1, W+Y/2;\ \pi_2, W)$$

where Y is the value of the house (10 million yen) and W is the value of the other assets (20 million yen). π_1 is the probability of half collapse (0.1025% per year) and π_2 is the probability of half collapse (0.1025% per year).

Under EU, willingness to pay for the full covered insurance wtp_f is determined by the equation below.

$$V(wtp_f) \equiv u(W+Y-wtp_f) = \tilde{u} \quad (1)$$

where $u(\cdot)$ is a utility function and $\tilde{u}$ is expected utility without any insurance.

$$\tilde{u} \equiv (1-\pi_1-\pi_2)u(W+Y) + \pi_1 u(W+Y/2) + \pi_2 u(W)$$

Now we move on to the probabilistic insurance setting. If household dose not perceive ambiguity in the appraisal risk, it face the prospect with reference probability of α. This is written as

$$Q = (q_0, W+Y; q_1, W+Y/2; q_2, W),$$

where $q_0 = 1-\alpha(\pi_1+\pi_2)$, $q_1 = \alpha(\pi_1+\pi_2)$, $q_2 = 0$ and α is the reference probability of appraisal risk. Under EU, the willingness to pay for the probabilistic insurance wtp_p is determined by the equation below.

$$\begin{aligned} &V(wtp_p) \\ &\equiv q_0 u(W+Y-wtp_p) + q_1 u(W+Y/2-wtp_p) \\ &+ q_2 u(W-wtp_p) \\ &= \tilde{u} \end{aligned} \quad (2)$$

5. 2 Maximum Expected Utility Model

Now, ambiguity of appraisal risk is considered by using MEU. In this model, ambiguity perceived by the decision maker is expressed as C : the set of subjective probability distributions that he has. Let denote a subjective probability by

$$P = (p_0, W+Y; p_1, W+Y/2; p_2, W).$$

That is, C represents the ambiguity that the decision maker may perceive in the decision problem. Under ambiguity, the willingness to pay for the probabilistic insurance wtp_p is determined by the equation below.

$$\begin{aligned} V_{MEU}(wtp_p) &= \min_{P\in C}\begin{bmatrix} p_0 u(W+Y-wtp_p) \\ + p_1 u(W+Y/2-wtp_p) \\ + p_2 u(W-wtp_p) \end{bmatrix} \\ &= \tilde{u} \end{aligned} \quad (4)$$

As for the full covered insurance, MEU is reduced to EU since no ambiguity exists.

To estimate the model, the form of C is necessary to be specified. We apply robust control theory of Hansen and Sargent (2001). The right side of equation (4) can be seen as "a constraint robust control problem" if C is specified as below.

$$C = \{P : R(P,Q) \le \eta\}$$

where $R(P,Q)$ is relative entropy between P and Q. η is a parameter that represents the size of ambiguity.

$$R(P,Q) = \sum_{K-1}^{3} \ln \frac{p_k}{q_k}$$

Hansen and Sargent (2001) shows that the constraint robust control problem has a same solution with "a multiplier robust control problem" as below.

$$\min_{P\in C}\begin{bmatrix} p_0 u(W+Y-wtp_p) + p_1 u(W+Y/2-wtp_p) \\ + p_2 u(W-wtp_p) + \theta R(P,Q) \end{bmatrix} \quad (5)$$

The parameter θ in the last problem (5) can be interpreted as an implied Lagrange multiplier on the constraint $R(P,Q) \le \eta$. Since $R(P,Q)$ is convex in p_0, p_2 and p_2, the first order condition gives the solution of (6).

$$P^* = (p_0^*, W+Y;\ p_1^*, W+Y/2;\ p_2^*, W)$$

where

$$p_0^* = \frac{q_0}{q_0 + q_1 e^{(u(W+Y-wtp_p)-u(W+Y/2-wtp_p))/\theta} + q_2 e^{(u(W+Y-wtp_p)-u(W-wtp_p))/\theta}}$$

$$p_1^* = \frac{q_1 e^{(u(W+Y-wtp_p)-u(W+Y/2-wtp_p))/\theta}}{q_0 + q_1 e^{(u(W+Y-wtp_p)-u(W+Y/2-wtp_p))/\theta} + q_2 e^{(u(W+Y-wtp_p)-u(W-wtp_p))/\theta}}$$

$$p_2^* = \frac{q_2 e^{(u(W+Y-wtp_p)-u(W-wtp_p))/\theta}}{q_0 + q_1 e^{(u(W+Y-wtp_p)-u(W+Y/2-wtp_p))/\theta} + q_2 e^{(u(W+Y-wtp_p)-u(W-wtp_p))/\theta}}$$

Thus, the probabilistic insurance purchase decision can be modeled by MEU where wtp_p is determined by the equation below.

$$
\begin{aligned}
&V_{MEU}(wtp_p) \\
&= p_0^* u(W + Y - wtp_p) + p_1^* u(W + Y/2 - wtp_p) \\
&+ p_2^* u(W - wtp_p) \\
&= \tilde{v}
\end{aligned} \tag{6}
$$

5. 3 Estimation method

Random utility model is applied to estimate the model. The value function consists of random part and non-random part. Respondent i choose B_j if

$$V_i(B_{j+1}) < V_i(wtp_i) + \varepsilon \le V_i(B_j),$$

where Bs are bids $(B_1 < \cdots < B_j < B_{j+1} < \cdots < B_J)$ shown to the respondent as insurance fee. Assume that ε follows normal distribution with mean 0 and variance σ^2. The log likelihood can be written as

$$\ln L = \sum_{i=1}^{N}\left[\ln\Phi\left(\frac{V_i(B_{j+1}) - \tilde{v}_i}{\sigma}\right) - \ln\Phi\left(\frac{V_i(B_j) - \tilde{v}_i}{\sigma}\right)\right].$$

where $\Phi(\cdot)$ is the normal distribution function. This log likelihood is maximized to estimate parameters.

5. 4 Specification of utility function

The constant relative risk attitude (CRRA) utility function is used here. The effect of risk aversion on the decision to purchase the earthquake insurance is represented by the Pratt-Arrow coefficient of relative risk aversion γ.

We assume that the relative risk aversion is constant in wealth, which derives the specific utility form,

$$u(x) = \frac{x^{1-\gamma}}{1-\gamma}.$$

The relative risk aversion may vary across demographic groups. Thus we connect it with respondent's social characteristics in linear

$$\gamma = \gamma_0 + \mathbf{x}'\boldsymbol{\beta}$$

where γ_0 is a intercept, $\mathbf{x}$ is a vector of respondent's characteristics variables, and $\boldsymbol{\beta}$ is a parameter vector.

The ambiguity size may vary across demographic groups. Hence we connect it with respondent's characteristics in linear,

$$\theta = \theta_{0.01} + \theta_{0.05} + \theta_{0.10} + \mathbf{x}'\boldsymbol{\beta}$$

where $\theta_{0.01}$, $\theta_{0.05}$ and $\theta_{0.05}$ are dummy variables (=1 if the reference probability of appraisal risk is 1%, 5%, and 10% respectively), $\mathbf{x}$ is a vector of respondent's characteristics variables, and $\boldsymbol{\beta}$ is a parameter vector.

6. Result

6. 1 Estimation results of simple models

First of all, we examine the estimation results of the model that has only constant term. This model is called "simple model" and ignores the effects of personal characteristics. These results are presented in Table 3. The estimated CRRA coefficients are 2.027 in the full-cover insurance, -2.483 in the probabilistic insurance, and 1.389 in the chance lottery with 1% statistical significance. Ljungqvist and Sargent (2000) and Gollier (2001) said by the thought experiment that the coefficient of relative risk aversion lies within the range from 1 to 4. The empirical literature supports this. Friend and Blume (1975) studied the demand for risky assets and conducted that γ generally exceeds unity and is probably greater than 2. Using expenditure data, Weber (1975) estimated γ to lie within a range from 1.3 to 1.8, and Szpiro (1986) obtained a similar range using aggregate time-series data on property insurance. In a careful study of consumption, Hansen and Singleton (1982) found relative risk aversion parameters ranging from 0.68 to 0.97. In a subsequent study of investments, Hansen and Singleton (1983) found nu-

Table3 Estimation results of simple models

	EU						MEU	
	Full cover insurance		Probabilistic insurance		Chance lottery		Probabilistic insurance	
	Coeff	p-value	Coeff	p-value	Coeff	p 値	Coeff	p-value
γ	2.027	0.00	-2.483	0.00	1.386	0.00	1.437	0.00
σ	2.089E+7	0.20	8.756E-3	0.32	2.711E+8	0.55	1.357E+8	0.00
$\theta_{0.01}$							1.247E+8	0.01
$\theta_{0.05}$							3.719E+8	0.07
$\theta_{0.10}$							3.041E+8	0.00
n	557		351		323		351	
Log-likelihood	-1687		-1110		-992		-1093	
AIC	6.064		6.336		6.157		6.256	

※ 1:AIC$=-2\ln L/n + 2k/n$, where $\ln L$ is log-likelihood, n is sample size, and k is the number of parameters

Table4 Estimation results of parametric models

	EU						MEU	
	Full cover insurance		Probabilistic insurance		Chance lottery		Probabilistic insurance	
	Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value
Estimation of γ								
Constant	1.444	0.00	-1.229	0.00	1.182	0.00	1.844	0.00
Age	0.004	0.00	0.010	0.00	-0.001	0.01		
Female	0.123	0.00	0.095	0.03	0.128	0.02	0.159	0.00
Education	-0.079	0.00	-0.120	0.00	-0.033	0.03	-0.178	0.00
Experience	0.006	0.63	-0.098	0.06	-0.068	0.06	-0.072	0.07
Marriage	0.021	0.16	-0.080	0.21	0.247	0.00	0.023	0.11
Unemployment	-0.114	0.00	-0.112	0.00	0.047	0.00	-0.032	0.17
Self-employment	0.018	0.38	0.013	0.59	-0.025	0.15	0.015	0.54
Civil servant	0.078	0.04	-0.111	0.04	0.131	0.05		
Child	0.061	0.12	0.071	0.19	-0.119	0.06	0.036	0.29
Estimation of θ								
$\theta_{0.01}$							0.840+E5	0.41
$\theta_{0.05}$							2.083+E5	0.00
$\theta_{0.10}$							4.719+E5	0.11
Age							0.024+E5	0.08
Female							-1.006+E5	0.00
Education							1.107+E5	0.10
Experience							0.576+E5	0.00
Purchase							1.926+E5	0.06
NeverPaid							0.051+E5	0.16
Trust							0.693+E5	0.19
Estimation of σ								
σ	4.138E+7	0.19	0.1322	0.45	2.211E+8	0.16	2.538+E7	0.11
$\hat{\gamma}$	1.801		-0.636		1.422		1.934	
n	557		308		289		306	
Log-likelihood	-1479		-908		-867		-886	
AIC	5.350		5.966		6.080		5.915	

merical estimates of γ, most of which ranged from 0.26 to 2.7, with outliers as low as -0.359 and as high as 58.25. Mankiw's γ study of consumption spending obtained relative risk aversion estimates ranging from 2.44 to 5.26 for nondurable consumption and from 1.79 to 3.21 for durable goods consumption.

The estimate in the full-cover insurance is a reasonable value. However, the one in the probabilistic insurance is unreasonable because it implies risk loving. This suggests that purchase decision of full cover insurance can be explained in EU but that of probabilistic insurance can not be explained in EU. The ambiguity of appraisal risk should be considered in the probabilistic insurance.

By applying the MEU in consideration of the ambiguity of appraisal risk, the estimated CRRA coefficient becomes a reasonable value, 1.486 for the probabilistic insurance. The CRRA coefficient γ, standard deviation of error term σ, and ambiguity parameters $\theta_{0.01}$, $\theta_{0.10}$ are all statistically significant with 5% level. $\theta_{0.05}$ is statistically significant with 10% level. These implies that risk and ambiguity parameter are both necessary to express purchase decision for the probabilistic insurance.

Then, we examine which is more consistent with data between EU and MEU for the probabilistic insurance. The smaller value of Akaike Information Criteria (AIC) indicates that the model is more consistent with the data. AIC of EU and MEU are 6.336 and 6.256 respectively, which shows that MEU is better for the probabilistic insurance. The log likelihood ratio test can be applied because MEU nests EU. Table 5 shows the result that MEU is better than EU with 1% statistical significance.

6. 2 Estimation results of models in consideration of personal characteristics

Now we consider the effects of personal characteristics. Table 4 shows the estimation results. Under EU estimates of γ for full covered insurance, probabilistic insurance, and chance lottery are 1.801, -0.636, and 1.422 respectively. This implies that EU is not suitable for probabilistic insurance in consideration of personal characteristics. The results of previous studies on the relationship between risk attitude and personal characteristics are summarized as follow. Female, older, married servant respondents are more risk averse and high educated, self-employed, and unemployed respondents are less risk averse than their correspondents. For full cover insurance, the obtained results are mostly consistent with them so that validity of our survey is indirectly supported. This holds for the chance lottery except that unemployment raises the risk aversion. For probabilistic insurance, inclusion of personal characteristics weakens the risk loving attitude. This may be attributed to the fact that they capture the effects of ambiguity aversion. That is why the sings of coefficients are quite different from previous studies.

Under MEU, the estimation results for probabilistic insurance are presented in the rightmost column in Table 4. Estimate of γ is 1.934 and close to that for full cover insurance and sings of coefficients are same with it other than Experience. Furthermore, AIC indicates that MEU explains their decisions for probabilistic insurance better than EU

Next, we will examine the relationship between ambiguity parameter and personal characteristics. Positive sign of coefficient shows that the correspondent variable reduces perceived ambiguity because the larger θ means the smaller perceived ambiguity. In 5% statistically significant level, the signs of Female and Experience are negative and positive respectively, which shows that female perceives larger ambiguity and the respondent who has experienced loss due to earthquake damage perceives less ambiguity. In 10% statistically significant level, the signs of Age, Education, Purchase are positive, which shows perceived ambiguity increases with age, higher education and purchase of the actual earthquake insurance. This is because that the higher educated respondent can understand information on insurance or earthquake. NeverPaid and Trust are not statistically significant in 10% level.

7. Implication

For the purpose of reduction of ambiguity, we should focus on the personal characteristics such as experience of earthquake loss or purchase of earthquake insurance, not on personal characteristics that can not be controlled such as age or gender. Purchase takes the largest positive value among other dummy variables, which shows that the purchase of earthquake insurance reduces the perceived ambiguity. of appraisal risk. This is natural because the respondent who purchase it get more knowledge on earthquake insurance than the correspondent. Experience of earthquake loss reduces the ambiguity of appraisal risk. The respondents who have experienced earthquake damage on their houses can image how appraisal of earthquake loss is carried out. These suggest that information on earthquake insurance or on how houses are damaged from earthquake can reduce the ambiguity of appraisal risk. Photographs or video movies of damaged house due to earthquake may be useful to reduce ambiguity of appraisal risk.

Table 5 shows the risk and ambiguity premium that are additional payments to buy earthquake insurance because of risk and ambiguity, respectively. Here, a willingness to pay consists of expected loss, risk premium, and ambiguity premium.

$$\begin{aligned}&\text{Wlllingness to pay}\\&= \text{Expected loss} + \text{Risk premium} + \text{Ambiguity premium}\end{aligned}$$

Risk premium is calculated by WTP without ambiguity ($\theta = +\infty$) minus expected loss. Ambiguity premium is calculated by WTP with ambiguity ($\theta = \hat{\theta}$) minus WTP without ambiguity ($\theta = +\infty$). Ambiguity premium of appraisal risk with reference probability 1%, 5%, and 10% are -2.198, -2.098 and -2.988 respectively and each reduces about 10% of the earthquake insurance value. Note that all responses WTP=0 are excluded because there is possibility that responses WTP=0 are caused by protesting insurance company and we should be on the conservative position. Therefore, the actual absolute values of ambiguity premium may be larger because some of them are caused from ambiguity.

Ambiguity premiums are not so different even though reference probability of appraisal risk varies: 1%, 5%, and 10%. This implies that reduction of appraisal risk is not effective as long as ambiguity of it is perceived. Appraisal risk itself is caused from difference between insurance company's appraisal and victim's expectation.

Reduction of this risk is very difficult because they are based on evaluation. On the other hand, ambiguity is caused from lack of information. Therefore, providing sufficient information can resolve the ambiguity. This seems better way.

8. Conclusion

In this paper we used data from the survey where a set of questions on hypothetical earthquake insurance is present. We empirically investigated the effect of ambiguity on the decision to buy hypothetical earthquake insurance and the relationship with individual characteristics. The main results of this paper may be summarized as follows.

First, we have observed that people dislike probabilistic insurance: Most respondents demanded more than 10% reduction in premium to offset a 1% appraisal risk. Ambiguity premiums are not so different even though reference probability of appraisal risk varies. Hence, reduction of ambiguity of appraisal risk is more effective than reduction of appraisal risk itself. Second, we have demonstrated that such preferences are generally inconsistent with expected utility theory. Third, we have shown that the reluctant to buy probabilistic insurance is better predicted by the Maximin Expected Utility model. Forth, the perceived ambiguity is smaller in men who purchase earthquake insurance, have experienced earthquake loss on their houses than each correspondents. And it decreases with age, education level.

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個人の異質性が曖昧性下の意思決定に及ぼす影響の定量分析

藤見俊夫*・多々納裕一

*熊本大学大学院自然科学研究科

要旨

本研究では、曖昧性下の意思決定において個人の異質性の及ぼす影響を定量分析するために、公理系から導かれる拡張期待効用理論であるマキシミン期待効用モデルに整合的な計量経済モデルを開発した。そのモデルに基づき、地震保険の被害査定リスクの曖昧性の影響を分析したところ、控えめに推計しても約2割程度の価値の減少が見られた。また、認知された曖昧性と個人の異質性の関係を分析したところ、世帯主が女性であるほうが男性より認知している曖昧性が大きいこと、また、年齢が高く、大学・大学院を卒業しており、実際の地震保険を購入しており、地震被害の経験のある世帯主ほうが、認知している曖昧性は小さいことが示された。

キーワード:曖昧性，地震保険，被害査定リスク，マキシミン期待効用