The "Spite" Dilemma in Voluntary Contribution Mechanism Experiments

TATSUYOSHI SAIJO
University of Tsukuba
Osaka University
HIDEKI NAKAMURA
Fukushima University

This article explains deviations from formal expectations regarding choice behavior in settings where economic rationality (i.e., own payoff maximization) dictates either cooperating (full contribution) or free riding (no contribution) in the provision of public goods via the voluntary contribution mechanism. The authors find that the difference between full contribution and the observed level of contribution is greater than or equal to the corresponding difference when free riding is the best strategy. This surprising result is interpreted as the "spiteful" behavior of subjects whose first priority is not the total amount of payoff they receive but the ranking among them.

1. INTRODUCTION

Experimental results about the voluntary contribution mechanism have accumulated during the last decade. One of the major findings is that participants contribute between 40% and 60% of their initial holding to the production of a public good although free riding (i.e., no contribution) is the dominant strategy in a one-shot game (see Marwell and Ames 1979, 1980,

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1981).[1] Although in a repeated game no contribution in all periods is a unique subgame perfect equilibrium, several researchers have observed a contribution pattern of early-period cooperation (typically 40%-60%) with eventual decay toward the free-riding outcome (typically 5%-30%) (Kim and Walker 1984; Isaac, Walker, and Thomas 1984; Isaac, McCue, and Plott 1985; Isaac and Walker 1988). Basic features of these experiments are that there is no communication among subjects and the marginal return from one unit of initial holding is less than 1.

We reconsider the following two important aspects of experimental designs. First, we investigate the role of the informational structure. There are two important points. Typically, subjects do not know the payoff structures and holdings of other participants. What is more important, subjects may not understand their own payoff structure well because of the presentation of the payoff tables; that is, the specific pattern of contribution in former experiments may have resulted from this *incompleteness* of information. The second aspect, related with the first, is the interpretation of the amount of contribution. We tend to conclude that a 40%-60% contribution is significantly high compared to no contribution. This comparison is based on theoretical results in which no contribution is the dominant strategy for all subjects and on experiments designed to test this theory. Therefore, significantly high contributions may be justified by various other theoretical results (e.g., no contribution is not the dominant strategy for some subjects) and the experiments generated by such results.

To deal with the first aspect, following Iwakura and Saijo (1994),[2] we designed experiments in which the information is as complete as possible. First, we explicitly notified participants that everyone has the same payoff structure and the same initial holdings and that the number of repetitions is 10. Second, we provided payoff tables called *detailed tables* that have complete payoff information and are qualitatively different from the payoff tables of previous experiments, which we call *rough tables*. Brookshire, Coursey, and Redington (1989) and Isaac and Walker (1989) found that there was no effect on contributions when comparing incomplete with complete information, using only rough tables in an identical subject case. Therefore, the payoff table effect is important in our experiments. For the second aspect,

1. There is an exception. Marwell and Ames (1981) found that economics graduate students at the University of Wisconsin contributed about 20%, significantly less than the others. Carter and Irons (1991) showed that students majoring in economics behave differently from others in a bargaining game. See also Davis and Holt (1992, chap. 6) and Ledyard (1995) for summaries of major conclusions of public-good experiments, and see Dawes and Thaler (1988) for repeated public-good experiments.

2. In a slightly different setting, Iwakura and Saijo (1991) found that subjects who used rough tables were more "cooperative" than were subjects who used detailed tables.

we designed experiments in which contributing all of the initial holding is the dominant strategy in both a one-shot game and the repeated game; that is, the marginal return from one unit of initial holding is greater than 1 as opposed to the previous experiments in which the marginal return is less than 1. Based on this experiment, we can measure the difference between experimental contribution and a theoretical prediction in which own payoff maximization implies all contributions and then compare this difference with the difference when the marginal return is less than 1.

Our major results follow. For the first aspect, we find that the information does matter. The mean investment with low marginal return in the detailed payoff table experiments is lower than that in the rough payoff table experiments. Similarly, the mean investment with high marginal return in the detailed payoff table experiments is significantly higher than that in the rough payoff table experiments. Further, no strong tendency for contributions to decay toward the end period is observed in either table experiments. For the second aspect, we find that the difference between the observed data profile and the equilibrium profile with *high* marginal return experiments is bigger than the difference between them with *low* marginal return experiments. Thus high contribution in the voluntary contribution mechanism is not a universal conclusion.

Why did subjects not contribute everything when, diametrically opposed to the prisoner's dilemma situation, full contribution was a dominant strategy? Although altruism is one of the major interpretations of high contribution in the public good experiments, we found that altruistic subjects are very rare. This suggests that a new behavioral interpretation other than a traditional own payoff-maximizing principle is needed. Our interpretation is the existence of "spiteful" subjects. The spiteful subjects care primarily about the *ranking* among subjects, and therefore the absolute amount of payoff is their second priority when the marginal return is higher than 1.[3] Moreover, spiteful subjects do free ride when the marginal return is lower than 1. Similar spiteful strategy phenomena when the marginal return is higher than 1 were reported by Toda et al. (1978) in the maximum difference game; by Frohlich and Oppenheimer (1984) in binary choice problems; by Gardner, Ostrom, and Walker (1990) in common-pool resource experiments; and by Holt (1995) in oligopoly experiments.[4]

3. Spiteful behavior is described in Hamburger (1979, 87-9). We follow Hamburger's terminology.

4. Gardner, Ostrom, and Walker (1990) observed that the common resource was dissipated even more than Nash equilibrium allocation. This is similar to the overproduction in Cournot oligopoly experiments in Holt (1995). See also Davis and Holt (1992, 350-5).

Section 2 summarizes theoretical properties of the voluntary contribution mechanism. Section 3 gives experimental designs. Section 4 presents the results of our experiments. The "spite" effects are investigated in section 5. Some further designs of experiments are discussed in the final section.

2. THE VOLUNTARY CONTRIBUTION MECHANISM[5]

There are n subjects, and subject i has w_i units of initial holding or money. Each subject faces a decision of splitting w_i between savings (x_i) and investments (t_i). The subject keeps the saving. From the investment, the subject receives $g(t)$ where $t = \Sigma t_i$ and g is the investment function. Actually, $g(t)$ is the production function of the public good, and hence it is the level of a public good when the sum of all participants' investments is t. In the following, we assume that $g(t) = \alpha t$ with $\alpha \geq 0$. Therefore the amount of money that the subject receives is $w_i - t_i + g(t) = x_i + \alpha t$. Assuming that the utility function of each subject is strictly monotonic in money, we can write i's utility function as

$$u(x_i, t) = x_i + \alpha t. \qquad (1)$$

Hence each subject's decision problem is

$$\max u(x_i, t) \text{ subject to } x_i + t = w_i + \Sigma_{j \neq i} t_j.$$

Consider the case with $1 > \alpha \geq 0$, which we call the *low* marginal return case. It is well known that no contribution to the investment is the dominant strategy for every subject in the one-shot game. Although there is no dominant strategy in the repeated game, no investment in all periods for every subject is a unique subgame perfect equilibrium. Consider the case with $\alpha >$ 1, which we call the *high* marginal return case. Regardless of the total investments of other subjects, investing all of his or her money is the subject's dominant strategy. Full investment of the initial holding in all periods for every subject is the unique dominant strategy equilibrium, and it is different from that in the former case.

3. EXPERIMENTAL DESIGN

We conducted the experiments during the fall of 1991 using 112 inexperienced students at the University of Tsukuba. They were a mixture of

5. For a theoretical treatment of the voluntary contribution mechanism, see Warr (1983), Bergstrom, Blume, and Varian (1986), and Saijo and Tatamitani (1995).

economics majors and other majors. The basic format of our experiments is based on Isaac and Walker (1988). As in Isaac and Walker's experiments, communication among the subjects was prohibited, and we declared that the experiments would be stopped if communication among the subjects was observed. This never happened. It took approximately 50 minutes to conduct one set of experiments with 7 subjects. The mean payoff per subject was \$10.40 (1,351.2 yen if \$1.00 = 130 yen). The maximum payoff among these subjects was \$13.90 (1,806 yen), and the minimum payoff was \$6.91 (898 yen) (see Appendix B).

The initial endowment, w_i, is 10 for all i, and the number of subjects in a group, n, is 7. There are two parameters in our experiments: (1) the marginal per-capita return from the investment ($\alpha = 0.7$ vs. $\alpha = 1/0.7$)[6] and (2) the payoff information (detailed table [*D*] vs. rough table [*R*]). Therefore there are four types of controls. Denote, for example, an experiment with detailed table and the high marginal return as *DH*. The 112 subjects were divided into two groups: one for the detailed tables and the other for the rough tables. Each group consisted of 56 subjects, and these 56 students were divided into eight subgroups. Each subgroup, which consisted of 7 subjects, faced two experiments consecutively; these are distinguished by the value of α.[7] Hence there are four types of subgroups: (*DH*, *DL*), (*DL*, *DH*), (*RH*, *RL*), and (*RL*, *RH*). For example, (*DH*, *DL*) represents a type in which a *DH* experiment is carried out first and then a *DL* experiment second. Therefore we repeated each type of experiment four times. The assignments of subjects to various conditions were random.

Let us describe a (*DH*, *DL*) experiment. Seven subjects and two experimenters gathered in a classroom at the University of Tsukuba. Experimenters distributed an experimental procedure sheet, a record sheet, a dividend table, 20 investment sheets, and 3 practice investment sheets. Each instruction was given by a tape recorder to minimize the interaction between subjects and experimenters. We carefully avoided the use of words such as "contribution," "public," and "group" to avoid the possibility that these words might change the amount of investment drastically because of the connotations of these words. First, each subject read the experimental procedure sheet while listening to the tape recorder. In the instructions, subjects were notified that there were two stages of experiments. In each stage, each subject faced 10 investment decisions. For each of these decisions, each subject had 10 units

6. We chose the high marginal return to be the reciprocal of the low marginal return for symmetry, and by chance the high return is about double the low return, but we have no theoretical basis for this choice.

7. Originally, we wanted to use four groups, one for each type of control; however, due to a limit on the size of the subject pool, we were forced to conduct the *H* versus *L* comparison sequentially.

of initial holding that was nontransferable between periods. In each period, each subject decided how many units of initial holding he or she should contribute based on the dividend table distributed. Once a subject had decided the investment from his or her initial holding, the subject circled the number on an investment sheet and handed it to an experimenter. One of the experimenters wrote the total sum of investment on the blackboard. Each subject computed the payoff of the period based on the dividend table, the total sum of investment, and the subject's own investment. This decision was repeated 10 times. Then each subject received a new dividend table, and 10 decision makings were completed in a similar manner. The first 10 decision makings corresponded to a *DH* experiment and the second 10 to a *DL* experiment.

We used two types of payoff tables. To understand the nature of the problem and the difference between these two payoff tables, consider an example with two subjects (1 and 2), each with 10 units of initial holding. Each subject has three choices: to invest 0, 5, or 10 units.[8] An example of a rough payoff table in which the marginal return is 0.7 is given in Table 1.

For example, subject 1 invests 5 and subject 2 invests 10. Then the total investment is 15. Because this number is not listed in the table, an experimenter announces that "your payoff" is 10.5. Because subject 1's investment is 5, his or her *saving* is 5 (= 10 – 5). Therefore subject 1's payoff is 15.5 (= 10.5 + 5).[9] The corresponding detailed payoff table is given in Table 2. Each column corresponds to the subject's own investment, and each row corresponds to the other's investment (the sum of the other subjects' investment if the number of subjects exceeds two). The detailed payoff table has every possible consequence or outcome from the investment, and hence the table includes payoffs from both investment and saving.

What are the differences between these two tables? First, even though we make a rough table that shows all five possible dividends from total amount of investment in Table 1, this payoff table does not contain the same information that the detailed payoff table provides; that is, the rough payoff table has only *one*-dimensional information corresponding to the total sum of investment. On the other hand, the detailed payoff table has *two*-dimensional information corresponding to the subject investment and the sum of others' investment. Second, a subject can read his or her actual payoff immediately from the detailed payoff table, but the subject must add the payoff from the total investment to the initial holding minus his or her investment in the rough table; that is, the rough payoff table requires one more step *after* reading the table. Third, this additional step veils the payoff structure to a subject who uses the rough payoff table. In other words, such a subject can see only *one* cell in the corresponding detailed table, but a subject using a detailed payoff table can see his or her entire payoff table. We conclude that detailed payoff tables provide *qualitatively* different information from rough payoff tables. Table A1 in Appendix A shows a rough payoff table used in actual experiments, which follows Isaac and Walker's (1988) payoff table, for $\alpha = 1/0.7$, and Table A2 is a detailed payoff table, which is introduced in Iwakura and Saijo (1991), for $\alpha = 1/0.7$.

8. In actual experiments, each subject chooses an integer number between 0 and 10.

9. Even well-trained economists took some time to understand that the payoff structure is a type of prisoner's dilemma. Further, even if the payoff function expressed by a utility function in equation (1) is a complete description of the payoff structure, information processing usually takes a considerable amount of time. Consider how much more difficult it must be for college students.

TABLE 1
An Example of a Rough Payoff Table

Total Amount of Investment	*Your Payoff*
0	0
10	7
20	14

TABLE 2
An Example of a Detailed Payoff Table

	Your Investment		
	0	*5*	*10*
Other's investment			
0	10.0	8.5	7.0
5	13.5	12.0	10.5
10	17.0	15.5	14.0

Our informational structure of experiments is different from that of the previous experiments mentioned in the Introduction. In our experiments, environmental information is *complete*. Every subject knows that everybody has the same payoff function and the same initial holding so that the assumption of complete information is satisfied.

4. RESULTS

To compare the investment behavior from period 1 to period 10, Figure 1 shows the patterns of mean investment for each type. The horizontal axis is for periods, and the vertical axis expresses the ratio of observed amount of investments to the sum of all subjects' initial holdings. For example, graph (*DH*, *DL*) shows the mean investment patterns for experiment (*DH*, *DL*). Graph *D* shows aggregated mean investment patterns for *DH* and *DL* in (*DH*, *DL*) and (*DL*, *DH*). Graph *R* is for (*RH*, *RL*) and (*RL*, *RH*). No investment for all periods is a unique subgame perfect Nash equilibrium in the low marginal return experiments, and all investments for all periods are the unique dominant strategy equilibrium in the high marginal return experiments. Hence the difference between the actual investment and the equilibrium investment provides a method of measuring how far away subjects are from theoretical behavior. Figure 2 shows the investment patterns for the low return and the *saving* patterns for the high return. For each graph in Figure 1, the corresponding graph can be drawn, but only two graphs—*D*- and *R*-—are given in Figure 2; they correspond to the respective *D* and *R* graphs in Figure 1.

Let us consider the cases with detailed payoff tables in Figures 1 and 2. Compare two low marginal return experiments *DL* in (*DH*, *DL*) and (*DL*, *DH*). First, no remarkable "order" effect is observed with respect to the pattern of investment and the percentage of investment.[10] Second, the mean investments for all low experiments are much lower than those in the experiments of Isaac and Walker (1988) and others; the mean is 21.6% for *DL* in (*DH*, *DL*) and 17.6% for *DL* in (*DL*, *DH*). For example, Isaac and Walker (1988) observed a mean investment of about 48% when there were 10 subjects and $\alpha = 0.75$ and of about 27% when $\alpha = 0.3$. Third, although the decay effect is one of the major conclusions in the voluntary contribution mechanism experiments, no specific decay effect toward period 10 is observed in the detailed table experiments.[11] This finding is due to detailed payoff tables and our *complete* information structure. The mean investment for high marginal return is much less than we expected. The mean of all 10 rounds together is 58.3% for *DH* in (*DH*, *DL*) and 75.7% for *DH* in (*DL*, *DH*).

Consider cases with rough payoff tables. When the marginal return is low, more than 30% of investment is observed in early rounds and the mean investment gradually decreases a little, but the decrease is not significant. The mean of all rounds together is 34.1% for the rough table experiments with low marginal return. On the other hand, it is 47.3% for the rough table experiments with high marginal return.

Summarizing these observations, we have the following.

10. There is no significant difference in the mean investments *DH* and *DL* between (*DH*, *DL*) and (*DL*, *DH*). Similarly, no remarkable "order" effect is observed in (*RH*, *RL*) and (*RL*, *RH*).

11. See Dawes and Thaler (1988) and Ledyard (1995).

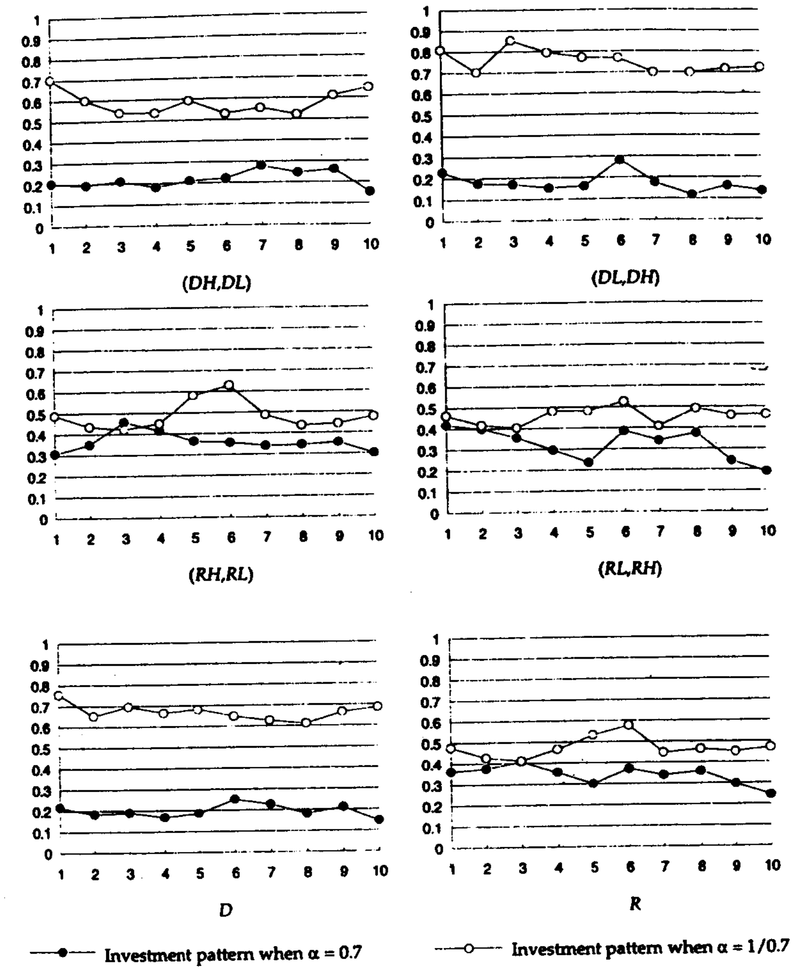

Figure 1: Mean Investment Patterns When $\alpha = 0.7$ and $\alpha = 1/0.7$

Observation 1

1. The investment pattern of each experiment is stable as periods proceed; that is, no strong tendency for contributions to decay toward the end period is observed.

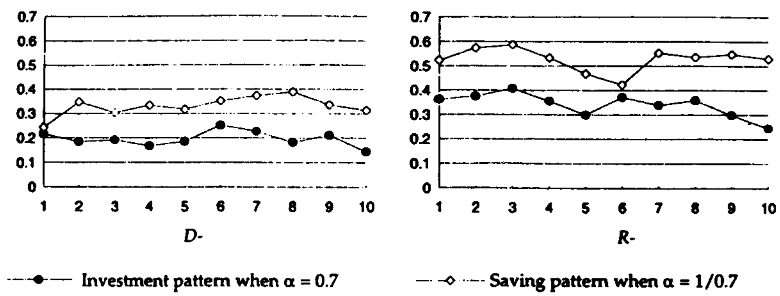

Figure 2: Mean Investment and Saving Patterns When $\alpha = 0.7$ and $\alpha = 1/0.7$

2a. In the detailed table experiments, the mean investment with high marginal return is significantly larger than that with low marginal return.
2b. In the rough table experiments, the mean investment with high marginal return is larger than that with low marginal return.
3. In both rough and detailed table experiments, the mean saving with high marginal return is larger than the mean investment with low marginal return.
4a. In each of the high marginal return experiments, the mean investment with a detailed payoff table is larger than that with a rough payoff table.
4b. In each of the low marginal return experiments, the mean investment with a rough payoff table is larger than that with a detailed payoff table.

To confirm observation 1, multivariate analysis is employed. Basic statistical results are in Appendix C. Detailed statistical results with data will be provided to readers on request to the first author.

5. THE SPITE DILEMMA

Why did subjects not invest their full initial holdings in the antidilemma situation? The basic understanding is high (low) contribution for the high (low) marginal return, respectively. We regard subjects who exhibited these strategic behaviors as subjects who understood the basic payoff structure. After participating in two consecutive experiments, each subject was asked to complete a questionnaire carefully designed to check how he or she behaved in the experiments. In the rough table experiments, we observed that, at most, 8 of 56 subjects did not show a basic understanding of the payoff structure. On the other hand, the corresponding figure in the detailed table

TABLE 3
Two Simplified Payoff Tables

$\alpha = 0.7$

	Invest nothing	Invest all
Invest nothing	10, 10	17, 7
Invest all	7, 17	14, 14

$\alpha = 1/0.7$

	Invest nothing	Invest all
Invest nothing	10, 10	24.3, 14.3
Invest all	14.3, 24.3	28.6, 28.6

TABLE 4
Illustration of the Spite Dilemma

	Invest nothing	Invest all
Invest nothing	0, 0	10, -10
Invest all	-10, 10	0, 0

$\alpha = 0.7$ and $\alpha = 1/0.7$

experiments was 0 of 56 subjects.[12] More interestingly, in addition to the basic understanding, there were many subjects who answered this way: "I want to make money but do not want to be defeated by the other participants."[13] To make money, the subject should invest all of his or her initial holding; to maximize ranking, the subject should invest none. To illustrate this phenomenon, which we name the *spite dilemma*, consider an example that is a further simplification of section 2's example. Suppose that each subject has only two choices: to invest all or to invest nothing. Then the payoff tables with $\alpha = 0.7$ and $\alpha = 1/0.7$ are as shown in Table 3. Construct payoff tables in which the payoff for each cell is the difference between your payoff and your opponent's payoff. In fact, these two payoff tables become the same (Table 4). If $\alpha = 0.7$, which is the prisoner's dilemma case, then

12. We felt that the *quality* of understanding of the payoff structure was different for each of the two payoff experiments after a study of the questionnaires.
13. There were 8 subjects who clearly showed a spite motive in the questionnaires in the rough table experiments. The number in the detailed table experiments was 13.

no investment is still the dominant strategy in the payoff difference table. If $\alpha = 1/0.7$, which is the no-dilemma case, then all investments are the dominant strategy; that is, the subject's mind wavers between investment and no investment depending on the relative strengths of the profit and spite motives.

For each of the four types of experiments—(*DH*, *DL*), (*DL*, *DH*), (*RH*, *RL*), and (*RL*, *RH*)—each participant's two mean investments for the high and low marginal returns are plotted in Figures 3 and 4. The horizontal axis is for the investment with $\alpha = 0.7$, and the vertical axis is for the investment with $\alpha = 1/0.7$. When $\alpha = 0.7$, the 0 investment corresponds to the free-riding side in the figure, whereas the 10 investment corresponds to the altruism side. Similarly, when $\alpha = 1/0.7$, the 10 investment corresponds to the non-spite side, which we call the pay-riding side, whereas the 0 investment corresponds to the spite side. The box in the figure is divided into four. Because the theoretical solution that is predicted by the dominant strategy is the upper-left corner of the box—that is, (0, 10)—the points that are close enough to (0, 10) are called the theoretical region. Although the choice of two numbers is arbitrary,[14] we define

$$T = \{(a, b) \mid 0 \le a < 4 \text{ and } 6 < b \le 10\}, AP = \{(a, b) \mid 4 \le a \le 10 \text{ and } 6 < b \le 10\},$$

$$FS = \{(a, b) \mid 0 \le a < 4 \text{ and } 0 \le b \le 6\}, \text{and } AS = \{(a, b) \mid 4 \le a \le 10 \text{ and } 0 \le b \le 6\},$$

where *T* stands for the theoretical region, *AP* for the altruistic and pay-riding region, *FS* for the free-riding and spiteful region, and *AS* for the altruistic and spiteful region. We can easily predict that it is hard to find *AS* subjects because it is hard to imagine a subject who invests a lot in the free-riding situation and spites other subjects when he or she can receive more than her investment. The focal point is the distribution of subjects among these three regions. Figure 4 shows the distribution of subjects for all four types.

Table 5 summarizes the fraction of subjects that are in that region as well as the mean ranking and mean payoff for those subjects. The mean ranking is distributed bewteen one and seven because the number of subjects in a group is seven. First, observe that the numbers of *AP* and *AS* subjects are very small except for those in the (*RH*, *RL*) experiments. Second, the number of *FS* subjects is about four to eight times the number of *AP* subjects. This observation partially explains why the difference between the dominant strategy of investing everything and the observed level of contribution is

14. If the dots in the box are distributed evenly, then the average theoretical subject invests 2 for $\alpha = 0.7$ and 8 for $\alpha = 1/0.7$, which reasonably approximates theoretical behavior.

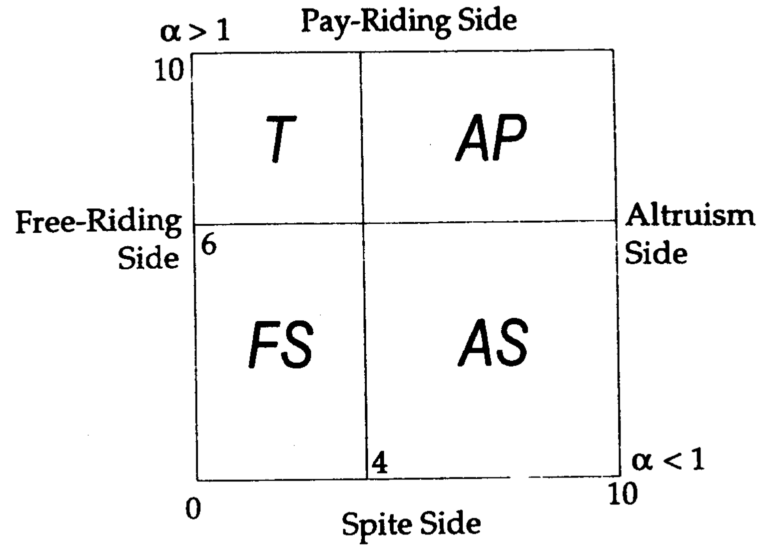

Figure 3: Mean Investment Distribution Box

much greater than the corresponding difference when free riding is the dominant strategy. Third, the number of *T* subjects in the detailed table experiments is about four to nine times that in the rough table experiments. Fourth, although mean rankings of *FS* subjects are better than those of *T* subjects, *T* subjects received better payoffs than did *FS* subjects, as Table B2 in Appendix B shows. Finally, *AP* subjects received "good" payoffs even though their rankings are low. Summarizing these observations, we conclude the following.

Observation 2

a. Pay-riding subjects are theoretical.
b. Spiteful subjects do free ride.
c. *FS* subjects' rankings are high, but payoffs are low.
d. *AP* subjects' rankings are low, but payoffs are high.

In observation 2, items a and b are easily observed in the detailed payoff table experiments; that is, subjects concentrate in regions *T* and *FS*, which is statistically justified by observations C5 and C6 in Appendix C. Therefore,

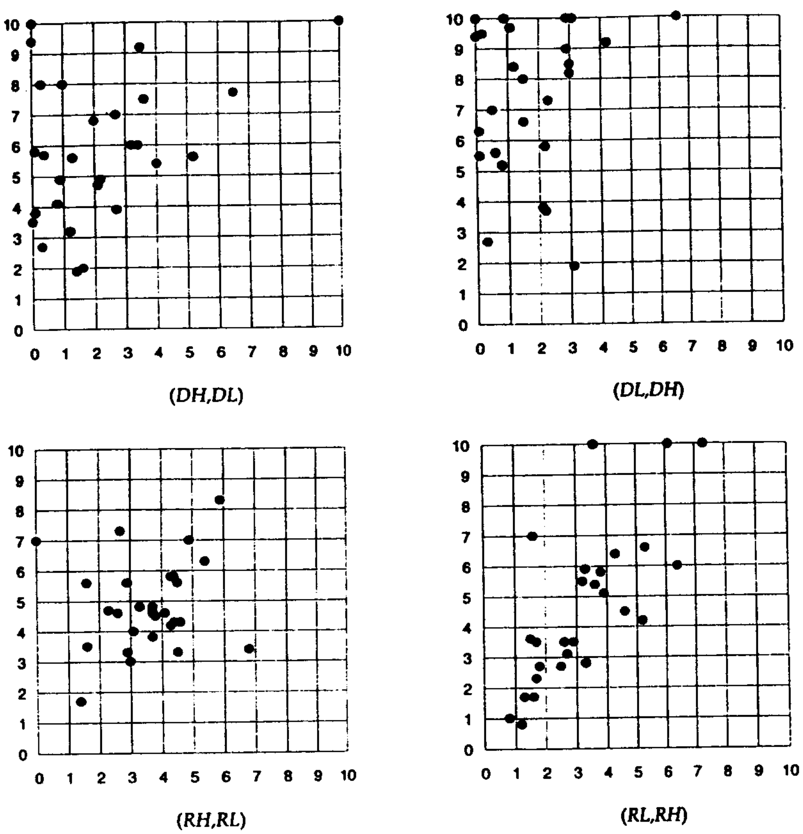

Figure 4: Mean Investment Distribution Box for Each Type of Experiment

the *saving* with high marginal return is much larger than the *investment* with low marginal return. It seems that items c and d are contradictory. Because *FS* subjects obtain better rankings than do *AP* subjects, *FS* subjects should have received more payoffs than did *AP* subjects. The ranking data in Appendix B explain this paradox. In experiments where relatively large numbers of *FS* subjects are observed, such as the third experiment in (*RL*, *RH*), each subject's payoff becomes relatively lower than those in the other experiments. On the other hand, in experiments where relatively large numbers of *T* subjects are observed, such as the third experiment in (*DL*, *DH*), each subject's payoff becomes relatively higher than those in the other experiments. For example, the last-ranked subject in payoff in the third experiment in (*DL*, *DH*) is an *AP* subject and obtained 1,587 yen. The

TABLE 5
Fraction of Subjects, Mean Ranking, and Mean Payoff in Each Region

	T	FS	AP	AS
(*DH*, *DL*) experiment				
Fraction	0.29	0.57	0.07	0.07
Ranking	4.50	3.19	6.50	6.00
Payoff (yen)	1,360	1,238	1,514	1,383
(*DL*, *DH*) experiment				
Fraction	0.64	0.29	0.07	0.00
Ranking	4.00	3.25	7.00	—
Payoff (yen)	1,530	1,206	1,579	—
(*RH*, *RL*) experiment				
Fraction	0.07	0.50	0.11	0.32
Ranking	2.00	2.71	6.33	5.67
Payoff (yen)	1,535	1,337	1,432	1,342
(*RL*, *RH*) experiment				
Fraction	0.07	0.68	0.14	0.11
Ranking	5.50	2.95	6.50	6.33
Payoff (yen)	1,344	1,311	1,317	1,141
D experiment				
Fraction	0.46	0.43	0.07	0.04
Ranking	4.15	3.21	6.75	6.00
Payoff (yen)	1,478	1,227	1,547	1,383
R experiment				
Fraction	0.07	0.59	0.13	0.21
Ranking	3.75	2.85	6.43	5.83
Payoff (yen)	1,440	1,322	1,367	1,292

first-ranked subject in the first experiment in (*DL*, *DH*) received 1,218 yen, much less than 1,587 yen.

Finally, the number of *T* subjects increases in later periods in rough table experiments, but the absolute values of the numbers in the rough table experiments are considerably smaller than those in the detailed table experiments, as Table 6 shows. Hence, if we think that the detailed table subjects are well informed, the subjects in the rough table experiments could not learn enough to understand the nature of payoffs even after period 8.

6. CONCLUDING REMARKS

There are two major findings in our experiments. Although the stylized observations in the voluntary contribution mechanism experiments are robust

TABLE 6

Distribution of Subjects in Four Regions

	Type	T	FS	AP	AS
Mean of 10 periods	*(DH, DL)*	8	16	2	2
	(DL, DH)	18	8	2	0
	(RH, RL)	2	14	3	9
	(RL, RH)	2	19	4	3
Mean of 8, 9, and 10 periods	*(DH, DL)*	12	11	3	2
	(DL, DH)	17	10	1	0
	(RH, RL)	3	16	4	5
	(RL, RH)	3	17	6	2

enough in the rough table experiments, we have considerably different observations with detailed table experiments in a complete information environment. We observed considerably less investment and no decay effect through periods. The second finding, which is our major observation, is that the mean of saving with high return is significantly higher than the mean investment with low return for both detailed and rough table experiments. Our interpretation of this rather surprising observation is that there are many spiteful subjects who do free ride with low marginal return. This also casts doubt on the efficacy of a theory based on altruism. In a slightly different framework with the commons, Ito, Saijo, and Une (forthcoming) developed a model explaining more rapid dissipation of the common-pool resource than the Nash equilibrium predicts. Given this rapid dissipation, they identify two behavioral principles: *share maximization* and *difference maximization*. Both can be considered principles to justify spiteful behavior in our experiments.

There are several alternatives for further analysis of our spite observations. First, the effects of varying the marginal returns must be pursued. Does the number of spiteful subjects decrease as the marginal return increases? Second, the universality of spite behavior in the voluntary contribution mechanism should be investigated. As Toda et al. (1978) and Frohlich and Oppenheimer (1984) showed, spite behavior may be strongly related to cultural backgrounds. Toda and others found that about 50% of the children in elementary schools in several countries use spiteful strategies, and Japanese children are more spiteful or competitive than are children in the United States, Greece, or Belgium. Frohlich and Oppenheimer found *difference-maximizing* behavior in simple binary choice problems. Moreover, they found that Canadian students are more spiteful than are American students; the former have a stronger tendency toward difference maximizing than do the latter. We plan to conduct exactly the same experiments in other (especially non-Asian) countries.

APPENDIX A
Rough and Detailed Payoff Tables

Tables A1 and A2 are payoff tables for the high marginal return case. In Table A1, the left column shows total investments, the step is 10, and the right column shows the corresponding payoff for each subject. The actual payoff is 1.2 times this number. In the procedure before the experiment, each subject is informed that the payoff is proportional to total investments. After an experimenter sums the investments of all subjects, he or she announces the payoff of each subject based on the proportionality of the payoff. For example, if total investments are 42, then the experimenter announces 60, which is each subject's payoff. Table A2 is a detailed table. Because we want to make the numbers in adjacent cells different, the entries are 10 times the actual payoffs.

TABLE A1

Rough Payoff Table

Total Investments	*Your Payoff*
0	0.0
10	14.3
20	28.6
30	42.9
40	57.1
50	71.4
60	85.7
70	100.0

TABLE A2
Detailed Payoff Table

Sum of others' investments	Your Investment 0	1	2	3	4	5	6	7	8	9	10
0	120	125	130	135	141	146	151	156	161	166	171
1	137	142	147	153	158	163	168	173	178	183	189
2	154	159	165	170	175	180	185	190	195	201	206
3	171	177	182	187	192	197	202	207	213	218	223
4	189	194	199	204	209	214	219	225	230	235	240
5	206	211	216	221	226	231	237	242	247	252	257
6	223	228	233	238	243	249	254	259	264	269	274
7	240	245	250	255	261	266	271	276	281	286	291
8	257	262	267	273	278	283	288	293	298	303	309
9	274	279	285	290	295	300	305	310	315	321	326
10	291	297	302	307	312	317	322	327	333	338	343
11	309	314	319	324	329	334	339	345	350	355	360
12	326	331	336	341	346	351	357	362	367	372	377
13	343	348	353	358	363	369	374	379	384	389	394
14	360	365	370	375	381	386	391	396	401	406	411
15	377	382	387	393	398	403	408	413	418	423	429
16	394	399	405	410	415	420	425	430	435	441	446
17	411	417	422	427	432	437	442	447	453	458	463
18	429	434	439	444	449	454	459	465	470	475	480
19	446	451	456	461	466	471	477	482	487	492	497
20	463	468	473	478	483	489	494	499	504	509	514
21	480	485	490	495	501	506	511	516	521	526	531
22	497	502	507	513	518	523	528	533	538	543	549
23	514	519	525	530	535	540	545	550	555	561	566
24	531	537	542	547	552	557	562	567	573	578	583
25	549	554	559	564	569	574	579	585	590	595	600
26	566	571	576	581	586	591	597	602	607	612	617
27	583	588	593	598	603	609	614	619	624	629	634
28	600	605	610	615	621	626	631	636	641	646	651
29	617	622	627	633	638	643	648	653	658	663	669
30	634	639	645	650	655	660	665	670	675	681	686
31	651	657	662	667	672	677	682	687	693	698	703
32	669	674	679	684	689	694	699	705	710	715	720
33	686	691	696	701	706	711	717	722	727	732	737
34	703	708	713	718	723	729	734	739	744	749	754
35	720	725	730	735	741	746	751	756	761	766	771
36	737	742	747	753	758	763	768	773	778	783	789
37	754	759	765	770	775	780	785	790	795	801	806

continued

TABLE A2 continued

	Your Investment 0	1	2	3	4	5	6	7	8	9	10
38	771	777	782	787	792	797	802	807	813	818	823
39	789	794	799	804	809	814	819	825	830	835	840
40	806	811	816	821	826	831	837	842	847	852	857
41	823	828	833	838	843	849	854	859	864	869	874
42	840	845	850	855	861	866	871	876	881	886	891
43	857	862	867	873	878	883	888	893	898	903	909
44	874	879	885	890	895	900	905	910	915	921	926
45	891	897	902	907	912	917	922	927	933	938	943
46	909	914	919	924	929	934	939	945	950	955	960
47	926	931	936	941	946	951	957	962	967	972	977
48	943	948	953	958	963	969	974	979	984	989	994
49	960	965	970	975	981	986	991	996	1,001	1,006	1,011
50	977	982	987	993	998	1,003	1,008	1,013	1,018	1,023	1,029
51	994	999	1,005	1,010	1,015	1,020	1,025	1,030	1,035	1,041	1,046
52	1,011	1,017	1,022	1,027	1,032	1,037	1,042	1,047	1,053	1,058	1,063
53	1,029	1,034	1,039	1,044	1,049	1,054	1,059	1,065	1,070	1,075	1,080
54	1,046	1,051	1,056	1,061	1,066	1,071	1,077	1,082	1,087	1,092	1,097
55	1,063	1,068	1,073	1,078	1,083	1,089	1,094	1,099	1,104	1,109	1,114
56	1,080	1,085	1,090	1,095	1,101	1,106	1,111	1,116	1,121	1,126	1,131
57	1,097	1,102	1,107	1,113	1,118	1,123	1,128	1,133	1,138	1,143	1,149
58	1,114	1,119	1,125	1,130	1,135	1,140	1,145	1,150	1,155	1,161	1,166
59	1,131	1,137	1,142	1,147	1,152	1,157	1,162	1,167	1,173	1,178	1,183
60	1,149	1,154	1,159	1,164	1,169	1,174	1,179	1,185	1,190	1,195	1,200

APPENDIX B
Payoff Ranking

TABLE B1
Payoff Ranking

Ranking	*1*	*2*	*3*	*4*	*5*	*6*	*7*
DH,DL	(0, 3.5) 1298	(0.1, 5.8) 1268	(1.3, 5.6) 1234	(2.2, 4.9) 1216	(2.0, 6.8) 1199	(2.7, 7.0) 1175	(3.2, 6.0) 1172
	(0.3, 2.7) 1193	(1.4, 1.9) 1170	(1.6, 2.0) 1163	(0.4, 5.7) 1154	(0, 10) 1115	(2.7, 3.9) 1107	(3.5, 9.2) 1019
	(0.1, 3.8) 1258	(1.2, 3.2) 1232	(0.9, 4.9) 1221	(0, 9.4) 1194	(2.1, 4.7) 1187	(3.4, 6.0) 1133	(4.0, 5.4) 1122
	(0.8, 4.1) 1795	(0.3, 8.0) 1763	(1.0, 8.0) 1742	(3.6, 7.5) 1670	(5.2, 5.6) 1645	(6.5, 7.7) 1581	(10, 10) 1448
DL,DH	(0.3, 2.7) 1218	(0.8, 5.2) 1173	(2.1, 3.8) 1151	(2.2, 3.7) 1149	(0, 9.4) 1147	(3.1, 1.9) 1144	(3.0, 8.2) 1071
	(0.1, 5 5) 1297	(0.1, 6.3) 1287	(0.6, 5.6) 1281	(0.2, 9.5) 1246	(1.5, 6.6) 1242	(2.2, 5.8) 1230	(2.3, 7.3) 1209
	(0.5, 7.0) 1806	(0, 10) 1785	(1.1, 9.7) 1756	(2.9, 9.0) 1710	(2.9, 10) 1698	(3.1, 10) 1692	(6.6, 10) 1587
	(0, 10) 1687	(1.2, 8.4) 1670	(1.5, 8.0) 1666	(0.9, 10) 1660	(3.0, 8.5) 1615	(2.9, 10) 1600	(4.2, 9.2) 1570
RH,RL	(2.3, 4.7) 1593	(3.7, 3.8) 1562	(2.7, 7.3) 1550	(4.1, 4.6) 1540	(4.5, 5.6) 1516	(4.9, 7.0) 1487	(5.9, 8.3) 1442
	(2.6, 4.6) 1390	(3.1, 4.0) 1382	(3.7, 4.6) 1357	(3.8, 4.5) 1355	(3.7, 4.8) 1354	(4.6, 4.3) 1333	(4.4, 5.8) 1321
	(0, 7.0) 1521	(1.6, 5.6) 1490	(2.9, 5.6) 1451	(4.4, 4.3) 1421	(4.3, 5.8) 1406	(5.4, 6.3) 1367	(6.8, 3.4) 1360
	(1.4, 1.7) 1207	(1.6, 3.5) 1179	(3.0, 3.0) 1143	(2.9, 3.3) 1142	(3.3, 4.8) 1112	(4.5, 3.3) 1094	(4.3, 4.2) 1090
RL,RH	(2.7, 3.1) 1590	(2.9, 3.5) 1579	(3.3, 2.8) 1575	(3.6, 5.4) 1535	(4.3, 6.4) 1502	(3.6, 10) 1480	(7.3, 10) 1369
	(0.8, 1.0) 1304	(2.5, 2.7) 1233	(2.6, 3.5) 1220	(2.9, 3.5) 1211	(1.6, 7.0) 1208	(4.6, 4.5) 1148	(5.3, 6.6) 1102
	(1.2, 0.8) 1099	(1.3, 1.7) 1086	(1.6, 1.7) 1077	(1.7, 2.3) 1066	(1.8, 2.7) 1059	(3.3, 5.9) 975	(6.4, 6.0) 881
	(1.5, 3.6) 1511	(1.7, 3.5) 1507	(3.2, 5.5) 1438	(3.9, 5.1) 1421	(3.8, 5.8) 1416	(5.2, 4.2) 1393	(6.1, 10) 1297

Table B1 shows the ranking among seven subjects by payoff. There are four types of experiments and four repetitions of each type. For example, in the second run of the type (*DH, DL*) experiment, the subject who received 1,163 yen is ranked third, and this subject's mean investment is 1.6 for the low return and 2 for the high return; that is, the upper pair of numbers is the coordinate pair in the mean investment distribution box and the lower number is the payoff that the subject received.

APPENDIX C
Statistical Analysis

To confirm observation 1, multivariate analysis is employed. First, we assume that in each experiment consisting of 28 subjects, the investment of each subject is mutually, independently, and identically distributed. Second, we assume that a distribution of investment is assumed concretely; in each experiment, investments of a subject with high and low marginal returns are independently distributed, and investment with each high and low marginal return follows a multivariate normal distribution,

$$\begin{pmatrix} x^{i}_{H1,j} \\ \vdots \\ x^{i}_{H10,j} \end{pmatrix} \sim N(\mu_{H,j}, \Sigma_{H,j}); \text{ and } \begin{pmatrix} x^{i}_{L1,j} \\ \vdots \\ x^{i}_{L10,j} \end{pmatrix} \sim N(\mu_{L,j}, \Sigma_{L,j}),\ i = 1, \cdots, 28;\ j = (DH, DL), \cdots, (RL, RH),$$

where $x^{i}_{t,j}$ is the subject *i*'s investment of period *t* of experiment *j*. Similar assumptions are made for experiments *D* and *R*.

First, we consider a linear trend model to see the time effect to investment. We take into account serial correlation of the error term. In the following, the parameters $\alpha_{k,m}$ and $\beta_{k,m}$ represent the constant and the time coefficient, respectively.

Test 1

a. H: $\alpha_{k,m} = 0$ versus A: $\alpha_{k,m} \neq 0$ for $m = (DH, DL), \ldots, (RL, RH)$, D and R; and
b. H: $\beta_{k,m} = 0$ versus A: $\beta_{k,m} \neq 0$ for $m = (DH, DL), \ldots, (RL, RH)$, D and R.

The result is given in Table C1. Figures in the table are the estimates of coefficients; figures in the parentheses are the values of the test statistic that follows an F distribution with $df(1, 19)$ for (*DH, DL*), (*DL, DH*), (*RH, RL*), and (*RL, RH*) experiments as well as with $df(1, 47)$ for *D* and *R* experiments. Asterisks (* and **) represent rejection at the upper 5% and 1% significance levels, respectively. We follow Srivastava and Carter (1983, sec. 6) for the estimation and test.

Observation C1

a. Except for the *R* experiments with low marginal return, there is no time effect because no coefficient of time is significant even at the 1% significance level.
b. In the *R* experiments with low marginal return, investment decreases as periods go by.

Second, we test the effect of marginal return (high vs. low) on the mean investment.

TABLE C1
Estimation of Linear Trend Model

\ m	(DH, DL)	(DL, DH)	(RH, RL)	(RL, RH)	D	R
$\hat{\alpha}_{H,m}$	6.360	9.198	4.604	4.134	7.566	4.483
	(88.18)**	(180.38)**	(54.04)**	(38.12)**	(273.55)**	(119.30)**
$\hat{\beta}_{H,m}$	−0.116	−0.135	0.030	0.019	−0.106	0.020
	(1.62)	(1.59)	(0.10)	(0.18)	(2.55)	(0.18)
$\hat{\alpha}_{L,m}$	1.951	1.430	3.621	3.473	1.857	3.977
	(12.57)**	(8.65)**	(49.68)**	(46.54)**	(30.95)**	(182.45)**
$\hat{\beta}_{L,m}$	0.011	−0.025	0.031	−0.133	−0.010	−0.115
	(0.05)	(0.14)	(0.19)	(5.49)*	(0.07)	(8.14)**

*Rejection at the upper 5% significance level; **Rejection at the upper 1% significance level.

Test 2

H: $\mu_{H,m} = \mu_{L,m}$ versus A: $\mu_{H,m} \neq \mu_{L,m}$ for $m = (DH, DL), \ldots, (RL, RH)$, R and D.

The test statistic under the null is distributed as an F variate with $df(10, 18)$ for $(DH, DL), \ldots, (RL, RH)$ and with $df(10, 46)$ for R and D. We followed Anderson (1984) when the covariance matrices under investigation are different from each other.

Table C2 and Figures 2 and 3 give us the following observation.

Observation C2

a. In the case of detailed table experiments, investment under high marginal return is larger than investment under low marginal return.
b. In the case of rough table experiments, investment under high marginal return is slightly larger than investment under low marginal return.

The following test is designed to compare the difference between the theoretical value and its observation (i.e., saving) under high marginal return with the difference between them (i.e., investment) under low marginal return.

Test 3

H: $\mathbf{10} - \mu_{H,m} = \mu_{L,m}$ versus A: $\mathbf{10} - \mu_{H,m} \neq \mu_{L,m}$ for $m = (DH, DL), \ldots, (RL, RH)$, R and D.

The **10** is the 10×1 vector whose elements are all 10. The test statistic under the null is distributed as an F variate with $df(10, 18)$ for $(DH, DL), \ldots, (RL, RH)$ and with $df(10, 46)$ for R and D.

TABLE C2
Test for Marginal Return to Mean Investment

m	(DH, DL)	(DL, DH)	(RH, RL)	(RL, RH)	D	R
	5.07*	14.20*	3.66*	3.55*	16.01*	4.95*

*Rejection at the upper 1% significance level.

Table C3 and Figures 2 and 3 give us the following observation.

Observation C3

a. In the detailed payoff table experiments, the amount of saving with high marginal return is slightly larger than (in the case of D) or the same as (in the case of [DH, DL] and [DL, DH]) the amount of investment with low marginal return.
b. In the rough payoff table experiments, the amount of saving with high marginal return is larger than the amount of investment with low marginal return.

Finally, we test the effect of detailed and rough tables on the mean investment.

Test 4

a. $H1$: $\mu_{k,(DH,DL)} = \mu_{k,(RH,RL)}$ versus $A1$: $\mu_{k,(DH,DL)} \neq \mu_{k,(RH,RL)}$ for $k = H, L$;
b. $H2$: $\mu_{k,(DL,DH)} = \mu_{k,(RL,RH)}$ versus $A2$: $\mu_{k,(DL,DH)} \neq \mu_{k,(RL,RH)}$ for $k = H, L$; and
c. $H3$: $\mu_{k,D} = \mu_{k,R}$ versus $A3$: $\mu_{k,D} \neq \mu_{k,R}$ for $k = H, L$.

Table C4 shows the results. The test statistic under the null is distributed as an F variate with $df(10, 18)$ for items a and b and with $df(10, 46)$ for item c.

Table C4 and Figures 2 and 3 give us the following observation.

Observation C4

a. In the comparisons between (DH, DL) and (RH, RL) and between (DL, DH) and (RL, RH), the difference of payoff tables does not give a significant difference to the mean investment.
b. In the case of R and D, the mean investment of detailed payoff experiments is larger than that of rough payoff experiments under high marginal return.
c. In the case of R and D, the mean investment of rough payoff experiments is larger than that of detailed payoff experiments under low marginal return.

TABLE C3
Marginal Return Effect to the Difference from Equilibrium

m	(DH, DL)	(DL, DH)	(RH, RL)	(RL, RH)	D	R
	1.34	1.80	3.14*	4.43**	2.29*	4.93**

*Rejection at the upper 5% significance level; **Rejection at the upper 1% significance level.

TABLE C4
Payoff Table Effect to Mean Investment

k\	*Test 4 (a)*	*Test 4 (b)*	*Test 4 (c)*
H	1.12	3.11*	3.65**
L	1.96	2.09	3.77**

*Rejection at the upper 5% significance level; **Rejection at the upper 1% significance level.

Observations C1 through C4 basically support observation 1. As observation C3 shows, the claim insisting that high investment is observed, even in a free-riding situation, seems to lose its luster.

We analyze the fractions of subjects statistically in section 5. Let us define some notations as follows: $P_{T,m}$, $P_{FS,m}$, $P_{AP,m}$, and $P_{AS,m}$ are the fractions of subjects in *T*, *FS*, *AP*, and *AS* regions, respectively, in *m* experiments where *m* = (*DH*, *DL*),. . .,(*RL*, *RH*), *D* and *R*. First, we see the fraction of subjects in regions *T* and *FS*.

Test 5

H: $P_{T,m} + P_{FS,m} = 0.5$ versus *A*: $P_{T,m} + P_{FS,m} \neq 0.5$ for *m* = (*DH*, *DL*),. . .,(*RL*, *RH*), *D* and *R*.

The result is given in Table C5. Each figure in the table is the estimate of $P_{T,m} + P_{FS,m}$.

Observation C5

The subjects are likely located in regions *T* and *FS* except for experiment (*RH*, *RL*).

Next, we investigate the effect of detailed and rough tables on the fraction of regions *T* and *FS*.

TABLE C5
Test of Fraction of Subjects

m	(DH, DL)	(DL, DH)	(RH, RL)	(RL, RH)	D	R
Test 5	0.86**	0.93**	0.57	0.75**	0.89**	0.66*

*Rejection at the upper 5% significance level; **Rejection at the upper 1% significance level.

Test 6

a. *H*1: $P_{T,(DH,DL)} + P_{FS,(DH,DL)} = P_{T,(RH,RL)} + P_{FS,(RH,RL)}$ versus *A*1: not *H*1;
b. *H*2: $P_{T,(DL,DH)} + P_{FS,(DL,DH)} = P_{T,(RL,RH)} + P_{FS,(RL,RH)}$ versus *A*2: not *H*2; and
c. *H*3: $P_{T,D} + P_{FS,D} = P_{T,R} + P_{FS,R}$ versus *A*3: not *H*3.

Table C6 shows the result. Each figure in the table is the estimate of the difference of the test.

Observation C6

a. In the comparison between (*DH*, *DL*) and (*RH*, *RL*), the fraction of regions *T* and *FS* of the detailed table experiment is larger than that of the rough table experiment.
b. In the case of *D* and *R*, the fraction of regions *T* and *FS of detailed table experiments is larger than that of rough payoff experiments.*

TABLE C6
Payoff Table Effect to Regions *T* and *FS*

Test 6 (a)	*Test 6 (b)*	*Test 6 (c)*
0.29*	0.18	0.23**

*Rejection at the upper 5% significance level; **Rejection at the upper 1% significance level.

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