Kumakawa, Takehisa

**Article**

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# Cooperation in a common pool resource game: Strategic behavior and a sense of intimacy

Takehisa Kumakawa[1]*

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*Corresponding author: Takehisa Kumakawa, Creative Engineering Education Center, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Aichi Prefecture, Nagoya, 466-8555, Japan
E-mail: kumakawa.takehisa@nitech.ac.jp

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Caroline Elliott, Aston University, UK

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**Abstract:** This study experimentally investigates two possible reasons for cooperative investment decisions in common pool resource games with two players. One reason is strategic behavior: subjects, who are allowed to interact with their partners repeatedly, attempt to build a long-term relationship and elicit cooperation from their partners. Another reason is a sense of intimacy: as the pairings of subjects are fixed throughout the experiment, subjects develop a sense of intimacy with their partners and make decisions by considering their benefit. The results suggest that cooperative decisions can be explained almost solely by subjects' strategic behaviors; however, the hypothesis that a sense of intimacy governed cooperative investment was not supported.

**Subjects: Letter; Economics; Microeconomics; Game Theory Economics**

**Keywords: common pool resources; cooperation; strategic behavior; sense of intimacy**

**JEL classifications: C72; C92; Q20**

## 1. Introduction

Previous experimental studies on common pool resource games have shown that subjects' behaviors can be approximated fairly well by the Nash equilibrium at the average investment level and that resource exploitation occurs in the laboratory, as the theory predicts (Keser & Gardner, 1999; Ostrom, 2006; Ostrom, Gardner, & Walker, 1994). More recently, however, Kumakawa's (2017) experiment has reported a result that is at complete variance with those from the past: when two players, instead of the eight players used in the previous experiments, make a pair and repeatedly

## ABOUT THE AUTHORS

The author is a research assistant professor at the Creative Engineering Education Center at the Nagoya Institute of Technology. He received a PhD in economics from Kyoto University. His research interests focus on experimental economics/economic psychology and applied game theory. He has been conducting experimental research on common pool resource games and the voluntary provision of a public good.

## PUBLIC INTEREST STATEMENT

The governance of common pool resources is an important and difficult agenda for local community members, as well as environmental scientists. Theoretically, individual members have strong incentives to increasingly exploit their resources, leading to its depletion. However, some economic experiments on common pool resources have shown that subjects sometimes exercise choice to restrict their harvesting, and succeed in maintaining their resources. Extending this result, this study considers what drives this cooperative decision. We focus on testing two hypotheses. The first hypothesis is that cooperation is a result of people's strategic behavior considering a future benefit. The second is that cooperation is derived from people's sense of intimacy with community members. The experimental results support the former hypothesis.

play the game, the average investment becomes significantly lower than the Nash equilibrium level and these cooperative investment decisions can be sustained across multiple rounds. Additionally, in a public good experiment using two players, van Dijk, Sonnemans, and van Winden (2002) observed a similar result: the average overall contribution was greater than the interior Nash equilibrium level, and dropped rapidly in the final round.[1]

There are at least two possible reasons for cooperative decisions in the common pool resource game with two players. One reason is strategic behavior. This possibility is derived from Kreps, Milgrom, Roberts, and Wilson's (1982) analysis on the finitely repeated prisoner's dilemma. If information about the types of players is incomplete, cooperative behavior in early rounds can be rational. For example, if a player believes that his or her opponent is altruistic, it would be rational to pretend to be altruistic in order to build a reputation for cooperation. Following this explanation, if feedback information about actions they have actually chosen is disclosed (or concealed), then cooperative decisions would become more (or less) prominent.

Another reason is a sense of intimacy. As the subjects' pairings are fixed throughout the experiment, subjects develop a sense of intimacy with their partners and make decisions considering their benefit. In traditional psychological experiments (e.g. Tajfel, Billig, Bundy, & Flament, 1971), subjects treat in-group members better than out-group members, although these groups are only distinguished by a minor and irrelevant criterion. In a game with paired players, a sense of intimacy is more likely to arise. Following this explanation, even when feedback information is not provided, subjects will be cooperative as long as they are aware that they are consistently paired with the same partners during the experiment.

This study experimentally investigates these two potential factors influencing cooperative decisions in common pool resource games. To determine the relative importance of these factors, we designed an experiment with two players and compared the results.

## 2. The common pool resource game

Consider two subjects, *a* and *b*. Each subject *i* (= *a*, *b*) has $e_i$ units of endowment. The subjects privately and simultaneously decide how to divide $e_i$ between an investment ($x_i$) in the market that represents a common pool resource, and a saving ($e_i - x_i$). Investments in the market yield a return depending on the total amount of investment of both subjects, $\sum x_i$, and a concave function $F\left(\Sigma x_i\right)$ transforms investments into returns. Savings yield a fixed rate of return, *w*. Each subject's final payoff is the sum of the returns from his or her investments and those from his or her savings; the payoff is determined by the following payoff function:

$$u_i(x_i) = we_i, \text{ if } x_i = 0, \text{ and } w(e_i - xi) + (x_i/\Sigma x_i)F(\Sigma x_i), \text{ if } x_i > 0,$$

where $(e_a, e_b) = (24, 24)$ and $w = 10$. We employ the following equation for the transformation function: $F\left(\Sigma x_i\right) = 610\,\Sigma x_i - 10\left(\Sigma x_i\right)^2$.

Note that, because $F\left(\Sigma x_i\right)$ is a concave function, $F'(0) > 10$ and $F'(48) < 0$. This implies that, at first, returns from investments in the market are greater than those from savings. However, when the total amount of investment exceeds a certain level, the returns from the market investments becomes less than those from saving; thus, very large investments lead to the depletion of the common pool resource. More specifically, with the parameters of the payoff function, the Pareto efficient investment level is $(x_a, x_b) = (15, 15)$, while the Nash equilibrium investment level is $(x_a, x_b) = (20, 20)$. Thus, the total amount of investment at the Pareto efficient level (30) is smaller than that at the Nash equilibrium level (40). In the experiment, this decision-making problem is repeated 20 times. Following backward induction logic, each player invests 20 units in every round, which is a unique subgame perfect equilibrium in the game.

## 3. Experimental design

### *3.1. Treatments*

The experiment has two control parameters: the matching control (partners [*P*] and strangers [*S*]) and feedback information control (full feedback information [*F*] and no feedback information [*N*]). Thus, there are four conditional pairs or treatments in the experiment; we hereinafter refer to the four possible treatments as *PF*, *SF*, *PN*, and *SN*. For example, *PF* denotes the treatment with partner matching and full feedback information.

First, let us describe the matching control. In partner matching, the same two subjects are paired repeatedly in every round and their matching does not change throughout the experiment. In contrast, in stranger matching, pairs change in every round in such a manner that subjects do not have the same partner twice in a row. The matching method to be used in the experiment is explicitly announced to subjects during the instruction phase, before they start playing.[2]

An important difference between the two matching methods is the ability of subjects to construct a long-term relationship with their partner in partner matching. For example, if a subject makes a disadvantageous decision against his or her partner, the partner may retaliate in subsequent rounds by performing a similar action to. Conversely, some subjects might make a cooperative decision to build each other's reputation, taking into consideration the future benefit obtained by doing so. However, such strategic behaviors are not possible in stranger matching.

Second, the feedback information control can be described as follows. Under the full feedback information condition, the following information was provided to each subject in each round: subject's investment number, the partner's investment number, and subject's individual payoff. However, under the no feedback information condition, this information was not disclosed. Thus, subjects had to repeatedly make decisions without considering the results of past rounds, including their own payoff value. After all the rounds had been completed, the sum of their payoff value in each round was announced.

### *3.2. Procedures*

We conducted the experiment at Osaka University. We ran two sessions per treatment, with 12 subjects participating in each session; thus, the sessions employed 96 student subjects. Communication among the subjects was prohibited and did not occur. Each treatment required approximately 2 h to complete. The average payoff per subject was US$ 34.20.

The experimental procedure can be described in the following manner. We instructed the six pairs, formed by the 12 subjects, to sit at desks. The pairings were anonymous and followed each matching method for all the treatments. Twenty rounds were conducted in each treatment. Each subject received instructions, a record sheet, and a payoff table (see Appendix 1 for an example of the instructions).

Each subject selected an integer investment number ranging from 0 to 24; entered the number into a computer; and recorded it on the record sheet.[3] Only in *PF* and *SF*, were the outcomes in each round—after calculating the payoffs—displayed on each subject's computer screen.

## 4. Results and discussion

First, we examined whether the average individual investment data were compatible with the Nash equilibrium prediction by pooling the data across the rounds. Since the data were not independent, we took into account the panel nature of the data and used a random error specification $v_{it} = e_i + \varepsilon_{it}$, where $e_i$ was a subject-specific error and $\varepsilon_{it}$ an IID error. The results of the panel data analysis are summarized in Table 1.

Figure 1 shows the average individual investment pattern for each treatment. It is apparent from Figure 1 that only in *PF* was the average individual investment substantially below the Nash

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**Table 1. Results of panel data analysis for differences in the average individual contributions**

| Comparison with the Nash equilibrium level | Estimated difference |
|---|---|
| *PF* | −1.819* |
| *SF* | 0.700* |
| *PN* | 0.402 |
| *SN* | 0.154 |
| *PF* versus *PN* | −2.221* |
| *SF* versus *SN* | 0.546 |

*Significance at the 1% level.

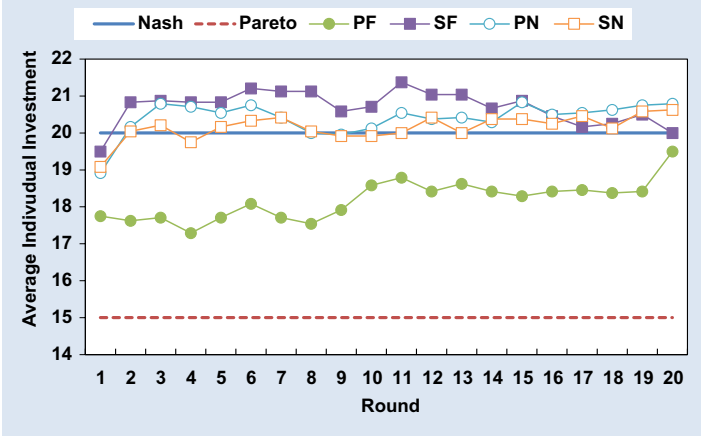


**Figure 1. Average individual investment pattern for each treatment.**

equilibrium level; the panel data analysis indicates that this difference was significant at the 1% level. In contrast, the average individual investment in *SF* was significantly greater than the Nash equilibrium level at the 1% level. The average individual investments in both *PN* and *SN* were not statistically different from the Nash equilibrium level at the 10% level. Thus, the resource depletion was alleviated only in *PF*.

Figure 2 describes an interaction effect between the two controls based on the average individual investments. When stranger matching was employed, the effect of the feedback information control was quite marginal; the panel data analysis indicates that the average individual investments were not statistically different between *SF* and *SN* at the 10% level. However, the average individual investment in *PF* was significantly smaller than that in *PN* at the 1% level. These results are also summed up in the bottom two rows of Table 1. As a result, when partner matching was applied, providing full feedback information significantly reduced the average individual investment, that is, it induced cooperative decisions. A strong interaction effect exists between the two controls, and feedback information only makes sense if repeated interactions are allowed.

If subjects' cooperative decisions derive from a sense of intimacy, they should be observed in *PF* and *PS* equally; however, they were concentrated in *PF*, which gave feedback information and allowed strategic consideration. This observation suggests that these decisions can be mainly explained by strategic behavior. The experimental results reported above support the strategic behavior hypothesis.

Finally, we focused on the distributions of individual investments. Figure 3 summarizes the frequency distribution of individual investments for each treatment. Investment numbers smaller than seven have never been chosen in any treatment, so these data ranges are omitted. From Figure 3, the most remarkable observation is that, in *PF*, the choices of the Pareto efficient investment of 15

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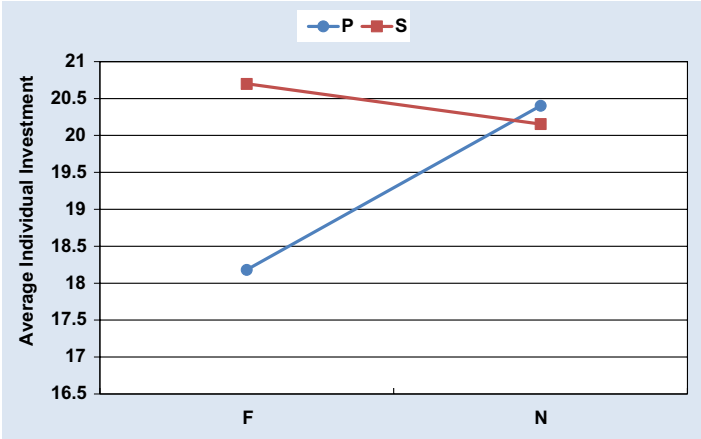


**Figure 2. Interaction effect between the two controls on average individual investments.**

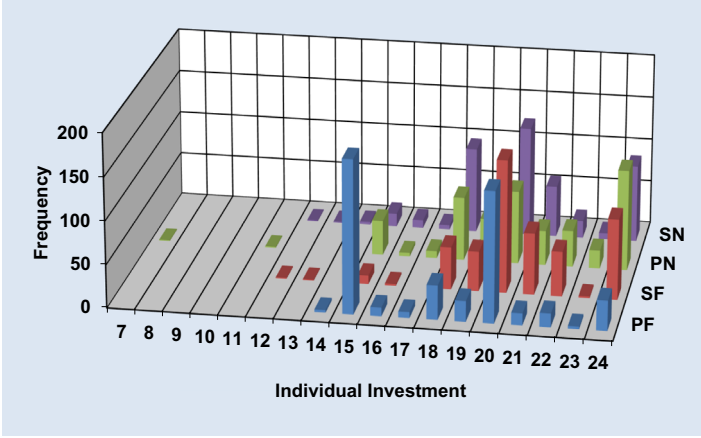


**Figure 3. Frequency distribution of individual investments for each treatment.**

Note: Investment numbers smaller than seven have never been chosen in any treatment.

stand out. Most subjects' decisions fall roughly into the Pareto efficient investment of 15 and the Nash equilibrium investment of 20. This result implies that the subjects accurately understood the payoff structure of the game.

When comparing *PN* with *SN*, it seems that, in *PN*, the choice of the Nash equilibrium investment of 20 was less frequent, while, in *PN*, the choice of the Pareto efficient investment of 15 was a little more frequent. Using Fisher's exact test, both differences in frequency were significant at the 1% level. Although not captured by the comparisons between average individual investments, just informing subjects that their partners were fixed across rounds promoted the Pareto efficient investment instead of the Nash equilibrium investment. This indicates that a sense of intimacy may exist, although it does not have a significant impact.

## 5. Concluding remarks

This study investigated two possible factors for cooperative investment decisions in common pool resource games with two players. The results suggest that cooperative decisions can be explained almost solely by the subjects' strategic behavior. They make these decisions with the aim of building long-term relationships and eliciting cooperation from their partners. The hypothesis that cooperative decisions are derived from a sense of intimacy with partners was not supported, while a marginal effect of promoting the Pareto efficient investment was observed.

In previous experiments using eight subjects per group, the average investments were consistent with the Nash equilibrium levels (Keser & Gardner, 1999; Ostrom, 2006; Ostrom et al., 1994).

Additionally, Andreoni (1988) designed the first experiment comparing the effect of the partner and stranger matching methods on contributions to the public good using five subjects per group. The experiment showed that the average individual contribution with partner matching is less than that with stranger matching.

If the number of players were two, as in our experiment, a subject's strategic behavior can serve as a signal that stimulates cooperative decisions. When the group size is large, however, it will be more difficult to express an intention to cooperate without communication. A sufficiently small group size might be a necessary condition for strategic behavior to work well in the baseline game. A systematic investigation is necessary to test this conjecture.

Finally, although the average investment across rounds was significantly smaller than the Nash equilibrium level, this investment level could not be sustained until the final round. If we do not tell subjects when the repetition of rounds will end, they will play the game as if it was an infinitely repeated game, and cooperative decisions may hold until the end. This possibility should be examined in future research.

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**Author details**
Takehisa Kumakawa[1]
E-mail: kumakawa.takehisa@nitech.ac.jp
[1] Creative Engineering Education Center, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Aichi Prefecture, Nagoya, 466-8555, Japan.

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**Notes**
1. As for public good experiments, Isaac and Walker (1988) confirmed that increasing the group size leads to a reduction in the contributions to the public good.
2. In both types of matching, subjects cannot distinguish their partner among the participants in the experiment.
3. We used the z-Tree program (Fischbacher, 2007).

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## Appendix 1.

*An example of the experimental instructions: Treatment PF*

In each period, you will have 24 units of money. Out of this, you must determine the number of units for your investment (hereafter, this will be called investment number). At the same time, your partner will also determine his or her investment number. Your earnings are determined according to your payoff, and the larger your payoff, the more earnings you get. Your payoff is determined by the sum of your investment number and your partner's investment number. Your partner does not change throughout the experiment.

In the experiment, you need to enter in your computer the investment number you have chosen. After everyone has input his or her investment number, your partner's investment number and your payoff will be displayed on the computer screen.



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