Separation of Intertemporal Substitution and Time Preference Rate from Risk Aversion: Experimental Analysis

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Abstract

This paper presents discussion of issues related to inter-temporal decision making. This study is intended to test the recursive utility model introduced by Epstein and Zin (1989). This study specifically addresses three factors to determine intertemporal decision making. The recursive utility theory by Epstein and Zin (1989) is developed to generalize the expected utility theory. Epstein and Zin (1989) define a narrower concept of risk aversion and put forth the proposition that the expected utility is a special case in which the level of parameter of risk aversion is at the same level as intertemporal substitution.

This study uses experiments to separately examine values of the discount rate of time, the values of intertemporal substitution, and the intensity of risk aversion or risk preference in intertemporal decision making. The first factor we examine is β: it is defined by the time preference rate δ as $\beta = \frac{1}{1+\delta}$. The proportion of $1-\beta$ to β indicates the subjective weighting of present and future values. The second factor is intertemporal substitution. Epstein and Zin (1989) define intertemporal substitution by the equation $U = [(1-\beta)c^{\rho} + \beta z^{\rho}]^{\frac{1}{\rho}}$, where c is the present consumption amount and z represents future consumption. Parameter ρ indicates substitution; the intertemporal elasticity of demand is given by the equation $\sigma = 1/(1-\rho)$. Our experiments examine the tendency of participants to prefer smoothness of consumption. These experimental results show the importance of this factor.

The last factor is 'narrowly' defined risk aversion. This is described as an '$\alpha - mean$' approach by Epstein and Zin (1989). The $\alpha - mean$ (or constant relative risk-aversion) specification replaces the expected value on the certainty equivalent value. The '$\alpha - mean$' approach has an underlying assumption that people always prefer a 'sure thing' to prospects that are described with probability. For a random variable $\tilde{x}$, the $\alpha - mean$ specification for μ is given as $\mu[\tilde{x}]=[E\tilde{x}^{\alpha}]^{\frac{1}{\alpha}}$ when $0 \neq \alpha < 1$, and $\log(\mu) = E\log(\tilde{x})$ when $\alpha = 1$. The α is interpreted as a parameter of relative risk aversion.

Epstein and Zin (1989) show that the recursive structure for intertemporal utility (if

$\alpha \neq 0$ and $\rho \neq 0$) is given by equation $U_t = \left[(1-\beta)c_t^{\rho} + \beta\left(E_t \widetilde{U}_{t+1}^{\alpha} \right)^{\rho/\alpha} \right]^{1/\rho}$ —— (1)

The concavity of this utility occurs by the influence of parameters ρ, α and δ: substitution, risk attitude, and time preference rate, respectively.

In our experiments, the choice of intertemporal consumption is replaced by the choice of intertemporal receipt of a meal ticket. Subjects are, however, not actually given these tickets. Some of them receive a small remuneration. Students in the first and third years of study at Keiai University and all degree students at Kyoto Sangyo University are participants in our experiments. We used paper questionnaires in our experiments. In those questionnaires, participants selected their most favorable choice. They were instructed to complete all questions and to select only one choice for each question. All questions inquired about preferences regarding receipt of a meal ticket. All questions Q1–Q12 were included in one questionnaire. Subjects were not required to answer all questions. Units of all numbers in the questions were 10,000 yen.

Procedures of our test of recursive utility question (1) are divided into four steps. The first step is the estimation of the level of $(1-\beta)^{\frac{1}{\rho}}$. The second step is the estimation of the level of ρ and β simultaneously. The 3rd step is the estimation of the level of α. The last step is a test of validity of the recursive utility by Epstein and Zin (1989).

Our experimental results show that the ratios of important questions to determine the sizes of β, ρ and α at both universities are almost equal. At both universities, the ratios of subjects who prefer consumption this year to the consumption next year are 0.75% at Keiai and 0.74% at Kyoto Sangyo University. Ratios of subjects who prefer smooth consumption are 056 at Keiai University and 0.55 at Kyoto Sangyo University. These results demonstrate the reproducibility of our experiments. Risk attitudes are different. More risk avertors were identified at Kyoto Sangyo University than at Keiai University. Ratios of risk avertors were 0.731 at Keiai University and 0.891 at Kyoto Sangyo University. Results of our tests indicated 31.2% of Keiai participants as risk avertors and 36.8% of those participants at Kyoto Sangyo University: these results confirm the theory.

The first chapter of this paper explains the purpose of the experiment. The experimental design and the test procedure are explained in Chapter 2. In the third chapter, experimental results and interpretations are described. The final chapter presents conclusions based on results of our experiments: tests of utility theory by Epstein and Zin (1989) were partly successful. The results support the validity of the theory. Nevertheless, our results suggest that a more sophisticated theory is needed to explain intertemporal risk attitude because something may have been overlooked: more than the half of the tests do not conform to the recursive utility model. One explanation is that the three factors are likely to be correlated.

1. Purpose of our Experiment

1.1 Introduction

This paper presents issues that are related to inter-temporal decision making. This study is intended to test the recursive utility model that was introduced by Epstein and Zin (1989). A theory is developed to generalize the expected utility theory.

According to the expected utility theory, intertemporal decisions are thought to be made using only risk attitude. Epstein and Zin (1989) reported that separation of observable behavior attributable risk aversion to time preference and to intertemporal substitution are needed. Our experimental results validate the theory of Epstein and Zin (1989).

The calibration theorem by Rabin[1] shows that decreasing marginal utility is insufficient to explain risk aversion. Thereby, we recognize the necessity of reviewing the insufficiency of the expected utility. In that theorem, if someone declines to participate in a lottery that costs 10 dollars with a 0.5 probability to win 11 dollars, then such a risk avertor will similarly aver from participating in a lottery that costs 1000 dollars with a 0.5 probability to win an almost infinite amount of money. This paradox arises partly because of the independence axiom, which is an axioms to construct the expected utility theory, is too strong to describe individuals' risk attitudes. The famous Allais paradox shows that the independence axiom is violated systematically. The Allais paradox is induced by the experimental result indicating that people do not always behave as expected utility maximizers. Most people select a certain payoff rather than a prospect that has higher expected value with a quite small probability of gaining no money at all. Experimental economists and behavioral economists consider the calibration theorem to be evidence supporting prospect theory. This may lead to adoption of subjective utility theories.

The calibration theorem dictates that a more sophisticated concept is needed than the definition of risk aversion advanced by expected-utility theory. We specifically address one theory by Epstein and Zin (1989). They define a narrower concept of risk aversion and advance the proposition that the expected utility is a special case in which the value of the risk aversion parameter is similar to the value of intertemporal substitution.

Footnote
1. Rabin, Matthew, Risk Aversion and Expected-Utility Theory: A Calibration Theorem, Econometrica,Vol.68, No.5, p.1281-1292, 2000.

1.2 Purpose of Our Experiment and Theoretical Background

We intend to determine the micro-behaviors of people in dynamic decision making. For that purpose, we use experimental analyses rather than econometric methods using macro data. These experiments test recursive utility as put forth by Epstein and Zin (1989)[1].

The present study uses experiments to separately elucidate values of the time discount rate and intertemporal substitution, and the intensity of risk aversion or risk preference in intertemporal decision making. The first factor we examine is β. It is defined by the time preference rate δ: $\beta = \frac{1}{1+\delta}$. The proportion of $1-\beta$ to β indicates the weight of the present and future. The second factor is intertemporal substitution. Epstein and Zin (1989) define intertemporal substitution by the equation $U = [(1-\beta)c^{\rho} + \beta z^{\rho}]^{\frac{1}{\rho}}$, where c indicates the present consumption and z indicates future consumption. The ρ is the parameter indicating substitution; the intertemporal elasticities of demand are given by the equation $\sigma = 1/(1-\rho)$. If an individual's elasticity of inter-temporal consumption is very low and the time preference rate also very low, then steady consumption is preferred to random consumption. Therefore, the value of a person's intertemporal utility is limited by the lower value between c and z. Our experiments examine the tendency of participants to prefer smoothness of consumption; our experimental results show the importance of this factor.

The last factor is 'narrowly' defined risk aversion. This is described as an '$\alpha - mean$' approach by Epstein and Zin (1989). The $\alpha - mean$ (or constant relative risk aversion) specification replaces the expected value on the certainty equivalent value. In the background of the '$\alpha - mean$' approach, there is an assumption that people always prefer a sure thing to the prospects described with probability. For a random variable $\tilde{x}$, the $\alpha - mean$ specification for μ is given as $\mu[\tilde{x}]=[E\tilde{x}^{\alpha}]^{\frac{1}{\alpha}}$ when $0 \neq \alpha < 1$, and $\log(\mu) = E\log(\tilde{x})$ when $\alpha = 1$. The α is interpreted as a parameter of (relative) risk aversion. If Taro has lower α =0.5 than Jiro α =0.8, then we can say strictly that Taro is more risk averse than Jiro. An evaluating function of probable outcome is μ. An example illustrates the meanings of μ: a person who believes that $\alpha = 0.5$ evaluates a lottery having probability 0.5 of winning 10 dollars and probability 0.5 of losing (getting nothing) as a certainty (with probability 1) of receiving 2.5 dollars because $\mu[10,0] = \left(\frac{1}{2} \times 10^{0.5}\right)^2 = 2.5$. The differences between μ and EU are: (1) Under the same value of $\alpha < 1$, a greater diversity of outcomes implies smaller μ. (2) Under the same value of $\alpha < 1$, a smaller probability of some outcome is evaluated as larger than the evaluation of expected utility function. This feature allows a reasonable explanation for the Allais paradox.

Epstein and Zin (1989) show that a recursive structure for intertemporal utility (if $\alpha \neq 0$ and $\rho \neq 0$) is given as $U_t = \left[(1-\beta)c_t^\rho + \beta\left(E_t\widetilde{U}_{t+1}^\alpha\right)^{\rho/\alpha} \right]^{1/\rho}$ —— (1)

The concavity of this utility is engendered by parameters ρ, α and δ, which represent, respectively, the substitution, risk attitude, and time preference rate.

1.3 Relations with Real Economic World

Epstein and Zin (1991)[4] pointed out that the equity premium puzzle, which means prices of equities are too high compared to fundamental characteristics, is engendered by all factors attributed to risk aversion. Therefore, our experiments also importantly clarify price formation in the stock market. Furthermore, most important factors for investors (especially for households as investors) will be clarified by our conclusions of these experiments.

Footnote
1. Epstein, Larry, Uncertainty Aversion, Working papers from the University of Toronto, Department of Economics,1997.
2. Ambiguity aversion is a concept that is defined well by Epstein (1997, footnote 1). Ambiguity aversion means that people dislike uncertainties that cannot be described with a probability.
3. Epstein and Zin, Substitution, Risk Aversion and Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework, *Econometrica*, no.57, p.937-969, 1989.
4. Epstein and Zin, Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis, *Journal of Political Economy*, vol.99, no.2, p.263-86, 1991.

2. Experimental Design

Our experiments are designed to test the validity of equation $U_t = \left[(1-\beta)c_t^\rho + \beta\left(E_t\widetilde{U}_{t+1}^\alpha\right)^{\rho/\alpha} \right]^{1/\rho}$ by Epstein and Zin. It is difficult to examine utility maximization under a budget constraint directly because follow-up surveys on consumption at a certain day in the future are thought to be difficult to execute. Our experiments show that the choice of intertemporal consumption is replaced by the intertemporal choice of receipt of a meal ticket. Subjects are not really given these tickets, but some of them receive small remuneration.

2.1 Subjects of Experiments

Students in the first and third years at Keiai University and all degree students at Kyoto Sangyo University were participants in our experiments. Some Keiai University students were inferred to have strong risk preferences because they enjoyed gambling daily.

Table 1	class	grade	class	grade
Keiai	Exercise 1	1	Exercise 3	3
Kyoto	Exercise 1	1	Exercise 4	4

Table 1	class	grade	class	grade
Kyoto	Microeconomics	2,3	Introductory Seminar	1

2.2 Basic Design of Experiments and Reward Design

We used paper questionnaires in our experiments. In the questionnaires, participants are required to select their most favorable choices. They were instructed to complete all questions and to select only one choice in each question. Major examples of choices are described later. Every choice contains streams of numbers and sometimes contains a few lottery numbers. Some choices include lotteries to decide the value of meal ticket in place of certain receipt of meal ticket. All lottery are designed to win with 0.5 probability, and to lose with 0.5 probability.

Table 2	place of operation	date of operation	reward
Experiment 1	Keiai Univ.	6/10/2004	500 yen per subject
		25/10/2004	1000 yen per subject
Experiment 2	Kyoto Sangyo Univ.	7/10/2004	no reward
		8/10/2004	

2.3 Questions and Procedures to Test Recursive Utility by Epstein and Zin (1989)

All questions were asked for the purpose of elucidating preferences of subjects regarding the receipt of a meal ticket. All questions Q1 to Q12 are included in one questionnaire. The subject is not required to answer all questions. Units of all numbers in questions are 10,000 yen.

The procedure of our test of recursive utility question (1) is divided into four steps.

1. Estimation of the level of $(1\text{-}\beta)^{\frac{1}{\rho}}$ (Q1–Q3)
2. Estimation of the level of ρ and β (Q4–Q7)
3. Estimation of the level of α (Q8, Q11,Q12)
4. Test of validity of the recursive utility by Epstein and Zin (1989).

Questions from Q1 to Q3 are used to estimate the range of $(1\text{-}\beta)^{\frac{1}{\beta}}$. Questions Q4–Q7 are used to estimate the range of ρ and β. Question Q8 assesses whether the subject is a risk avertor or not. Risk avertor subjects are required to answer Q9 and Q11.Risk-newtral and risk-prefered subjects are requied to answer Q10 and Q12.

2.3.1. Estimation of the range of $(1-\beta)^{\frac{1}{\rho}}$

The first step is to measure levels of $(1-\beta)^{\frac{1}{\rho}}$.

Our questionnaire contains many questions. Q1–Q3 are prepared for evaluation of the level of $(1-\beta)^{\frac{1}{\rho}}$. Q1 is the most basic question.

Q1. Which do you prefer? A(10,0) B(0,10)
If your answer is A, you are given 100,000 yen this year, and nothing next year.
The term of validity of a meal ticket is for one year. There is no inflation or deflation
If your answer is A, please answer Q2. If your answer is B, please answer Q3.

Table 3

	objective choice for comparison
Q2	A(10,0)
Q3	B(0,10)

Q2(Q3)-1	Q2(Q3)-2	Q2(Q3)-3	Q2(Q3)-4	Q2(Q3)-5	Q2(Q3)-6
C(0,10.1)	D(0,10.5)	E(0,11)	F(0,12)	G(0,15)	H(0,20)
CA(10.1,0)	DA(10.5,0)	EA(11,0)	FA(12,0)	GA(15,0)	HA(20,0)

If a subject answers A in Q1, the $(1\text{-}\beta)^{\frac{1}{\rho}}$ of the subject is equal to or larger than 0.5 when recursive utility is given by equation (1). If a subject answers B in Q1, $(1\text{-}\beta)^{\frac{1}{\rho}}$ is equal to or smaller than 0.5. We exclude the answer that means 'A is equal to B for me' because the choice makes it easy for subjects to answer.

We can infer from the answers to Q2 or Q3 how close the individual's $(1\text{-}\beta)^{\frac{1}{\rho}}$ is to 0.5.

The pattern of answers and the level of $(1\text{-}\beta)^{\frac{1}{\rho}}$ are as follows.

Table 4

Q2-1	Q2-2	Q2-3	Q2-4	Q2-5	Q2-6	range of $(1\text{-}\beta)^{\frac{1}{\rho}}$	average of $(1\text{-}\beta)^{\frac{1}{\rho}}$
A	A	A	A	A	A	$1 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.666$	0.333
A	A	A	A	A	H	$0.666 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.6$	0.633
A	A	A	A	G	H	$0.6 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.545$	0.573
A	A	A	F	G	H	$0.545 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.524$	0.535
A	A	E	F	G	H	$0.524 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.512$	0.518
A	D	E	F	G	H	$0.512 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.502$	0.507
C	D	E	F	G	H	$0.502 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.5$	0.501

Table 5

Q3-1	Q3-2	Q3-3	Q3-4	Q3-5	Q3-6	RANGE OF $(1-\beta)^{\frac{1}{\rho}}$	AVERAGE OF $(1-\beta)^{\frac{1}{\rho}}$
A	A	A	A	A	A	$0.333 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0$	0.176
A	A	A	A	A	HA	$0.4 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.333$	0.367
A	A	A	A	GA	HA	$0.455 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.4$	0.427
A	A	A	FA	GA	HA	$0.476 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.455$	0.465
A	A	EA	FA	GA	HA	$0.488 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.476$	0.482
A	DA	EA	FA	GA	HA	$0.498 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.488$	0.493
CA	DA	EA	FA	GA	HA	$0.5 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.498$	0.499

The level of β shows the relative psychological weight of an individual's judgment of today and the future, the risk receptivity, and the level of substitution.

2.3.2. Presumption of parameter sizes that demonstrate substitution of consumption and time preference rate

Questions from Q4 to Q6 presume a range of ρ.

> Q4. WHICH DO YOU PREFER? R(8,8,8) S(10,8,6) T(6,8,10)
> IF YOUR ANSWER IS S, YOU AER GIVEN A MEAL TICKET WORTH 100,000 YEN THIS YEAR, A MEAL TICHET 80,000 WORTH YEN NEXT YEAR AND A MEAL TICKET WORTH 60,000 YEN IN THE YEAR AFTER NEXT. THE TERM OF VALIDITY OF A MEAL TICKET IS FOR ONE YEAR. THERE IS NO INFLATION OR DEFLATION.
> IF YOUR ANSWER IS R, PLEASE ANSWER FROM Q5-1 TO Q5-5. IF YOUR ANSWER IS S, PLEASE ANSWER FROM Q6-1 TO Q6-6.
> IF YOUR ANSWER IS T, PLEASE ANSWER Q7-1 TO Q7-6 .

A participant who selects R has a stronger preference for smooth receipts than for time preference. For that reason, her intertemporal substitution is inferred to be smaller than that of a person who chooses S or T.

A participant who selects S has a time preference that exceeds a preference for smoothness of receipts. If a participant selects T, he has an anomaly in time preference and his intertemporal substitution is inferred to be larger than who choose R.

TABLE 6	OBJECTIVE CHOICE FOR COMPARISON
Q5	A(10,0)
Q6	A(10,0)
Q7	B(0,10)

TABLE 6	Q5(6,7)-1	Q5(6,7)-2	Q5(6,7)-3	Q5(6,7)-4	Q5(6,7)-5	Q6(7)-6
Q5	U1(4.7,4.7)	U2(4.5,4.5)	U3(4,4)	U4(3.5,3.5)	U5(3,3)	–
Q6	V1(8,1.5)	V2(8,1)	V3(7,2.5)	V4(7,2)	V5(6,3.5)	V6(6,3)
Q7	W1(1.5,8)	W2(1,8)	W3(2.5,7)	W4(2.7)	W5(3.5,6)	V6(3,6)

The range of ρ of a subject depends on the value of (1-β)$^{\frac{1}{\rho}}$ and answers to Q5 and Q6.

The Q5 is the easiest to estimate the range of ρ. Even for Q5, one matrix including all patterns of answers is needed for every (1- β)$^{\frac{1}{\rho}}$. We show a few examples to estimate the matrix as follows. We estimate the range of values $[(1-\beta)c^{\rho}+\beta z^{\rho}]^{1/\rho}$ by simulating several ρ.

For example, when $(1-\beta)^{\frac{1}{\rho}} = 0.501$, (c, z)=(10,0) is equivalent to (4.5,4.5) for a subject whose ρ =0.933 .

Therefore, the larger the value of (1-β), the larger the value of the time preference rate, and the smaller the value of the ρ is because (10,0) is more favorable to a person who is $\beta = 0.667$ than to a person for whom $\beta = 0.501$

TABLE 7

RANGE OF ρ	ANS. Q5-1	ANS. Q5-2	ANS. Q5-3	ANS. Q5-4	ANS. Q5-5	VALUE OF $[(1-\beta)c^{\rho}+\beta z^{\rho}]^{1/\rho}$	C	Z	$(1-\beta)^{\frac{1}{\rho}}$
1≧ ρ ≧0.96	A	A	A	A	A	J>4.7	10	0	0.501
0.96≧ ρ ≧0.933	U1	A	A	A	A	4.7≧J>4.5	10	0	0.501
0.933≧ ρ ≧0.86	U1	U2	A	A	A	4.5≧J>4	10	0	0.501
0.86≧ ρ ≧0.777	U1	U2	U3	A	A	4≧J>3.5	10	0	0.501
0.777≧ ρ ≧0.682	U1	U2	U3	U4	A	3.5≧J>3	10	0	0.501
0.682≧ ρ	U1	U2	U3	U4	U5	J>3	10	0	0.501

TABLE 8

RANGE OF ρ	ANS. Q5-1	ANS. Q5-2	ANS. Q5-3	ANS. Q5-4	ANS. Q5-5	VALUE OF $[(1-\beta)c^{\rho}+\beta z^{\rho}]^{1/\rho}$	C	Z	$(1-\beta)^{\frac{1}{\rho}}$
1≧ ρ ≧0.816	A	A	A	A	A	J>4.7	10	0	0.667
0.816≧ ρ ≧0.793	U1	A	A	A	A	4.7≧J>4.5	10	0	0.667
0.793≧ ρ ≧0.731	U1	U2	A	A	A	4.5≧J>4	10	0	0.667
0.731≧ ρ ≧0.660	U1	U2	U3	A	A	4≧J>3.5	10	0	0.667
0.660≧ ρ ≧0.579	U1	U2	U3	U4	A	3.5≧J>3	10	0	0.667
0.579≧ ρ	U1	U2	U3	U4	U5	J>3	10	0	0.667

When the answer of Q4 is S or T, the estimation of ρ is more complicated because characteristics of questions search the range of ρ that suffices to preference orders that are known for all questions and answers.

After estimatation of the average size of ρ, β is calculated by the size of $(1-\beta)^{\frac{1}{\rho}}$, and we can infer the time preference rate δ by definition $\beta = \frac{\delta}{1+\delta}$.

2.3.3 Estimation of size parameters that show a risk attitude

Next, we calculate the sizes of the parameters that show risk attitudes in one moment.

Q8 separates risk avertors from risk-neutral and risk-preferent persons.

Q8 It is decided to get the meal ticket of 10 thousand yen this year. Which do you prefer regarding meal tickets of next year?
X A certain 10 thousands yen.
Y A lottery ticket: you get 20 thousand yen if you win, and you get nothing if you lose.
If your answer is X, please answer from Q9-1 to Q9- and Q11-1 to Q11-5.
If your answer is X, please answer from Q10-1 to Q10 - and Q12-1 to Q12-6.

If a subject answers X, he is called a risk avertor. We estimate the strength of the subject to avoid risk in one moment in Q11. In Q11, the amount of money offered for certain meal tickets decreases gradually.

Table 9

Q11	Objective choice for comparison			
Points you get	Z {20 if you win; 0 if you lose}			
Q11-1	Q11-2	Q11-3	Q11-4	Q11-5
Xf1	Xf2	Xf3	Xf4	Xf5
certain10	certain9	certain8	certain6	certain4

The range of α is estimated as follows by the pattern of answers of Q11.

Table 10

Q11-1	Q11-2	Q11-3	Q11-4	Q11-5	range of α
Z	Z	Z	Z	Z	$\alpha \geqq 1$
Z	Z	Z	Z	Xf5	$1 \geqq \alpha \geqq 0.868$
Z	Z	Z	Xf4	Xf5	$0.868 \geqq \alpha \geqq 0.7565$
Z	Z	Xf3	Xf4	Xf5	$0.7565 \geqq \alpha \geqq 0.5757$
Z	Xf2	Xf3	Xf4	Xf5	$0.5757 \geqq \alpha \geqq 0.4307$
Xf1	Xf2	Xf3	Xf4	Xf5	$0.4307 \geqq \alpha \geqq 0$

If a subject answers Y, she is thought to be risk-neutral or risk-preferent. We estimate the degree of the subject to assume risk in one moment in Q12.

Table 11

Q12	Objective choice for comparison
Points you get	Xf certain10

Q12-1	Q12-2	Q12-3
$Z1\begin{Bmatrix} 19 \text{ IF YOU WIN} \\ 0 \text{ IF YOU LOSE} \end{Bmatrix}$	$Z2\begin{Bmatrix} 18 \text{ IF YOU WIN} \\ 0 \text{ IF YOU LOSE} \end{Bmatrix}$	$Z3\begin{Bmatrix} 16 \text{ IF YOU WIN} \\ 0 \text{ IF YOU LOSE} \end{Bmatrix}$
Q12-4	**Q12-5**	**Q12-6**
$Z4\begin{Bmatrix} 14 \text{ IF YOU WIN} \\ 0 \text{ IF YOU LOSE} \end{Bmatrix}$	$Z5\begin{Bmatrix} 14 \text{ IF YOU WIN} \\ 2 \text{ IF YOU LOSE} \end{Bmatrix}$	$Z6\begin{Bmatrix} 14 \text{ IF YOU WIN} \\ 4 \text{ IF YOU LOSE} \end{Bmatrix}$

The range of α is estimated as follows by the pattern of answers. In Q12, a subject who answers Z4 in Q12-4 is the most risk-preferent.

TABLE 12

Q12-1	Q12-2	Q12-3	Q12-4	Q12-5	Q12-6	RANGE OF α
XF	XF	XF	XF	XF	XF	$1.0799 \geqq \alpha$
Z1	XF	XF	XF	XF	XF	$1.1793 \geqq \alpha \geqq 1.0799$
Z1	Z2	XF	XF	XF	XF	$1.4749 \geqq \alpha \geqq 1.1793$
Z1	Z2	Z3	XF	XF	XF	$2.06 \geqq \alpha \geqq 1.4749$
Z1	Z2	Z3	Z4	XF	XF	$\alpha \geqq 2.06$
Z1	Z2	Z3	XF	XF	Z6	$2.06 \geqq \alpha \geqq 1.7425$
Z1	Z2	Z3	XF	Z5	Z6	$2.06 \geqq \alpha \geqq 2$
Z1	Z2	Z3	Z4	Z5	Z6	$\alpha \geqq 2.06$

2.3.4 Procedure for estimating intertemporal α

Next, we estimate the degree of intertemporal risk aversion using Q9-1–Q9-7.

TABLE 13

Q9	OBJECTIVE CHOICE FOR COMPARISON
POINTS YOU GET	$Y\begin{Bmatrix} 20 \text{ IF YOU WIN} \\ 0 \text{ IF YOU LOSE} \end{Bmatrix}$ IN THE NEXT YEAR

Q9-1	Q9-2	Q9-3	Q9-4
X1	X1	X1	X1
CERTAIN10	CERTAIN6	CERTAIN5	CERTAIN4
IN THIS YEAR	IN THIS YEAR	IN THIS YEAR	IN THIS YEAR

Q9-5	Q9-6	Q9-7
X1	X1	X1
CERTAIN3	CERTAIN2	CERTAIN1
IN THIS YEAR	IN THIS YEAR	IN THIS YEAR

The degree of α is determined depending upon the levels of β and ρ; for that reason, we cannot show the matrix. We only describe the procedure to estimate the values of intertemporal α.

The second to last step is to estimate values of intertemporal α to estimate the amount of z (future consumption) that is equal to one certain unit of consumption today.

We calculate z from the equation using the marginal rate of substitution: $\frac{\partial U/\partial z}{\partial U/\partial c}$ $=(\frac{1-\beta}{\beta})\left(\frac{z}{c}\right)^{\rho-1} = 1$. The equation is solved for z after one is substituted for c. Then, the size of z that compensates c=1 is calculated using this equation: $1/\left(\frac{\beta}{1-\beta}\right)^{\frac{1}{\rho-1}}$.Note that $\frac{1}{1-\rho}$ represents the elasticity of intertemporal substitution. We estimate the value of z using average β and ρ. A value of next year equivalent to 10 of this year is calculated. Similarly, a value of next year equivalent to six of this year, corresponding to Q9-2, is also calculated. In this manner, values corresponding to Q9-3–Q9-6 are calculated: those values change with each value of β and ρ. Preparation that predicts α was completed at last.

Next, patterns of answers are investigated in Q9. The patterns expected of answers are as follows. If a subject shows pattern 2, the important value of z to calculate the range of α is both a value that is equivalent to 10 of this year and a value that is equivalent to six of this year, set the former value to a and the latter value to b.

This procedure means that we replace the intertemporal decision-making problems, including risks, to temporal risk-taking (or avoiding) problems.

Thereby, we can estimate the range of α using the equation $\mu[\tilde{x}]=[E\tilde{x}^{\alpha}]^{\frac{1}{\alpha}}$ when $0 \neq \alpha < 1$. The α is calculated so that the value μ is equivalent to a, and the value is set to be μ_a. The value of μ_a is the upper bound of α.The lower bound of α is calculated similarly. Relationships between patterns of answers in Q9 and ranges of α are as follows. Finally, the range of α calculated by Q11 is compared with the range of α presumed from values of Q9, and β and ρ. If there is a range that fulfills both conditions, we judge that the experimental results are conformable to an E-Z recursive utility model.

TABLE 14

VALUE EQUIVALENT TO 10	VALUE EQUIVALENT TO 6	VALUE EQUIVALENT TO 5	VALUE EQUIVALENT TO 4
$a = z \times 10$	$b = z \times 6$	$c = z \times 5$	$d = z \times 4$
Q9-1	Q9-2	Q9-3	Q9-4
Y	Y	Y	Y
X1	Y	Y	Y
X1	X2	Y	Y
X1	X2	X3	Y
X1	X2	X3	X4
X1	X2	X3	X4
X1	X2	X3	X4
X1	X2	X3	X4

VALUE EQUIVALENT TO 3	VALUE EQUIVALENT TO 2	VALUE EQUIVALENT TO 1	
$e = z \times 3$	$f = z \times 2$	$g = z \times 1$	
Q9-5	Q9-6	Q9-7	
Y	Y	Y	PATTERN 1 $\Rightarrow 1 \geqq \alpha \geqq \mu_a$
Y	Y	Y	PATTERN 2 $\Rightarrow \mu_a \geqq \alpha \geqq \mu_b$
Y	Y	Y	PATTERN 3 $\Rightarrow \mu_b \geqq \alpha \geqq \mu_c$
Y	Y	Y	PATTERN 4 $\Rightarrow 1\mu_c \geqq \alpha \geqq \mu_d$
Y	Y	Y	PATTERN 5 $\Rightarrow 1\mu_d \geqq \alpha \geqq \mu_e$
X5	Y	Y	PATTERN 6 $\Rightarrow 1\mu_e \geqq \alpha \geqq \mu_f$
X5	X6	Y	PATTERN 7 $\Rightarrow 1\mu_f \geqq \alpha \geqq \mu_g$
X5	X6	X7	PATTERN 8 $\Rightarrow 1\mu_g \geqq \alpha \geqq 0$

As risk-neutral and risk-preferent subjects, they are required to answer Q10-1–Q10-6.

TABLE 15

Q10	OBJECTIVE CHOICE FOR COMPARISON
POINTS YOU GET	X1 CERTAIN10 IN THIS YEAR

Q10-1

$$Z1\left\{\begin{array}{l}19 \text{ IF YOU WIN}\\ 0 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

Q10-2

$$Z2\left\{\begin{array}{l}18 \text{ IF YOU WIN}\\ 0 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

Q10-3

$$Z3\left\{\begin{array}{l}16 \text{ IF YOU WIN}\\ 0 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

Q10-4

$$Z4\left\{\begin{array}{l}14 \text{ IF YOU WIN}\\ 0 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

Q10-5

$$Z5\left\{\begin{array}{l}14 \text{ IF YOU WIN}\\ 2 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

Q10-6

$$Z6\left\{\begin{array}{l}14 \text{ IF YOU WIN}\\ 4 \text{ IF YOU LOSE}\\ \text{IN NEXT YEAR}\end{array}\right\}$$

The test is more complicated than for a risk lover. The expected patterns are as follows. First, we calculate a value that is equivalent to 10 of this year from β and ρ.We set that value as a. Next, we investigate the range of α that suffices to the pattern of answer. Using $\mu[\tilde{x}]=[E\tilde{x}^{\alpha}]^{\frac{1}{\alpha}}$,we investigate the value that is equivalent to $a = \left(\frac{\beta}{1-\beta}\right)^{\frac{1}{\rho-1}} \times 10$, the future value that is equivalent to 10 of this year. Next, set a value μ_{z1} that is equivalent to lottery Z1. We calculate μ_{z2}.....μ_{z6} similarly. We replace an intertemporal problem with a one moment problem. Finally, we compare the value of a to the value that is equivalent to each lotter ticket. Note that the relations $\mu_{z4} \geqq \mu_{z5} \geqq \mu_{z6}$ are always realized.

TABLE 16

$\mu_{z1} = (\frac{1}{2}19^{\alpha})^{\frac{1}{\alpha}}$	$\mu_{z2} = (\frac{1}{2}18^{\alpha})^{\frac{1}{\alpha}}$	$\mu_{z3} = (\frac{1}{2}16^{\alpha})^{\frac{1}{\alpha}}$	$\mu_{z4} = (\frac{1}{2}14^{\alpha})^{\frac{1}{\alpha}}$
X1 IF $a \geqq \mu_{z1}$	X1 IF $a \geqq \mu_{z2}$	X1 IF $a \geqq \mu_{z3}$	X1 IF $a \geqq \mu_{z4}$
Z1 IF $\mu_{z1} \geqq a$	Z2 IF $\mu_{z2} \geqq a$	Z3 IF $\mu_{z3} \geqq a$	Z4 IF $\mu_{z4} \geqq a$
Q12-1	Q12-2	Q12-3	Q12-4
X1	X1	X1	X1
Z1	X1	X1	X1
Z1	Z2	X1	X1
Z1	Z2	Z3	X1
Z1	Z2	Z3	Z4
Z1	Z2	Z3	X1
Z1	Z2	Z3	X1
Z1	Z2	Z3	Z4

$\mu_{z5} = (\frac{1}{2}14^{\alpha} + \frac{1}{2}2^{\alpha})^{\frac{1}{\alpha}}$	$\mu_{z6} = (\frac{1}{2}14^{\alpha} + \frac{1}{2}4^{\alpha})^{\frac{1}{\alpha}}$	
X1 IF $a \geqq \mu_{z5}$	X1 IF $a \geqq \mu_{z6}$	$a = \left(\frac{\beta}{1-\beta}\right)^{\frac{1}{\rho-1}} \times 10$
Z5 IF $\mu_{z5} \geqq a$	Z6 IF $\mu_z 6 \geqq a$	RANGE OF α
Q12-5	Q12-6	
X1	X1	PATTERN 1 $\Rightarrow \mu_{z1} \geqq \alpha$
X1	X1	PATTERN 2 $\Rightarrow \mu_{z2} \geqq \alpha \geqq \mu_{z1}$
X1	X1	PATTERN 3 $\Rightarrow \mu_{z3} \geqq \alpha \geqq \mu_{z2}$
X1	X1	PATTERN 4 $\Rightarrow \mu_{z4} \geqq \alpha \geqq \mu_{z3}$
X1	X1	PATTERN 5 $\Rightarrow \alpha \geqq \mu_{z4}$
X1	Z6	PATTERN 6 $\Rightarrow \mu_{z5} \geqq \alpha \geqq \mu_{6}$
Z5	Z6	PATTERN 7 $\Rightarrow \mu_{z4} \geqq \alpha \geqq \mu_{z5}$
Z5	Z6	PATTERN 8 $\Rightarrow \alpha \geqq \mu_{z4}$

3. Results of our Experiments

3.1 Results for estimation of β

Major results of our experiments are summarized as follows.

Table 17 shows the result of Q1. Different answers were obtained from those that were expected: values of β are inestimable. At Kyoto Sangyo University, the ratio of inestimable values is much higher than at Keiai University. The reasons are clear: no reward was given to any subjects and the number of students was vastly different. At Kyoto Sangyo University, many students participated. Therefore, experimenters were not able to check all the answers. Ratios of X at both universities are nearly equal. Ratio of inestimable is including no answer for some questions.

TABLE 17

□	Q1		ratio of X	ratio of Y
Keiai Univ.	X(10,0)	Y(0,10)	20/25=0.750	5/25=0.250
Kyoto Sangyo Univ.	X(10,0)	Y(0,10)	66/89=0.742	21/89=0.256

	ratio of no answer	ratio of inestimable (including no answe
Keiai Univ.	0/25=0	1/25=0.040
Kyoto Sangyo Univ.	2/89=0.022	19/89=0.213

Table 18 depicts the distribution of the range of β. Difference in distributions is clear. At Keiai university, (1-β)$^{\frac{1}{\rho}}$ tends to be higher than at Kyoto Sangyo University.

Table 18

range of (1-β)$^{\frac{1}{\rho}}$	average of (1-β)$^{\frac{1}{\rho}}$	ratio in Keiai	ratio in Kyoto Sangyo
$1 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.666$	0.833	2/25=0.08	4/70=0.057
$0.666 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.6$	0.633	1/25=0.04	3/70=0.043
$0.6 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.545$	0.573	5/25=0.10	15/70=0.214
$0.545 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.524$	0.535	6/25=0.24	6/70=0.086
$0.524 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.512$	0.518	2/25=0.08	5/70=0.071
$0.512 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.502$	0.507	2/25=0.08	9/70=0.129
$0.502 \geqq (1-\beta)^{\frac{1}{\beta}} \geqq 0.5$	0.501	3/25=0.12	14/70=0.2

range of (1-β)$^{\frac{1}{\rho}}$	average of (1-β)$^{\frac{1}{\rho}}$	ratio in Keiai	ratio in Kyoto Sangyo
$0.333 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0$	0.167	0/25=0	1/70=0.014
$0.4 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.333$	0.367	0/25=0	0/70=0
$0.455 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.4$	0.427	1/25=0.04	1/70=0.014
$0.476 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.455$	0.465	1/25=0.04	0/70=0
$0.488 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.476$	0.482	1/24=0.04	3/70=0.043
$0.498 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.488$	0.493	0/25=0	1/70=0.014
$0.5 \geqq (1-\beta)^{\frac{1}{\rho}} \geqq 0.498$	0.499	1/25=0.04	8/70=0.012

3.2 Results of Estimation of the Ranges of ρ and β

Table 19 shows ratios of R, S and T in Q4. Answers in Q4 are used to separate subjects into three types according to intertemporal substitution.

A subject who answers R in Q4 prefers smoother consumption than the others: his ρ is inferred to be relatively low. A subject who answers S is thought to have a greater time preference than others. His ρ may also be higher than that of a subject who answers R because he receives a different amount of consumption. A subject who answers T has an anomaly in the time preference rate; her ρ may be higher than that of a subject who answers R, for the same reason as one who has answered S.

The ratio of inestimability is not small, partly because there is contradiction in answers of Q1–Q3 and partly because the answer of a subject in Q5 or Q6 may contain some anomaly or contradiction.

Furthermore, it is impossible to presume ρ if there is no presumed value of (1-β)$^{\frac{1}{\rho}}$.

The fact that the ratios of answers R, S, and T are quite similar at Keiai University and Kyoto Sangyo University suggests that this experiment is highly reproducible.

TABLE 19

□	Q4			RATIO OF R	RATIO OF S	RATIO OF
KEIAI UNIV.	R(8,8,8)	S(10,8,6)	T(6,8,10)	14/26=0.538	7/26=0.250	5/26=0.19
KYOTO SANGYO UNIV.	R(8,8,8)	S(10,8,6)	T(6,8,10)	49/88=0.557	24/88=0.273	15/88=0.1

□	RATIO OF NO ANSWER	RATIO OF INESTIMABILITY (INCLUDING NO ANSWER)
KEIAI UNIV.	0/25=0	4/25=0.160
KYOTO SANGYO UNIV.	1/89=0.011	19/89=0.213

Table 20 shows the distribution of ρ (average) whose answers are R in Q4. The results at Keiai University and Kyoto Sangyo University differ substantially. The value of ρ is lower at Keiai University than at Kyoto Sangyo University. This result arises from the difference in size of β. At Keiai University, the value of β is larger than at Kyoto Sangyo University, which engenders a lower value of ρ. The denominater discludes the inestimable answers.

TABLE 20

Q5 THE ANSWER IS R IN Q4 RANGE OF AVERAGE ρ	KEIAI UNIV.	KYOTO SANGYO UNIV.
$1 \geqq \rho \geqq 0.9$	5/14=0.357	24/36=0.666
$0.9 > \rho \geqq 0.7$	6/14=0.429	8/36=0.222
$0.7 > \rho \geqq 0.5$	0/14=0	1/36=0.028
$0.5 > \rho$	3/14=1.428	4/36=0.111
RATIO OF INESTIMABILITY	0/14=0	13/49=0.265

Table 21 shows the distribution of ρ (average) whose answers are S in Q4. The results at Keiai University differ from those at Kyoto Sangyo University. The value of ρ is lower at Keiai University than at Kyoto Sangyo University. From recursive utility theory, we test whether the levels of ρ in Q6 are expected to be higher than those of Q5. The expected results were obtained at both of University. It seems that a result was obtained that supports the theory.

TABLE 21

Q6 the answer is S in Q4 range of average ρ	Keiai Univ.	Kyoto Sangyo Univ.
$1 \geqq \rho \geqq 0.9$	3/4=0.75	13/16=0.812
$0.9 > \rho \geqq 0.7$	0/4=0	4/16=0.250
$0.7 > \rho \geqq 0.5$	0/4=0	0/16=0
$0.5 > \rho$	1/4=0.25	0/16=0
ratio of inestimability	3/7=0429	7/24=0.292

Table 23 shows the distribution of ρ for those subjects who display a time-preference rate anomaly in Q4. Results also differed greatly at Keiai University and Kyoto Sangyo University. A tendency toward lower estimated ρ was observed at Kyoto Sangyo University. That fact contradicts the theory of Epstein and Zin.

Table 23

Q7 the answer is S in Q4 range of average ρ	Keiai Univ.	Kyoto Sangyo Univ.
$1 \geqq \rho \geqq 0.9$	1/5=0.200	1/5=0
$0.9 > \rho \geqq 0.7$	0/5=0	4/5=0.800
$0.7 > \rho \geqq 0.5$	0/5=0	0/5=0
$0.5 > \rho$	0/5=0	0/5=0
ratio of inestimability	4/5=0.8	10/15=0.667

Table 24 shows the result of estimation of the range of 1-β. The average value of ρ of each subject is substituted for an expression of relations $(1-\beta)^{\frac{1}{\rho}}$, and his 1-$\beta$ is presumed. The ratio of the percentage of subjects who has $\beta < 0.5$, who has anomaly in time preference rate, is quite small means that the apparent anomaly on time preference results from a small substitusion ratio between present and future consumption.

Table 24

range of β	Keiai Univ.	Kyoto Sangyo Univ.
$0.5 > \beta$	1/19=0.052	1/58=0.017
$0.5 = \beta$	1/19=0.052	1/58=0.017
$0.55 \geqq \beta > 0.5$	5/19=0.263	23/58=0.397
$0.6 \geqq \beta > 0.55$	4/19=0.211	17/58=0.293
$0.7 \geqq \beta > 0.6$	4/19=0.211	9/58=0.155
$1 \geqq \beta > 0.7$	4/19=0.211	6/58=0.103

3.3 Results of Risk Attitude Estimation

Ratios of risk aversion, risk-neutrality, and risk preference are as follows. More risk avertors were identified at Kyoto Sangyo University than at Keiai University.

Table 25

□	Q8	ratio of X	ratio of Y
$X(10,10)$	Keiai Univ.	19/26=0.731	7/26=0.269
$Y\left(10, \left\{\begin{array}{l}\text{you get 20 if you win} \\ \text{you get 0 if you lose}\end{array}\right\}\right)$	Kyoto Sangyo Univ.	82/92=0.891	10/92=0.109

Table 2 shows results of estimation of the strength of risk aversion. All replies at Keiai University are effective to estimate α temporally. There was one non-respondent for Q11 at Kyoto Sangyo University; there were six inestimable answers received from subjects at Kyoto Sangyo University. The effective replies in temporary α presumption at Kyoto Sangyo University were 73 .

Distributions of α at Keiai University differed little from the distribution at Kyoto Sangyo University, except for the highest range of α.

Table 26

range of α	ratio at Keiai Unv.	ratio at Kyoto Sangyo Univ.
$\alpha = 1$	0/19=0	2/73=0.027
$1 \geqq \alpha \geqq 0.868$	1/19=0.053	8/73=0.106
$0.868 \geqq \alpha \geqq 0.7565$	1/19=0.053	5/73=0.068
$0.7565 \geqq \alpha \geqq 0.5757$	5/19=0.263	19/73=0.261
$0.5757 \geqq \alpha \geqq 0.4307$	7/19=0.368	20/73=0.273
$0.4307 \geqq \alpha \geqq 0$	5/19=0.263	19/73=0.260

Table 27 shows results of strength estimations for risk-preferent subjects. Although the results from the two universities differ, a common feature exists: there are numerous subjects with α larger than 2.

Table 27

range of α	ratio at Keiai Unv.	ratio at Kyoto Sangyo Univ.
$1.0799 \geqq \alpha > 1$	0/7=0	3/10=0.300
$1.1793 \geqq \alpha \geqq 1.0799$	0/7=0	0/10=0
$1.4749 \geqq \alpha \geqq 1.1793$	1/7=0.143	2/10=0.200
$2.06 \geqq \alpha \geqq 1.4749$	2/7==0.286	1/10=0.100
$2.06 \geqq \alpha \geqq 1.7425$	0/7=0	0/10=0
$2.06 \geqq \alpha \geqq 2$	0/7=0	0/10=0
$\alpha \geqq 2.06$	4/7=0.571	4/10=0.40

3.4 Test of Recursive Utility

The complicated procedures to test recursive utility of equation (1) have already been explained in 2.3.4. We explain only the results of tests in Table 28. Results at both universities of tests yielded the result that 31–37% of answers conformed to recursive utility theory by Epstein and Zin (1989).

Table 28	ratio at Keiai Univ.	ratio at Kyoto Sangyo Univ.
Confirmable	5/16=0.313	21/57=0.368
Unconfirmable	11/16=0.688	36/27=0.632
Inestimable	8/(16+8)=0.333	32/(57+32)=0.359

4 . Conclusions of Our Experiments

4.1 Conclusions

Our experimental results concur approximately with the theoretical results of Epstein and Zin (1989) They partly agree with empirical results of Epstein and Zin (1999). We conclude that Rabin's calibration theorem shows the insufficiency of expected utility theory and that we should adopt new theories.

We conclude the following from our experiments.

1. The test of recursive utility theory by Epstein and Zin (1989) was partially successful. Each participant's decision-making depends upon three factors: the time preference rate, preference for smoothness of intertemporal receipts, and a narrowly defined risk attitude.
2. Nevertheless, these results suggest a more sophisticated theory for explaining intertemporal risk attitude. Some oversight may have engendered the result that more than half of the tests do not conform to the recursive utility model. Correlations among the three factors may explain that non-conformity.
3. We nearly succeeded in estimating values of the three factors in intertemporal decision making of each subject: time preference rate, substitution, and narrowly defined risk aversion (risk attitude).
4. Subjects who exhibited behavior that was entirely according to utility theory were quite few: a few cases demonstrated approximately $\alpha = \rho$., so our experimental facts agree with the statement that expected utility is a special case when parameter ρ (ρ is parameter to decide elasticity σ of intertemporal consumption described by the equation $\sigma = 1/(1-\rho)$) is equal to the degree of narrowly defined risk aversion α.
5. Time preference rates of most people are positive. This conflicts with results in Epstein and Zin (1991) that macro estimators of time preference rates become negative. The positive time preference rates of most participants suggest that experimental methods are superior to empirical estimation of macro data.
6. Inestimable cases are too numerous in these experiments. Our questionnaires should be revised.

4.2 Direction of Further Experiments

We are convinced of the robustness of our conclusions because the important ratios of these results are almost the same. Particularly, the three factors will always be estimated in any experiments that are designed similarly.

Future studies will examine more complicated concepts affecting inter-temporal decision making. First, development will be done to treat decision-making under uncertainty. Thereby, we will be able to distinguish ambiguity aversion from risk aversion. Our experiment is easy to develop and reproduce. For those reason, we can reform our experiments to clarify behaviors in intertemporal decision making in consumption and securities investment.