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Isolating and identifying motivations: A voluntary contribution mechanism experiment with interior Nash equilibria

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Abstract

What motivates subjects in their decision making is a lingering issue in public goods experiments. Using a nonlinear payoff function and a two-subject model, we create a one-to-one correspondence between contributions and motivations, enabling us to isolate and identify the following three possible motivations: Nash, cooperative, and altruistic motivations. The experimental results show that Nash-motivated behavior accounts for more than 70% of all decisions. Some subjects reveal a cooperative motivation when they know the other subject's payoff information. Altruistic motivation is found to be rare throughout the experiment.

Keywords: Motivation; Nash; Cooperation; Altruism; Voluntary contribution mechanism

JEL Classification: C92; H41

> *In personal, social, and economic exchange, as studied in two-person games, cooperation exceeds the prediction of traditional game theory.*[1]
>
> —from the opening of *Rationality in Economics* by Vernon L. Smith

1. Introduction

Economists continue to be intrigued by the tendency of people to contribute to a public good even when they have economic incentives not to do so, creating one of the most difficult questions in economics. Over the last few decades, a considerable number of experimental studies have been conducted on the voluntary provision of public goods. When a payoff function is linear, as in the case with most of these studies, the dominant strategy is to contribute nothing. In contrast, the experimental results have demonstrated that subjects consistently contribute more than the dominant strategy predicts, and complete free riding is

[1] If we regard "the prediction of traditional game theory" as the outcome of the Nash or dominant strategies, the outcomes of "cooperation" such as Pareto efficient outcomes always exceed the Nash or dominant strategy outcomes. Therefore, "cooperation" in the citation implicitly means "experimental outcomes."

rare, although the average contribution gradually decays over time (see Ledyard, 1995, for a survey).

This overcontribution has evoked many interpretations. Andreoni (1995) has broadly divided the reasons for overcontribution into social preferences and decision errors. He found that approximately half of overcontribution comes from social preferences and the other half from decision errors, a finding that is also supported by Houser and Kurzban (2002). Palfrey and Prisbrey (1997) have shown that both warm-glow and decision errors play important roles, while Brandts and Schram (2001) have cast some doubts on warm-glow and valued altruism. Goeree et al. (2002) observed a positive effect of altruism and decision errors on average contributions. Croson (2007) distinguished between commitment, altruism, and reciprocity, and confirmed that reciprocity predominates. Ferraro and Vossler (2010) suggested that the magnitude of decision errors can correlate with experimental designs.

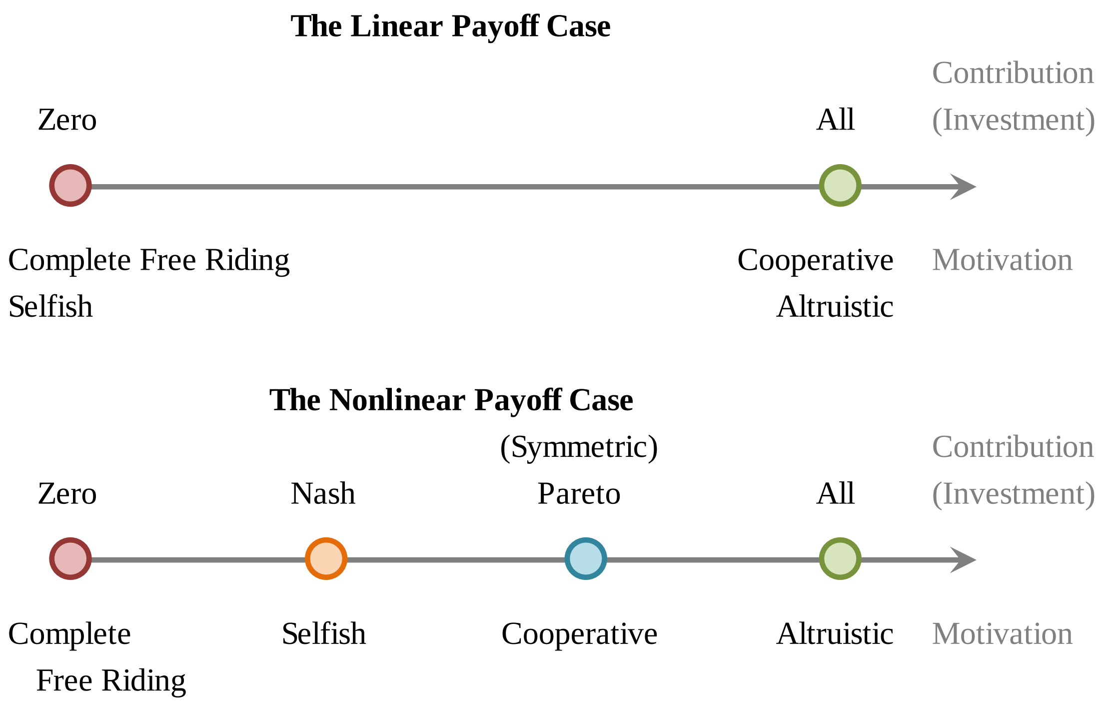

Fig. 1. Contributions and motivations in linear and nonlinear payoff functions.

However, as indicated in Fig. 1, the use of linear payoff functions does not allow for the isolation of several motivations; complete free riding coincides with selfish motivation, and cooperative motivation coincides with altruism.[2] The former phenotype contribution level is zero, and the latter is all; that is, one outcome has multiple motivations.

In order to isolate these motivations, we need to use a nonlinear payoff function (e.g., a Cobb-Douglas or quasi-linear function). With nonlinear preferences, complete free riding no longer represents a selfish strategy. Instead, in the Nash equilibrium, each subject chooses a nonzero contribution to the public good. Similarly, a symmetric Pareto efficient contribution represents cooperative motivation when all the subjects have the same payoff function. Furthermore, contributing one's entire endowment to the public good corresponds to altruistic motivation.

However, in the case of nonlinear public good experiments, the question regarding which motivation is important remains to be answered. Numerous studies have uniformly shown that when an interior Nash equilibrium is below the midpoint of the total endowment, as in the case of boundary equilibrium, the average contribution significantly exceeds the interior Nash equilibrium level.[3] In this setting, decision errors would be canceled out as such errors appear in two different directions (above and below the equilibrium). Therefore, social preferences seem to be the source of this overprovision.

However, earlier works offer no clear indication regarding what types of motivations contribute to deviations from the standard theory. This is partly because such experiments have not identified an experimental environment supporting theoretical predictions. Therefore, in this paper, we attempt to present an experimental model—in its simplest form—that follows the assumptions of the standard theory. The following paragraphs describe our strategies for building our experimental model.

First, we set the number of subjects at two, as Smith (2008) suggests. Most of the previous experiments on the provision of public goods have used at least three subjects per

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[2] Here, we define altruistic motivation as maximizing the other's payoff, and cooperative motivation as achieving a Pareto efficient allocation.

[3] See, for example, Keser (1996), Sefton and Steinberg (1996), Isaac and Walker (1998), Laury et al. (1999), Willinger and Ziegelmeyer (1999, 2001), and Hichri (2004). Isaac and Walker (1998), who compared the results from two designs where an interior Nash equilibrium was symmetrically located above and below the midpoint of the decision space, found that the upward bias of the former was significantly greater than the downward bias of the latter. See also Laury and Holt (2008) for a survey on nonlinear public good experiments.

group.[4] Owing to the smaller number of participants, the two-subject design can reduce misunderstandings on the payoff structure and allow each subject to consider only one opponent's behavior.

Second, in order to render the strategic nature of the game more transparent for the subjects, we use two types of payoff tables that are mathematically equivalent. One is a payoff table *in the nonstrategic form*, or the "*N* table," and the other is a payoff table *in the strategic form*, or the "*S* table." In the voluntary contribution mechanism, each subject i receives a payoff from the consumption of i's private good and a payoff from the level of the public good. Therefore, the payoff expression is the sum of these two payoffs, which is displayed as the *N* table. This is the type of table given to the subjects in most previous experiments. Conversely, the *S* table shows subject i's payoff expressed by a matrix specifying the interdependence of i's own contribution and the other's contribution to the public good.[5]

These two tables have two major differences. The first difference is in the degree to which the subjects see the strategic interaction between them. In the *N* table, the interaction is obscure, whereas in the *S* table, it is seen clearly by the subjects, since it is a matrix payoff table. The second difference is that the *N* table gives the subjects the economic framework of public good provision, but the *S* table does not.[6]

Third, we examine how the information regarding the other's payoff structure given to each subject, in addition to the payoff table control, affects his/her decision. Under the complete information condition, each subject knows that the other has the same payoff table as his/her own. Under the incomplete information condition, each subject is unaware of this fact.[7] We call this the *information control*. Isaac and Walker (1998) and Marks and Croson

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[4] There are a few exceptions (Cason et al., 2002; Van Dijk et al., 2002; Cason et al., 2004, 2008).

[5] In our experiment, we used a 1×49 table for the public good and a saving box for the private good for the *N* table (see Table 1); we used a 25×25 matrix for the *S* table (see Table 2).

[6] Saijo and Nakamura (1995) first compared the effects of the two payoff tables with a linear payoff function. Their *N* table, which they call the "rough payoff table," presents the payoffs from the public good for every 10 units of investment, while our *N* table presents those for every possible level of investment.

[7] Here, the definition of the term "incomplete information" is different from that of game theory, and we follow the pioneering works of Isaac and Walker (1998) and Marks and Croson (1999).

(1999) have found that information control has little effect in linear and threshold public goods experiments, respectively; however, they used only the *N*-type tables.[8]

Since there are two payoff table conditions and two information conditions, we have four distinct treatments. Let us summarize the main results. First, when the *S* table was used, the average individual contributions were not statistically different from the average Nash equilibrium level. However, when the *N* table was used, they were significantly greater than the average Nash equilibrium level. This result suggests that although the payoff structure is exactly the same, how we present it determines the level of contributions.

Second, the frequencies of the Nash motivation were more than 80% under the *S*-table condition and more than 70% under the *N*-table condition. When the subjects knew the other's payoff information, some of them revealed cooperative motivation, represented by their symmetric Pareto efficient contribution. Altruistic motivation that corresponded to contributing everything was rare under both conditions.

Third, under the *S*-table condition, the variance of contributions with complete information was significantly greater than that with incomplete information. The reason was that some subjects who knew the payoff matrix of the other sought out the symmetric Pareto efficient contribution, although pairs of subjects who attained this contribution were rare. This result was also observed in the case of the *N* table; that is, providing the other's payoff information promotes cooperative motivation.

The remainder of the paper is organized in the following manner. Section 2 explains the voluntary contribution mechanism. Section 3 describes the experimental design, and Sect. 4 presents the results. Section 5 discusses the differences between our results and those of previous works.

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[8] In fact, the treatment of incomplete information is slightly different across each experiment. In Isaac and Walker's (1998) incomplete information treatment, the subjects do not know other subjects' marginal returns from the private good and the distribution of endowments among them. In Marks and Croson's (1999) incomplete information treatment, the subjects know the sum of the group members' benefits from the public good, but do not know the value of each under the known sum condition, whereas they know neither the sum nor the value under the unknown sum condition. Moreover, the marginal benefits from the public good are actually heterogeneous among subjects.

2. The voluntary contribution mechanism

There are two subjects, a and b, such that subject i (= a, b) has w_i units of the endowment of a private good. Each subject faces the decision of dividing w_i between his/her own consumption of the private good (x_i) and investment (y_i) in the public good (y). From the investment, each subject enjoys $y = y_a + y_b$; that is, the level of the public good is the sum of the investments of two subjects. Therefore, each subject's decision problem is to maximize his/her own payoff $u_i(x_i, y)$, subject to $x_i + y_i = w_i$. We use a quasi-linear function to transform the contributions and the consumption of the private good into each subject's payoff; all subjects have the same payoff function. We specify that payoff function in the following manner:

$$u_i(x_i, y) = \alpha\left(x_i + \beta y - \beta y^2/\gamma\right), \tag{1}$$

where $(w_a, w_b) = (24, 24)$, $\alpha = 220$, $\beta = 7/6$, and $\gamma = 112$. With these parameters, the Nash equilibrium investment level is $\hat{y} = \hat{y}_a + \hat{y}_b = 8$. The subjects can choose only integer investment numbers between 0 and 24, and there are nine Nash equilibrium investment pairs—$(y_a, y_b) = (0, 8), (1, 7), (2, 6), \ldots, (8, 0)$. The interior Pareto efficient level of the public good, which is 32, is also determined uniquely by the Samuelson and the feasibility conditions.[9] Apparently, the Nash equilibrium level of the public good is less than the Pareto efficient level. The proportion of the Nash equilibrium investment to the total endowment is 8/48 (16.7%), and the proportion of the interior Pareto efficient investment to the total endowment is 32/48 (67.7%).[10]

Conversely, experimenters usually employ a linear payoff function in the form $u_i(x_i, y) = x_i + \delta y$, where $0 < \delta < 1$. We define altruistic investment as full investment, since it maximizes the other's payoff for any given investment of the other. Thus, we have the following simple but important proposition in our experimental setup:

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[9] In addition to interior Pareto efficient allocations, there are boundary Pareto efficient allocations: $(y_a, y_b) = (24, 0), \ldots, (24, 8), (0, 24), \ldots, (8, 24)$.

[10] These ratios are almost equal to those in the *low endowment treatment* in Laury et al. (1999) (the first and second percentages are 16.0 and 67.2, respectively). Note that the location of equilibrium may affect the level of contributions (Isaac and Walker, 1998; Willinger and Ziegelmeyer, 2001).

Proposition 1:

(*a*) *With the linear payoff setting, we have*

zero investment = the dominant strategy investment < the symmetric Pareto efficient investment = altruistic investment (= 24).

(*b*) *With the nonlinear payoff setting in* (1), *we have*

zero investment < the average Nash equilibrium investment (= 4) *< the symmetric Pareto efficient investment* (= 16) *< altruistic investment* (= 24).

In other words, using a nonlinear payoff function creates a *one-to-one correspondence* between investments and motivations.

3. Experimental design

3.1. Treatments

Our experiment has two parameters of control: (i) the payoff table control (the *S* table [*S*] vs. the *N* table [*N*]), and (ii) the information control (complete information [*C*] vs. incomplete information [*I*]). Thus, there are four condition pairs. By using each initial, we hereinafter refer to each treatment as *SC*, *SI*, *NC*, and *NI*, respectively. For example, *SC* denotes the treatment with the *S* table and complete information.

First, let us describe the payoff table control. We employ Table 1, which is the *N* table, and the *S* table after deleting the tag and highlighting from Table 2. Since the payoff function is quasi-linear, it can be written as $u_i(x_i, y) = u_i(w_i - y_i, y) = \varphi(y) + \alpha(w_i - y_i)$, where $\varphi(y)$ is the quasi-linear part of the payoff function. In Table 1, the left 1 × 49 table shows the $\varphi(y)$ part, and the middle saving box shows the $\alpha(w_i - y_i)$ part. Alternatively, the payoff function can be written as $u_i(w_i - y_i, y) = v_i(y_i, y_j)$, and the *S* table expresses the payoff matrix of $v_i(y_i, y_j)$. Since it is easy to construct the *S* table out of the *N* table, we recover the *N* table out of the *S* table. As an example, consider $v_1(4, 5) = 6524$. Let us raise player 1's investment by one unit, while keeping the level of the public good at 9. Then, $v_1(5, 4) = 6304$. Therefore, the value of one unit of the private good is 6524 − 6304 = 220.

Table 1. The payoff table in the nonstrategic form (the *N* table).

Payoff from Investment

Total Amount of Investment	0	1	2	3	4	5	6	7	8	9
Your Payoff	0	254	504	749	990	1226	1458	1684	1907	2124

Total Amount of Investment	10	11	12	13	14	15	16	17	18	19
Your Payoff	2338	2546	2750	2949	3144	3334	3520	3701	3878	4049

Total Amount of Investment	20	21	22	23	24	25	26	27	28	29
Your Payoff	4217	4379	4538	4691	4840	4984	5124	5259	5390	5516

Total Amount of Investment	30	31	32	33	34	35	36	37	38	39
Your Payoff	5638	5754	5867	5974	6078	6176	6270	6359	6444	6524

Total Amount of Investment	40	41	42	43	44	45	46	47	48
Your Payoff	6600	6671	6738	6799	6857	6909	6958	7001	7040

+

Payoff from Saving

(24 - Your Investment Number) × 220

=

Your Payoff

Table 2. The payoff table in the strategic form (the *S* table) and subject's own best response curve.

Your Investment Number

The Other's Investment Number

Your Payoff	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	5280	5314	5344	5369	5390	5406	5418	5424	5427	5424	5418	5406	5390	5369	5344	5314	5280	5241	5198	5149	5097	5039	4978	4911	4840
1	5534	5564	5589	5610	5626	5638	5644	5647	5644	5638	5626	5610	5589	5564	5534	5500	5461	5418	5369	5317	5259	5198	5131	5060	4984
2	5784	5809	5830	5846	5858	5864	5867	5864	5858	5846	5830	5809	5784	5754	5720	5681	5638	5589	5537	5479	5418	5351	5280	5204	5124
3	6029	6050	6066	6078	6084	6087	6084	6078	6066	6050	6029	6004	5974	5940	5901	5858	5809	5757	5699	5638	5571	5500	5424	5344	5259
4	6270	6286	6298	6304	6307	6304	6298	6286	6270	6249	6224	6194	6160	6121	6078	6029	5977	5919	5858	5791	5720	5644	5564	5479	5390
5	6506	6518	6524	6527	6524	6518	6506	6490	6469	6444	6414	6380	6341	6298	6249	6197	6139	6078	6011	5940	5864	5784	5699	5610	5516
6	6738	6744	6747	6744	6738	6726	6710	6689	6664	6634	6600	6561	6518	6469	6417	6359	6298	6231	6160	6084	6004	5919	5830	5736	5638
7	6964	6967	6964	6958	6946	6930	6909	6884	6854	6820	6781	6738	6689	6637	6579	6518	6451	6380	6304	6224	6139	6050	5956	5858	5754
8	7187	7184	7178	7166	7150	7129	7104	7074	7040	7001	6958	6909	6857	6799	6738	6671	6600	6524	6444	6359	6270	6176	6078	5974	5867
9	7404	7398	7386	7370	7349	7324	7294	7260	7221	7178	7129	7077	7019	6958	6891	6820	6744	6664	6579	6490	6396	6298	6194	6087	5974
10	7618	7606	7590	7569	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6884	6799	6710	6616	6518	6414	6307	6194	6078
11	7826	7810	7789	7764	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7019	6930	6836	6738	6634	6527	6414	6298	6176
12	8030	8009	7984	7954	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7150	7056	6958	6854	6747	6634	6518	6396	6270
13	8229	8204	8174	8140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7276	7178	7074	6967	6854	6738	6616	6490	6359
14	8424	8394	8360	8321	8278	8229	8177	8119	8058	7991	7920	7844	7764	7679	7590	7496	7398	7294	7187	7074	6958	6836	6710	6579	6444
15	8614	8580	8541	8498	8449	8397	8339	8278	8211	8140	8064	7984	7899	7810	7716	7618	7514	7407	7294	7178	7056	6930	6799	6664	6524
16	8800	8761	8718	8669	8617	8559	8498	8431	8360	8284	8204	8119	8030	7936	7838	7734	7627	7514	7398	7276	7150	7019	6884	6744	6600
17	8981	8938	8889	8837	8779	8718	8651	8580	8504	8424	8339	8250	8156	8058	7954	7847	7734	7618	7496	7370	7239	7104	6964	6820	6671
18	9158	9109	9057	8999	8938	8871	8800	8724	8644	8559	8470	8376	8278	8174	8067	7954	7838	7716	7590	7459	7324	7184	7040	6891	6738
19	9329	9277	9219	9158	9091	9020	8944	8864	8779	8690	8596	8498	8394	8287	8174	8058	7936	7810	7679	7544	7404	7260	7111	6958	6799
20	9497	9439	9378	9311	9240	9164	9084	8999	8910	8816	8718	8614	8507	8394	8278	8156	8030	7899	7764	7624	7480	7331	7178	7019	6857
21	9659	9598	9531	9460	9384	9304	9219	9130	9036	8938	8834	8727	8614	8498	8376	8250	8119	7984	7844	7700	7551	7398	7239	7077	6909
22	9818	9751	9680	9604	9524	9439	9350	9256	9158	9054	8947	8834	8718	8596	8470	8339	8204	8064	7920	7771	7618	7459	7297	7129	6958
23	9971	9900	9824	9744	9659	9570	9476	9378	9274	9167	9054	8938	8816	8690	8559	8424	8284	8140	7991	7838	7679	7517	7349	7178	7001
24	10120	10044	9964	9879	9790	9696	9598	9494	9387	9274	9158	9036	8910	8779	8644	8504	8360	8211	8058	7899	7737	7569	7398	7221	7040

Subject's Own
Best Response Curve

Thus, the saving value is (24 − 4) × 220 = 4400 and, hence, the public good value at 9 is 6524 – 4400 = 2124, which is the value of the public good at 9 in Table 1. It is important to note that the above procedure implicitly assumes that the target function is quasi-linear, and there are two goods, one private and one public. In other words, $u_i(w_i - y_i, y)$ cannot be recovered from $v_i(y_i, y_j)$ without having this economic structure. Therefore, the mathematical equivalence is valid under the knowledge of the structure.[11] A quasi-linear payoff function is one of the sufficient conditions for guaranteeing the interchangeability of the two payoff tables that secures their mathematical equivalence.[12]

However, the two payoff tables have at least two important differences. The first difference is, as Saijo and Nakamura (1995) have pointed out, the visibility of the strategic interaction between the subjects, that is, how the payoffs depend on the combination of a subject's own and another's strategies. Each subject can find his/her own total payoff immediately from the *S* table, but not from the *N* table. For example, suppose that subject *a* invests 4 and subject *b* invests 8. Accordingly, the total investment is 12. By using the *N* table, the subjects can only know their payoffs from the public good (2750), but they have to calculate their payoffs from their private consumption by themselves. In this case, subject *a*'s total payoff is 220 × (24 − 4) + 2750 = 7150. The *N* table requires this two-step information processing, which veils the strategic interaction, while it is evident in the *S* table. Subject *a* can be immediately aware of his/her own total payoff by simply looking at cell (4, 8) in the table, where each column corresponds to each subject's own investment and each row corresponds to the other's investment.

The second difference is in the visibility of the economic framework under which the subjects' total payoffs are derived from both the public good and the private good. The *N* table highlights this economic structure, since it contains two separate tables representing the payoffs from the public good and the private good respectively. In contrast, such a framework is missing in the *S* table, since it lists the total payoffs from the first. Even if the subjects'

[11] We showed the payoff equation (1) with the numerical values for the parameters in the instructions.

[12] For example, if we use a Cobb-Douglas payoff function, it is impossible to construct the *N* table, although it is possible to construct the *S* table.

strategies are labeled as A, B, C, …, instead of investments 1, 2, 3, …, in the table, it makes no difference in the choice of strategies.

Next, we consider information control. Under the complete information condition, each subject knows that the other’s payoff table is the same as his/her own. Conversely, under the incomplete information condition, no subject knows the other’s payoff table.

3.2. Procedures

Our experiment comprises four treatments, *SC*, *SI*, *NC*, and *NI*. We conducted the experiment at Osaka University. We ran two sessions per treatment and twenty subjects participated in each of the four treatments; thus, the sessions reported herein employed a total of 160 student subjects. We recruited these subjects through a campus-wide advertisement. The subjects were told that there would be an opportunity to earn money in a research experiment. Communication among the subjects was prohibited and did not occur. Each treatment required approximately 90 minutes to complete. The average payoff per subject was $31.56. The maximum payoff among the 160 subjects was $41.12, and the minimum was $23.14.

The experimental procedure can be described in the following manner. We instructed the 10 pairs from 20 subjects to sit at desks. The pairings were anonymous and determined in advance so as not to pair the same two subjects more than once—a so-called strangers design. There 19 rounds were conducted in each treatment. Before the actual 19 rounds, the subjects had the opportunity to practice in 3 rounds by using a payoff table that was different from the one employed in the actual experiment. However, in these non-monetary rounds, the investment numbers to be chosen were decided in advance by experimenters. Each subject received an experimental procedure sheet, instructions, a record sheet, and a payoff table. The instructions were read aloud through a microphone by the same experimenter for each treatment. During the experiment, we avoided the use of words such as “pair,” “opponent,” or “contribution.”

Each subject selected an integer investment number from the range between 0 and 24, and then inputted the number into a computer and recorded it on the record sheet.[13] After calculating the payoffs, the following information was displayed on each subject's computer screen: his/her own investment number, the other's investment number, and his/her own payoff. Each subject was asked to record these values on the record sheet. Neither the other's realized payoff nor the outcomes of the pairs other than his/her own were shown on the computer screen. Before the actual rounds began, we allowed the subjects 10 minutes to examine the payoff table.

4. Results

4.1. Average investment data

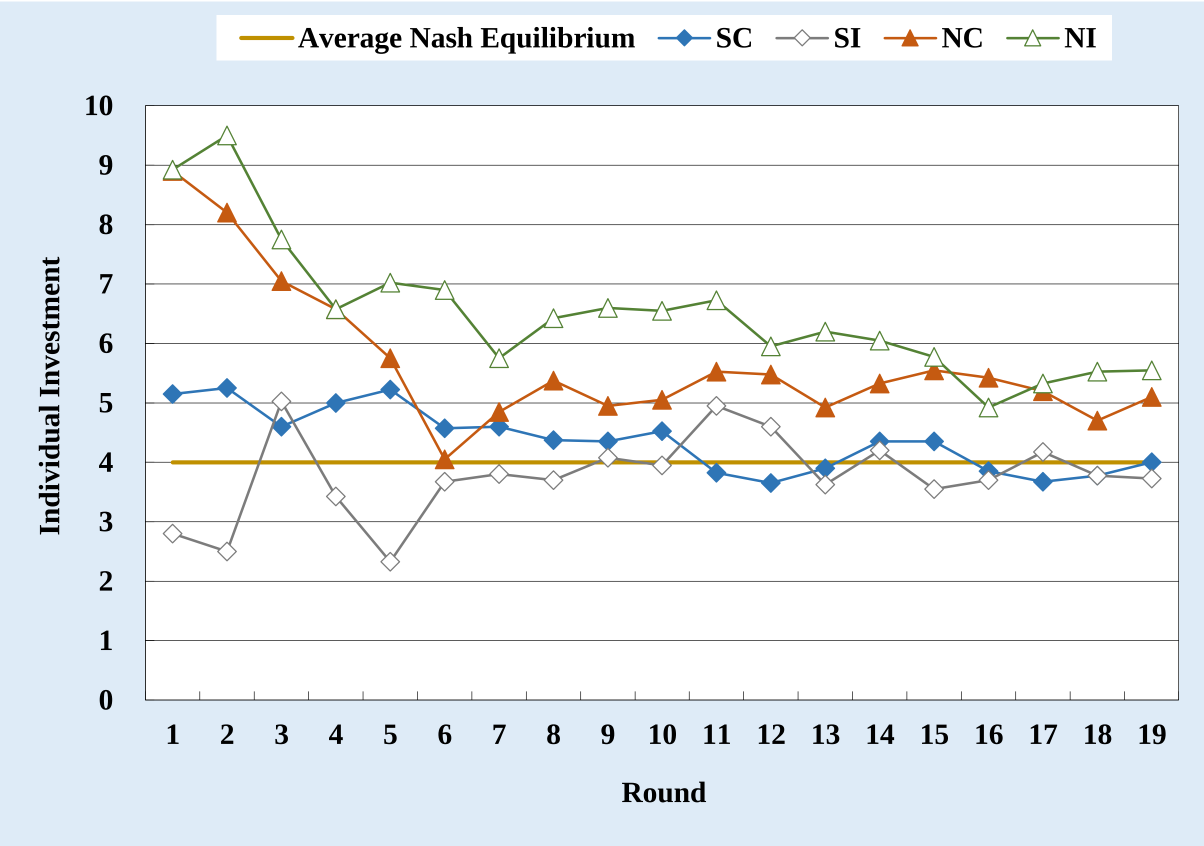

Fig. 2. Average individual investment pattern for each treatment.

[13] We used the z-Tree program (Fischbacher, 2007).

Figure 2 shows the average individual investment pattern for each treatment. First, we tested the hypothesis that the average individual investment would equal the average Nash equilibrium level (4) by pooling the data across the rounds. Since the data were not independent, we took into account the panel nature and used a random error specification $v_{it} = e_i + \varepsilon_{it}$, where e_i was a subject-specific error and ε_{it} an IID error.

The following are the results of the panel data analysis. In both *NC* and *NI*, the Nash equilibrium hypothesis was rejected at the 1% level (t = 3.406 and 3.244, respectively). However, in both *SC* and *SI*, it was not rejected at the 10% level (t = 0.626 and 0.602, respectively).

We also conducted round-by-round Wilcoxon rank-sum tests of the Nash equilibrium hypothesis. Of all the 19 rounds, it was rejected in 5 rounds in *NC* and 7 rounds in *NI* at the 5% level. In contrast, it was rejected in one round in *SC* and three rounds in *SI* at the same level.[14] Accordingly, the Nash equilibrium hypothesis was supported more frequently under the *S*-table condition. These results led to the following observation:

Observation 1:

(*a*) *Under the nonstrategic table condition, the average individual investments are significantly greater than the average Nash equilibrium level.*

(*b*) *Under the strategic table condition, the average individual investments are not statistically different from the average Nash equilibrium level.*

Observation 1-(*a*) duplicates the results of previous experiments with the *N*-type tables (Keser, 1996; Sefton and Steinberg, 1996; Isaac and Walker, 1998; Laury et al., 1999; Willinger and Ziegelmeyer, 1999, 2001; Hichri, 2004). Conversely, Observation 1-(*b*) is similar to the results of some studies using the *S*-type tables (Andreoni, 1993; Chan et al.,

[14] For those who prefer the *t* test, we also conducted round-by-round *t* tests. As a result, the Nash equilibrium hypothesis was rejected in 8, 13, 0, and 3 rounds in *NC*, *NI*, *SC*, and *SI*, respectively.

1996; Chan et al., 2002).[15, 16] Saijo and Nakamura (1995), who first compared the effects of the two payoff tables on contributions with a linear payoff function, observed that the average contribution under the *S* table was considerably smaller than that under the *N* table.

Second, we examined the effect of the payoff table control on the average individual contributions.[17] As evident from Fig. 2, the contributions in the early rounds under the *N*-table condition differed greatly from those in subsequent rounds; therefore, we divided the total of 19 rounds into two, a first half (rounds 1 through 10) and a second half (rounds 11 through 19) round. In the same manner as above, we used a panel data regression to compare the pooled data under the *S*-table condition (*SC* and *SI*) with those under the *N*-table condition (*NC* and *NI*) for both periods. In the first-half round, the difference in the average individual contribution between the *S*- and *N*-table conditions was significant at the 1% level ($t = 3.732$), while in the second-half round, it was not significant at the 1% level, but was significant at the 5% level ($t = 2.515$). The following could be a possible explanation for the greater difference in the first-half round. As described in Sect. 3.1, compared with the payoff matrix of the *S* table, the *N* table requires more complicated reasoning to arrive at the interdependency between the decisions of both subjects and the resulting payoffs; therefore, some subjects may have sampled several strategies to ascertain this interdependency by trial and error. If this is true, it leads to overcontribution, since the decision space above the Nash equilibrium strategy is relatively much greater than that below the Nash equilibrium strategy (see Sect. 2).

Finally, we examined whether the average individual investment would decrease as the rounds advanced, which was one of the most common findings in voluntary contribution mechanism experiments (Ledyard, 1995). The following are the results of the random effects

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[15] One exception is Van Dijk et al. (2002). In their experiment, where an *S*-type table was used and the same two subjects repeatedly played the voluntary contribution mechanism with an interior Nash equilibrium, the average overall contribution was greater than the Nash equilibrium level, and dropped rapidly in the final round.

[16] In a gift-exchange game experiment, Charness et al. (2004) observed that both the wages and worker efforts were significantly reduced and, hence, became closer to the dominant strategy equilibrium levels by introducing an *S*-type table.

[17] In contrast to the payoff table control, the effect of the information control on the average individual contributions was not observed; the comparison between the pooled data across 19 rounds under the complete information condition (*SC* and *NC*) and under the incomplete information condition (*SI* and *NI*) did not show a significant difference at the 10% level ($t = 0.218$).

GLS regression. In *NC* and *NI*, the coefficients of linear time trend were −0.135 and −0.172, respectively, and both were significant at the 1% level. Also, in *SC*, the coefficient was −0.079 and significant at the 1% level, but in *SI*, the coefficient was 0.043 and significant at the 5% level; that is, the average individual investment did not decline. These results are summarized as follows:

Observation 2:

(*a*) *Under the nonstrategic table condition, the average individual investments decrease as the periods advance.*

(*b*) *Under the strategic table condition, the average individual investment with complete information decreases as the periods advance, but that with incomplete information does not.*

Observation 2-(*a*) is consistent with the results of earlier studies with the *N*-type tables or without any payoff tables. In contrast, with the *S* table, the average individual investment decreased as the rounds advanced only under the complete information condition. We will consider the reason for this later.

4.2. Identifying motivations

There are three focal investments in our experiment: investments "0–8," "16," and "24." We specify each motivation behind each investment in the following manner:

(i) The motivation behind investment 0–8 is called "Nash motivation," since each subject chooses an investment number between 0 and 8 in every Nash equilibrium.[18]

(ii) The motivation behind investment 16 is called "cooperative motivation," since its purpose is to attain a cooperative outcome (16, 16), which is symmetrically Pareto efficient.

(iii) The motivation behind investment 24 is called "altruistic motivation," since its purpose is to maximize the other's payoff.

[18] Although the motivation behind investment 0 is either complete free riding or Nash, we regard investments 0–8 on the whole as Nash motivation. Cason et al. (2004) isolated complete free riding and Nash motivations by using a two-stage model proposed by Saijo and Yamato (1999).

Note that an outcome does not always accord with each subject's motivation. For example, if subject *a* chooses 16 with cooperative motivation, and subject *b* chooses 4 with the Nash motivation, the outcome (16, 4) is neither the cooperative one nor the Nash one.

Table 3. Frequency of individual contributions by value of contribution.

	Treatment			
Contribution	*SC*	*SI*	*NC*	*NI*
0–8	669	724	625	598
9–15	29	27	75	92
16	58	2	27	10
17–23	1	4	21	31
24	3	3	12	29
Total	760	760	760	760

Let us identify the subjects' motivations using Table 3 along with Fig. 1 and Proposition 1. In addition to the three investments, Table 3 also lists two intermediate investments, "9–15" and "17–23." The motivations behind these are collectively called "intermediate motivations." The distribution of each motivation for each treatment showed the following tendency.

In the *SC* case, the Nash and cooperative motivations accounted for more than 95% of motivations, and the Nash, cooperative, and intermediate (i.e., 9–15) motivations accounted for 99.4%. Furthermore, altruistic motivation was rare.

In the *SI* case, the basic motivation was Nash (more than 95% of motivations), and the subjects hardly paid attention to the cooperative outcome, since no payoff information for the other was given.

In the *NC* case, the Nash, cooperative, and intermediate (i.e., 9–15) motivations accounted for more than 95% of motivations, whereas altruistic motivation was rare.

In the *NI* case, the Nash and two intermediate (i.e., 9–15 and 17–23) motivations accounted for more than 94% of motivations, whereas altruistic motivation was rare.

We examined the effect of each control on the frequency of each motivation. By using Fisher's exact test, we compared (i) the pooled data under the *S*-table condition (*SC* and *SI*) with those under the *N*-table condition (*NC* and *NI*) and (ii) those under the complete information condition (*SC* and *NC*) with those under the incomplete information condition (*SI* and *NI*). First, while comparing the *S*- and *N*-table conditions, the frequency of the Nash motivation under the *S*-table condition was found to be significantly greater than that under the *N*-table condition at the 1% level ($u = 8.900$). On the contrary, the frequency of altruistic motivation under the *S*-table condition was significantly smaller than that under the *N*-table condition at the 1% level ($u = 5.145$). The frequency of cooperative motivation under the *S*-table condition was significantly greater than that under the *N*-table condition at the 5% level ($u = 2.373$).

Second, while comparing the complete and incomplete information conditions, the frequency of cooperative motivation under the complete information condition was significantly greater than that under the incomplete information condition at the 1% level ($u = 7.533$), while the frequency of altruistic motivation under the complete information condition was significantly smaller than that under the incomplete information condition at the 5% level ($u = 2.499$). The frequency of the Nash motivation under the complete information condition was not statistically different from that under the incomplete information condition at the 10% level ($u = 1.466$). In Sect. 4.3, we further investigate the effect of information control on cooperative motivation.

If a contribution exceeds the cooperative level (16), we may identify the motivation behind it as "quasi-altruistic motivation." The ratios of quasi-altruistic motivation were 0.1%, 0.5%, 2.8%, and 4.1% in *SC*, *SI*, *NC*, and *NI*, respectively; that is, even when the notion of altruistic motivation was expanded as much as possible, quasi-altruistic motivation was rare under the *S*-table condition and less than 5% under the *N*-table condition.[19] Summarizing the above results, we present the following observation:

Observation 3:

(*a*) *The frequency of the Nash motivation under the strategic table condition is significantly greater than that under the nonstrategic table condition.*

(*b*) *The frequency of altruistic motivation under the strategic table condition is significantly smaller than that under the nonstrategic table condition.*

(*c*) *The frequency of cooperative motivation under the complete information condition is significantly greater than that under the incomplete information condition.*

4.3. The effects of information control: symmetric Pareto efficient contribution and variance

In the previous subsection, we saw that the ratios of the Nash equilibrium investment pairs under the complete information condition were almost the same as those under the incomplete information condition. However, we will show below that the variance of individual investments and the ratio of the symmetric Pareto efficient contribution (16) in *SC* are different from those in *SI*.

First, we examined whether the variance of individual investments was the same between *SC* and *SI*, and between *NC* and *NI*. We conducted round-by-round Levene tests for the equality of variances.[20] As a result, while comparing *SC* and *SI*, the null hypothesis was rejected in 14 out of 19 rounds, but while comparing *NC* and *NI*, it was rejected in only 2 rounds.[21] Therefore, the information control affected the variance of contributions only under the *S*-table condition.

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[19] Although the number of observations was small, the frequency of quasi-altruistic motivation under the *S*-table condition was significantly smaller than that under the *N*-table condition at the 1% level (u = 6.285).

[20] The Levene test is preferable to the Bartlett test in this case because the former is less sensitive to the presupposition that data follow a normal distribution. See Brown and Forsythe (1974).

[21] The variances of individual investments across the rounds were 25.9, 14.7, 28.1, and 37.9 in *SC*, *SI*, *NC*, and *NI*, respectively.

The difference in variance between *SC* and *SI* results mainly from the investments greater than eight. Of all the 760 individual investment choices, these high investments accounted for 12% in *SC*, but 4.7% in *SI*. If two subjects in a pair chose some investments greater than the Nash equilibrium levels, both could receive higher payoffs (i.e., Pareto improvement). Under the complete information condition, the subjects would have taken account of this payoff structure. However, this was not possible under the incomplete information condition, since the other's payoff information was unknown.[22]

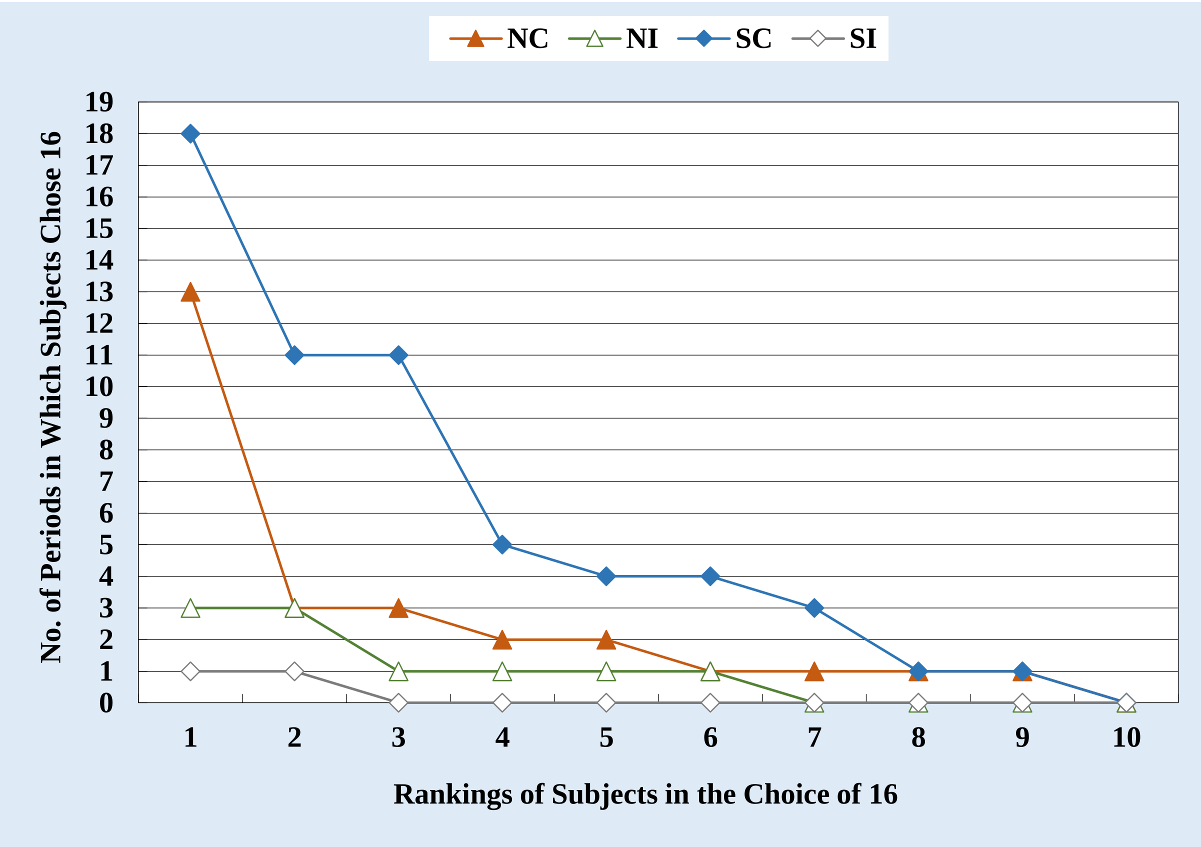

Fig. 3. Comparison of the frequencies of the symmetric Pareto efficient investment 16.

Second, we focus on the symmetric Pareto efficient investment, that is, 16. As indicated in Table 3, investment 16 was chosen 58, 2, 27, and 10 times out of all the 760 decisions in *SC*, *SI*, *NC*, and *NI*, respectively. Figure 3 compares the frequencies of investment 16 in the

[22] The strategic table underlines this payoff structure, but the nonstrategic table does not, which may be one reason that there is little difference in variance under the nonstrategic table condition.

four treatment cases. We counted the number of periods in which each subject chose investment 16, and then ranked him/her according to the number. In Fig. 3, the horizontal axis represents the rankings of the subjects in their choice of 16, and the vertical axis represents the number of periods in which they chose 16. For example, in *SC*, the first-ranked subject chose 16 in 18 periods, the second-ranked subject did so in 11 periods, the third-ranked subject also did so in 11 periods (i.e., the two tied for the second rank), the fourth-ranked subject in 5 periods, and so on. Letting n_i^X denote the number of periods in which the *i*th ranked subject of treatment *X* chose 16, we say that treatment *A dominates* treatment *B* if $n_i^A \geq n_i^B$ for all *i* = 1, …, 40 and $n_i^A > n_i^B$ for some *i*. Following this definition, *SC* dominated *SI*, and *NC* dominated *NI*; that is, providing the other's payoff information promoted the symmetric Pareto efficient contribution.

We confirmed this point statistically. By the Fisher's exact test, we compared *SC* and *SI*'s as well as *NC* and *NI*'s relative frequency of investment 16. The null hypothesis for the equality of distribution was rejected in both comparisons at the 1% level (u = 7.377 and 2.829, respectively). Nevertheless, the symmetric Pareto efficient investment pair (16, 16) was observed only 3, 0, 2, and 0 times in *SC*, *SI*, *NC*, and *NI*, respectively.[23] We summarize these results in the following observation:

Observation 4:

(*a*) *Under the strategic table condition, the variance of contributions with incomplete information is significantly smaller than that with complete information.*

(*b*) *Under the nonstrategic table condition, the variance of contributions with incomplete information is not statistically different from that with complete information.*

(*c*) *Under the strategic and nonstrategic table conditions, providing the other's payoff information significantly promotes the symmetric Pareto efficient contribution. However, the ratio of the Pareto efficient investment pairs is low in each treatment.*

[23] The numbers of all the Pareto efficient investment pairs including the boundary ones were still small: 5, 2, 10, and 26 in *SC*, *SI*, *NC*, and *NI*, respectively.

In Sect. 4.1, we found that the decay of contributions occurred in *SC*, but not in *SI*. In *SC*, the choice of investment 16 accounted for 63.7% of investment choices greater than 8, thereby suggesting that some subjects attempted to materialize a cooperative outcome. However, the investment pair (16, 16) was realized only three times out of 58 investment pairs that contained at least one choice of investment 16, and the frequency of investment 16 decreased as the rounds proceeded (with simple OLS, the coefficient was −0.126 and significant at the 5% level).

However, in *SI*, the subjects rarely chose investment 16 in the first place. This difference would be one reason why the average individual contribution declined as the rounds advanced in *SC*, but not in *SI*.[24]

5. Discussion

We have confirmed that (i) when the *S* table was used, the average individual contribution was not statistically different from the average Nash equilibrium level, and (ii) providing the other's payoff information significantly promoted a cooperative motivation. Some previous experiments with an interior Nash equilibrium showed similar results and others did not. Therefore, it would be useful to discuss the differences in the experimental design and compare the results.

Laury et al. (1999) also paid attention to the effect of payoff information and conducted two treatments using different payoff tables. There are three differences between their experimental design and ours. First, the payoff tables they used were different from ours. In their *summary information treatment*, they used a basic payoff table that presented total group earnings and each subject's earnings from the public good for only some of the cases. In their *detailed information treatment*, they gave two other payoff tables in addition to the basic payoff table. These payoff tables provided information about the marginal benefits from the public good for limited cases as well. Conversely, the *S* table that we used showed all payoffs for every possible strategy combination, but we did not provide information about the

[24] Andreoni (1995) also notes that the decay of contributions might result from the "frustration" of cooperative subjects, not only from learning.

marginal returns from the public good. Second, in their *detailed information treatment*, they indicated the Nash equilibrium contribution and the Pareto efficient contribution during the instruction phase, whereas we did not. Third, they used five subjects per group, and these subjects remained in the same group throughout the experiment (the partners design). We used pairs of subjects, and the matching changed in every round (the strangers design).

As a result, Laury et al. (1999) observed that the average group contribution in their *detailed information treatment* was significantly smaller than that in their *summary information treatment*.[25] This result, as well as ours, suggests that the manner in which payoff information is given may influence the level of contributions. By itself, the nonstrategic payoff table may fail to adequately convey the strategic nature of public good games to the subjects.

Andreoni (1993) and Chan et al. (1996), who used *S*-type tables, observed results consistent with ours. Andreoni (1993) tested the effect of crowding-out by lump-sum tax on the voluntary provision of a public good. He used a Cobb-Douglas payoff function, so there was a unique interior Nash equilibrium. The number of subjects per group was three, and they were matched in an intermediate method between the partners and strangers' matching: the subjects played the game with the same group members for four rounds, and after every four rounds, they were reassigned to a new group. With this design, the average individual contribution was close to the Nash equilibrium level in his *no-tax treatment*, but a little smaller than that (2.78 as opposed to 3).

Chan et al. (1996) tested the prediction of the model given by Bergstrom et al. (1986), which stated that voluntary contributions to a public good would increase as the distribution of endowments become more unequal. They used a quadratic payoff function with a unique interior Nash equilibrium. Each group comprised three subjects, and their matching did not

[25] Conversely, the former was still significantly greater than the Nash equilibrium level, unlike ours. Note that the partners' matching may be one reason for the overcontribution in their experiment. In the partners' setting, as Kreps et al. (1982) have pointed out, the subjects can behave strategically for a future benefit. Some studies showed that the subjects tended to contribute more in the partners' setting than in the strangers' setting (e.g., Croson, 1996; Fehr and Gächter, 2000; Keser and van Winden, 2000), but others did not (e.g., Andreoni, 1988; Weimann, 1994; Brandts and Schram, 2001). See Andreoni and Croson (2008) for a discussion on the two types of matching.

change throughout the experiment (the partners design). As a result, in their *treatment A*, where the distribution of endowments was equal among the subjects, the average group contribution was not statistically different from the Nash equilibrium level (the former was 15.8 and the latter 15).[26] Conversely, in only one session under their *treatment A*, the symmetric Pareto efficient outcome was maintained during 11 rounds. In this regard, the manner in which the matching took place might have influenced the results to some extent, although the data of this session were excluded as an exception by the Judd and McCelland's outlier test in their analysis. If we had employed the partners' matching instead of the strangers' matching, the Pareto efficient outcome might have been more frequently achieved. This possibility will be examined in a future agenda.

The results of Cason et al. (2004) contrast considerably with ours, thereby suggesting that cooperation in *SC* might be attributed to the multiple Nash equilibria. They used a Cobb-Douglas payoff function, so the Nash equilibrium was unique, unlike ours, but the other conditions were the same as ours: (i) they used the *S* table and (ii) gave the payoff information for the other. As a result, in spite of the complete information condition, the symmetric Pareto efficient contribution was seldom chosen in their experiment. On the contrary, the subjects behaved *spitefully* in order to reduce their opponents' payoffs at the cost of their own, so the average individual contribution was slightly smaller than the Nash equilibrium level.[27] Conversely, in our *SC*, where the Nash equilibrium was multiple and payoff information complete, some subjects behaved cooperatively by choosing the symmetric Pareto efficient contribution, although these choices did not affect the average contribution. When a Nash equilibrium is *unique*, as with Cason et al. (2004), the subjects can estimate the outcome of the Nash equilibrium and choose a spiteful strategy. However, when a Nash equilibrium is *multiple*, as with our study, the subjects cannot easily estimate which outcome will occur, and such spiteful behavior is virtually impossible. Whether the

[26] Chan et al. (2002) also observed a result similar to this, using a quadratic payoff function with a unique interior Nash equilibrium. In their *no-tax treatment*, the average individual contribution was not statistically different from the Nash equilibrium level (the former was 5.31, and the latter was 5).

[27] Andreoni (1993), Cason et al. (2002), and Cason et al. (2008) also observed spiteful behavior under a unique interior Nash equilibrium, although Andreoni (1993) did not refer to it.

outcomes are determinant might lead to different motivations in decision making. We plan to investigate this issue systematically in future experiments.

In addition, an important question that remains is why overcontribution occurs under the nonstrategic payoff table but not under the strategic payoff table. As we have seen earlier, there are at least two key differences between the two payoff tables: strategic interaction and economic framework. The relatively more important factor will be demonstrated by using both the payoff tables at the same time and comparing the results with those of the current experiment involving either one of the payoff tables.

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