The Effect of Group Competition in the Prisoner's Dilemma Game*

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Abstract:

How does competition between groups affect individuals' behavior? To study this, I conducted an experiment in which two groups compete with each other. In each group, subjects play the iterated prisoner's dilemma game, and the group that has the larger number of people who cooperated, wins, and each member of that group gains stakes. The stakes come from fines from the losing group. Theoretically, cooperation is a dominant strategy when the amount of the stakes is sufficiently high, and betrayal is a dominant strategy when the amount of stakes is low enough.

The result of the experiment shows that i) subjects cooperate if the stakes are high enough, ii) subjects also keep a high-level cooperation rate even if the stakes are moderate, hence betrayal is the dominant strategy for every player, iii) no significant difference is found between the high and moderate stakes treatments though their dominant strategy is different, and iv) the cooperation level of high and moderate stakes treatments are significantly higher than that of the zero stakes treatment.

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1. Introduction

This study focuses on the effect of intergroup competition in the prisoner's dilemma game. The prisoner's dilemma (PD) and the public good (PG) game are the simplest models that describe the conflict between social profit and personal profit. In a basic context of a PD or PG game, theoretical analysis predicts that players will choose uncooperative strategy as a rational decision in the games and thereby fail to attain the Pareto efficient. A large number of experimental studies show that many of the subjects make cooperative decisions in a one shot game or in the beginning of the repeated game, but such decisions deteriorate as the game is repeated.

Some studies introduced inter-group competitions in which several groups are matched, and the team that produced a larger contribution (cooperation for one's group) than the other team wins points.

Bornstein et al. and Goren (Bornstein, Erev and Goren(1994), Bornstein and Ben-Yossef (1994), Bornstein(1992), Goren(2001), Goren and Bornstein (1999)) investigated the group competition of a special prisoner's dilemma. Their special game fits examples like lobbying, wars, etc, because 1) in their game, no contribution is a dominant strategy for all players, 2) no contribution is the collectively (i.e. Pareto) efficient outcome of the game. The studies show that competition has a positive effect on the cooperative decision but it does not last when the game is repeated.

In this study, I focus on the effect of competition in a very normal PD game, in which defecting is the dominant strategy for each player, but cooperation of both players brings the Pareto efficient outcome. The main purpose of this study is to investigate how competition works as a mechanism that helps an economy to achieve the Pareto efficient outcome.

Nalbantian and Schotter (2001), studied an inter-group competition in an iterated normal public goods game. They set a sufficiently high stakes level so as to make the dominant strategy of the game to bring the Pareto efficient outcome. In their setting, subjects continued high-level contribution until the end of the game. Not only from theoretical, but also from instinctive perspectives, it is not an unexpected result. People must work hard for their group when competition may lead to a great gain or a severe loss. But people often make much effort to win a competition even when the gain or loss in the competition is not so large. (Imagine a bridge party with a token prize. Despite a very small prize, winning or losing may not make any difference to the players' lives, but they will play to win!)

Therefore, I studied the inter-group prisoner's dilemma game not only with high stakes but with moderate and zero stakes. In the experiment, two groups are matched. The competition between the groups depends on the numbers of individuals within the groups who choose the cooperative strategy. The losing team must pay stakes to the winning team. I ran 3 treatments in this game. In the high stakes treatment, cooperation is a dominant strategy for all players, whereas in the moderate and zero stakes treatment, betrayal is the dominant strategy. In each treatment, players are informed of the opponent group's contribution level. The game with zero stakes is introduced to distinguish the effect of the practical profit (stakes) and information (won or lost).

The result of the experiment shows that i) subjects cooperate if the stakes are high enough, ii) subjects also a keep high-level cooperation rate even if the stakes are moderate, hence betrayal is the dominant strategy for every player, iii) no significant difference is found between the high and moderate stakes treatments though their

dominant strategy is different, iiv) the cooperation level of high and moderate stakes treatments are significantly higher than that of the zero stakes treatment. The results also show that the effect of competition has inertia, so the subjects that formerly experienced high stakes (moderate stakes) competition tend to maintain a high level of cooperation (attain full cooperation quickly) in moderate stakes (high stakes) competition.

The reminder of the paper is structured as follows. In section 2, I introduce a model of PD game with the inter-group competition. Section 3 describes the experimental procedure. In section 4, I present the results on average contribution of behaviors of different stakes levels. Analyses of results are also provided in section 4. Section 5 discuss the results and concludes.

2. The Model

In the experiment, subjects are assigned to two-person groups. They are given 1 token at the beginning of each period, and are asked to decide whether they will keep the token (betray strategy in the prisoner's dilemma game context) or invest it in a group project (cooperate strategy). Subjects earn 10 points from the 1 token that they keep for themselves and earn 6 points from each token that their group members, including themselves, invest[1].

Two groups are matched and the groups compete for stakes. Each member of the group that collected the biggest investment wins stakes. Members of the smallest investment group have to pay stakes. If the groups tie, no stakes are paid.

[1] Thus this game was conducted as a 2 person simple PG game, because I am going to extend this study as a multi person PG game

A subject's payoff function is as follows;

$$U_{mi} = \begin{cases} 10(E_{mi} - g_{mi}) + 6\sum_{i=1}^{2} g_{mi} & if \sum_{i=1}^{2} g_{mi} = \sum_{i=1}^{2} g_{ni} \\ 10(E_{mi} - g_{mi}) + 6\sum_{i=1}^{2} g_{mi} + \mathrm{T} & if \sum_{i=1}^{2} g_{mi} > \sum_{i=1}^{2} g_{ni} \\ 10(E_{mi} - g_{mi}) + 6\sum_{i=1}^{2} g_{mi} - \mathrm{T} & if \sum_{i=1}^{2} g_{mi} < \sum_{i=1}^{2} g_{ni}, \quad m \neq n \end{cases}$$

where E_i is the initial endowment and g_i is a voluntary contribution to the group project. T is the stake. I tried 3 levels of T; T=5, 3, 0. We name the case of T=5 as GC5, T=3 as GC3 and T=0 as GC0, respectively.

In GC5, to invest a token in the group project (cooperation) is a dominant strategy. In GC3 and GC0, to keep it (betrayal) is a dominant strategy.

I ran 3 series of sessions. In the first session, subjects play GC5 at first, GC3, second, and finally GC0. Each phase consists of 20 game periods. I name this session Session 530. In the second session, the order of competition treatments is changed; GC3 at first, GC5 second, finally GC0. I call this Session 350. In the last session, subjects play only GC0, and so I name it Session 0.

Group members and the matching of groups were not changed during the experiments (Partner treatment).

3. Experimental procedure

I hired 44 Kyoto Sangyo University students as subjects for Session 530, 48 for Session350 and 28 for Session 0. None of the subjects had any experience in similar experiments. Subjects arrived at the laboratory of Kyoto Sangyo University and were

seated at computer terminals that are divided by partitions. Printed instructions were given, and were also explained verbally. After the instruction was finished, subjects had an examination on the rules of the game on the computer screens, and the experiment started when every subject answered all questions correctly. When the first phase was finished, additional verbal and paper instructions on the new payoff function were given. Subjects had another test for the new rule before the second phase started. The same procedure was conducted between the second and third phase.

In the instructions, I did not use words like “win” and “lose”, because if the experimenter uses such words, subjects may suspect that winning has some important but hidden meaning. I used as neutral words as possible to avoid the so called “flaming effect”.

The experiments were conducted with the computerized laboratory and z-Tree. Each session lasted for about an hour, and the subjects earned an average of ￥3,360 in Session 350 and 530 and ￥1,120 in Session 0.

4. Results

4.1 Outline of Results

The results of Session 530 are shown in Figure 1. The average contribution rate of GC5, the first phase, over 20 periods was 83.4%. Except for the beginning periods of the phase, the behavior of the subjects was virtually rational. In GC3, the second phase, the average contribution rate was 80%. Most of subjects kept a similar strategy to the first phase except for the last few periods, though the dominant strategy of the

treatment is different from that of the previous phase. Unlike normal PD and PG experiments, contributions did not decay over periods. In GC0, the last phase, the average contribution was 53.4%. The deterioration of the contribution rate was accelerated in the last few periods of the phase.

Figure 2 shows the results of Session350. The average contribution rate in GC3, the first phase, over 20 periods was 74.1%, and the contribution rate of each period did not decrease over periods; nevertheless, contribution was not a dominant strategy. In GC5, the second phase, the average contribution rate was 87.0%. All the group contributions over 20 periods in GC5 were higher than that of the first phase, GC3. In GC0, the last, the average contribution rate was 56.3%. Like that of Session530, it was obviously lower than that of the first and second phases.

The results of Session 0 are shown in Figure 3 with the results of first phases of the other sessions. The contribution rate was 53.4%. The average contribution of each period decreased gradually as the end of the game approached.

4.2 Results of the first Phases

To investigate the effect of the stakes, we should focus primarily on the first phases because they were the only phases in which subjects started from identical conditions; they got no inertia from the former phases or no restart effect.

In the first phases, contribution is the dominant strategy in Session 530, and free-riding is the dominant strategy in Session 350 and Session0. Figure 3 plots the average contributions in the first phases of the three sessions. The visual inspection suggests that the average contribution of Session 530 and 350 is obviously higher than that of Session 0.

Table 2 shows U values of the pair-wise robust rank order test[2] between the first phases. The average contribution of Session 530 is slightly higher than that of Session 350, but the a pair wise robust rank order test accepts the null hypothesis at 5% significance level, which means the contributions are not significantly different. In other words, the contribution rate in the first phase of Session 350 is similar to that of Session 530, although their dominant strategies of them are different from each other.

A null hypothesis is rejected at 5% significance level between Session 530 and Session 0. It also is rejected between Session 350 and Session 0. We find that the contribution in the first phase of Session 350 is significantly larger than that of Session 0 though the dominant strategies of these sessions are the same.

4.3 Results within a session

The analysis of first phases shows that the result of GC3 is close to GC5, not GC0. Are similar observations found between the treatments within the same session? If the effect of the stakes is large enough, similar results could be found. Though we cannot conclude this because the results of treatments in the same session are not independent, just for reference, z-values of a non-parametric Wilcoxon test between the phases in a session is indicated in Tables 3 and 4.

In both Session 530 and Session 350, the differences between GC5 and GC0 are significant at 5% level. The null hypothesis is rejected between GC3 and GC0 at 5% level in Session 530 and at 10% level in Session 350. In Session 530, there is no

[2] For the statistical tests, I did not use group contributions but each matched group contributions as units of observation results, because decisions of a group's member are not independent from the behavior of their opponent groups. Therefore a unit of matched group data contains 4 persons' decisions. Hence the size of the data is 11 for Session 350, 12 for Session 350 and 7 for Session0.

significant difference between GC5 and GC3.

On these findings, we could say again that the result of GC3 is similar to GC5, rather than GC0. An exception is a significant difference between GC5 and GC3 in Session 350. As I mentioned above, in Session 350, all the paired group contributions of the second phase, GC5, were higher than that of the first phase, GC3. GC3 worked as a springboard to make the results nearly full contribution in CG5. Therefore the Wilcoxon test made out a significant difference although contribution levels are similar.

5. Discussion

The most remarkable result of this study is that of GC3. In this treatment, the dominant strategy was free-riding. But average contribution rates were 80.0% in Session530 and 74.2% in Session 350. All of these results are significantly larger than that of GC0s and the theoretical prediction.

It is well known that the individuals' decisions in an experiment are not always rational. In a typical PD or PG experiment, players are more cooperative than the dominant strategy of free-riding. The cooperation rates of GC0 and GC3 in this study are also larger than 0, the theoretical prediction. Many of theories like reciprocity, warm-glow, framing and so on have been examined to explain the cooperative decision in PD and PG games. Such studies show that there is no doubt that individual's behavior is affected not only by monetary incentives, but by many of the psychological and sociological factors. It suggests that one can control subjects' behaviors without changing the dominant strategy of the game. In this experiment, by introducing competition with moderate stakes in GC3, I tried to make subjecs evade the dominant

strategy of free riding. As a result, contributions in GC3 were similar to those observed in GC5, not GC0.

Why do subjects contribute so much in GC3? In GC0, though the stakes are zero, players are informed of how many individuals of the opponent group selected the contribution strategy. Hence, at the end of each period, players can notice whether their group won, lost or tied with the opponent group in the contribution level. Having no benchmark result, I cannot conclude how effective such no-stakes competition is , but we can see that the competition with no stakes did not have sufficient potential to make subjects cooperative like when they are playing a game in which contribution is the dominant strategy. Thus it would not be reasonable to conclude that subjects' willingness to beat their opponent group or to be loyal to their own group changed the result evidently. Rather, it seems that the high contribution in GC3 was caused by the stakes.

Why are the stakes important? One possible reason is that subjects had a tendency to evade the negative stakes. Subjects might think that the payoff of the inner-group game is a kind of given profit, and tried to avoid losing it by losing the inter-group competition.

Gacher (2001) found that if subjects can punish the other uncooperative members in their group, they try to do it even if punishing worsens their payoff, and as a result they keep high level contribution. The result of GC3 suggests that competition is also effective to attain the Pareto Efficient in PD or PG game. If employers want their employee to be more productive, they can divide their employees into several groups and can give an extra bonus to the member of the group that attains the best performance. One advantage of applying this method to the real-world Public Goods

problem is that the operation is relatively easy. A conductor need not observe all players, and players do not need to watch each other. Another advantage of the moderate competition is acceptability for employees. A highly severe competition may cause employees to object because it may worsen their lives too much. The result of this study suggests that small stakes works well to encourage cooperative decisions.

Though this experiment tried to remove it as much as possible, introducing the flaming effect by emphasizing the winners' honor and the losers' disgrace could make individuals more cooperative.

We should not overlook the fact that subjects have some feasible advantages to attain cooperative outcomes in this study. For example, in this experiment, the group size is only two. It may help to attain a high contribution rate. A larger group size could lessen the effect of competition. We should also keep in mind that the condition of each member is homogeneous in this game. The difference in the marginal cost for the group project or in the marginal profit from the group project may worsen individuals' desire for contribution. These issues need to be studied further in future experiments.

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Figure 1
Session 530

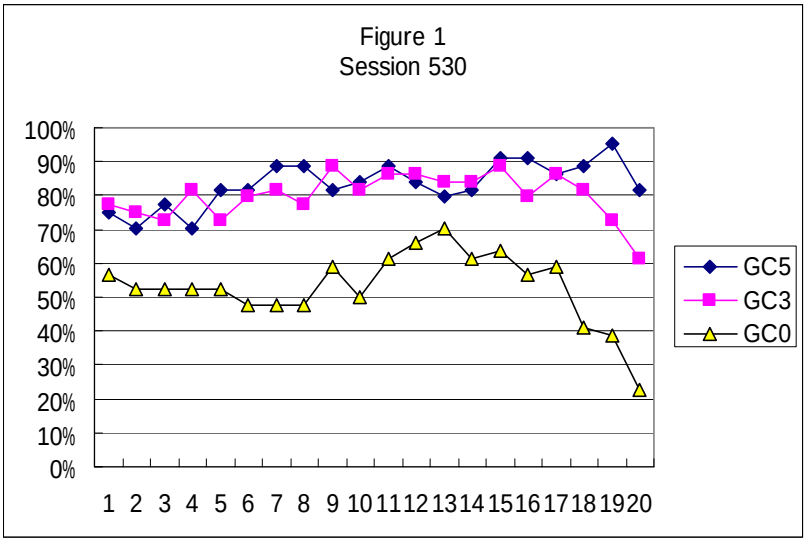

Figure 2
Session 350

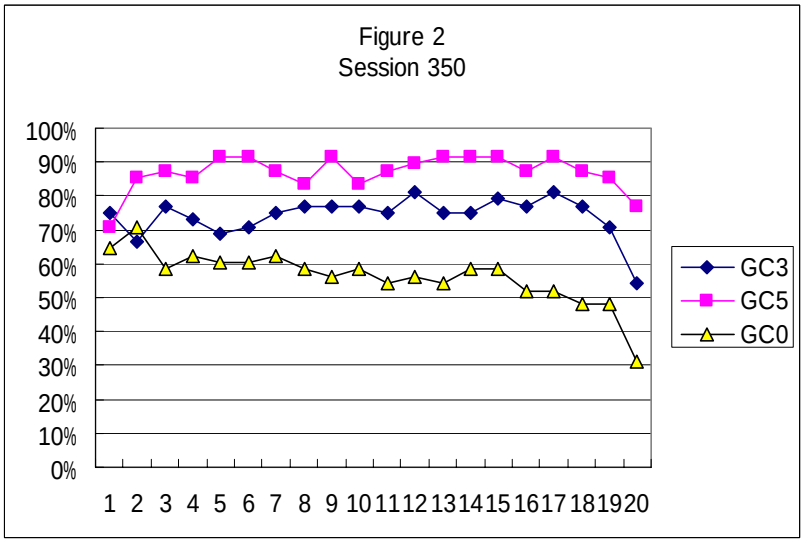

Figure 3
First Phases

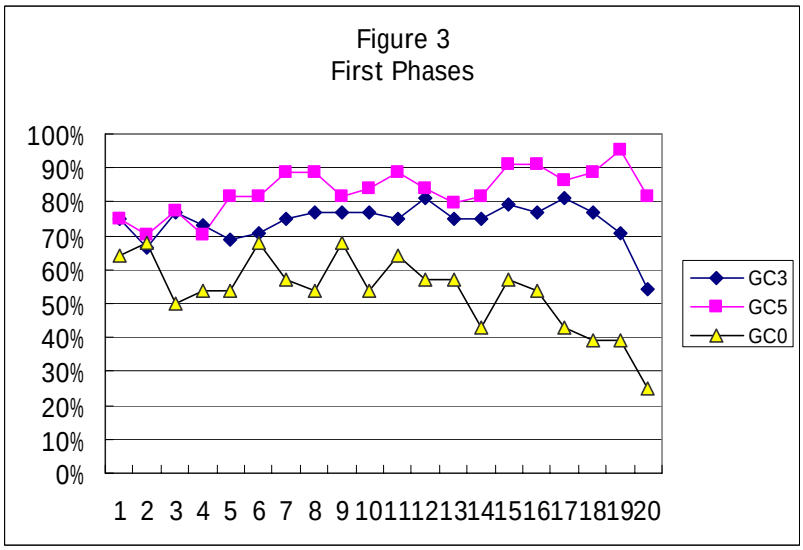

Table 1

Average Contributions over 20 Periods

	GC5	GC3	GC0
Session 530	0.834 (0.11)	0.8 (0.119)	0.53 (0.216)
Session 350	0.87 (0.158)	0.742 (0.218)	0.563 (0.356)
Session 0	-	-	0.534 (0.219)

standard deviations are in parenthesis

Table2

Compersions of Treatments in First Phases

	Session 350 GC3 74.2%	Session 0 GC0 53.4%
Session 530 GC5 83.4%	0.73	3.05**
Session 350 GC3 74.2%		2.17**

U-values of Robust Rank Order Test

*,** Indicates significance at 10%, 5%, respectively.

Table3

Compersions of Treatments in Session 530

	GC3 80.0%	GC0 53.0%
GC5 83.4%	0.87	2.85**
GC3 80.0%		2.83**

z-values of Wilcoxson test

*,** Indicates significance at 10%, 5%, respectively.

Table 4

Wilcoxson test of Session 350

	GC3 74.2%	GC0 56.3%
GC5 87.0%	3.06**	1.84*
GC3 74.2%		3.06**

z-values of Wilcoxson test

*,** Indicates significance at 10%, 5%, respectively