The experimental multimarket contact defined by a Prisoner's Dilemma and a Coordination games does not facilitate cooperation.*

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Abstract

This paper experimentally investigates whether the multimarket contact defined by a Prisoner's Dilemma (G_D) and a Coordination (G_C) games facilitates cooperation in the repeated PD game. In standard game theory, such a contact does not promote cooperation in the PD game. The experimental result indicates that the multimarket contact defined by G_C and G_D does not facilitate cooperation in

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the repeated PD game. Standard game theory predicts that the cooperation rate is higher in the multimarket contact defined by G_D and G_E, which is easiler to cooperate than G_D, than defined by G_D and G_C. Thus, the experimental result shows that the reverse is true.

1 Introduction

This paper experimentally examines whether playing coordination and PD games simultaneously and repeatedly facilitates cooperation more than the simultaneous and repeated play of the PD game. Although there are some experimental studies on playing multiple PD games simultaneously and repeatedly, nobody has investigated the situation that people face with PD and another payoff structure games at the same time.

The simultaneous and repeated play of the multiple PD games is called the "multimarket contact" in the industrial organization (Edward, 1955 [5] Bernheim and Whinston, 1990 [3], Spagnolo, 1999a [12] and 1999b [13]). This situation is also called the "linked game" from the socio-economic viewpoint (Aoki, 2001 [2]). The situation of this paper belongs to the "multimarket contact"or the "linked game", although the combination of the games is different.

Generally speaking, a coordination game (CG) is easier for mutual cooperation than a PD game. The former game has two pure strategy Nash equilibria and people easily choose the Pareto optimal strategy. On the other hand, the Pareto optimal strategy in the PD game is dominated. It is more difficult to choose the Pareto optimal strategy in the this game than in the CG.

In Knez and Camerer's experiments [8], the subjects played first a coordination game then played a PD game. In the CG treatment, they easily reached Pareto optimal Nash equilbrium with their counterpart. In the PD treatment, since the previous cooperation in the CG affects their behavior, they chose cooperative action more than those who only previously played the PD game .

Ahn et al. (2001, [1]) also considered the effect of the history of play in coordination games on the play of PD games. They found that the successful experience in coordinating on the payoff dominant equilibrium in previous play of coordination games increases the probability of cooperation in the PD game. This effect is especially strong when the player are matched with the same person in previous play of the coordination game.

Therefore, connecting a PD game with a coordination game may facilitate cooperation. If this is true, the cooperation rate will be higher under playing coordination and PD games simultaneously and repeatedly than the rate under the PD games simultaneously and repeatedly. Connecting a game with relatively difficulty for cooperation with a game with relatively easy for cooperation may improve the cooperation rate of the former game.

Bernheim and Whinston [3] investigated when the risk neutral player played only the game or multiple games infinitely with the identical counterpart. In their theory, players are assumed to use the following trigger strategy; in the first round, they always offer cooperative choices in all the games. From the second round, until their counterpart offered the defection in at least one game, they offer cooperation in all the games in every round. If the counterpart did so, they offered the defection in all the games as long as the play goes on.

There are some the multimarket contact experiments. These studies suggest that playing multiple PD games facilitates cooperation. In Philipps and Maison's experiments ([10], [11]), players played two different PD games simultaneously and repeatedly. The games had different payoff structures but the identical discount factor. Their result indicated that the cooperation rate raiesd in one of the games but it decreased in another game. This confirms one of the theoretical results in Bernheim and Whinston (1990) [3].

Feinberg and Sharman [6] conducted two treatments. First was an iterated PD game treatment. In the second treatment, players played the identical three PD games with the anoymous but identical counterpart simultaneously and repeatedly. Their result indicated that the cooperation rate was significantly higher under the second treatment than that under the first treatment.

The exceptional result was shown in Ogawa et al.(2007) [9]. They showed that as the number of possible combinations of actions in the stage game increased, the cooperation rate significantly decreased. Thus, the cooperation rate was lower when playing multiple PD games than when playing a PD game.

Although we cannot find the experimental study on the simultaneous play of coordination and PD games, as mentinoned before, there are some experimental studies in which players play a coordination game first and then play a PD games. Experimental results indicates that first experience of playing a coodination game facilitates cooperation in a later PD game. Therefore, a coordination game has the potential power to facilitate cooperation in a PD game.

We conducted a series of experiments to confirm the prediction that the linkage between a CG and a PD game promotes cooperation in the PD. Our basic experiments consisted of two treatments. First was the treatment G_{CD} under which players played a PD game and a coordination game simultaneously and repeatedly with the identical counterpart. Second was the treatment G_D under which players played the PD game repeatedly with the identical conunterpart.

Our experimental results seems to indicate that the multimarket contact with a PD game and a CG did not aid in reaching mutual cooperation in the PD. This suggests that players treated the games separately. They did not reach mutual cooperation in the PD game by taking advantage of cooperation in the CG.

However, connecting a coordination game with a PD game facilitates cooperation within the multimarket contact. we found that the cooperation rate of a PD game was significantly higher under the treatment G_{CD} than under the treatments G_{DD} [1], where playeres play identical two games, and under the treatment G_{DDD}, where they play identical three games.

Although the theory by Bernheim and Whinston predicts that the cooperation rate is higher under the treatment G_{DE} than under the treatment G_{CD}, the experiment shows the reverse result. We found that the cooperation rate was significantly higher under the treatment G_{CD} than under the treatments G_{DE}, where playeres play two different PD games.

The content of this paper is as follows. The section 2 explains the prediction. In the section 3, the experimental setting is introduced. The section 4 shows the experimenal result and investigates whether the cooperation rate when playing only a PD game and a coordination game was higher than the one when playing only the PD game. Then we investigate the cooperation promotion of the coordination game in the multimarket contact. The section 5 discusses the difference between Knez and Camerer [8] and our experiments and the reason why connecting the coordination game facilitates cooperation. The section 6 concludes this paper.

[1] The cooperation rates under the treatments G_{DD} and G_{DDD} are the avarage value.

2 Theoretical Prediction

This paper utilizes two payoff matrices (Tables 1 and 2). The game G_D in the table 1 is a prisoner's dilemma. The game G_C in the table 2 is a coordination game.

When playing a G_D infinitely repeatedly, the minimum discount factor at which cooperation in all the periods realizes a sub-game Nash equilibrium (SPNE) is $\frac{1000-800}{1000-350} \cong 0.308$. On the other hand, when playing a G_C infinitely repeatedly, one of SPNE is that both players keep on choosing A at any level of the discount factor.

When playing a G_D and a G_C simultaneously and infinite repeatedly, players virtually face with the payoff matrix showin in the table 3. In this table, by the iterated elimination of dominated strategies, we find that (Y,A) and (Y,B) is not dominated by any other strategies; the large payoff matrix changes into a coordination game with the pure strategy Nash equilibria ((Y,A), (Y,A)) and ((Y,B), (Y,B)). [2] Therefore, in the experiment, players may keep on choosing Y and A or Y and B. Especially, they may keep on choosing Y and A rather than Y and B. The cooperation rate in the game G_D is zero.

Prediction one: The subjects may keep on choosing Y and A. The cooperation rate in the game G_D is zero.

We define the cooperate rate in the following way.

$$CR() = \frac{\sum_{t=1}^{78} C_t}{T \times 78}, \tag{1}$$

where T is the number of the games. $C_t \in (0, 1, 2, 3)$ is the number of the games in which the subject offer cooperation in the tth round. 78 is the number of rounds that all the treatments lasted. For example, under the treatment G_D, if a subject chose cooperation in thirty five rounds, his or her cooperation rate is $CR(G_D) = 35/78 \cong 0.45$. Under the treatment G_{CD}, if a subject chose cooperation forty times in the game G_D and sixty times in the game G_E, his or her cooperation rate is $CR(G_C D) = (40 + 60)/(2 \times 78) \cong 0.64$.

[2]This structure is maintained when any PD game is linked to any coordination game.

Let us suppose that a player adopts the following trigger strategy. The strategy consits of three parts. First, in the first period, a player chooses X and A. Second, from the second period, he or she chooses X and A unless his or her opponent chose Y in the last period. Third, if his or her opponent did so in the last period, he or she chooses Y and A forever. [3] In this case, the minimum discount factor at which cooperation in all the periods is the same as when playing only a game G_D.

Prediction Two: The cooperation rate of the game G_D under the treatment G_{CD} is as large as the one under the treatment G_D. In the game G_C, both players choose A.

According to the experimental result in Ogawa et al.(2007) [9], the cooperation rate is affected by the possible combinations of actions in the stage game. For example,it is two in the repeated PD game G_D and four in the multimarket contact coprised of G_D and G_C. [4] They found that the increases in the number decreases the cooperation rate.

In the treatment G_{CD} and G_D, the number of combination is four [5] and two, respectively. Therefore, we propose the following prediction.

Prediction Three: The cooperation rate of the game G_D under the treatment G_{CD} is smaller than the one under the treatment G_D.

[3] There is not much point in defining the trigger strategy with (X, A) and (Y, B), since (X, A) only survives after the iterated elimination of the strategy in the payoff matrix made from (X, A) and (Y, B). The payoff matrix does not have a PD structure. Considering that the trigger strategy is usually defined in the various PD games, it is not valid to define the trigger strategy in this matrix. On the other hand, the matrix made from (X, A) and (Y, A) has a PD structure.

[4] A subject can choose one of the following combinations: (X, A), (X, B), (Y,A), and (Y,B)

[5] In the treatment G_{CD}, in every stage, a player can choose (X, A), (X, B), (Y, A) or (Y,B). Thus, the player has four combinations of actions in the stage game.

3 Experiment

We conducted a series of experiments at Kyoto sangyo university Experimental Economics Laboratory (KEEL) from June, 2005 to June, 2008. Table 4 reports the experimental profile. For our purpose, it is enough to conduct the treatments G_D and G_{CD}. However, we take advantage of other treatments conducted for Ogawa et al. (2007) [9] in order to elucidate the cooperation rate difference between the treatments G_D and G_{CD}.

Following experimental procedure is in common with all the treatments. First, a seat of each subject is separated from the other subjects. A subject cannot take a look inside of the other subjects' decision. The experimenter explains four cautions. First, the experiment lasts about about three hours. Second, the counterpart of each subject is the subject in the same room, who is decided by the computer server and identical throughout the experiment. Third, all the subjects do not know in advance that the experiment consists of how many rounds. Fourth, the experiment is done through the computer network. [6] Then we explained how to read a payoff matrix and gave some questions to the subjects in order to check their understanding of how to read the payoff matrix.

Let us explain how to decide an offer in each treatment. Under the treatment G_D, each player simultaneously and independently chooses X or Y in each round. After both players decide, the computer display shows their own action, the counterpart's action, and their own payoff. In this screen, players can check the results of all the previous rounds.

In the treatment G_{CD}, each player chooses X or Y from the game G_D and A or B from the game G_{CD} simultaneously and independently. After both players choose two actions, the computer display shows their own action in each game, the counterpart's action in each game, and their own payoff in each game. In this screen, players can check the results of all the previous rounds as under the treatment G_D.

The monetary reward (JPY) was calculated in the following way: under the treatment G_D, $800 + 0.4 \times$ the selected profit and under the treatment G_{CD}, $800 + 0.2 \times$ the selected profit. [7] The selected profit is the sum of randomly drawn profits of ten rounds. For example, if rounds one to six and round nine, eleven, twenty, and thirty one are drawned by the z-Tree

[6] Experimental programs were created by z-Tree [7].

[7] In the treatment G_{DDD}, $800 + 0.13 \times$ the selected profit. The reason why the value of the coefficient is to reach the average monetary reward at the same level.

program, the z-Tree calculates the total profit of these ten rounds. The drawn number is in common with all the subjects in the same day.

4 Experimental Result

4.1 The cooperation rate is significantly higher under the treatment G_D than under the treatment G_{CD}.

Table 5 reports the cooperation rate of each game under the treatment G_{CD}. This table indicates that the cooperation rate is significantly higher in the CG than in the PD. The cooperation rate in the CG is almost one even in the earlier rounds.

On the other hand, the rate in the PD is low in the eariler rounds but increases in the later rounds. The cooperation rates is significantly higher in the second thirty nine rounds than in the first thirty nine rounds.

Table 6 shows the cooperation rate under the treatment G_D. Figure 1 indicates the evolution of the cooperation rate. Using the seventy eight round data, the non-repeated two-way ANOVA (round difference × the treatment difference) indicates that the cooperation rate is significantly higher under the treatment G_D than under the treatment G_{CD} ($p < 0.01$). Using the first thirty nine round data, the same analysis indicates the same result ($p < 0.01$). However, the same analysis with the last thirty nine round data indicates that he cooperation rate is not significantly higher under the treatment G_D than under the treatment G_{CD}.

Let us confirm the validity of the three predictions by comparing the cooperation rate of the game G_D under the treatment G_{CD} with the one under the treatment G_D. The *prediction one* is obviously rejected; the cooperation rate of the game G_D is much higher than zero, although the subjects kept on choosing A in the game G_C.

The *prediction Two* is half supported; In the first thirty nine rounds, the cooperation rate of the game G_D under the treatment G_{CD} is significantly smaller than the one under the treatment G_D. However, in the second thirty nine rounds, the prediction is supported. Additionally, almost of all the players offer A in the game G_C.

The *prediction three* is half supported. The result when using 78 round data and first 39 round data supports *Prediction three* (1% significance, respectively), but it is not supported in the last thirty nine rounds. However, the total cooperation rate under the treatment G_{CD} is 0.779 (Table 5) and is significantly higher than under the treatment G_D.

4.2 Connecting a CG facilitates cooperation within the multimarket contact.

The previous subsection shows that the cooperation rate of the game G_D is not higher when connecting the game G_C with the game G_D than when playing only the game G_D. This result seemingly indicates that the game G_C does not facilitate cooperation in the game G_D.

Considering that the *Prediction three* is half supported, the cooperation rate is affected by the possible combnations of actions in the stage game. The increase in the number of the possible combnation of actions decreases the cooperation rate of the G_D.

However, we did not check the cooperation rate difference in the fixed number of the possible combnation of actions in the stage game is fixed. In this subsection, when the number of the possible combnations of actions in the stage game is four, we check the *Prediction two*.

Let us deeply examine whether connecting the game G_C really facilitates cooperation or not by comparing the treatment G_{CD} with three treatments; G_{DDD}, G'_{DD} and G_{DE}. Tables 8 and 7 indicate G'_D and G_E, respectively. These experiments were done from October 2005 to November 2006 (Table 4).

These treatments have four possible combinations of actions in the stage game. The number is the same as that under the treatment G_{CD}. Given the number of possible combination of actions, if the cooperation rate is the highest under the treatment G_{CD}, connecting the CG is important for increasing the cooperation rate. In this case, the *Prediction Two* is rejected.

Let us compare the cooperation rate under the treatments G_{DDD} with G_{CD}. We use the same analysis as the previous subsection and attain the following result. In the first thirty nine rounds, the cooperation rate of the game G_D is not significantly higher under the treatment G_{DDD} [8] than under the treatment G_{CD}. On the other hand, in the second thirty nine rounds, the cooperation rate of the game G_D under the treatment G_{CD} is significantly higher than the cooperation rate under the treatment G_{DDD}.

Second, we compare the cooperation under the treatment G'_{DD} with the

[8] The cooperation rate of the game G_D under the treatment G_{DDD} is the average rate of all the games, since players in this treatment play the identical three games.

treatment G_{CD}. The game G'_D (Table 8) is as cooperative as the game G_D from the discount factor calculation. The result is exactly the same as comparison between the treatment G_{DDD} and the treatment G_{CD}.

Therefore, when the number of the possible combinations of actions is four, in order to increase coopration, playing the PD with the CG is better than playing three identical PD games and two different games, which have almost the same discount factor.

Finally, we compare the cooperatoin rate of the game G_D under the treatment G_{DE} and under the treatment G_{CD}. From the viewpoint of the discount factor calculation, the treatment G_{CD} is more cooperative than the treatment G_{CD}. In the first thirty nine rounds, the cooperation rate is not so higher under the treatment G_{CD} than under the treatment G_{DE}. However, in the second thirty nine rounds, it is significantly higher under the treatment G_{CD} than under the treatment G_{DE}.

Let us examine these results from the viewpoint of the standard game theory. According to the theory, the cooperation rate of the game G_D does not differ between under the treatment G_{DDD} and under the treatment G_{CD}. It is significantly higher under the treatment G_{DE} than under the treatment G_{CD}.

Our experimental results reject these predictions in the second thirty nine rounds : the cooperation rate of the game G_D is the highest under the treatment G_{CD} among the four treatements; G_{DDD}, G'_{DD}, G_{DE} and G_{CD}. This suggests that connecting a CG with a PD game promote cooperation significantly. The theory does not expect such a result.

5 Discussion

Let us compare Knez and Camerer (2000) [8]'s results with our experimental results. As noted before, Knez and Camerer (2000) [8] experimentally showed that previous play of the CG facilitates cooperation in the PD game played later. By comparison between our experimental results and Knez and Camerer (2000) [8]'s results, simultaneous play of the PD game and the CG promotes cooperation much more weakly than the sequential play of these games does.

The reason of the difference between our experimental results and Knez and Camerer (2000) [8]'s results seems to be the possible combinations of the actions in the stage game. The increase in the number of the combinations obstructs cooperation. Knez and Camerer (2000) [8]'s experiments has two combinations, while our experiments has four combinations.

However, within the multimarket contact, the cooperation rate when connecting the CG with the PD is the highest. Even if people simultaneously play the PD game and another PD game which is easiler to cooperate, the cooperation rate is only second highest.

There seems to be two possible reasons why connecting the CG with the PD game promotes cooperation. First, keeping on choosing the pareto optimal strategy (A) in the game G_C may affect that the players choose X in the game G_D in the second thirty nine rounds. Though they offer A in the game G_C, they may sense that they are better off in offering X in the game G_D with each other.

Second reason is that the effect of the possible combination of the actions will vanish as rounds advances. In the earlier rounds, the playeres under the treatment G_{CD} play the games as if they face with the large payoff matrix (Table 3). If doing so, they play the games with four possible combinations. However, in the later rounds, they may ignore the game G_C since strategy A is the Pareto optimal and dominant in this game. If they do so, they play only the game G_D. Our experimental result supports this scenario: the *Prediction two* is supported in the second half rounds and the *Prediction three* is supported in the first half rounds.

Our results have two hints for relationship-building between human agents. First, the increase in the number of games with which players simultaneously face does not promote cooperation but prevent cooperation. Therefore even adding a coordination game to the PD game decreases the cooperation rate. Second, when there has been already multiple relationships between the human agents, introducing a coordination game instead of a PD game promotes cooperation. Especially the most cooperative PD game cannot match the CG.

6 Concluding Remarks

This paper examines whether the multimarket contact comprised of a coordination game and a PD game facilitates cooperation of the PD game. The result indicates that the cooperation rate is under this contact playing only the PD game promotes cooperation more than this kind of the multimarket contact. However, within the multimarket contact, connecting the coordination game really facilitates cooperation.

The multimarket contact is observed in the relationship not only among firms but also between countries, and among people in the organizations. Our result will be useful to understand the human behavior under the multimarket contact and suggest how to promote cooperation in the real world.

Our future study is to find out what kind of the PD game promotes cooperation on the same level as the CG. In the real world, there are a lot of dilemma situations. Therefore, it is important to discover the PD game that have the same effect when linking the CG. In particular, we will use the PD game that the difference between Reward and Temptation is very small and conduct the multimarket contact experiments.

	X	Y
X	800, 800	0, 1000
Y	1000, 0	350, 350

Table 1: Game G_D

	A	B
A	800, 800	0, 0
B	0, 0	350, 350

Table 2: Game G_C

	(X,A)	(X,B)	(Y,A)	(Y,B)
(X,A)	1600, 1600	800, 800	800, 1800	0, 1000
(X,B)	800, 800	1150, 1150	0, 1000	350, 1350
(Y,A)	1800, 800	1000, 0	1150, 1150	350,350
(Y,B)	1000, 0	1350,350	350,350	700, 700

Table 3: Game G_D + Game G_C

date	treatment	# of subjects	# of rounds	reward (ave., JPY)
2005.6.1	G_D	26	123	3,552
2005.6.4	G_{DE}	22	123	3,211
2005.7.6	G_D	16	116	3,836
2005.7.9	G_{DE}	18	116	3,712
2005.10.15	G_{DDD}	18	78	3,959
2006.3.4	G_{DD}	16	84	3,565
2006.6.10	G'_{DD}	26	92	3,066
2006.11.25	G_{DDD}	12	83	3,037
2008.7.9	G_{CD}	24	83	3,822
2008.7.12	G_{CD}	18	85	3,832

Table 4: Treatment Profile

	78	first 39	second 39
Coop. Rate of G_D	0.565	0.478	0.651
Coop. Rate of G_C	0.992	0.992	0.991
Coop. Rete (average)	0.779	0.735	0.821

Table 5: Experimental result of the treatment G_{CD}

Game	78	first 39 rounds	second 39 rounds
G_D (116)	0.6630	0.6484	0.6777

Table 6: The percentage of cooperation in the PD game

	α	β
α	800, 800	0, 1000
β	1000, 0	210, 210

Table 7: Game G_E

	α	β
α	780, 780	0, 1000
β	1000, 0	260, 260

Table 8: Game G_E

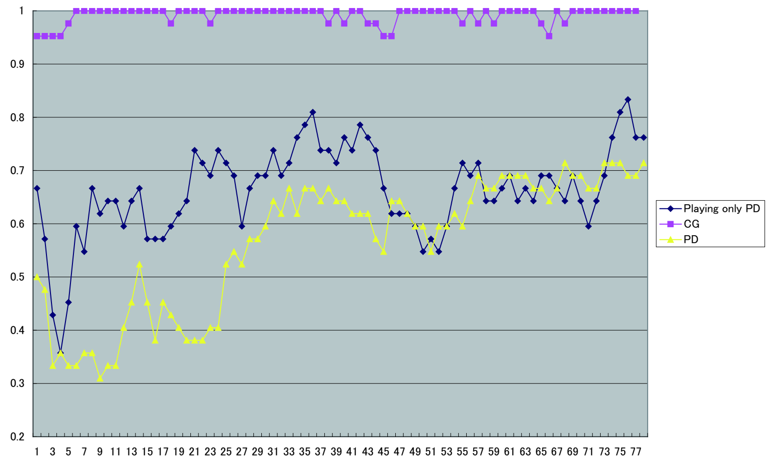

Figure 1: Evolution of the cooperation rate. “CG”, “PD”, and “playing only PD” indicate the cooperation rate of the CG game under the treatment G_{CD}, the PD game under the treatment G_{CD}, and the PD game under the treatment G_D, respectively.

Game	78	first 39 rounds	second 39 rounds
G_{DD} (84)	0.6161	0.5646	0.6676
G_{DDD} (78)	0.5013	0.5000	0.5026
G_D in G_{DE} (116)	0.5458	0.4705	0.6212

Table 9: The percentage of cooperation in the multimarket treatment

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