Ambiguity, Risk and Earthquake Insurance Premiums: An Empirical Analysis

Toshio FUJIMI

COE researcher,

Disaster Prevention Research Institute, Kyoto University

Background

- Low purchase rate of Earthquake insurance (18.5%)
  - Bias of risk perception
  - Adverse selection
  - Ambiguity of insurance appraisal
    - By missing information of insurance appraisal, people doubt that insurance claim is paid as they expect.

* Insurance appraisal

the insurance company's judgment on the extent of damage due to disaster

↓

Based on this, the amount of insurance payment is decided.

Ambiguity of insurance appraisal

- Difficulty of understanding the contents of insurance contract
- Rare occurrence of earthquake
  - People can not guess the insurance payment because they are not familiar with actual payment of earthquake insurance.

Ambiguity of insurance appraisal

Appraisal risk

People perceive the risk of reduced payment by insurance appraisal

Objective

Hypothesis

1. Ambiguity causes the appraisal risk.
2. Even if actual appraisal risk is very small, people perceive it large due to ambiguity.

↓

People do not purchase earthquake insurance.

Objective

How much may the appraisal risk reduce the value of earthquake insurance?

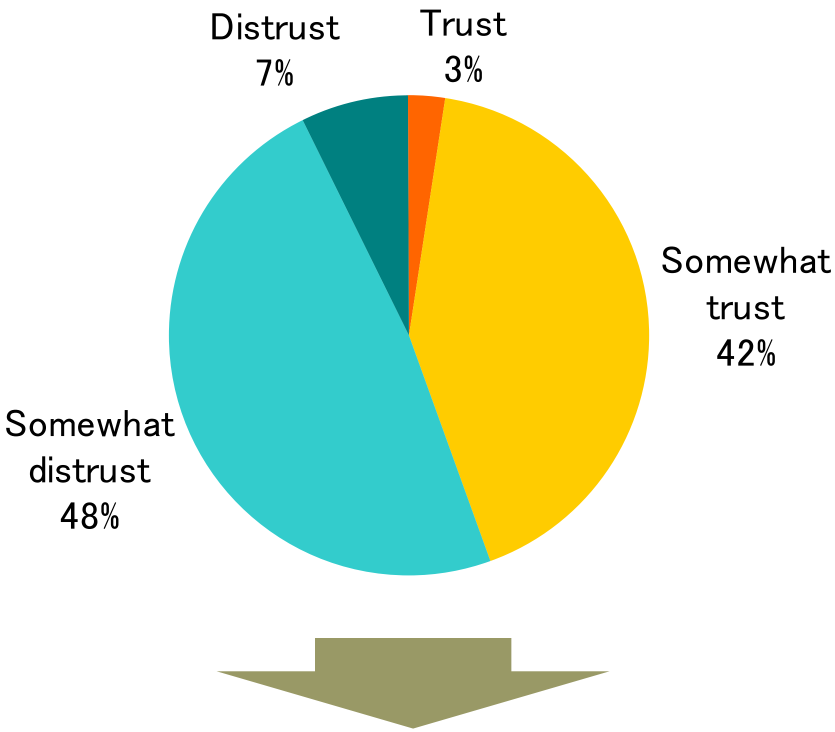
Outline of survey

- Questionnaire by mail
  - Period：2006/1/12~23
  - Subject: 3000 households in Jyoyo city, Kyoto
  - Response rate: 23.4%

- Questions
  - Personal characteristics
  - Knowledge of earthquake and insurance
  - Trust of insurance company's appraisal
  - Willingness to pay for hypothetical earthquake insurance

Trust in appraisal

- Do you trust an insurance company's appraisal of earthquake insurance?



More than half people may perceive the appraisal risk.

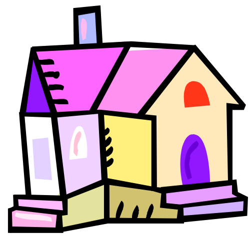
Hypothetical earthquake insurance

Hypothetical situation

Wealth

House

10 million yen



+

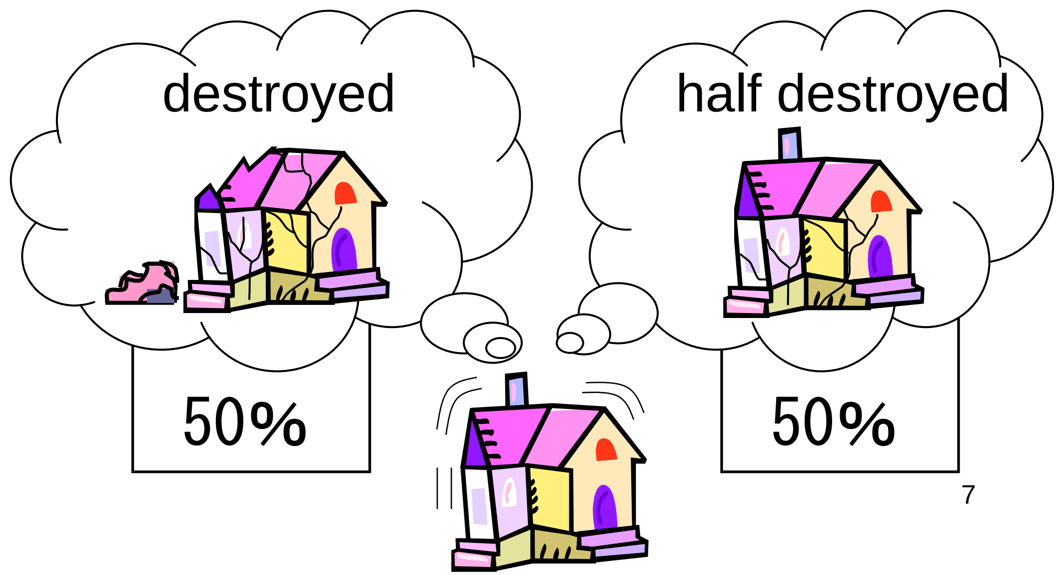
others

20 million yen

Earthquake risk

Seismic intensity 7

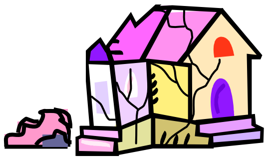
5% in 25 years



Full cover insurance: insurance without appraisal risk

destroyed

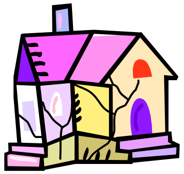
10 million yen loss



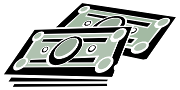
Insurance payment is 10 million yen.

half destroyed

5 million yen loss



Insurance payment is 5 million yen.



How much are you willingness to pay for this insurance?

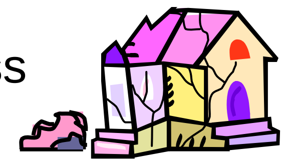
1. don't buy	2. 1,000 yen	3. 5,000 yen	4. 8,000 yen
5. 10,000 yen	6. 12,000 yen	7. 15,000 yen	8. 18,000 yen
9. 20,000 yen	10. 25,000 yen	11. 30,000 yen	12. 40,000 yen
13. 50,000 yen	14. 60,000 yen	15. 80,000 yen	16. 100,000 yen

Probabilistic Insurance: insurance with appraisal risk

About α % = mean α, unknown variance

Destroyed

10 million yen loss



Half destroyed

5 million yen loss

appraisal

Insurance payment is 5 million yen.

No payment

Otherwise Same as full cover insurance

How much are you willingness to pay for this insurance?

Expected value of full cover insurance = 15,375 yen

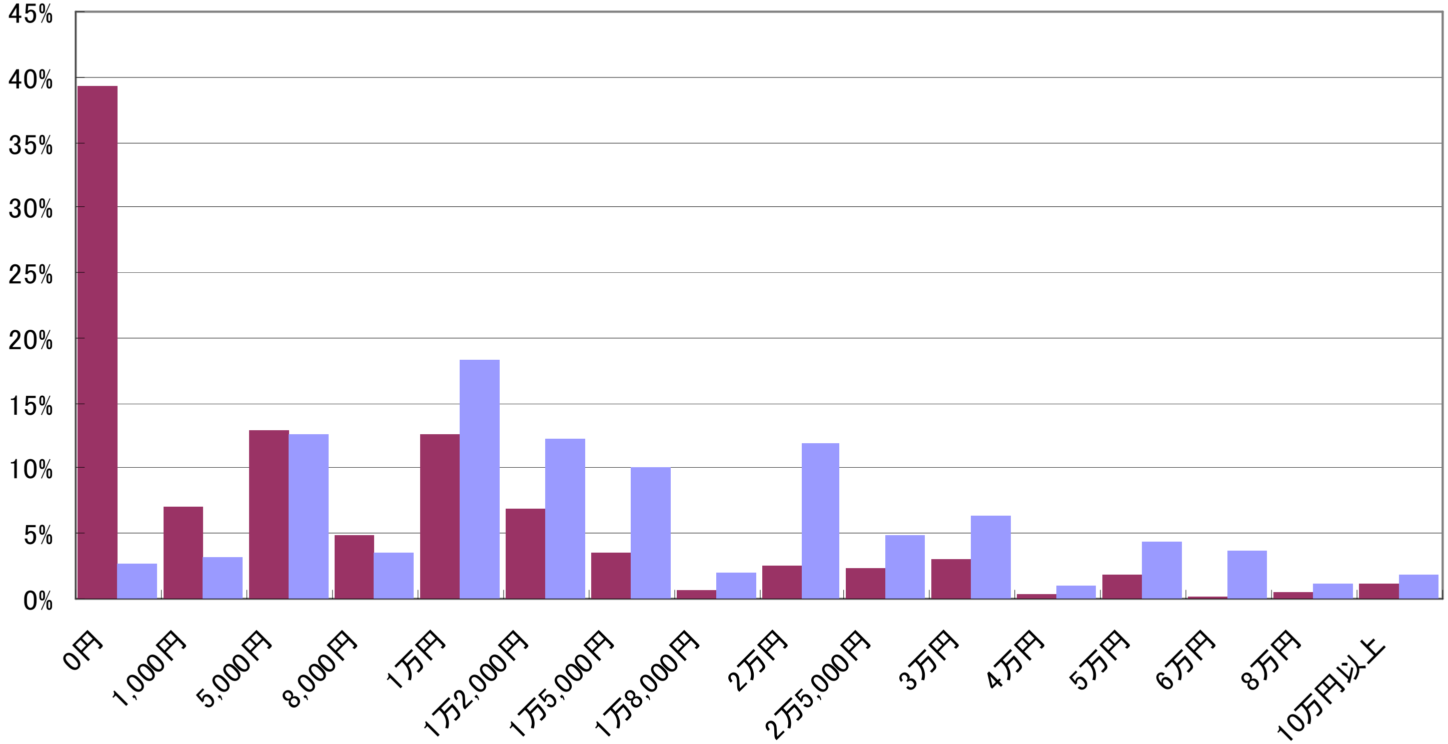
Expected value of probabilistic insurance

15,270 yen（α=1%)，14,850 yen（α=5%)，14,325 yen（α=10%)

} Similar

However,

Distribution of WTP



Expected utility model: traditional model

Expected utility model

WTP is determined by the risk attitude (= concavity of utility)

Full cover insurance

$$u(W + Y - wtp_{full}) = \tilde{v}$$

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

wtp_{full} : Willingness to pay for the full cover insurance

$u(\cdot)$: utility function

W : wealth without house

Y : value of house

π_1 : probability of half destroy

π_2 : probability of destroy

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

γ : coefficient of relative risk aversion

Expected utility model: traditional model

Probabilistic insurance

$$(1-\pi_1\alpha-\pi_2\alpha)u(W+Y-wtp_{risk})+(\pi_1+\pi_2)\alpha\cdot u(W+Y/2-wtp_{risk})$$
$$=\tilde{v}$$

wtp_{risk} : Willingness to pay for probabilistic insurance

α : mean of appraisal risk

Estimation result

	Full covered insurance		Probabilistic insurance	
	Coeff	p-value	Coeff	p-value
Intercept	1.2561	0.000	-17.635	0.000
Age	0.0047	0.000	0.0091	0.000
Gender	0.1267	0.001	0.0616	0.259
Married	0.0123	0.056	-0.1044	0.126
Childe	0.0792	0.038	0.1083	0.024
Education	-0.0775	0.000	-0.0897	0.002
Unemployed	-0.1246	0.000	-0.0941	0.005
Self-employed	0.0118	0.483	0.0299	0.476
Civil servant	0.0746	0.077	-0.1090	0.043
Experience	0.0118	0.493	-0.0836	0.110
sigma	76.284 E-6	0.212	4.7355 E+23	0.946
mean gamma	1.6276		-17.176	
N	506		506	
Log likelihood ratio	0.0456		0.0676	

The result of full cover insurance
is consistent with most previous studies.

➡ Our data is reliable.

Estimated coefficient of CRRA

Estimation of γ

$\gamma > 0$ ··· risk averse

$\gamma = 0$ ··· risk neutral

$\gamma < 0$ ··· risk loving

（plausible range: $\gamma = 0$~4 ）

full cover insurance

$$\gamma = 1.628$$

probabilistic insurance

$$\gamma = -17.177$$

→ unreasonable

Risk attitude (Expected utility model) is not sufficient to explain the observed decision to the probabilistic insurance.

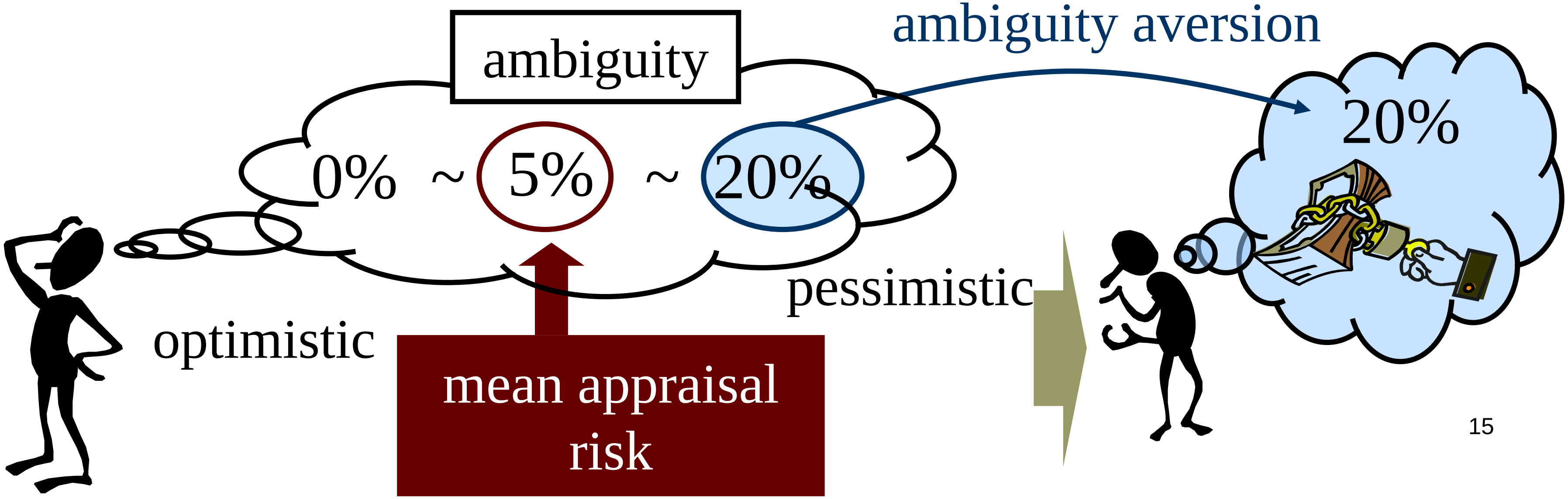
We need to consider an additional factor.

Ambiguity aversion

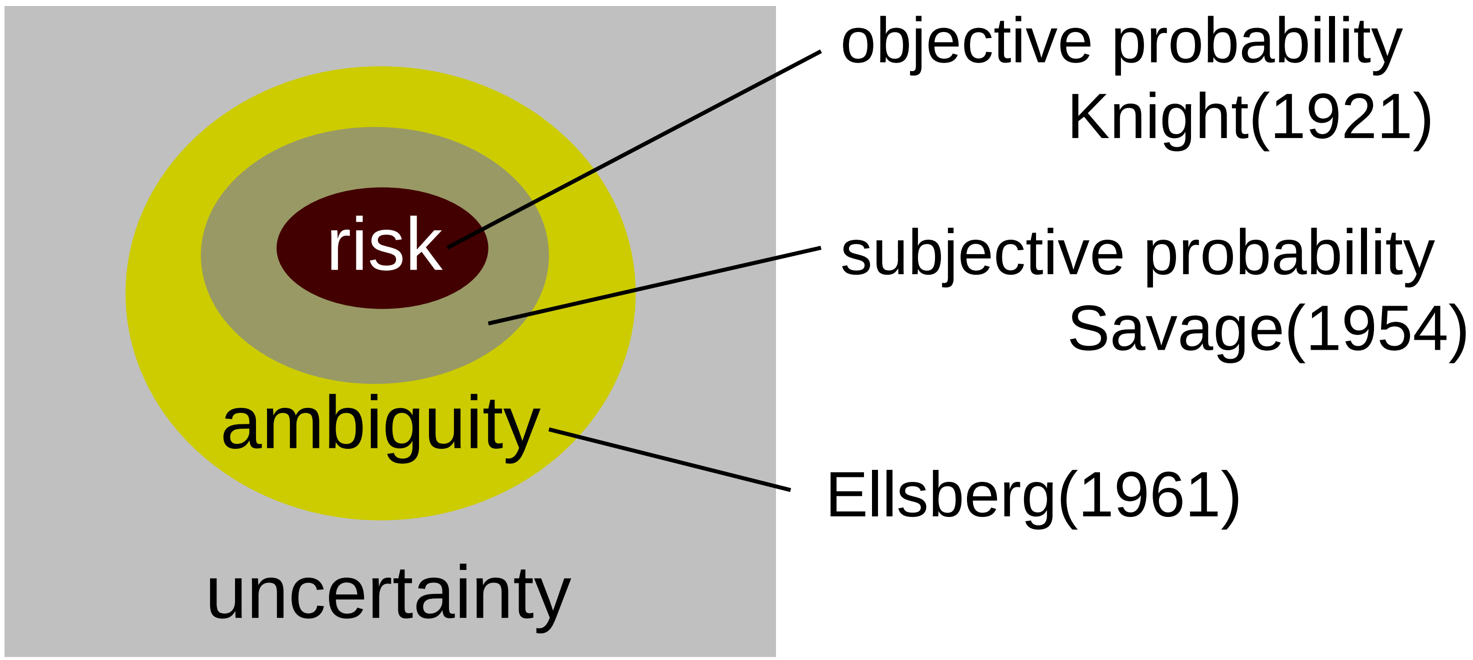
People do not know the insurance appraisal well

They perceive some range to the appraisal risk

They behave for the worst case (Ambiguity aversion)



What is ambiguity?



- Ambiguity
  - Indeterminacy of an unique subjective probability due to missing information about the decision problem.

Maxmin Expected Utility Model (MEU)

Gilboa and Schmeidler (1989)

$$V(f) = \min_{p \in C} \int_S u\big(f(s)\big) dp(s)$$

C : closed convex set of probability measures

$s \in S$: state（e.g. rain tomorrow, or 6 on a cast dice ）

$f(s)$: act (real-value function of *S*)

- C is the set of probability distributions that the decision maker has.

Specification of C

$$C = \{P : R(P;Q) \leq \eta\}$$

subjective probability distribution

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

probability distribution using mean of the appraisal risk

$$Q = (q_0, W + Y - wtp;\ \ q_1, W + Y/2 - wtp;\ \ q_2, W - wtp)$$
$$= (1 - \alpha\pi_1 - \alpha\pi_2, W + Y - wtp;\ \ (\pi_1 + \pi_2)\alpha, W + Y/2 - wtp;\ \ 0, W - wtp)$$

Relative entropy（distance between *P* and *Q*）

$$R(P;Q) = \sum_{i=0}^{2} p_i \ln \frac{p_i}{q_i}$$

η : parameter

wtp : willingness to pay

MEU for probabilistic insurance

Constraint problem

$$\min_{P \in \{P:R(P,Q \le \eta)\}} \left[p_0 u(W+Y-wtp) + p_1 u(W+Y/2-wtp) + p_2 u(W-wtp) \right]$$

Both problems have the same solution.

θ and η have one-to-one correspondence.

Multiplier problem

$$\min_{P} \left[p_0 u(W+Y-wtp) + p_1 u(W+Y/2-wtp) + p_2 u(W-wtp) + \theta R(P,Q) \right]$$

$\theta \ge 0$: Ambiguity parameter

（ambiguity becomes small as it's value gets large）

By the first order conditions,

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

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

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

WTP is decided by the following equation

$$p_0^* u(W+Y-wtp) + p_1^* u(W+Y/2-wtp) + p_2^* u(W-wtp) = \tilde{v}$$

Estimation result of MEU

Estimate the ambiguity parameter θ

(Larger value means smaller ambiguity)

Gender is 1 if respondent is male.

Purchase is 1 if respondent actually purchase real earthquake insurance.

Trust is 1 if respondent trust insurance company's appraisal.

	Estimation of θ	
	Coeff	p-value
dummy_1%	2.907E-3	0.000
dummy_5%	4.942E-3	0.000
dummy_10%	6.481E-3	0.000
Age	0.116E-4	0.188
Gender	8.560E-4	0.003
Education	-1.225E-4	0.161
Experience	-1.123E-4	0.586
Purchase	1.181E-3	0.027
Never_Paid	0.620E-4	0.121
Trust	4.239E-4	0.070
sigma	9.141E-5	0.000
Estimated theta for 0.01	4.934E-3	
Estimated theta for 0.05	6.968E-3	
Estimated theta for 0.10	8.508E-3	
N	506	
Log likelihood ratio	0.0377	

Subjective probability

Subjective probability of 25 million yen in wealth level

Mean appraisal risk	$\alpha = 1\%$	$\alpha = 5\%$	$\alpha = 10\%$
①Probability using α	0.00205%	0.01025%	0.02050%
②Subjective probability	0.2104%	0.2717%	0.3000%
②/①	102.7	26.5	14.6

Ambiguity premium

Willingness to pay = **Expected loss** + **Risk premium** + **Ambiguity premium**

Risk premium: additional payment due to risk aversion

Ambiguity premium: additional payment due to ambiguity aversion

(yen)

Mean appraisal risk	α = 1%	α = 5%	α = 10%
Expected loss	15,273	14,863	14,350
Risk premium	5,725	5,661	5,551
Ambiguity premium	-13,060	-16,132	-17,151
Willingness to pay	7,937	4,391	2,750

Conclusion

- Appraisal risk probably exists because many people don’t trust insurance company's appraisal.
- Small appraisal risk can considerably reduce the value of earthquake insurance.
  - Only 1% mean appraisal risk diminishes more than half of the insurance value.
- Male who actually purchases the earthquake insurance and trusts insurance company’s appraisal perceives less ambiguity than the correspondent.

Thank you

Comparison between sample and population

	sample	population
age of head of household	63	55
income (thousand yen)	6,041	6,616
size of houshold	2.99	2.93

Earthquake and appraisal risk

- We present two type of hypothetical forecasts.
  - Earthquake risk
    - Earthquake with seismic intensity of 7 occurs with the probability of 5% in 25 years.
  - appraisal risk
    - Insurance payment is reduced by half with *about* α% probability when the house is destroyed.
    - Insurance payment vanish with *about* α % probability when the house is half destroyed.
- Respondents believe the former forecast while not the latter.

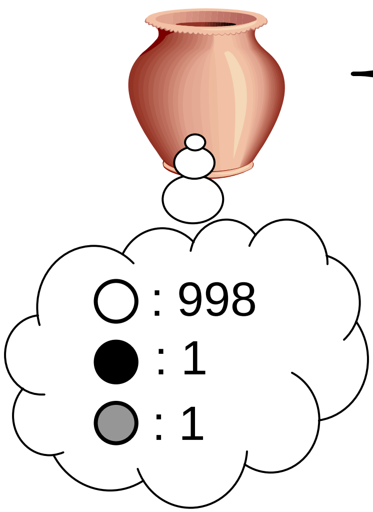
Lottery question

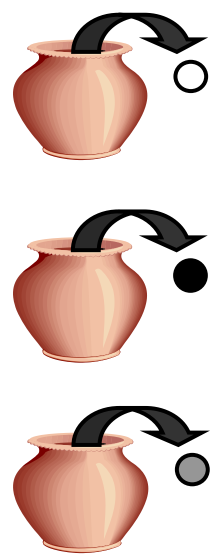
Initial wealth

30 million yen

Lottery

You must draw a ball from the urn.





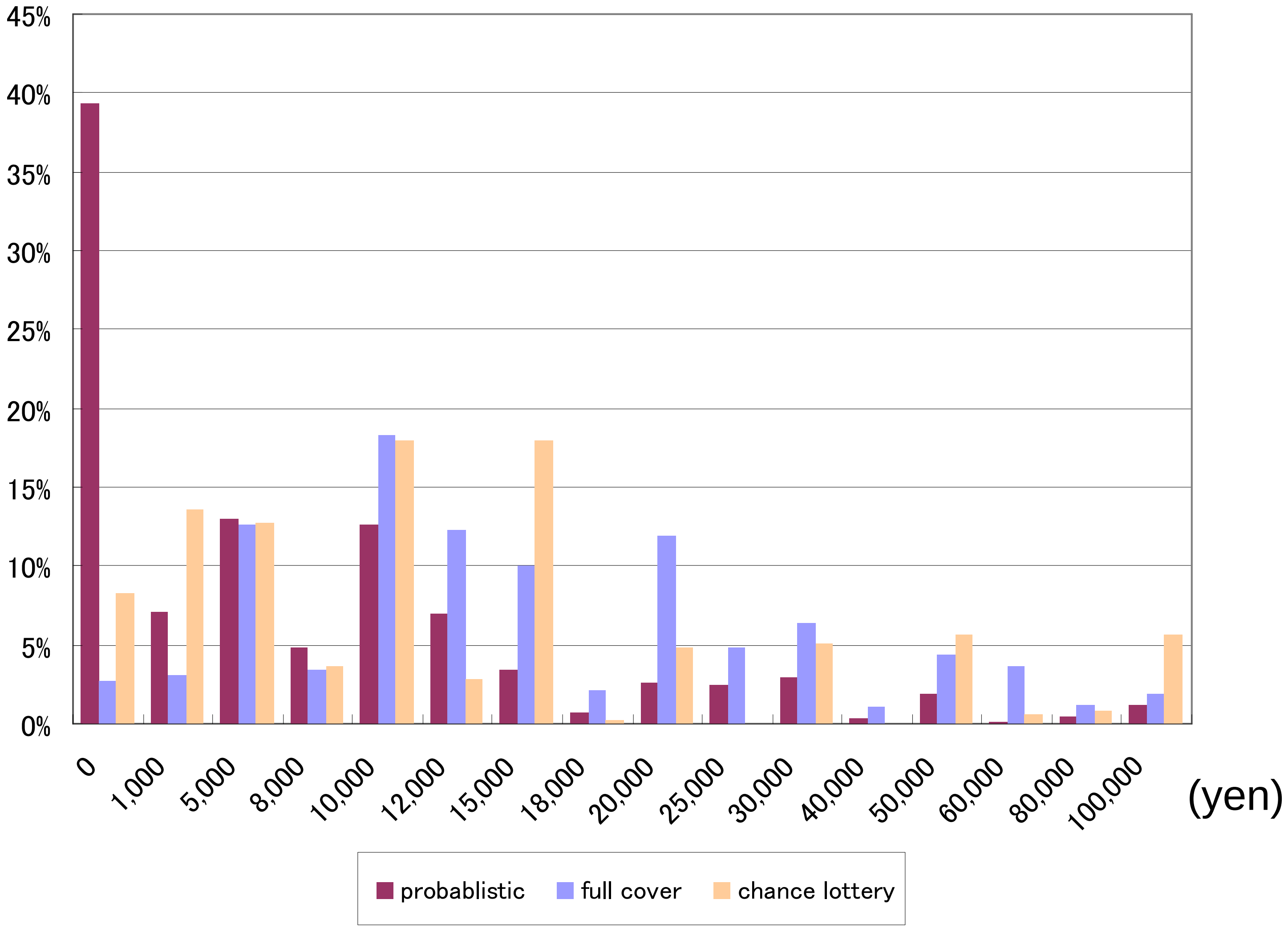
⇨ Nothing happens

⇨ You must pay 10 million yen
with almost same probability of collapse
in the earthquake scenario

⇨ You must pay 5 million yen
with almost same probability of half collapse

How much are you willingness to pay for avoiding this lottery?

WTP in three settings



WTP distribution of Chance lottery is close to that of full cover insurance.

The payoffs and probabilities presented in 3 scenario are almost same.

Under expected utility model

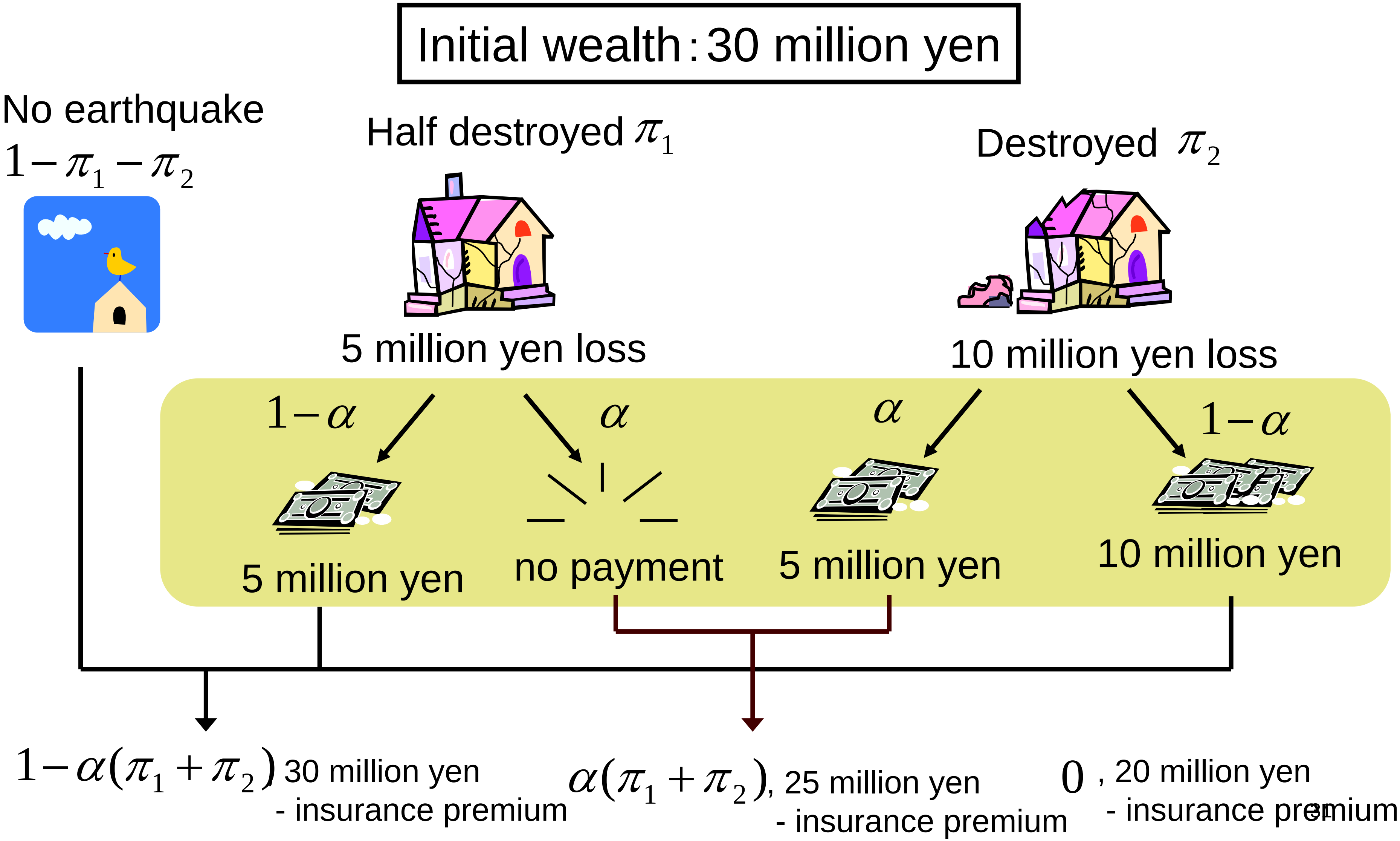
γ is the parameter that represents
the average respondent's behavior toward risk.

lottery	objective risk	$\gamma = 1.204$	similar reasonable
full cover insurance	earthquake risk	$\gamma = 1.628$	
probabilistic insurance	earthquake risk appraisal risk	$\gamma = -17.177$	unreasonable

He decides in the similar way both to lottery and full cover insurance,
but in the different way to the probabilistic insurance

Lottery is unambiguous. → He perceive earthquake risk unambiguous.
appraisal risk can be ambiguous

Wealth situation of probabilistic insurance



Estimation

$V_i(wtp_i)$: utility with insurance at price wtp_i

$\tilde{v}_i$: utility without insurance

$$V_i(wtp_i) = \tilde{v}_i$$

Random utility model

If respondent *i* selects bid B_j $\quad (B_1 < \cdots < B_j < \cdots < B_J)$

$$V_i(B_{j+1}) < V_i(wtp_i) + \varepsilon \le V_i(B_j) \quad \Rightarrow \quad \Phi\left(\frac{V_i(B_{j+1}) - \tilde{v}_i}{\sigma}\right) - \Phi\left(\frac{V_i(B_j) - \tilde{v}_i}{\sigma}\right)$$

probability of choosing B_j

$\varepsilon \sim Normal(0, \sigma)$

$\Phi(\cdot)$: Standard normal distribution

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

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

γ : coefficient of relative risk aversion

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

$$\Phi\left(\frac{V_i(B_{j+1}) - \tilde{v}_i}{\sigma}\right) - \Phi\left(\frac{V_i(B_j) - \tilde{v}_i}{\sigma}\right)$$

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