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# Experimental Analysis of Individual Choice Models Accommodating Risk Variations

Ryoko Wada　Faculty of Economics, Keiai University

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KEIAI UNIVERSITY

〒263-8588
Chiba City Anagawa 1-5-21, Chiba Prefecture, Japan
The Keiai Institute for Area Studies

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# Experimental Analysis of Individual Choice Models Accommodating Risk Variations

Ryoko Wada

*rwada@u-keiai.ac.jp*
*Keiai University,*
*Chiba city Anagawa 1-5-21, Chiba prefecture, Japan*

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## Abstract

This study identifies the theory that best explains individuals' risk preference when all lotteries have equivalent expected returns for the various risks and the worst outcome is not bad. Under this experimental setting, safe outcomes were not selected as much as economic theories suggest. Additionally, some subjects discontinuously take risk. Those who select safe outcomes from the small and middle choice sets select risky lotteries from sets with a larger maximum. The selected lotteries are ranked according to the prediction by expected utility theory, disappointment aversion theory, cumulative prospect theory, security-potential/aspiration (SP/A) theory, the and 1/n rule as a heuristic. The ranks under the superior theory are expected to be higher than the ranks under the other theories. The ranks of selected lotteries show that the selected lotteries are best predicted by expected utility theory, and further by SP/A theory in terms of average of ranks. When the selections' noise within subjects are also considered, SP/A theory is more descriptive of less risk averse subjects and succeeds in explaining discontinuous risk-taking behaviors.

*Keywords:*
, Experimental Finance Behavioral Finance Choice under Risk Expected Utility Theory SP/A Theory $1/n$ Heuristics
*PACS:* JEL classification D81 D91 C51 C12

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## 1. Introduction

Since the general criticism of the expected utility theory (EUT) by Neumann and Morgenstern (1947), more complex theories have been proposed.

However, most experimental studies have found that EUT is not outperformed by these other theories. For instance, Daniels and Keller (1990) find that the lottery-dependent expected utility of Becker and Sarin  (1989), that is, the utility depending on the best and worst attainable outcomes, exhibits a higher probability of predicting subjects' risky choices than EUT. Harless and Camerer  (1994) test the EUT, fanning out theory and fanning in theory of Machina  (1987), prospect theory, and expected value through maximum-likelihood estimation, and find that EUT is not strongly dominated by the other theories. Hey and Orme (1994) test economic theories extensively under the assumption that the choices under risk are described by a core model plus noise, and conclude that EUT plus noise is not strongly dominated by any other models plus noises, including the disappointment aversion theory (DAT), prospective reference theory of Viscusi  (1989), quadratic utility theory developed by Chew,Epstein and Segal (1991), regret aversion theory of Loomes and Sugden  (1982), rank dependent theory by Quiggin, J.  (1991) and Yaari  (1987), and weighted utility theory of Chew.,Hong, S. (1983) and Dekel, E. (1986).  Hey, J. D. (1995),Buschena and Zilberman  (2000), and Schmidt and Neugebauer  (2007) also support this finding. Loomes, Moffatt and Sugden  (2002) find that stochastic variation in selections is an essential feature.

Moreover, Harrison and Rutström (2009) explicitly deny the "representative agent assumption" through the application of statistical mixture models with the grand likelihood specified as a probability-weighted average of the likelihood from EUT and prospect theory, and conclude that EUT slightly surpasses prospect theory overall. By contrast, Bruhin, Fehr-Duda and Epper (2010) estimate a mixture model of the cumulative prospect theory (CPT) by Tversky and Kahneman  (1992) with the error term depending on differences of lottery outcomes endogenously, in which the EUexpected utility maximizer is defined as subjects with specific parameters, and conclude that 80% of subjects weights probabilities and 20% are EU maximizers.

Although there is a consensus on the heterogeneity of individuals, economic theory commonly assumes that individuals are reluctant to take risks and prefer a safe outcome over a risky one for the same expected value. However, the legitimacy of this claim cannot be confirmed in experimental settings wherein there are positive correlations between the expected values and the variances of lotteries. I test this claim directly by keeping the expected value of all lotteries in the choice sets fixed for various levels of risk, including zero risk. Under this setting, all economic theories predict that risk averse subjects will only select safe outcomes. However, the experiment results show that safe outcomes are selected only in 18.1% of all choices. As for consistency, most subjects are inconsistent even in identical choice sets. Furthermore, some subjects who prefer safer lotteries discontinuously select risker lotteries when the maximum outcomes of choice sets are enlarged.

As zero correlation between an expected value and variation makes it difficult to estimate each individual's parameters in each theory from only ten observations, I investigate explanatory economic theories/heuristic by ranking subjects' selection by predictions under EUT, DAT by Gul (1991), CPT with subjective probabilities by Tversky and Kahneman (1992), CPT with objective probabilities, and the "1/n rule" that investment is made into available n kind of securities equally. Additionally, I select the SP/A theory introduced by Lopes (1987) and Lopes and Oden (1999), which is a specific model of the CPT. Instead of introducing the reference point, SP/A theory hypothesizes that individuals enjoy taking risks after ensuring "at least the secured outcomes."

A smaller average rank according to each theory's prediction implies an advantage of that theory, and the standard deviation (noise) of ranks within subjects implies stability in choices. The findings show that average ranks predicted by EUT and SP/A theory are the first and the second highest, respectively, being significantly higher than those of the other theories/heuristics. When I focus on the noise within subjects measured by standard deviation, the SP/A theory has an advantage over EUT. Additionally, only the SP/A theory can explain the observed discontinuous risk preference.

The inferiority of DAT in this experiment is in great contrast to the findings of Choi et al. (2007) that at most 70% of subjects' selections are described by DAT because kinked indifferent curves are observed. Harrison and Rutström (2009) state that the participation fees and experimental rewards affect which model is descriptive: CPT is more descriptive if subjects look upon initial endowment (or participation fee) as a reference point, while EUT is more descriptive if subjects psychologically offset their loss caused by their selection by initial endowment.

From this perspective, the results of Choi et al. (2007) can be attributed to the USD 5 participation fee, which may incentivize subjects to earn some certain additional reward. To avoid an ambiguous interpretation of the participation fee, in this experiment, subjects are given an initial endowment as a principal of investments and are not paid for the participation. This study also provides insights into how initial endowments affect which model is applicable.

The remainder of this paper is organized as follows. Section 2 describes the experimental design and Section 3 details the observations. Section 4 presents the ranks of selected lotteries according to each theory's prediction. Section 5 describes which theory can explain within subjects' choices. Section 6 concludes which theory provides the best explanation of choices and proposes themes for future research.

## 2. Experiment

In 2.1, the intention and design of choice sets are described while 2.2 presents the procedures of two experiments.

### *2.1. Choice Sets*

The subjects are given 10 choice sets comprising the two securities in Table 1. For each choice set, they are asked to select one preferable lottery by investing in two different securities. The return of any lotteries from any choice sets is 1.1 times the principle of JPY 2,000 [1]. The features of the five securities that comprise the choice sets are shown in Table 1. The outcomes of risky assets are contingent on two states: State 1 occurs with probability 1/3 and State 2 occurs with probability 2/3. Security S denotes a safe asset. Security L has the lowest standard deviation (0.08) and can yield payoffs up to JPY 3000 in State 1. Security M has the middle standard deviation (0.32) and can give payoffs up to JPY 3,800 in State 1. Security H has the largest standard deviation (0.72) and can give the largest payoff of JPY 4,600 in State 1, and can give the worst payoff of JPY 1,000 in State 2. Security P has the lowest standard deviation (0.08). Security P is the probability-bet-type (hereafter p-bet-type) security and has negative covariance with securities L, M, and H, and yielding JPY 2,600 in State 2 at maximum. Sets 1, 2, and 3 are equivalent choice sets with a small maximum. Sets 4 and 5 are choice sets with a medium maximum, and Sets 7 and 8 are equivalent choice sets with the highest maximum. Set 10 consists of only p-bet-type lotteries. Sets 1, 2, 5, 7, and 10 are comprised of one safe asset and one risky asset. Sets 3, 4, 6, 8. and 9 are comprised of two risky assets with negative covariance. The sizes of all choice sets are graphically shown in Figure 1.

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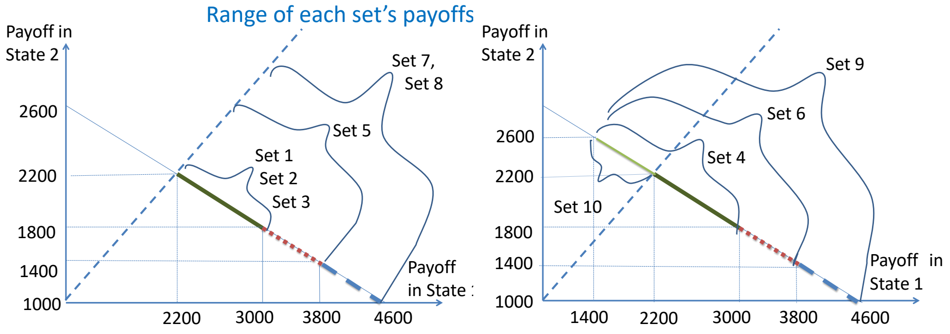
[1] JPY 1,000 is equal to USD 10 at the exchange rate of 100 JPY to USD 1 dollar

| Securities | Rate of Return in State 1 (p$_1$=1/3) | Rate of Return in State 2 (p$_2$=2/3) | Expected returns | Standard variation |
|---|---|---|---|---|
| Safe asset (S) | 1.1 | 1.1 | 1.1 | 0 |
| Low risky asset (L) | 1.5 | 0.9 | 1.1 | 0.08 |
| Middle risky asset(M) | 1.9 | 0.7 | 1.1 | 0.32 |
| High risky asset (H) | 2.3 | 0.5 | 1.1 | 0.72 |
| P-bet type risky asset(P) | 0.7 | 1.3 | 1.1 | 0.08 |

Table 1: Securities that comprise all choice sets



[Sets 1, 2, 3, 5, 7, and 8] [Sets 4, 6, 9, and 10]

Figure 1: Range of expected payoffs in States 1 ($p_1 = \frac{1}{3}$) and 2 ($p_2 = \frac{2}{3}$)

In every choice set, subjects can choose the perfectly safe lottery, $(x_1, x_2) = (2200, 2200)$. Sets 1–3, and Sets 7 and 8 are perfectly identical choice sets comprising different securities (Table 2). The correspondence between domain of investment and range of outcomes in Sets 1–3 are shown in Figure 2. The same structure holds for Sets 7 and 8. This settings is useful to understand how subjects invest. If an infinite risk averse subject is consistent, in Sets 1 and 2, he/she will invest JPY 2,000 only into Security S, and, in Set 3, he/she will invest equally in securities M and P to acquire the JPY 2,200 in any states. (Figure 2). If a subject applies the $1/n$ rule strategy, he/she will always equally divide the JPY 2,000 into two securities, and will earn JPY 2,600 in Set 1, JPY 3,000 in Set 2, and JPY 2,200 in Set 3 if State 1 comes true. Subjects can consistently select a lottery throughout 10 choice sets except for Set 10, if the most preferable lottery is inside the lowest stake choice problems in Sets 1–3. For instance, a subject who selects the lottery $(x_1, x_2) = (2400, 2100)$ in Set 1 can select the same lottery from Sets 1 to 9.

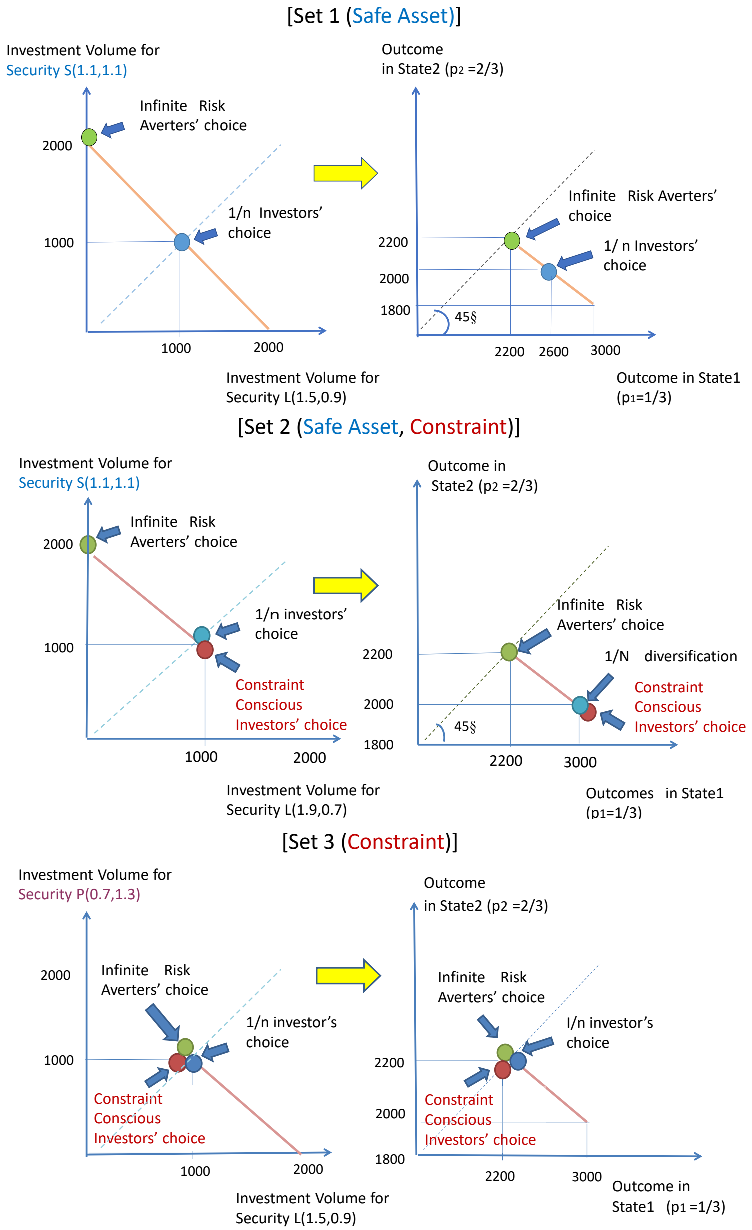


Figure 2: Relationship between investment volumes and payoffs in both states

For the figures on the left-hand side, the x-axes denote investment volumes for securities L, M, and H and the y-axes represent the investment volume for securities S and P. For those on the right-hand side, the x-axes show the payoffs in State 1 and the y-axes represent the payoffs in State 2.

| Set (Q) | Security | Rate of Return | | Existence of constraint | Max and Min of payoff in State 1 |
|---|---|---|---|---|---|
| | | in State 1 ($p_1$=1/3) | in State 2 ($p_2$=2/3) | | |
| Set 1(s) | L | 1.5 | 0.9 | No | 3000 |
| (Q4) | S | 1.1 | 1.1 | No | 2200 |
| Set 2(s,c) | M | 1.9 | 0.7 | Up to 1000 | 3000 |
| (Q8) | S | 1.1 | 1.1 | From 1000 | 2200 |
| Set 3(c) | L | 1.5 | 0.9 | From 1000 | 3000 |
| (Q10) | D | 0.7 | 1.3 | Up to 1000 | 2200 |
| Set 4 | L | 1.5 | 0.9 | No | 3000 |
| (Q1) | D | 0.7 | 1.3 | No | 1400 |
| Set 5(s) | M | 1.9 | 0.7 | No | 3800 |
| (Q2) | S | 1.1 | 1.1 | No | 2200 |
| Set 6 | M | 1.9 | 0.7 | No | 3800 |
| (Q5) | D | 0.7 | 1.3 | No | 1400 |
| Set 7(s) | H | 2.3 | 0.5 | No | 4600 |
| (Q6) | S | 1.1 | 1.1 | No | 2200 |
| Set 8(c) | H | 2.3 | 0.5 | From 500 | 4600 |
| (Q3) | D | 0.7 | 1.3 | Up to 1500 | 2200 |
| Set 9 | H | 2.3 | 0.5 | No | 4600 |
| (Q9) | P | 0.7 | 1.3 | No | 1400 |
| Set 10(s) | P | 0.7 | 1.3 | No | 2600 |
| (Q7) | S | 1.1 | 1.1 | No | 1400 |

Table 2: Choice Problems

(s) is the inclusion of a safe asset in the set and (c) denotes the problems that have a constraint of in the investment volumes.

### *2.2. Procedures*

The two experiments were conducted with a different presentation to subjects: the first one was a pencil-and-paper experiment (hereafter, PP) and the second one used Microsoft Excel on a PC experiment (hereafter, PC). [2] Subjects attended a lecture and trained how to select the best lottery by combining two securities' payoffs while referring to tables with the correspondence between investment volumes and expected outcomes in each state, similar to Table3. In practice, the expected return of investment was one time that of the principal (see the Appendix). I checked subjects' answers to gauge whether they understood how to make the best lottery choice. The details of the procedures for both experiments are described in 2.2.1 and 2.2.2.

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[2] I do not use the term of "treatment," because they only differ in procedures. I chose the PC experiment because I observed many violations of constraints in the PP experiment.

| Investment amount | | Payoff | |
|---|---|---|---|
| security A | security B | in State 1 | in State 2 |
| A(1.5,0.9) | B(0.7,1.3) | with $p_1 = 1/3$ | with $p_2 = 2/3$ |
| 2000 | 0 | 3000 | 1800 |
| 1800 | 200 | 2840 | 1880 |
| 1600 | 400 | 2680 | 1960 |
| 1400 | 600 | 2520 | 2040 |
| 1200 | 800 | 2360 | 2120 |
| 1000 | 1000 | 2200 | 2200 |
| 800 | 1200 | 2040 | 2280 |
| 600 | 1400 | 1880 | 2360 |
| 400 | 1600 | 1720 | 2440 |
| 200 | 1800 | 1560 | 2520 |
| 0 | 2000 | 1400 | 2600 |

Table 3: Payoffs according to the amounts of the two securities in Set 4

### *2.2.1. Pencil-and-Paper Experiment*

All subjects were given the 10 choice sets in Table 2 in five papers. Each paper contains two choice problems: the first paper contains Sets 4 and 5, namely, Q1 and Q2; the second contains Sets 8 and 1, namely, Q3 and Q4; the third contains Sets 6 and 7, namely, Q5 and Q6; the fourth contains Sets 2 and 9, namely, with Q6 and Q7; and the last paper contains Sets 9 and 3, namely, Q9 and Q10. For each choice problem, subjects could recognize the minimum and the maximum from the attached tables, as in Table 3. After having answered previous choice problems, subjects were distributed another paper. They were not allowed to revise their answers retrospectively.

The questions are as follows:

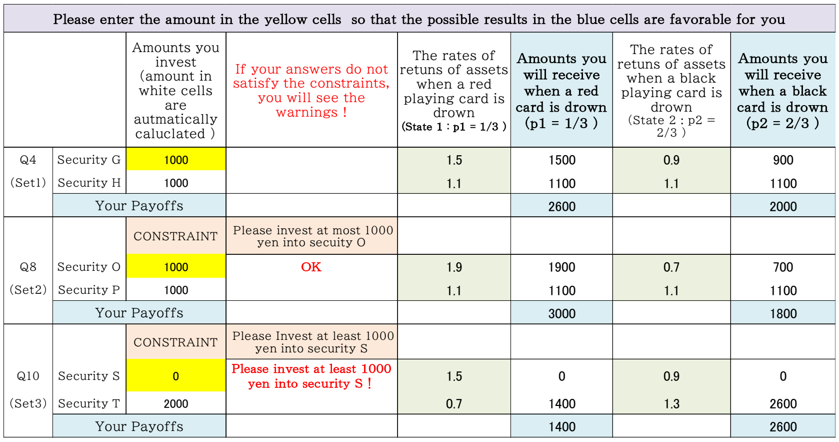
`Assume you are given JPY 2,000. You can invest your money in two securities. Please decide how you would divide this endowment into each security.`

The responses are framed as follows:

`I will invest JPY [ ] in security A and JPY [ ] in security B to acquire JPY [ ] in State 1 and JPY [ ] in State 2.`

### *2.2.2. PC Experiment*

Subjects were distributed printed instructions with practical examples as in the PP experiment. Each subject was given two Excel (Office 97) files with her/his ID on the computer screen. One file was used to learn how to enter the investment amount in cells and the other to answer all choice problems. The order of sets from Q1 to Q10 on the Excel sheet was the same as in the PP experiment. Part of this Excel sheet, translated into



Please enter the amount in the yellow cells so that the possible results in the blue cells are favorable for you

| | | Amounts you invest (amount in white cells are autmatically caluclated ) | If your answers do not satisfy the constraints, you will see the warnings ! | The rates of retuns of assets when a red playing card is drown (State 1 : p1 = 1/3 ) | Amounts you will receive when a red card is drown (p1 = 1/3 ) | The rates of retuns of assets when a black playing card is drown (State 2 : p2 = 2/3 ) | Amounts you will receive when a black card is drown (p2 = 2/3 ) |
|---|---|---|---|---|---|---|---|
| Q4 | Security G | 1000 | | 1.5 | 1500 | 0.9 | 900 |
| (Set1) | Security H | 1000 | | 1.1 | 1100 | 1.1 | 1100 |
| | Your Payoffs | | | | 2600 | | 2000 |
| | | CONSTRAINT | Please invest at most 1000 yen into secuity O | | | | |
| Q8 | Security O | 1000 | OK | 1.9 | 1900 | 0.7 | 700 |
| (Set2) | Security P | 1000 | | 1.1 | 1100 | 1.1 | 1100 |
| | Your Payoffs | | | | 3000 | | 1800 |
| | | CONSTRAINT | Please Invest at least 1000 yen into security S | | | | |
| Q10 | Security S | 0 | Please invest at least 1000 yen into security S ! | 1.5 | 0 | 0.9 | 0 |
| (Set3) | Security T | 2000 | | 0.7 | 1400 | 1.3 | 2600 |
| | Your Payoffs | | | | 1400 | | 2600 |

Figure 3: Example of the Excel sheet for the PC experiment

English, is shown in Figure 3. Different from the PP experiment, the subjects could view all choice problems simultaneously. They could select the most preferable possible outcomes by trying to enter various investment volumes in the yellow cells. In Sets 2, 3, and 8, if subjects entered the investment volume outside the constraint, they got an error messages; otherwise, "OK" was displayed on the screen. After answering all choice problems, subjects were asked to send their answers to the experimenter by e-mail.

In both experiments, as a final step, one choice problem to pay rewards was selected using a public die with 10 faces. Then, one of the 2 states came true with a bag contains 10 red playing cards and 20 black playing cards. This procedure is explained in the Appendix. Rewards are paid up to JPY 1 (values below JPY 1 were rounded up). The average reward was JPY 2375.12, the maximum was JPY 4,600, and the minimum was JPY 1,000.

## 3. Results of Experiments

In 3.1, the average and standard deviation of selection are observed and, in 3.2, the consistency for both in aggregated and within subjects is described.

### *3.1. Basic Data and Observations*

Basic data on the experiments are shown in Table 4 and all choices are shown in Figure 3.1 and Figure 3.1. The choices of each subject are sectioned by the theory that describes them best, as explained in section 4. The outcomes in State 1 of all choice sets, average, standard deviation, and the

| The Day performed | No. of Subjects (Female) | Subjects' attribution | ID | Rewarded Set (State) | Average of Rewards |
|---|---|---|---|---|---|
| May 28, 2008 | 27(1) | Keiai Univ., economics | 101 to 127 | Set 9 (2) | 1595.6 |
| June 11, 2008 | 12(1) | Keiai Univ., economics | 128 to 140 | Set 1 (2) | 2230.7 |
| July 12, 2008 | 9 (8) | Hokenhukushiiryo Univ., nursing | 141 to 148 | Set 8 (2) | 1604.4 |
| May 26, 2009 | 25 (5) | Keio Univ., policy & environment | 201 to 226 | Set 9 (1) | 3183.3 |
| September 9, 2009 | 17 (1) | Keiai Univ., economics | 227 to 240 | Set 5 (1) | 2234.0 |

Table 4: Basic experiment data

frequency of p-bet lotteries are shown. The 48 subjects in the PP experiment are assigned IDs from 101, and the 42 subjects in the PC experiment are assigned IDs from 201. In total, 16 women (ID 110, 137, 140, 141, 142, 143, 144, 145, 146 and 147 in the PP experiment and ID 209, 222, 225, 229, 231, and 241 in the PC experiment) were recruited. The IDs of the female respondents are shown in pink. The average of $x_1$ from Set 1 to Set 10 for all female respondents is 2155, which is much greater than that of the male ones, at 2912.9.

Among the 900 collected observations (90 subjects × 10 choices), 890 observations (473 in the PP experiment and 417 in the PC experiment) are available because of the 10 error choices as below. Two selections of ID 104 in Set 2 and ID 105 in Set 5 are beyond budget. Seven selections of ID 112 in Set 2, 135, 140, 141, 143, 212, 215, and 239 in Set 3 are beyond restrictions in investment volumes. These subjects' selection are shown in red.

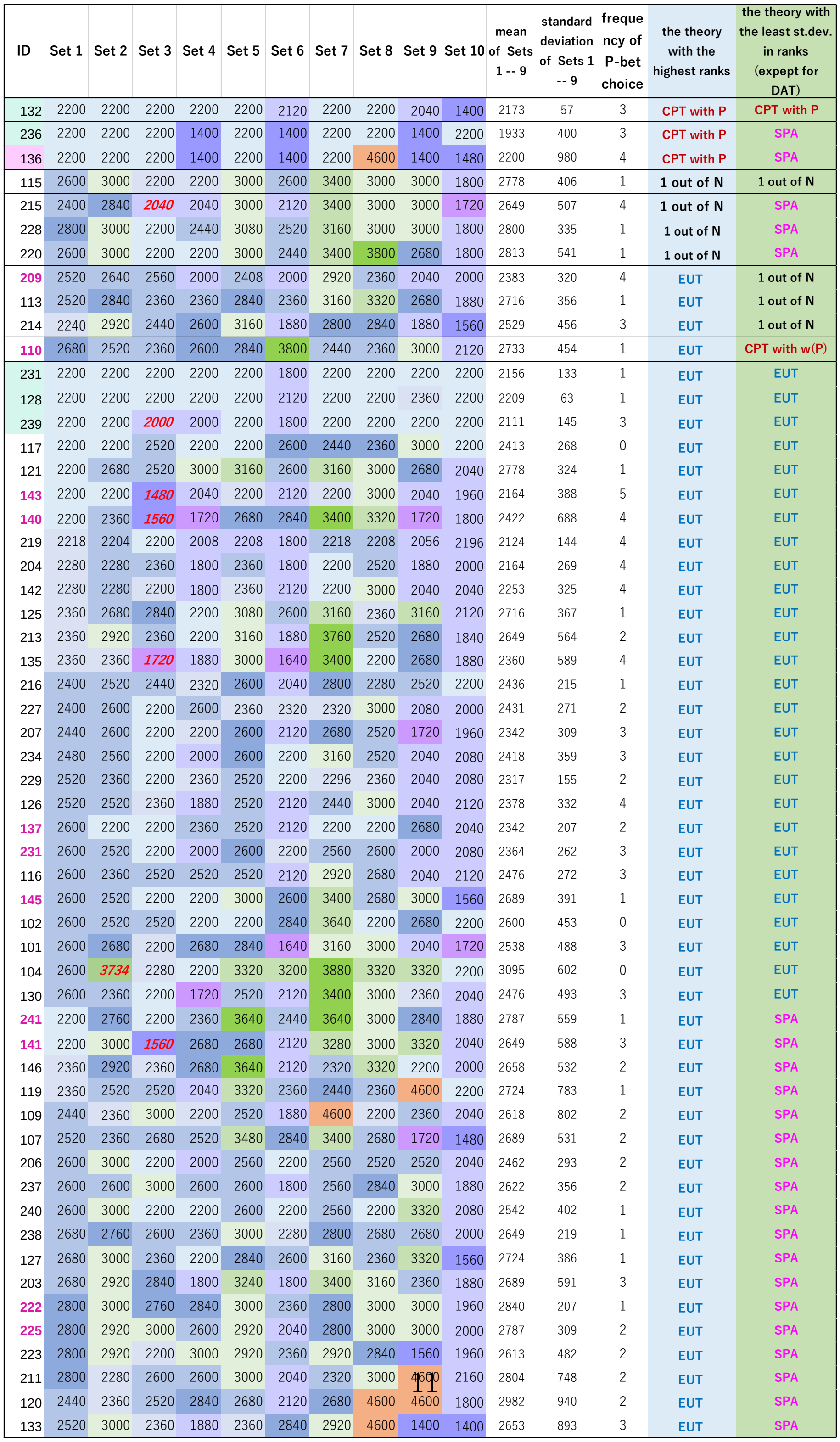
Table 5 provides a summary of the aggregated choices in each set. Figure **??** illustrates all experiments thereof. Sets 1, 2, 3, 5, 6, 8, and 10 include only \$-bets-lotteries; therefore, the larger averages of outcomes in State 1 denote the selection of riskier lotteries. Sets 4, 7, and 9 include both $\$-bet$ lotteries and p-bet lotteries; therefore, the larger averages of outcomes in State 1 do not simply reflect the risk preference. Set 10 includes only p-bet lotteries, and larger averages of outcomes in State 1 denote smaller risks.

### *3.2. Observation for Risk Attitudes and Consistency*

From the subjects' selections, we observe (1) to what extent are safe outcomes preferred and (2) whether subjects select consistently within identical choice sets in 3.2.1, and (3) how subjects take risks between sets and subsets in 3.2.2.

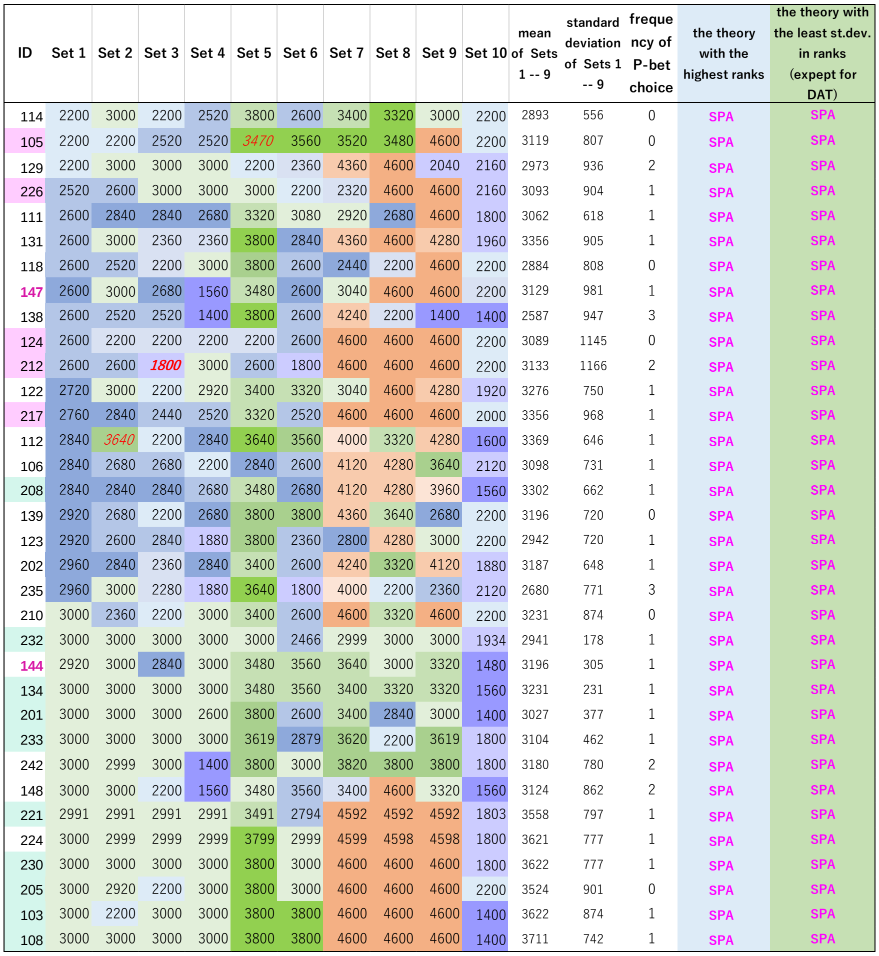
#### *3.2.1. Consistency among identical choice sets*

**Observation 1** All subjects took a certain amount of risk in each of the 10 choice problems.



| ID | Set 1 | Set 2 | Set 3 | Set 4 | Set 5 | Set 6 | Set 7 | Set 8 | Set 9 | Set 10 | mean of Sets 1 -- 9 | standard deviation of Sets 1 -- 9 | frequency of P-bet choice | the theory with the highest ranks | the theory with the least st.dev. in ranks (expept for DAT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 132 | 2200 | 2200 | 2200 | 2200 | 2200 | 2120 | 2200 | 2200 | 2040 | 1400 | 2173 | 57 | 3 | CPT with P | CPT with P |
| 236 | 2200 | 2200 | 2200 | 1400 | 2200 | 1400 | 2200 | 2200 | 1400 | 2200 | 1933 | 400 | 3 | CPT with P | SPA |
| 136 | 2200 | 2200 | 2200 | 1400 | 2200 | 1400 | 2200 | 4600 | 1400 | 1480 | 2200 | 980 | 4 | CPT with P | SPA |
| 115 | 2600 | 3000 | 2200 | 2200 | 3000 | 2600 | 3400 | 3000 | 3000 | 1800 | 2778 | 406 | 1 | **1 out of N** | **1 out of N** |
| 215 | 2400 | 2840 | ***2040*** | 2040 | 3000 | 2120 | 3400 | 3000 | 3000 | 1720 | 2649 | 507 | 4 | **1 out of N** | SPA |
| 228 | 2800 | 3000 | 2200 | 2440 | 3080 | 2520 | 3160 | 3000 | 3000 | 1800 | 2800 | 335 | 1 | **1 out of N** | SPA |
| 220 | 2600 | 3000 | 2200 | 2200 | 3000 | 2440 | 3400 | 3800 | 2680 | 1800 | 2813 | 541 | 1 | **1 out of N** | SPA |
| **209** | 2520 | 2640 | 2560 | 2000 | 2408 | 2000 | 2920 | 2360 | 2040 | 2000 | 2383 | 320 | 4 | EUT | **1 out of N** |
| 113 | 2520 | 2840 | 2360 | 2360 | 2840 | 2360 | 3160 | 3320 | 2680 | 1880 | 2716 | 356 | 1 | EUT | **1 out of N** |
| 214 | 2240 | 2920 | 2440 | 2600 | 3160 | 1880 | 2800 | 2840 | 1880 | 1560 | 2529 | 456 | 3 | EUT | **1 out of N** |
| **110** | 2680 | 2520 | 2360 | 2600 | 2840 | 3800 | 2440 | 2360 | 3000 | 2120 | 2733 | 454 | 1 | EUT | CPT with w(P) |
| 231 | 2200 | 2200 | 2200 | 2200 | 2200 | 1800 | 2200 | 2200 | 2200 | 2200 | 2156 | 133 | 1 | EUT | EUT |
| 128 | 2200 | 2200 | 2200 | 2200 | 2200 | 2120 | 2200 | 2200 | 2360 | 2200 | 2209 | 63 | 1 | EUT | EUT |
| 239 | 2200 | 2200 | ***2000*** | 2000 | 2200 | 1800 | 2200 | 2200 | 2200 | 2200 | 2111 | 145 | 3 | EUT | EUT |
| 117 | 2200 | 2200 | 2520 | 2200 | 2200 | 2600 | 2440 | 2360 | 3000 | 2200 | 2413 | 268 | 0 | EUT | EUT |
| 121 | 2200 | 2680 | 2520 | 3000 | 3160 | 2600 | 3160 | 3000 | 2680 | 2040 | 2778 | 324 | 1 | EUT | EUT |
| **143** | 2200 | 2200 | ***1480*** | 2040 | 2200 | 2120 | 2200 | 3000 | 2040 | 1960 | 2164 | 388 | 5 | EUT | EUT |
| **140** | 2200 | 2360 | ***1560*** | 1720 | 2680 | 2840 | 3400 | 3320 | 1720 | 1800 | 2422 | 688 | 4 | EUT | EUT |
| 219 | 2218 | 2204 | 2200 | 2008 | 2208 | 1800 | 2218 | 2208 | 2056 | 2196 | 2124 | 144 | 4 | EUT | EUT |
| 204 | 2280 | 2280 | 2360 | 1800 | 2360 | 1800 | 2200 | 2520 | 1880 | 2000 | 2164 | 269 | 4 | EUT | EUT |
| 142 | 2280 | 2280 | 2200 | 1800 | 2360 | 2120 | 2200 | 3000 | 2040 | 2040 | 2253 | 325 | 4 | EUT | EUT |
| 125 | 2360 | 2680 | 2840 | 2200 | 3080 | 2600 | 3160 | 2360 | 3160 | 2120 | 2716 | 367 | 1 | EUT | EUT |
| 213 | 2360 | 2920 | 2360 | 2200 | 3160 | 1880 | 3760 | 2520 | 2680 | 1840 | 2649 | 564 | 2 | EUT | EUT |
| 135 | 2360 | 2360 | ***1720*** | 1880 | 3000 | 1640 | 3400 | 2200 | 2680 | 1880 | 2360 | 589 | 4 | EUT | EUT |
| 216 | 2400 | 2520 | 2440 | 2320 | 2600 | 2040 | 2800 | 2280 | 2520 | 2200 | 2436 | 215 | 1 | EUT | EUT |
| 227 | 2400 | 2600 | 2200 | 2600 | 2360 | 2320 | 2320 | 3000 | 2080 | 2000 | 2431 | 271 | 2 | EUT | EUT |
| 207 | 2440 | 2600 | 2200 | 2200 | 2600 | 2120 | 2680 | 2520 | 1720 | 1960 | 2342 | 309 | 3 | EUT | EUT |
| 234 | 2480 | 2560 | 2200 | 2000 | 2600 | 2200 | 3160 | 2520 | 2040 | 2080 | 2418 | 359 | 3 | EUT | EUT |
| 229 | 2520 | 2360 | 2200 | 2360 | 2520 | 2200 | 2296 | 2360 | 2040 | 2080 | 2317 | 155 | 2 | EUT | EUT |
| 126 | 2520 | 2520 | 2360 | 1880 | 2520 | 2120 | 2440 | 3000 | 2040 | 2120 | 2378 | 332 | 4 | EUT | EUT |
| **137** | 2600 | 2200 | 2200 | 2360 | 2520 | 2120 | 2200 | 2200 | 2680 | 2040 | 2342 | 207 | 2 | EUT | EUT |
| **231** | 2600 | 2520 | 2200 | 2000 | 2600 | 2200 | 2560 | 2600 | 2000 | 2080 | 2364 | 262 | 3 | EUT | EUT |
| 116 | 2600 | 2360 | 2520 | 2520 | 2520 | 2120 | 2920 | 2680 | 2040 | 2120 | 2476 | 272 | 3 | EUT | EUT |
| **145** | 2600 | 2520 | 2200 | 2200 | 3000 | 2600 | 3400 | 2680 | 3000 | 1560 | 2689 | 391 | 1 | EUT | EUT |
| 102 | 2600 | 2520 | 2520 | 2200 | 2200 | 2840 | 3640 | 2200 | 2680 | 2200 | 2600 | 453 | 0 | EUT | EUT |
| 101 | 2600 | 2680 | 2200 | 2680 | 2840 | 1640 | 3160 | 3000 | 2040 | 1720 | 2538 | 488 | 3 | EUT | EUT |
| 104 | 2600 | ***3734*** | 2280 | 2200 | 3320 | 3200 | 3880 | 3320 | 3320 | 2200 | 3095 | 602 | 0 | EUT | EUT |
| 130 | 2600 | 2360 | 2200 | 1720 | 2520 | 2120 | 3400 | 3000 | 2360 | 2040 | 2476 | 493 | 3 | EUT | EUT |
| **241** | 2200 | 2760 | 2200 | 2360 | 3640 | 2440 | 3640 | 3000 | 2840 | 1880 | 2787 | 559 | 1 | EUT | SPA |
| **141** | 2200 | 3000 | ***1560*** | 2680 | 2680 | 2120 | 3280 | 3000 | 3320 | 2040 | 2649 | 588 | 3 | EUT | SPA |
| 146 | 2360 | 2920 | 2360 | 2680 | 3640 | 2120 | 2320 | 3320 | 2200 | 2000 | 2658 | 532 | 2 | EUT | SPA |
| 119 | 2360 | 2520 | 2520 | 2040 | 3320 | 2360 | 2440 | 2360 | 4600 | 2200 | 2724 | 783 | 1 | EUT | SPA |
| 109 | 2440 | 2360 | 3000 | 2200 | 2520 | 1880 | 4600 | 2200 | 2360 | 2040 | 2618 | 802 | 2 | EUT | SPA |
| 107 | 2520 | 2360 | 2680 | 2520 | 3480 | 2840 | 3400 | 2680 | 1720 | 1480 | 2689 | 531 | 2 | EUT | SPA |
| 206 | 2600 | 3000 | 2200 | 2000 | 2560 | 2200 | 2560 | 2520 | 2520 | 2040 | 2462 | 293 | 2 | EUT | SPA |
| 237 | 2600 | 2600 | 3000 | 2600 | 2600 | 1800 | 2560 | 2840 | 3000 | 1880 | 2622 | 356 | 2 | EUT | SPA |
| 240 | 2600 | 3000 | 2200 | 2200 | 2600 | 2200 | 2560 | 2200 | 3320 | 2080 | 2542 | 402 | 1 | EUT | SPA |
| 238 | 2680 | 2760 | 2600 | 2360 | 3000 | 2280 | 2800 | 2680 | 2680 | 2000 | 2649 | 219 | 1 | EUT | SPA |
| 127 | 2680 | 3000 | 2360 | 2200 | 2840 | 2600 | 3160 | 2360 | 3320 | 1560 | 2724 | 386 | 1 | EUT | SPA |
| 203 | 2680 | 2920 | 2840 | 1800 | 3240 | 1800 | 3400 | 3160 | 2360 | 1880 | 2689 | 591 | 3 | EUT | SPA |
| **222** | 2800 | 3000 | 2760 | 2840 | 3000 | 2360 | 2800 | 3000 | 3000 | 1960 | 2840 | 207 | 1 | EUT | SPA |
| **225** | 2800 | 2920 | 3000 | 2600 | 2920 | 2040 | 2800 | 3000 | 3000 | 2000 | 2787 | 309 | 2 | EUT | SPA |
| 223 | 2800 | 2920 | 2200 | 3000 | 2920 | 2360 | 2920 | 2840 | 1560 | 1960 | 2613 | 482 | 2 | EUT | SPA |
| 211 | 2800 | 2280 | 2600 | 2600 | 3000 | 2040 | 2320 | 3000 | 4600 | 2160 | 2804 | 748 | 2 | EUT | SPA |
| 120 | 2440 | 2360 | 2520 | 2840 | 2680 | 2120 | 2680 | 4600 | 4600 | 1800 | 2982 | 940 | 2 | EUT | SPA |
| 133 | 2520 | 3000 | 2360 | 1880 | 2360 | 2840 | 2920 | 4600 | 1400 | 1400 | 2653 | 893 | 3 | EUT | SPA |

Figure 4: All selections 1



| ID | Set 1 | Set 2 | Set 3 | Set 4 | Set 5 | Set 6 | Set 7 | Set 8 | Set 9 | Set 10 | mean of Sets 1 -- 9 | standard deviation of Sets 1 -- 9 | frequency of P-bet choice | the theory with the highest ranks | the theory with the least st.dev. in ranks (expept for DAT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 114 | 2200 | 3000 | 2200 | 2520 | 3800 | 2600 | 3400 | 3320 | 3000 | 2200 | 2893 | 556 | 0 | SPA | SPA |
| 105 | 2200 | 2200 | 2520 | 2520 | *3470* | 3560 | 3520 | 3480 | 4600 | 2200 | 3119 | 807 | 0 | SPA | SPA |
| 129 | 2200 | 3000 | 3000 | 3000 | 2200 | 2360 | 4360 | 4600 | 2040 | 2160 | 2973 | 936 | 2 | SPA | SPA |
| 226 | 2520 | 2600 | 3000 | 3000 | 3000 | 2200 | 2320 | 4600 | 4600 | 2160 | 3093 | 904 | 1 | SPA | SPA |
| 111 | 2600 | 2840 | 2840 | 2680 | 3320 | 3080 | 2920 | 2680 | 4600 | 1800 | 3062 | 618 | 1 | SPA | SPA |
| 131 | 2600 | 3000 | 2360 | 2360 | 3800 | 2840 | 4360 | 4600 | 4280 | 1960 | 3356 | 905 | 1 | SPA | SPA |
| 118 | 2600 | 2520 | 2200 | 3000 | 3800 | 2600 | 2440 | 2200 | 4600 | 2200 | 2884 | 808 | 0 | SPA | SPA |
| **147** | 2600 | 3000 | 2680 | 1560 | 3480 | 2600 | 3040 | 4600 | 4600 | 2200 | 3129 | 981 | 1 | SPA | SPA |
| 138 | 2600 | 2520 | 2520 | 1400 | 3800 | 2600 | 4240 | 2200 | 1400 | 1400 | 2587 | 947 | 3 | SPA | SPA |
| 124 | 2600 | 2200 | 2200 | 2200 | 2200 | 2600 | 4600 | 4600 | 4600 | 2200 | 3089 | 1145 | 0 | SPA | SPA |
| 212 | 2600 | 2600 | ***1800*** | 3000 | 2600 | 1800 | 4600 | 4600 | 4600 | 2200 | 3133 | 1166 | 2 | SPA | SPA |
| 122 | 2720 | 3000 | 2200 | 2920 | 3400 | 3320 | 3040 | 4600 | 4280 | 1920 | 3276 | 750 | 1 | SPA | SPA |
| 217 | 2760 | 2840 | 2440 | 2520 | 3320 | 2520 | 4600 | 4600 | 4600 | 2000 | 3356 | 968 | 1 | SPA | SPA |
| 112 | 2840 | *3640* | 2200 | 2840 | 3640 | 3560 | 4000 | 3320 | 4280 | 1600 | 3369 | 646 | 1 | SPA | SPA |
| 106 | 2840 | 2680 | 2680 | 2200 | 2840 | 2600 | 4120 | 4280 | 3640 | 2120 | 3098 | 731 | 1 | SPA | SPA |
| 208 | 2840 | 2840 | 2840 | 2680 | 3480 | 2680 | 4120 | 4280 | 3960 | 1560 | 3302 | 662 | 1 | SPA | SPA |
| 139 | 2920 | 2680 | 2200 | 2680 | 3800 | 3800 | 4360 | 3640 | 2680 | 2200 | 3196 | 720 | 0 | SPA | SPA |
| 123 | 2920 | 2600 | 2840 | 1880 | 3800 | 2360 | 2800 | 4280 | 3000 | 2200 | 2942 | 720 | 1 | SPA | SPA |
| 202 | 2960 | 2840 | 2360 | 2840 | 3400 | 2600 | 4240 | 3320 | 4120 | 1880 | 3187 | 648 | 1 | SPA | SPA |
| 235 | 2960 | 3000 | 2280 | 1880 | 3640 | 1800 | 4000 | 2200 | 2360 | 2120 | 2680 | 771 | 3 | SPA | SPA |
| 210 | 3000 | 2360 | 2200 | 3000 | 3400 | 2600 | 4600 | 3320 | 4600 | 2200 | 3231 | 874 | 0 | SPA | SPA |
| 232 | 3000 | 3000 | 3000 | 3000 | 3000 | 2466 | 2999 | 3000 | 3000 | 1934 | 2941 | 178 | 1 | SPA | SPA |
| **144** | 2920 | 3000 | 2840 | 3000 | 3480 | 3560 | 3640 | 3000 | 3320 | 1480 | 3196 | 305 | 1 | SPA | SPA |
| 134 | 3000 | 3000 | 3000 | 3000 | 3480 | 3560 | 3400 | 3320 | 3320 | 1560 | 3231 | 231 | 1 | SPA | SPA |
| 201 | 3000 | 3000 | 3000 | 2600 | 3800 | 2600 | 3400 | 2840 | 3000 | 1400 | 3027 | 377 | 1 | SPA | SPA |
| 233 | 3000 | 3000 | 3000 | 3000 | 3619 | 2879 | 3620 | 2200 | 3619 | 1800 | 3104 | 462 | 1 | SPA | SPA |
| 242 | 3000 | 2999 | 3000 | 1400 | 3800 | 3000 | 3820 | 3800 | 3800 | 1800 | 3180 | 780 | 2 | SPA | SPA |
| 148 | 3000 | 3000 | 2200 | 1560 | 3480 | 3560 | 3400 | 4600 | 3320 | 1560 | 3124 | 862 | 2 | SPA | SPA |
| 221 | 2991 | 2991 | 2991 | 2991 | 3491 | 2794 | 4592 | 4592 | 4592 | 1803 | 3558 | 797 | 1 | SPA | SPA |
| 224 | 3000 | 2999 | 2999 | 2999 | 3799 | 2999 | 4599 | 4598 | 4598 | 1800 | 3621 | 777 | 1 | SPA | SPA |
| 230 | 3000 | 3000 | 3000 | 3000 | 3800 | 3000 | 4600 | 4600 | 4600 | 1800 | 3622 | 777 | 1 | SPA | SPA |
| 205 | 3000 | 2920 | 2200 | 3000 | 3800 | 3000 | 4600 | 4600 | 4600 | 2200 | 3524 | 901 | 0 | SPA | SPA |
| 103 | 3000 | 2200 | 3000 | 3000 | 3800 | 3800 | 4600 | 4600 | 4600 | 1400 | 3622 | 874 | 1 | SPA | SPA |
| 108 | 3000 | 3000 | 3000 | 3000 | 3800 | 3800 | 4600 | 4600 | 4600 | 1400 | 3711 | 742 | 1 | SPA | SPA |

Figure 5: All selections 2

| Set | Average | | | Standard Deviation | | |
|---|---|---|---|---|---|---|
| | All | △ PP | △ PC | All | △ PP | △ PC |
| 1 | 2587.2 | - 49.7 | + 56.8 | 255.6 | - 14.4 | + 22.1 |
| 2 | 2665.4 | - 60.2 | + 65.9 | 301.0 | + 8.8 | - 92.9 |
| 3 | 2489.5 | - 22.2 | + 25.1 | 308.4 | - 27.6 | + 30.4 |
| 4 | 2372.9 | - 41.2 | + 40.1 | 458.6 | + 1.9 | - 1.2 |
| 5 | 2994.7 | + 1.9 | - 2.2 | 541.4 | + 32.1 | - 31 |
| 6 | 2470.0 | +182.5 | -208.6 | +63.6 | + 58.7 | -161.1 |
| 7 | 3239.8 | + 15.2 | - 17.3 | 782.6 | - 38.8 | + 50.9 |
| 8 | 3165.3 | + 71.4 | - 81.5 | 865.7 | - 18.9 | - 38.3 |
| 9 | 3035.4 | + 11.3 | - 12.9 | 1018.2 | + 0.7 | + 11.4 |
| 10 | 1929.0 | -29 | 33.21 | 250.0 | + 39.2 | - 55.7 |

Table 5: Averages and standard deviations in State

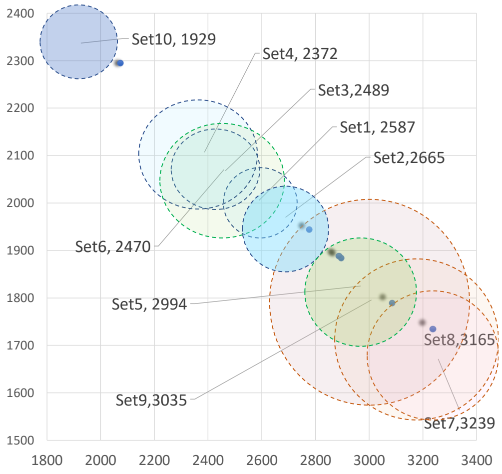


Figure 6: Averages and standard deviations in State 1 of all experiments
The small points in the circles show each average payoff in both states for each choice set. The x-axis shows the payoffs in State 1 and the y-axis the payoffs in State 2. The sizes of radii show the size of noises measured by the standard deviations from averages

**Support** Subjects selected the perfect safe lottery 163/900 times (18.1%) in total: 91/480 times (19.0%) in the PP experiment and 72/420 times (17.1%) in the PC experiment. No subjects selected the perfectly safe lotteries throughout all 10 choice problems, although they could do so.

Observation 1 does not support EUT, CPT, and DAT, which rank safe outcomes first.

**Observation 2** No subject chose consistently throughout all choice sets, except for Set 10, but some subjects' choices were almost consistent.

**Support** Eight out of ninety (8.8%) subjects' selection are almost perfectly consistent.[3] ID 231 selected perfect safe outcomes, except for Set 6. ID 128 selected perfect safe outcomes, except for Sets 6 and 9. ID 236 selected perfect safe outcomes in all sets with \$-bet choice sets and selected $(x_1, x_2) = (1800, 2400)$ in all sets with the p-bet zone. ID 232 consistently selected $(x_1, x_2) = (3000, 1800)$, except for Sets 5 and 6 and 10. ID 108 selected the largest risk in all choice sets. ID 224 selected almost the largest risk in all choice sets. IDs 230 and 103 took risk consistently except for one choice set.

**Observation 3** Most subjects' choices have some variations, even in the identical choice sets.

**Support** Sets 1, 2, and 3 are the identical small stake choice sets and Sets 7 and 8 are identical large stake choice sets. As for Sets 1, 2 and 3, 15 out of the 90 subjects (16.6%) selected perfectly or almost perfectly consistent lotteries. In the PP experiment, 14.2%, 5 subjects (IDs 108, 128, 132, 134, and 136) out of 48, in the PC experiment, 19.5% of subjects (8 subjects (IDs 201, 208, 221, 230, 231, 232, 233, and 236) out of 42. These subjects' cells are colored in blue-green (except for No. 136 in pink, which shows inconsistency). As for the Sets 7 and 8, 16.7% (15/90 of subjects) were consistent: In the PP experiment, 16.3% (8/49), and in the PC experiment, 16.7% (7/42) were consistent.

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[3] Consistency of choices is judged as follows. Because Sets 4–9 have the smallest choice sets (Sets 1–3) as their subsets, if a subject selects $2200 < x_1 < 3000$ in Sets 1–4, the lottery could be the optimal one for him/her, and he/she can select perfectly consistent throughout the nine choices, except for Set 10.

After elimination of 24 subjects who selected p-bet lotteries, from Set 9, 66 choice from the dollar-bet zone can be compared with Sets 7 and 8, 3 out of subjects 37 (8.1%) (IDs 103, 108, and 124) in the PP experiment, and 7 out of 25 (28.0%)subjects (IDs 205, 212, 217, 221, 230, 231 and 239) in the PC experiment are consistent in their selections among Sets 7, 8 and 9. These subjects' cells are colored in blue-green (except for IDs 205 and 230 in pink cells for inconsistent risk taking). In the PC experiment, because subject could view all choice sets simultaneously, consistency is higher than in the PP experiment.

**Observation 4** Small and large stake treatments lead to different choices.

**support** From the binary t-test for selection in the small identical choice sets (Table 6), $Set2 > Set1 > Set3$ are observed in all experiments are observed (In the PP experiment, only $Set2 > Set3$ are observed). As for the choice from middle stake sets only in the \$-bet-zone, $Set5 > Set6$ are observed, and for the large stake sets, $Set7 = Set9 > Set8$ are observed.

For reasons of inconsistency, three behavioral hypothesis are possible.

**Safe asset framing** If choice sets contain safe security S, subjects are possibly encouraged to take greater risk because they could easily recognize how much they invest into the safe asset. I name this hypothesis the "safe asset framing effect."

**Constraint effect** If these constraints work as an anchoring, subjects' decision-making may be dragged up to the constraint. I name this effect the "constraint effect."

$1/n$ **rule** Subjects can possibly apply a simple rule of thumb.

"Safe asset framing effect" seems to matter for the choices from the small and/or middle choice sets because of the observation Set 1 > Set 3 and Set 2 > Set 3; however, Set 7(s) = Set 8(c) implies that safe asset framing does not matter for the choices from the large choice sets.

If the "constraint" matters, Set 2 > Set 3 is predicted, because, in Set 2, the constraint "you can invest security M up to JPY 1,000" may induce subjects to select $(x_1, x_2) = (3000{,}1800)$, and in Set 3, the constraint "you can invest security P up to JPY 1,000" may induce subjects to select $(x_1, x_2)$

| $H_0$ | t-value and p- value of $Pr(\|T\| > \|t\|)$ ) | | |
|---|---|---|---|
| | All Experiments<br>(p-value) | PP Experiment<br>(p-value) | PC Experiment<br>(p-value) |
| Set 1(s) = Set 2 (s,c) | t(86) = -2.6409**<br>(0.0098) | t(45) = -1.5762<br>(0.1220) | t(41)= -2.3065*<br>(0.0262) |
| Set 1(s) = Set 3 (c) | t(82) = 3.4797***<br>(0.0008) | t(43) = 1.9599<br>(0.0565) | t(38) = 3.0311**<br>(0.0044) |
| Set 2(s,c) = Set 3 (c) | t(80) = 4.5501***<br>(0.0000) | t(41) = 2.3726*<br>(0.0224) | t(38) = 4.2244***<br>(0.0001) |
| Set 5(s) = Set 6 - Set 10 | t(56) = 6.5153***<br>(0.0000) | t(31) = 2.5414*<br>(0.0163) | t(25) = 12.7642***<br>(0.0000) |
| Set 7(s) = Set 8(c) | t(89) = 0.8777<br>(0.3825) | t(46) = 0.1373<br>(0.8913) | t(41)= 1.3883<br>(0.1726) |
| Set 7(s) = Set 9 - Set 10 | t(66) = -0.4004<br>(0.6902) | t(35) = -0.6327<br>(0.5310) | t(30) = 0.1911<br>(0.8497) |
| Set8(c) = Set 9 - Set 10 | t(75) = -2.1513*<br>(0.0351) | t(43) = -1.5840<br>(0.1222) | t(31) = -1.4928<br>(0.1456) |

Table 6: Test of consistency for identical choice sets

The numbers in the t(.) shows the degrees of freedom.
$*$ shows that the result of the t-test (p-value) is significant at the 5% level.
$**$ shows that the result of the t-test (p-value) is significant at the 1% level.
$***$ shows that the result of the t-test (p-value) is significant at the 0.1% level.

= (2200,2200). Similarly, the constraint in Set 8, "you can invest security P up to JPY 1,500," may induce the subject to select $(x_1, x_2)$ = (2200,2200). Under no constraint in Set 7, the prediction of Set 7 > Set 8 in the average of $x_1$ is obtained; however, it contradicts the observation of Set 7 = Set 8

An application of the $1/n$ rule predicts that the averages of $x_1$ become Set 2 > Set 1 > Set 3 and Set 7 > Set9 = Set 8. As a typical example, if a subject invests the JPY 2,000 equally into two securities, the $x_1$ in Set 2 becomes JPY 3,000 and the $x_1$ in Set 1 becomes JPY 2,600, and $x_1$ in Set 3 is JPY 2,200 (see Figure 2). Observation 4 suggests that the 1/n rule is valid only for the small stake choice problems because the observation of $x_1$ in Set 7 = Set 8 contradicts the 1/n rule's prediction (Table6).

### *3.2.2. Selection of Sets and their Subsets*

Observing subjects' choices between sets and subsets may help understand the inconsistency within the identical sets.

**Observation 5** As aggregated behaviors, the subjects take risk proportionally to the maximum outcomes in State 1 of the choice sets.

| $H_0$ | t-value and p-value of $Pr(\|T\| > \|t\|)$ | | |
|---|---|---|---|
| | All Experiments (p-value) | PP Experiment (p-value) | PC Experiment (p-value) |
| Set 1(s) $\subset$ Set 5 (c) | t(88) = -8.8963*** | t(46) = -6.4673*** | t(41) = -6.2894*** |
| | (0.0000) | (0.0000) | (0.0000) |
| Set 1(s) $\subset$ Set 7 (s) | t(89) = -9.0927 *** | t(45) = -7.3880*** | t(38) = -5.42880*** |
| | (0.0000) | (0.0000) | (0.0000) |
| Set 5(c) $\subset$ Set 7 | t(88) = -3.4162** | t(46) = -2.2481** | t(38) = -2.7593** |
| | (0.0010) | (0.0294) | (0.0086) |

Table 7: Selections between sets and subsets

The numbers in the t(.) shows the degrees of freedom.

$*$ shows that the result of the t-test (p-value) is significant at the 5% level.

$**$ shows that the result of the t-test (p-value) is significant at the 1% level.

$***$ shows that the result of the t-test (p-value) is significant at the 0.1% level.

**support** In Table 7, Set 1 $\subset$ Set 5 $\subset$ Set 7 is obtained. To compare the selection through t-test, the subjects who selected $x_1 = 3000$ in Set 1 are omitted to distinguish consistent risk takers.

**Observation 6** Some subjects' risk-taking behaviors were discontinuous.

**support** Although IDs 105, 120, 124, 133, 136, 217, and 212 selected safer lotteries both in choice sets with small and middle stake choice sets, they preferred one of the riskiest lotteries from the large stake choice sets (these ID are colored in pink in Figure 3.1). Specifically, ID 136 selected perfect safe lotteries in Sets 1, 2, 3, 5, and 7, but then selected the riskiest lotteries in Set 8.

Although Observation 5 shows that the majority of subjects apply the $1/n$ rule, Observations 4 and 6 do not support it. Altogether, subjects' inconsistency is not fully explained by the behavioral hypothesis above. Specifically, Observation 6 suggests that choices have some regularities, but that are not enough to give up the explanation by economic theories. Therefore, this article takes another approach to identifying the theory that better describes subjects' selection.

## 4. Ranking the Selected Lotteries by Predictions of Theories

Here, the selected lotteries are ranked by prediction according to testable theories. In 4.1, the assumption to calculate values is shown; then, in 4.2, the choices are ranked by the valuation of each theory.

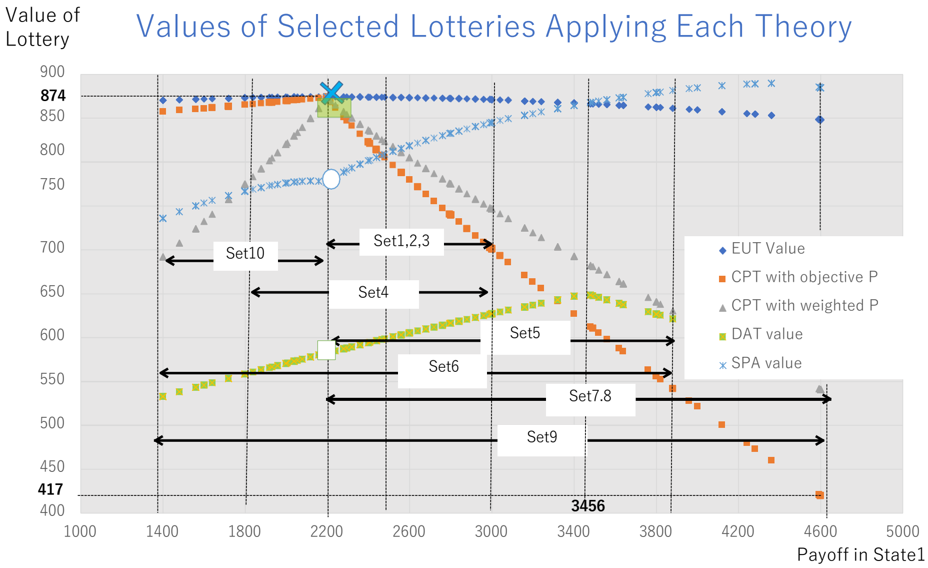

Figure 7: Values of Selected Lotteries under Each Theory

### *4.1. Selected Lotteries' Values of Each Theory*

To describe the selections in this experiment, I consider the EUT, DAT, and CPT as basic economic theories. In addition, SP/A theory by Lopes (1987) and Lopes and Oden  (1999) is considered because this psychological theory can accommodate discontinuous risk preferences in Observation 6. To identify which theory/heuristics best predicts the observed choices, I rank the selected lotteries on a scale from 1 to 11 by each theory's predictions. If a theory/heuristics describes the subjects' selections better than the other theories do, the average of ranks must be higher and the standard deviations smaller.

In Figure 4.1, the selected lotteries' outcomes in State 1 ($x_1$) are drawn on the horizontal axis and the values of EUT, DAT, CPT, and SP/A theory at every $x_1$ are drawn on the vertical axis, as well as the range of choice sets. The details and assumptions of the calculations of the values according to each theory are provided below.

#### *4.1.1. Expected Utility Theory*

If a subject is an expected value maximizer, his/her values of the lotteries are expressed as:

$$EV = \sum_{i=1}^{n} p_i x_i.$$

For the expected value maximizer, all lotteries are indifferent, and the selection must be perfectly random. However, Observations 1 to 6 show that subjects select their lotteries with some consistency/regularity to some extent; therefore, I exclude the possibility that the majority of subjects are expected value maximizers.

EUT is characterized by a concave valuation of outcomes:

$$EU = \sum_{i=1}^{n} p_i u(x_i).$$

An endogenous estimation of each individual's risk parameter is difficult because all choices have an inconsistency for identical expected values. Therefore, I assume $u(x) = x^{\alpha}$, as estimated by Tversky and Kahneman (1992), to obtain

$$V_{EUT} = \frac{1}{3}x_1^{0.88} + \frac{2}{3}x_2^{0.88}.$$

EUT maximizers rank perfectly safe lottery $(x_1, x_2) = (2200, 2200)$ first, with $V_{EU} = 874$, and the riskiest lottery in Sets 7–9 is ranked last, with $V_{EUT} = 871$ (See Figure 4.1). Note that whatever the size of $\alpha$ ¡ 1 is, the structure of ranking by EUT is maintained.

### *4.1.2. Disappointment Aversion Theory*

DAT was developed by Gul (1991) and includes an additional parameter to decide on the elation/disappointment thresholds in addition to risk attitudes. I use the formation of DAT valuation as in Choi et al. (2007):

$$V_{DAT} = min\{p_1 \alpha u(x_1) + p_2 u(x_2), p_1 u(x_1) + \alpha p_2 u(x_2)\}.$$

If $\alpha = 1$, DAT reduces to the EUT. With $\alpha$=0, the indifference curve kinks vertically, where individuals' utility is precisely limited by smaller payoffs. If $0 \leq \alpha < 1$, the indifference curves of the two outcomes have a kink in the 45 degree line. I assume the case in which $\alpha = 0.5$ to see the typical but not extreme feature of DAT. DAT predicts that individuals will choose their lotteries, so that weighted expected payoffs are equivalent in both states. By introducing $u = (v^{0.88})$, the DAT value peaks at $v_1$=3456, where $p_1 \alpha u(v_1) + p_2 u(v_2) = p_1 u(v_1) + \alpha p_2 u(v_2)$. As shown in 4.1, the DAT maximizer will take larger risks in smaller stake Sets 1-3 and Set 10, although he/she prefers safer lotteries in the largest stake Sets 7–9.

### *4.1.3. Cumulative Prospect Theory*

In the values of lotteries according to the CPT proposed by Tversky and Kahneman (1992), $v_x$ is concave for gains but convex for losses and with weighted cumulative probabilities function $w(p_i)$, where individuals evaluate outcomes $x_i$ with subjective weights of probabilities:

$$u(v) = \begin{cases} v^{\alpha} & if \quad v \geq 0 \\ -\lambda(-v^{\beta}). & if \quad v < 0 \end{cases} \tag{1}$$

$$WU = \Sigma_{i=1}^{n} w(p_i) v(x_i). \tag{2}$$

Both the valuation of outcomes and the decumulative weighting function differ between gains and losses from the reference points:

$$w^{+}(P) = \frac{P^{\gamma}}{(P^{\gamma} + (1-P)^{\gamma})^{1/\gamma}} \qquad w^{-}(D) = \frac{D^{\delta}}{(D^{\delta} + (1-D)^{\delta})^{1/\delta}}, \tag{3}$$

From equations 1, 2, and 3, certainty equivalent (CE) values of lotteries are:

$$CE = w^{+}(P)(v_1)^{\alpha} - w^{-}(D)\lambda(v_2)^{\beta} \tag{4}$$

CPT predicts that individuals prefer safer lotteries to riskier ones even more than EU maximizers. I hypothesize that all subject set safe outcome $(x_1, x_2)$=(2200 2200) to the reference point. Following Tversky and Kahneman (1992), $\alpha = 0.88$, $\beta = 0.88$, and $\delta = 2.25$ for the coefficient of loss aversion, probability weighting parameter for gains $\gamma = 0.61$, and probability weighting parameter for losses $\sigma$=0.69 are applied:

$$v(x) = \begin{cases} (x_1 - 2200)^{0.88} & if \quad x_1 \geq 2200 \\ -2.25 * (2200 - x_2)^{0.88}. & if \quad x_1 < 2200 \end{cases}$$

As for \$-bet-type lotteries, for gain domain $x_1 > 2200$, CE values are evaluated with $w(P)^{+} = 0.3360$ from $p_1 = \frac{1}{3}$; and for loss domain $x_1 < 2200$, CE values are evaluated with $w^{+}(P) = 0.3360$ from $p_1 = 1/3$ and $w^{-}(D) = 0.5636$ from $p_2 = 2/3$. Substituting budget constraint $x_2 = 3300 - \frac{1}{2}x_1$, values of CPT are

$$V_{CPT} = 0.3360(x_1 - 2200)^{0.88} - 2.25 \times 0.5636(\frac{1}{2})^{0.88} \times (x_1 - 2200)^{0.88} + 2200^{0.88}$$
$$if \quad x_1 > 2200.$$

As for p-bet-type lotteries, for loss domain $x_1 < 2200$, CE values are evaluated with $w^{-}(P) = 0.5128$ from $p_1 = \frac{2}{3}$; and for the gain domain $x_2 > 2200$, CE values are evaluated with $w(D)^{+} = 0.3498$ from $p_1 = \frac{1}{3}$. CPT values are

$$V_{CPT} = 0.5128(\frac{1}{2})^{0.88} \times (2200 - x_1)^{0.88} - 2.25 \times 0.3498(x_1 - 2200)^{0.88} + 2200^{0.88}$$
$$if \quad x_1 < 2200.$$

The CPT value takes the maximum of $(2200)^{0.88} = 874$ for perfectly safe lotteries and takes the minimum of 419 for the riskiest lottery (4800 with p=1/3; 1000 with p=2/3). (See Figure 4.1.) CPT predicts that p-bet type lotteries are more attractive than dollar-bet type lotteries: the CE value of 798 for the riskiest p-bet lottery (1400: p = 1/3; 2600: p = 2/3) in Set 10 is higher than the riskiest $-bet lottery (4800 with p=1/3; 1000 with p=2/3). This prediction supports the selection of IDs 132, 136, and 236, who prefer the riskiest p-bet-type lotteries over dollar-bet ones in Sets 4, 6, and 9. In both experiments, p-bet type lotteries are selected for 27.8% from Set 4 (13/48 subjects in PP and 12/42 in PC),35.6% from Set 6 (15/48 in PP and 17/42 in PC), and 25.6% from Set 9, 25.6% (12/48 subjects in PP and (11/42) in PC).

### *4.1.4. SP/A Theory*

Under the SP/A theory by Lopes (1987), individuals are assumed to use an aspiration level as a second criterion in the choice process: an investment is evaluated by both the risk-averse "security mindedness" and risk-seeking "potential mindedness," where individuals seek risky chances after they ensure at least outcomes in line with their aspiration levels.[4]

To calculate SP values, $x_i$ are ordered from the lowest to the highest and evaluated with decumulative probability $h(D_i)$ of obtaining an outcome at least as high as $x_i$. With $h(D_i) = 1$ (decumulative probability of the worst outcome) = 1, and introducing $u = (v^{0.88})$

$$\begin{aligned} V_{SP} &= \sum_{i=3}^{n} h(D_i)(x_i - x_{i-1})^{0.88} + (h(D_1) \times A)^{0.88} \\ &= \sum_{i=3}^{n} h(D_i)(x_i - x_{i-1})^{0.88} + 1000^{0.88} \end{aligned} \tag{5}$$

$h(D_i)$ takes the following form:

$$h(D) = wD^{q_s+1} + (1-w)[1-(1-D)^{q_p+1}] \tag{6}$$

Parameter $w$ has an important role in SP/A theory because the size of w determines which feelings the individuals are leaning toward between security and potential minded. If $w = 1$, the decision-maker is strictly security minded. If $w = 0$, the decision-maker is strictly potential-minded. If $0 < w < 1$, the decision-maker is hopeful with the degrees of "caution and of

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[4] By Lopes (1987), the idea of "aspiration" was originally proposed by Allais, M. (1990) and predicts individuals' contradictory risk hedging and taking behaviors, such as buying both insurance and lottery tickets, as proposed by Friedman and Savage (1948).

hope," depending on the magnitudes of w. I apply the $w = 0.505$ estimated by Lopes and Oden (1999) with assumption of $q_s = q_p = 1.053$. [5]

I hypothesize the aspiration level to be JPY 1,000, for at least certain outcomes, for all subjects: $h(D_1) = h(1000) = 1$.

As for the \$-bet lottery, SP values are calculated by

$$V_{SP} = h(D_1)(x_1 - x_2)^{0.88} + h(D_2)(x_2 - 1000)^{0.88} + (1000)^{0.88} \tag{7}$$

In equation 7, $x_1 > 2200$ is evaluated with $h(D_3) = 0.3360$ and $1000 < x_1 < 2200$ is evaluated with $h(D_2) = 0.5636$.

As for the p-bet lottery, SP values are calculated by:

$$V_{SP} = h(D_2)(x_2 - x_1)^{0.88} + h(D_1)(x_1 - 1000)^{0.88} + (1000)^{0.88} \tag{8}$$

In equation 8, $x_1 > 2200$ is evaluated with $h(D_2) = 0.5636$ and $1000 < x_1 < 2200$ is evaluated with $h(D_1) = 0.3359$.

Then, with $u(x) = x^{0.88}$, the SP values are

$$V_{SP} = \begin{cases} 0.6627(x_2 - x_1)^{0.88} + 0.3326(x_1 - 1000)^{0.88} + 1000^{0.88} & if \quad 1400 \leq x_1 < 2200 \\ 2200^{0.88} & if \quad v_1 = 2200 \\ 0.3326(x_1 - x_2)^{0.88} + 0.6627(x_2 - 1000)^{0.88} + 1000^{0.88} & if \quad 2200 < v_1 \leq 4600 \end{cases} \tag{9}$$

The SP value curve in Figure 4.1 has two peaks, and is discontinuous around the first peak at $v_1 = 2200$, with $V_{SP}$=874 giving the largest security to subjects. The SP value at $v_1 = 2201$ discontinuously drops to 777 from 874, then increases as the lotteries' become riskier. The SP value takes the minimum 608 at $v_1 = 2199$, where $v_1$ is slightly lower than $v_2$. The second peak appears at $x_1 = 4333$. This feature comes from the concave preference in extra outcomes in both states. These peaks depend on the assumption of curvature of utility function. In Figure 4.1, for Sets 1–4, all risky portfolios are less attractive than the perfect safe lotteries. Because the SP value of $(x_1, x_2) = (3268, 1667)$ is equal to the value 874 of the safe outcome, the risky portfolios $3268 \leq x_1$ are preferable to the perfectly safe portfolio in Sets 5–9. This features makes it possible to explain the discontinuous risk preference in Observation 6.

### *4.2. Comparison of Choices and Predictions*

Here, I investigate how far are the observed choices are from the predictions of each theory. If a theory has an advantage of explaining individuals'

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[5] Although Lopes and Oden (1999) also provide 10 parameters for the differences between $q_s$ and $q_p$, I use the simpler six parameters.

| Experiment | Moment | EUT | SPA | CPT with p | CPT with w(p) | DAT | 1/N |
|---|---|---|---|---|---|---|---|
| All | mean | 4.057 | 4.101 | 5.050 | 5.394 | 8.309 | 6.048 |
|  | st. dev. | 3.614 | 2.400 | 3.555 | 3.365 | 3.230 | 3.724 |
| Pencil and Paper | mean | 4.035 | 3.966 | 4.964 | 5.351 | 8.118 | 6.130 |
|  | st. dev. | 3.570 | 2.413 | 3.483 | 3.353 | 3.377 | 3.785 |
| PC | mean | 4.082 | 4.254 | 5.147 | 5.442 | 8.524 | 5.956 |
|  | st. dev. | 3.669 | 2.380 | 3.636 | 3.383 | 3.043 | 3.656 |

Table 8: Averages and standard deviations of ranks

lottery choices, the theory ranks observed choices higher than other theories do. Additionally, predictable theory's ranks within subjects must be stable and the standard deviations of ranks are expected to be smaller than those of other theories. The averages and standard deviations of ranking under the tested theories/heuristic are shown in Table 8.

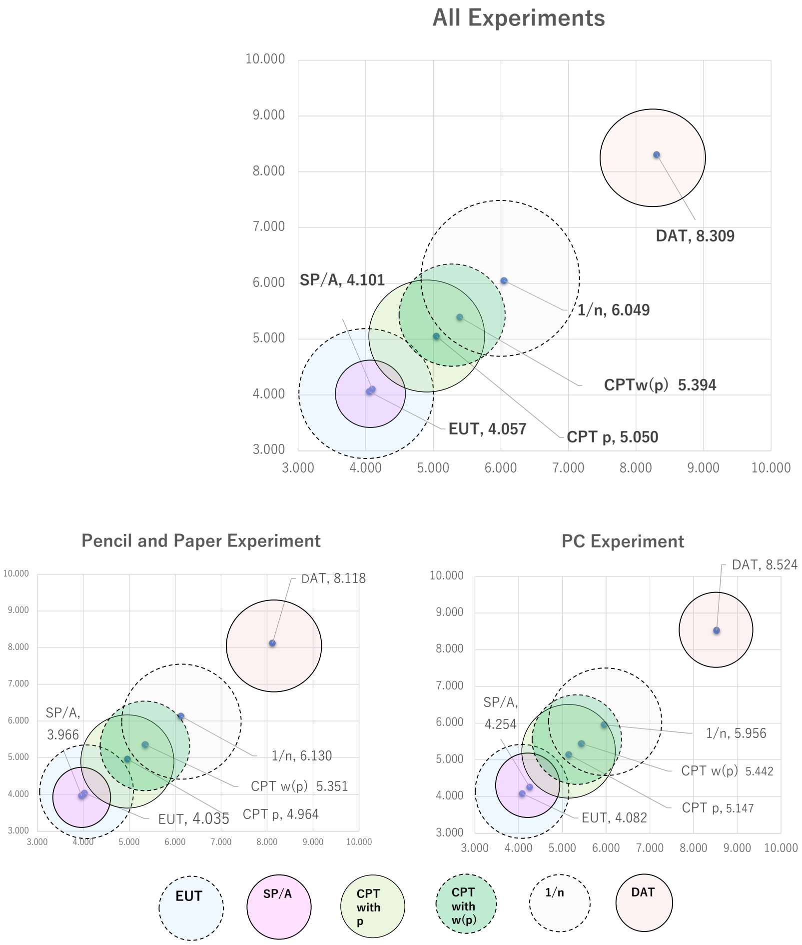
I test whether the averages and standard deviations of the predicted ranks according to different theories are significantly different. The main observations are as below.

**Observation 7 (EUT and SP/A)** The average ranks under EUT is highest (lowest) among all theories and the rank under SP/A theory is the second highest. The difference between EUT and SP/A is not statistically significant, whereas the standard deviations are significantly smaller under the assumption of SP/A theory than those under EUT in both experiments.

**Observation 8 (CPT)** The average ranks under CPT with/without weighted probabilities are the third and fourth highest. The standard deviations of both CPTs are smaller than that of EUT in both experiments; however, the differences are not significant.

**Observation 9 (DAT)** The average rank under DAT is ranked last and significantly greater than the other economic theories in both experiments. The standard deviation of the ranks under DAT is the second highest in PC experiment and the third highest in PP experiment. Especially in the PP experiment, the standard deviation is significantly smaller than the other theories/heuristics.

**Observation 10($1/n$)** The average of ranks under the $1/n$ rule is the second last and significantly different from the other economic theories, except for DAT. The standard deviations of ranks of $1/n$ are largest among all models.



The diameters of circles are drawn in proportion to standard deviation of each theory's rank

Figure 8: Averages and standard deviations of ranks by tested theories

The x-axes and y-axes show the ranks. The points for SP, CPT, EU, and 1/n denote the averages of subjects' average ranks.
The radius of the circles show the standard deviations within subjects.

| All experiments (N = 890) | EUT | SPA | CPT(p) | CPT w(p) | $1/n$ | DAT |
|---|---|---|---|---|---|---|
| Average Rank | 4.057 | 4.101 | 5.050 | 5.394 | 6.049 | 8.309 |
| EUT (t-value) | - | -0.2692 | -15.8326*** | -31.4474*** | -13.7338*** | -32.4695*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | (0.3939) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| SPA | - | - | -6.0505*** | -8.9471*** | -12.5254*** | -47.6804*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| CPT (p) | - | - | - | -5.7280*** | -6.1267*** | -26.5524*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | | | (0.0000) | (0.0000) | (0.0000) |
| CPT w(p) | - | - | - | - | -4.2033*** | -27.8706*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | | | - | (0.0000) | (0.0000) |
| DAT | - | - | - | - | - | -13.3178*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | | | | | (0.0000) |

Table 9: Results of t-tests for the averages between binary theories in all experiments

| PP experiment (N = 473) | EUT | SPA | CPT(p) | CPT w(p) | $1/n$ | DAT |
|---|---|---|---|---|---|---|
| Average Rank | 4.035 | 3.966 | 4.964 | 5.351 | 6.412 | 8.118 |
| EUT (t-value) | - | 0.3165 | -9.7409*** | -21.8162*** | -10.5101*** | -13.2275*** |
| Pr($\lvert T\rvert < \lvert t\rvert$) | | (0.6241) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| SPA | - | - | -4.7596*** | -7.1859*** | -9.7852*** | -33.4334*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| CPT (p) | - | - | - | -4.3427*** | -5.0925*** | -19.3084*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | (0.0002) | (0.0000) | (0.0000) |
| CPT w(p) | - | - | - | - | -3.5971*** | -19.9748*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | - | (0.0004) | (0.0000) |
| 1 out of N | - | - | - | - | - | - 8.0965*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | | | (0.0000) |

Table 10: Results of the t-tests for the averages between binary theories in the PP experiment

| PC experiment (N = 417) | EUT | SPA | CPT(p) | CPT w(p) | $1/n$ | DAT |
|---|---|---|---|---|---|---|
| Average Rank | 4.082 | 4.254 | 5.147 | 5.442 | 5.956 | 8.524 |
| EUT (t-value) | - | -0.7104 | -13.5276*** | -22.8135*** | -8.8634*** | -22.8527*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | (0.2389) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| SPA | - | - | -3.7884*** | -5.4591*** | -7.84649*** | -34.1362*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | (0.0001) | (0.0000) | (0.0000) | (0.0000) |
| CPT (p) | - | - | - | -3.7438*** | -3.4956*** | -18.2383 *** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | (0.0002) | (0.0005) | (0.0000) |
| CPT w(p) | - | - | - | - | -2.2933* | -19.4704*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | - | (0.0223) | (0.0000) |
| 1 out of N | - | - | - | - | - | -11.1229*** |
| Pr($\lvert T\rvert > \lvert t\rvert$) | | | | | | (0.0000) |

Table 11: Results of the t-tests for the averages between binary theories in the PC experiment

t(.) shows the degrees of freedom.

$*$ shows that the result of the t-test (p-value) is significant at the 5% level.

$**$ shows that the result of the t-test (p-value) is significant at the 1% level.

$***$ shows that the result of the t-test (p-value) is significant at the 0.1% level.

| All experiments (N = 890) | SPA | DAT | CPTw(p) | EUT | CPT | $1/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation of Ranks | 2.400 | 3.230 | 3.365 | 3.614 | 3.555 | 3.590 |
| SPA (f-value) | - | 1.8105*** | 1.9661*** | 2.2678*** | 2.1933*** | 2.4074*** |
| Pr(F>f) | | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| DAT (f-value) | - | - | 1.0859 | 1.2525*** | 1.2114** | 1.3296*** |
| Pr(F>f) | | | (0.1097) | (0.0004) | (0.0021) | (0.0008) |
| CPT w(p)(f-value) | - | - | - | 1.1534* | 1.1155 | 1.2244** |
| Pr(F>f) | | | | (0.0167) | (0.0516) | (0.0013) |
| EUT (f-value) | - | - | - | - | 1.0340 | 1.0616 |
| Pr(F>f) | | | | - | (0.3093) | (0.1867) |
| CPT | - | - | - | - | - | 1.0976 |
| Pr(F>f) | | | | | | (0.0826) |

Table 12: Results of the F-tests for the standard deviations between binary theories in all experiments

| PP experiments (N = 476) | SPA | CPTw(p) | DAT | CPT | EUT | $1/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation of Ranks | 2.413 | 3.777 | 3.493 | 3.570 | 3.353 | 3.229 |
| SPA (f-value) | - | 1.9594*** | 1.9313*** | 2.0839*** | 2.1894*** | 2.4609*** |
| Pr(F>f) | | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| CPT w(p)(f-value) | - | - | 1.0145 | 1.0790 | 1.1336 | 1.2742** |
| Pr(F>f) | | | (0.0867) | (0.2045) | (0.4377) | (0.0043) |
| DAT(f-value) | - | - | - | 1.0635 | 1.1174 | 1.2560** |
| Pr(F>f) | | | | (0.2518) | (0.1142) | (0.0067) |
| CPT (f-value) | - | - | - | - | 1.0506 | 1.1809* |
| Pr(F>f) | | | | - | (0.2960) | (0.0356) |
| EUT | - | - | - | - | - | 1.1240 |
| Pr(F>f) | | | | | | (0.1022) |

Table 13: Results of the F-tests for the standard deviations between binary theories in the PP experiment

| PC experiments (N = 417) | SPA | DAT | CPT w(p) | CPT(p) | $1/n$ | EUT |
|---|---|---|---|---|---|---|
| Standard Deviation of Ranks | 2.380 | 3.043 | 3.383 | 3.492 | 3.656 | 3.669 |
| SPA (f-value) | - | 1.6355*** | 2.0212*** | 2.3347*** | 2.3608*** | 2.3766 |
| Pr(F>f) | | (0.0000) | (0.0000) | (0.0000) | ( 0.0000) | (0.0000) |
| DAT | - | - | 1.2358* | 1.4275*** | 1.4434*** | 1.4531*** |
| Pr(F>f) | | | (0.0155) | (0.0001) | (0.0001) | (0.0001) |
| CPT w(p) | - | - | - | 1.1551 | 1.1680 | 1.0842 |
| Pr(F>f) | | | | (0.0709) | (0.0568) | (0.2050) |
| CPT(p) | - | - | - | - | 1.0112 | 1.1037 |
| Pr(F>f) | | | | | (0.4550) | (0.1574) |
| $1/n$ | - | - | - | - | - | 1.0179 |
| Pr(F>f) | | | | | | (0.4281) |

Table 14: Results of the F-tests for the standard deviations between binary theories in the PC experiment

t(.) shows the degrees of freedom.
$*$ shows that the result of the t-test (p-value) is significant at the 5% level.
$**$ shows that the result of the t-test (p-value) is significant at the 1% level.
$***$ shows that the result of the t-test (p-value) is significant at the 0.1% level.

**Support for Observations 7–10** The averages and standard deviations of ranking of aggregated subjects are shown in Table 9, 10, 11, 12, 13 and 14. Figure 8 gives an intuitive observations. The distances between each center of each circle and the original points show the averages of ranks of choices according to each theory's prediction. The radii of the circle are drawn proportionally to the standard deviation of ranks.

The averages of ranks assuming EUT and SP/A theory are significantly smaller than those of any other theories/heuristics, and the standard deviations of ranks assuming SP/A theory are significantly smaller than those of any other theories, including EUT at the 0.1% level. Because DAT's standard deviation is smaller than most of the economic theories, DAT stably gives a poor prediction of selections. Further, the SP/A theory plus noise has an advantage over the other theories/heuristics plus noise.

## 5. Each Individual's Decision Models

Focusing on each subject's decision, I regard the theory that gives the least average of ranks and/or the least standard deviation of ranks of the selected lotteries within subjects as the core theory for each subject. Because there are no significant differences between the PP and PC experiments' main findings, the descriptions below are aggregated for both the PP and PC experiments. The details of the average ranks for each subject are shown in Table 15. In Table 16, the smallest standard deviation for each subject is shown. DAT is the smallest for 31/90 (34.4%) subjects; however, their average ranks of DAT are worse than 9th, except for ID 115, so for the left 89 subjects, DAT is excluded as a core theory. Similarly, even though standard deviations of some theories/heuristics other than DAT are the smallest, if the theories' ranks are worse than 8th, they are excluded (This rule is applied for $1/n$ for ID 108, ID 136, and ID 144). The Table 17 shows this results after these considerations, and Observations 11 to 14 are based on the Table 17.

**Observation 11 (EUT)** For 49/90 (54.4%) of subjects, average ranks in the 10 choice sets are highest under EUT (Table 15), and, for 27/90 (32.2%) of subjects, the standard deviations of ranks are smallest when EUT is assumed as the core theory (Table 17).

| Experiment | EUT | SP/A | CPT (p) | CPT w(p) | DAT | $1/n$ |
|---|---|---|---|---|---|---|
| ALL | 49 | 34 | 3 | 0 | 0 | 4 |
| (N=90) | (54.4%) | (37.8%) | (3.3%) | (0%) | (0%) | (4.4%) |
| Pencil and | 25 | 19 | 2 | 0 | 0 | 2 |
| Paper (N=48) | (52.1%) | (39.6%) | (4.2%) | (0%) | (0%) | (4.2%) |
| PC | 24 | 15 | 1 | 0 | 0 | 2 |
| (N=42) | (57.1%) | (35.7%) | (2.4%) | (0%) | (0%) | (4.8%) |

Table 15: The model with the highest(lowest) rank average in each individual's decision

| Experiment | EUT | SP/A | CPT (p) | CPT w(p) | DAT | $1/n$ |
|---|---|---|---|---|---|---|
| All | 24 | 30 | 2 | 0 | 31 | 3 |
| (N=90) | ( 26.7% ) | (33.3%) | (2.2%) | (0%) | (34.4%) | (3.3%) |
| Pencil and | 13 | 18 | 1 | 0 | 13 | 3 |
| Paper (N=48) | ( 27.1%) | (37.5%) | (2.1%) | (0.0%) | (27.1% ) | (6.3%) |
| PC | 11 | 12 | 1 | 0 | 18 | 0 |
| (N=42) | (26.2%) | (28.6%) | (2.4%) | (0%) | (42.9%) | (0%) |

Table 16: The model with the least noise in each individual's decision
The numbers in the tables show how many subjects' behaviors are best described by each theory.

| Experiment | EUT | SP/A | CPT (p) | CPT w(p) | DAT | $1/n$ |
|---|---|---|---|---|---|---|
| All | 27 = 24 + 3DAT | 57 = 30+25DAT+2($1/n$) | 2 | 1= 0 + 1 DAT | 0 † | 3=3-2SPA +2DAT |
| | ( 30.0%) | (63.3%) | (2.2%) | (1.1%) | (0%) | (3.3%) |
| PP | 15 = 13+ 2DAT | 28= 18 + 8DAT+2($1/n$) | 1 | 1= + 1 DAT | 0 †† | 1=3-2SPA |
| | (31.3%) | (58.3%) | (2.1%) | (2.1%) | (0%) | (2.1%) |
| PC | 12=2 + 1DAT | 29= 12+ 17DAT | 1 | 0 | 0 † † † | 2 = 0+2DAT |
| | (28.6%) | (69.0%)) | (2.4 0%) | (0%) | (0%) | (4.8%) |

Table 17: The model with the least noise in each individual's decision unless the average rank according to the theory is worse than 8th

The numbers in the tables show how many subjects' behaviors are best described by each theory.

† DAT 0 = 31 - 3EUT - 27SPA - 1CPTw(p) - 21/$n$

†† DAT 0 = 13 - 2EUT - 8SPA - 1CPTw(p) -21/$n$

† † † DAT = 18 - - 1EUT - 17SPA

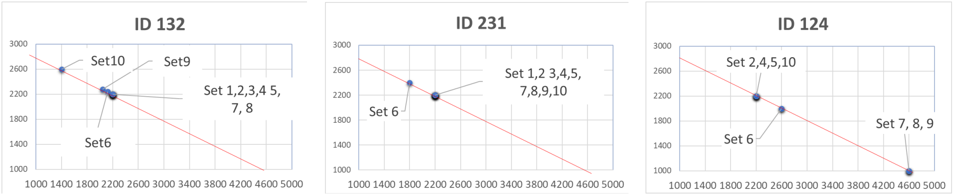
**Observation 12 (SP/A and DAT)** For 34/90 (37.8%) of subjects, the average ranks under SP/A theory are highest and, for 30/90(33.3%) of subjects, the standard deviations of ranks are smallest when SP/A theory is assumed as the core theory. (Table 16) No subjects' average ranks are highest under DAT, and for 31/90 (34.4%) of subjects, the standard deviation of the rank are smallest because DAT ranks are stably low. For the subjects with the smallest standard deviation under DAT, the SP/A theory has the second smallest standard deviation. Therefore, the SP/A theory can be assumed as the core theory for them when DAT is removed from consideration, 57/90(63.3%) of subjects' standard deviations' are smallest. (Table 17)

**Observation 13 (CPT)** Only 3/90 subjects'(IDs 132, 136, and 236) (3.3%) average ranks are highest under CPT with objective probabilities. For 1/90 subjects (1.1%, ID132), the standard deviations under CPT with objective probabilities are smallest, and for 1/90 subjects (2.2%, ID 110), the standard deviations under CPT with weighted probabilities are smallest.

**Observation 14 (1 out of n)** For 4/90 (4.4%, IDs 115, 145, 228, 220) of subjects, the average ranks are highest under the $1/n$ rule. ID 115's standard deviation is zero because all his choices are ranked first. Conversely, ID 113's standard deviation is zero because all his choices are ranked last. ID 113's second smallest standard deviation is under SP/A theory, I regard his selections are best described by SP/A theory.

Considering each subject's theory and noise, the selections by 27/90 subjects (30.0%) are ranked highest with the lowest noise under EUT, and the selections by 34/90 subjects (37.8%) are ranked highest under SP/A theory with the least noise (see Figures 3.1 and 3.1). Therefore, SP/A theory plus noise is more explanatory than EUT plus noise. CPT with objective probabilities plus noise is best applied only to ID 132 and 236 (2.2% of subjects). The superiority of SP/A theory is attributed to the least-bad worst payoff and no loss domain for the subjects. By contrast, the inferiority of CPT is attributed both to(psychologically) no negative outcome and the moderate probabilities of one- and two-thirds.

The examples of individuals' choice who are best described by each theory are shown in Figures 9. ID 231, who is best described by EUT, takes little risk, and ID 132, who is best described by CPT with objective probability,



[CPT] [EUT] [SPA]

Figure 9: Individual choices that typically apply to each theory

is also highly consistent in choosing safe outcomes. In contrast, ID 124, who takes risk discontinuously, is best described by SP/A theory. He selects the perfectly safe lotteries in Sets 1, 2, 4, and 10, and takes the maximum risk in Sets 7–9.

## 6. Conclusions

This paper sheds light on the individuals' risk-taking behaviors under settings with fixed expected returns for various risks. Safe outcomes were not selected as much as economic theories predict. Furthermore, some subjects who selected almost perfect safe lotteries from the small stake choice sets took great risk when given large stake choice problems. They enjoyed safe and risky choices simultaneously. Although these observations make us suspect that subjects just invest into two securities proportionally, the selected lotteries' evaluation through EUT, DAT, CPT, SP/A theories, and the $1/n$ rule denies the possibility of the application of this rule, except for one subject.

The average ranks of prediction under each theory show that the selections are best described under both predictions of EUT and SP/A theory, and the noises of ranks within subjects are the smallest if the SP/A theory is assumed.

CPT's inferiority to EUT in this experiment is attributed to the medium probabilities of one- and two-thirds. Additionally, the results suggest that the subjects did not perceive the initial endowment JPY 2,000 as a reference point, but focused on at least securing the JPY 1,000 outcome from any of the lotteries.

The ranking analysis within subjects showed that 54% of the subjects are considered to be EUT maximizers because of the least average ranks within subjects. This result supports the findings of Hey and Orme (1994), Hey, J. D. (1995), Buschena and Zilberman (2000), Schmidt and Neugebauer

(2007), and Harrison and Rutström (2009). Although this result is limited by the condition that there are no small probabilities, I conclude that EUT has strong predictive power even under no trade-off between expected value and deviation.

At the same time, the SP/A theory provides good prediction of the behaviors of less risk averse individuals when I focus on the noise of selection within subjects. For 62% of subjects, assuming the SP/A theory plus noise yields the lowest noise. The SP/A theory also provides a sound interpretation for discontinuous risk taking behaviors, such that individuals who prefer safer lotteries suddenly take large risks when the maximums of choice sets are increased. However, this result can be attributed to the gender distribution of subjects. If I could recruit more female respondents, EUT and CPT might prove to be more explanatory.

DAT could have predicted discontinuous investment; however, under this experimental setting, DAT yields the worst prediction of the selections, except for the $1/n$ rule. This article's results do not support DAT's advantageous explanatory power in Choi et al. (2007). This difference is possibly partly attributed to the how subjects interpret initial endowments. The subjects in Choi et al. (2007) might have an incentive to earn the reward additional to the USD 5 participation fee "for sure." If the subjects were given a participation fee of USD 10, more subjects might have tried to maximize outcomes from the aspiration potential. Conversely, if I gave my subjects JPY 500 as participation fee and set the worst outcomes from investment to be JPY 0, more subjects might have behaved as DAT maximizers.

In contrast to most previous experiments, including "zero outcomes with some participation fee," this study's experiment provides no participation fee to the subjects, but instead offers the "not bad" worst reward. This initial endowment seems to have had subjects set their reference point to the least-bad outcome directly. From this viewpoint, this experiment adds insight to Harrison and Rutström (2009)' suggestion that how subjects perceive the participation fee and/or initial endowment may affect which theory they apply. As such, testing how the reward structure affects the theories subjects apply is left to future studies.

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## Appendix: Instructions for Practice

(The general instructions, such as cautions for answering, are omitted) Assume that you will be given JPY 2,000 to invest into at most two securities. You will acquire the return of investment as a reward. Please answer all 10 choice problems below. However, only one answer will be selected as reward by a public die after I collect all of your answers. The investment amounts should be exactly JPY 2,000; otherwise, you will not be rewarded.

| | Return in State 1 $p_1 = 1/3$ | Return in State 2 $p_2 = 2/3$ |
|---|---|---|
| Security A | 1.6 | 0.7 |
| Security B | 0.6 | 1.2 |

| Investment amount | | Payoff | |
|---|---|---|---|
| security A | security B | in State 1 $p_1 = 1/3$ | in State 2 $p_2 = 2/3$ |
| 2000 | 0 | 3200 | 1400 |
| 1800 | 200 | 3000 | 1500 |
| 1600 | 400 | 2800 | 1600 |
| 1400 | 600 | 2600 | 1700 |
| 1200 | 800 | 2400 | 1800 |
| 1000 | 1000 | 2200 | 1900 |
| 800 | 1200 | 2000 | 2000 |
| 600 | 1400 | 1800 | 2100 |
| 400 | 1600 | 1600 | 2200 |
| 200 | 1800 | 1400 | 2300 |
| 0 | 2000 | 1200 | 2400 |

Now, let us practice how to answer. Please make a favorable investment by combining securities A and B. The rate of return differs for each security and also depends on States 1 and 2. These states are determined by the color of a drawn card from the bag by the assistant at the end of the experiment. I put these 10 red and 20 black playing cards in the bag. State 1 occurs if a playing card with red patterns with $p_1 = 1/3$ and State 2 occurs if a playing cards with black patterns appears with $p_2 = 2/3$.

Please look at the table showing the correspondence between the investment volumes for each security and the payoff in each state with increments of JPY 200. To practice how you would divide JPY 2,000 for each security, let us pick a preferred amount from the table 6 and fill in the values as practice. When a red card is drawn, the payoff becomes

$$\underline{\hspace{2em}}\,JPY \times 1.6 + (2000 - \underline{\hspace{2em}}\,JPY) \times 0.7 = \underline{\hspace{2em}}\textcircled{1}JPY. \tag{10}$$

When a black card is drawn, the payoff becomes

$$\underline{\hspace{2em}}\,JPY \times 0.6 + (2000 - \underline{\hspace{2em}}\,JPY) \times 1.2 = \underline{\hspace{2em}}\textcircled{2}JPY. \tag{11}$$

I will check each person's answer to judge whether the calculation is correct. You can ask me questions if you need help. Please be patient and wait silently until the actual experiment will start.

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