On the effects of information and expected cooperation in utilizing CPR: An experimental approach

Toyoaki WASHIDA*

November 20, 2008

(Draft version 17/11/2008)

Abstract

The purpose of this paper is to show the result and the analysis of economic experiments that focus on the information given to players and the expectation of cooperation. In this research, we have performed some economic experiments to seek the factors that affects the environmental consciousness. The framework of the experiments is the game of common pool resources (CPR). We designed the experiments to clarify (1) the effects of information how the other player utilize the resource, (2) the effects of the expectation for the cooperative behaviors of other players. We will show preliminary results for the role of information and expectation by players. Information enhances the reality of Nash equilibrium. The direction of the effects for the expectation is not clear. It suggests, however, that a opposite tendencies appear depending on whether people are altruistic or individualistic. We do not repeat those details. Instead, let us show the subjects we should challenge.

1 Introduction

The purpose of this paper is to show the result and the analysis of economic experiments that focus on the information given to players and the expectation of cooperation. Such information and the expectation are closely related to the formation of environmental consciousness of people. Policy makers and researchers become increasingly paying attention to the environmental consciousness for attaining the appropriate level of environmental conservation. In most cases, the environment has the feature of public goods. It means that individual decision brings not only himself costs or benefits but the others the some amount of costs or benefits. This economic relationship inevitably affects behaviors of others. Free rider problems appear in this context. On this point, we have to know that the higher income level automatically realizes the higher level of environmental consciousness. Hypothetically, we think that there exists the negative relationship between the increase information owing to economic growth and the increase of behavior for preserving the environment owing to environmental consciousness.

In this research, we have performed some economic experiments to seek the factors that affects the environmental consciousness. The framework of the experiments is the game of common pool resources (CPR). We designed the experiments to clarify (1) the effects of information how the other player utilize the resource, (2) the effects of the expectation for the cooperative behaviors of other players.

The factors that affect the environmental consciousness should be many aspects and complex. Though we do not think the factors we have employed are dominant, it gives the principal and important insight into the environmental consciousness to know how people behave in a managed environment.

Ostrom, Gardner and Walker 1994 (OGW1994) have carried out major experiments for CPR. We have executed some experiments based on the same framework as them focusing on the information and the expectation of behaviors of others which are no paid attention to in their research work. We also inquire the effect of communication, which is performed in their experiments and in the other experiment for public goods, for the sake of investigation of factors that effect on the expectation of cooperative behavior.

We will show the framework of the experiments in the second section and the major results in the section three. In the section four, we will show the implication of the result and the analysis. In the final section, we will show the subjects to have been left.

*Graduate School of Global Environmental Studies, Sophia University

2 Framework of Experiments

Let us show the CPR game model (abbreviated to OGW model) which is used in OGW1994 and Keser et al and we use in this paper.

Players face two investment opportunities. The one (say Market 1) is that the rate of return is constant and the other (Market 2) is the rate of return depends on the total amount of investment done by the players in the same group. Let x_i be the investment to Market 2. The return given by the Market 2 is determined by the $x_i V(X)$ where V_X is the rate of return depending on the total investment X in the group that the players belong to[1]. That is, the players are numbered as $j = 1, 2, \cdots, N$, $j = 1, 2, \cdots, N$ として、

$$X = \sum_{j=1}^{N} x_j.$$

The total amount of investment without the player i is expressed as follows.

$$X_{-i} = \sum_{j=1, j\neq i}^{N} x_j$$

Let the return by the investment of Market 1 be $w(> 0)$ and the initial fund be $e(> 0)$. Then the function of the individual return is expressed as follwos.

$$u_i(\mathbf{x}) = w(e - x_i) + x_i V(X), \tag{1}$$

where $\mathbf{x}$ is a vector $\mathbf{x} = (x_1, x_2, \cdots, x_N)$. The function V is $V > 0$ and $V' < 0$.

Those functions satisfy the following two conditions. (1) The sum of the investment for Market 2 is positive. That is, $V(0) > w$. (2) If all players invest their all fund in Market 2, the rate of return is negative. This is expressed as follows. The amount of the sum of the initial fund that all players have is $X = eN$. Suppose if this amount of fund is invested in Market 2. The marginal rate of return is negative.

$$\frac{d(XV)}{dX} = XV' + V < 0,$$

This means $V < -XV'$. The amount of reduction of return caused by the decrease of the marginal rate of return exceeds the return of the increase of one unit of investment[2].

Pareto optimal investment X^p satisfies the following equation.

$$w = V(X^p) + X^p V'(X^p)$$

Furthermore the symmetric Nash equilibrium X^n is expressed as follows.

$$w = V(X^n) + \frac{X^n}{N} V'(X^n)$$

As far as $V''(X) \leq 0$, the total investment in the Nash equilibrium is greater than that of the Pareto optimal investment. This means the CPR is excessively utilized.

In out experiments, the function V is specified as follows.

$$V(X) = a - bX,$$

where it satisfies $w < a < 2beN$ based on the restriction we have posed.

Parameters on our experiments are also due to the OGW model. We fixed the initial fund 12 points. They are summarized in the Table 1.

The scenarios for this model are summarized in the Table 2.

The return table is partly shown in Tble 3. The first column is the total amount of investment in Market 2 for a group. Though it is required to show up to 96 points, the table only shows up to 56 points. Players

Group		2
Number of players (per group)	N	8
Initial fund	e	12
Rate of return Market1	w	5
Parameter for Market2	a	23
Parameter for Market2	b	0.25
Optimal Investment for a group		36 (4.5 per player)
Symmetric Nash Equilibrium Investment		64 (8 per player)

Table 1: Configuration of Experimental Model

	Number of stages	Feature	Scenario
Experiment 1	15	No information	Player knows only his investment and the total investment of the group he belongs to.
Experiment 2	15	Information provided	Player knows the investment of each player in his group
Experiment 3	10	Communication	Player can chat with other players in his group in the beginning of each stage

Table 2: Experiment Scenarios

are provided the full table. The second column is the per capita group investment in Market 2. The first row is the amount of investment for each player (1 to 12 points).

At the beginning, we explain how to use this return table. We have confirmed that players understood this explanation sufficiently as far as seeing the player 's comments given after the experiments.

We require players to express privately how much other players in the same group behave cooperatively. The question is " What do you think the number of players who behave cooperatively? " The players who is cooperative are defined as the player who invest less considering the negative effect his investment.

In experiment 3, this question is given after the chats. The chats are not performed for each group but all players. At the first stage, the chat spent ten minutes and the other chat is performed for three minutes.

3 Results of Experiments

3.1 Average Investment for CPR

The average investment in each experiment is shown in the table Table 1. In the case of " No information ", the average of the investment in Market 2 is less than 8 points (Nash equilibrium) for the first half stage of the experiment except for initial period, in the last half stage, it is higher than the Nash equilibrium. This is similar tendency as the average investment approaches to the Nash equilibrium observed in the other experiments. On the other hand, in the experiments with information, investments are higher than the Nash equilibrium.

3.1.1 Effects of Information

We cannot immediately deny the notion that tendency of the result of experiments with information is simply due to the carrying out of the stages. Figure 2 shows how players change average investment in Market 2 before and after the information given.

If the tendency is due to the progress of stages, the change should appears on all players. This figure shows, however, that players who invest above the average (7.94 points) in the stages without information decrease their investment in the stages with information, except for one player. Inversely, players who invest

[1]OGW1994 used the total return $F(X)$. That is, $F(X) = XV(X)$.
[2]OGW1994 expresses this as $F'(0) > w$ and $F'(eN) < 0$

p

		個人の市場2への投資額												
G総投資	平均投資	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0.0	60												
1	0.1	60	78											
2	0.3	60	78	95										
3	0.4	60	77	95	112									
4	0.5	60	77	94	111	128								
5	0.6	60	77	94	110	127	144							
6	0.8	60	77	93	110	126	143	159						
7	0.9	60	76	93	109	125	141	158	174					
8	1.0	60	76	92	108	124	140	156	172	188				
9	1.1	60	76	92	107	123	139	155	170	186	202			
10	1.3	60	76	91	107	122	138	153	169	184	200	215		
11	1.4	60	75	91	106	121	136	152	167	182	197	213	228	
12	1.5	60	75	90	105	120	135	150	165	180	195	210	225	240
13	1.6	60	75	90	104	119	134	149	163	178	193	208	222	237
14	1.8	60	75	89	104	118	133	147	162	176	191	205	220	234
15	1.9	60	74	89	103	117	131	146	160	174	188	203	217	231
16	2.0	60	74	88	102	116	130	144	158	172	186	200	214	228
17	2.1	60	74	88	101	115	129	143	156	170	184	198	211	225
18	2.3	60	74	87	101	114	128	141	155	168	182	195	209	222
19	2.4	60	73	87	100	113	126	140	153	166	179	193	206	219
20	2.5	60	73	86	99	112	125	138	151	164	177	190	203	216
21	2.6	60	73	86	98	111	124	137	149	162	175	188	200	213
22	2.8	60	73	85	98	110	123	135	148	160	173	185	198	210
23	2.9	60	72	85	97	109	121	134	146	158	170	183	195	207
24	3.0	60	72	84	96	108	120	132	144	156	168	180	192	204
25	3.1	60	72	84	95	107	119	131	142	154	166	178	189	201
26	3.3	60	72	83	95	106	118	129	141	152	164	175	187	198
27	3.4	60	71	83	94	105	116	128	139	150	161	173	184	195
28	3.5	60	71	82	93	104	115	126	137	148	159	170	181	192
29	3.6	60	71	82	92	103	114	125	135	146	157	168	178	189
30	3.8	60	71	81	92	102	113	123	134	144	155	165	176	186
31	3.9	60	70	81	91	101	111	122	132	142	152	163	173	183
32	4.0	60	70	80	90	100	110	120	130	140	150	160	170	180
33	4.1	60	70	80	89	99	109	119	128	138	148	158	167	177
34	4.3	60	70	79	89	98	108	117	127	136	146	155	165	174
35	4.4	60	69	79	88	97	106	116	125	134	143	153	162	171
36	4.5	60	69	78	87	96	105	114	123	132	141	150	159	168
37	4.6	60	69	78	86	95	104	113	121	130	139	148	156	165
38	4.8	60	69	77	86	94	103	111	120	128	137	145	154	162
39	4.9	60	68	77	85	93	101	110	118	126	134	143	151	159
40	5.0	60	68	76	84	92	100	108	116	124	132	140	148	156
41	5.1	60	68	76	83	91	99	107	114	122	130	138	145	153
42	5.3	60	68	75	83	90	98	105	113	120	128	135	143	150
43	5.4	60	67	75	82	89	96	104	111	118	125	133	140	147
44	5.5	60	67	74	81	88	95	102	109	116	123	130	137	144
45	5.6	60	67	74	80	87	94	101	107	114	121	128	134	141
46	5.8	60	67	73	80	86	93	99	106	112	119	125	132	138
47	5.9	60	66	73	79	85	91	98	104	110	116	123	129	135
48	6.0	60	66	72	78	84	90	96	102	108	114	120	126	132
49	6.1	60	66	72	77	83	89	95	100	106	112	118	123	129
50	6.3	60	66	71	77	82	88	93	99	104	110	115	121	126
51	6.4	60	65	71	76	81	86	92	97	102	107	113	118	123
52	6.5	60	65	70	75	80	85	90	95	100	105	110	115	120
53	6.6	60	65	70	74	79	84	89	93	98	103	108	112	117
54	6.8	60	65	69	74	78	83	87	92	96	101	105	110	114
55	6.9	60	64	69	73	77	81	86	90	94	98	103	107	111
56	7.0	60	64	68	72	76	80	84	88	92	96	100	104	108

Table 3: Return Table (Part)

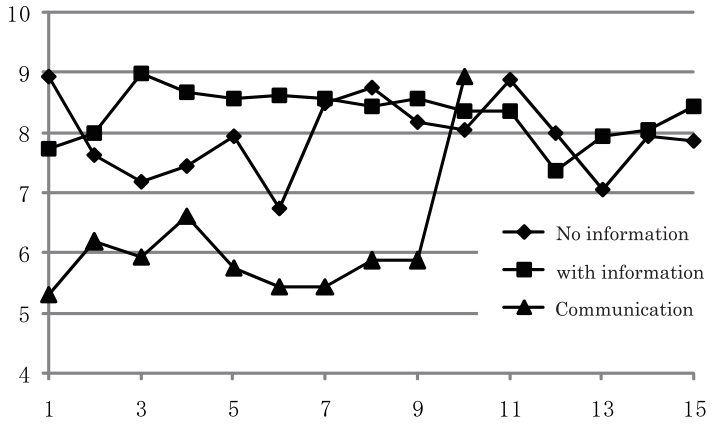

Figure 1: Average Investment in Total

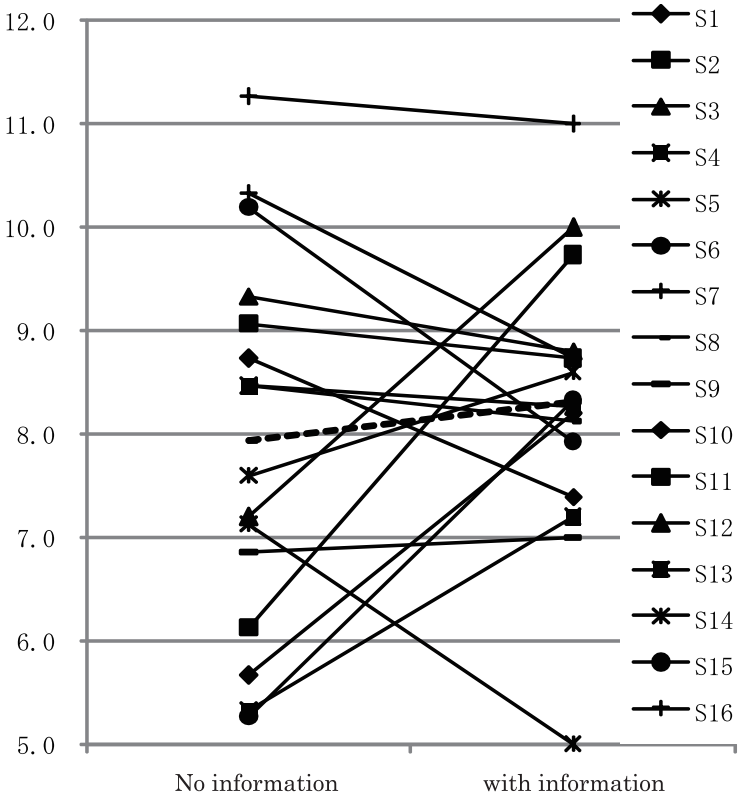

Figure 2: Change in Investment (Dotted line is the change in average

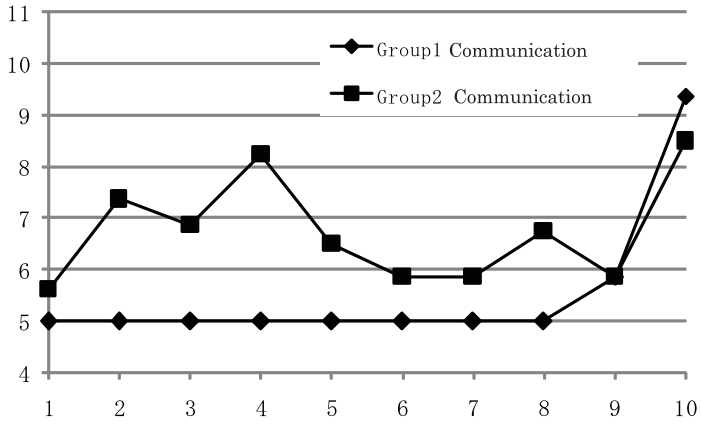

Figure 3: Average Investment with Communication

less without information invest higher than the average in the stages with information. Players who invest above the average adjust it investment towards the cooperative behavior. On the other hand, players who invest less than the average are encouraged to invest more. Those adjustments make the dominance of the Nash equilibrium be stronger. This point is confirmed in the comments written by participants after all experiments finished.

3.1.2 Effect of Communication

We told all players that the chats are anonymously carried out and players are not restrained by remarks said in the chats. The average of investments with chats drastically approaches the Pareto optimal investment, 4.5 point, see Figure 3. We can confirm the significant effect of communication on the investment from this result. In the chats, players speak each other that the most cooperative investment is about 5 points. Those results have already been shown not only in OGW1994 but in many public goods experiment. See Mori 1996.

Figure 3 also shows the difference of effects between two groups. Players in group 1 behave cooperatively except for last two stages. They positively respond the appeal "Invest 5 points" in the chats. On the other hand, for Group 2, there is no stage that all player in the group invest 5 point. This is because that there are two players, one invests quite small amount and the other invest quite large amount (nearly maximum amount). Therefore, the other player cannot believe such appeal.

3.2 Cooperate Expectation and Investment

Let us show the result for the expectation for cooperative behavior. In all stages, players report their estimation of the number of players who behave cooperatively. The summary of the estimation for each number is show in the Table 4. The average of the estimated number is 3.6.

Number of Cooperative Players	0	1	2	3	4	5	6	7
Estimated Number	53	44	122	112	82	83	64	80

Table 4: Distribution Cooperative Player Expected

First, let us show the relationship between the expectation and the investment behavior. The result for all experiments are shown Figure 4.

The responses of players for their expectation are not changed. The investments stay around the Nash equilibrium. It shows the strong tendency to keep investments near by the equilibrium. Moreover we see that the investment levels are decreased by communications.

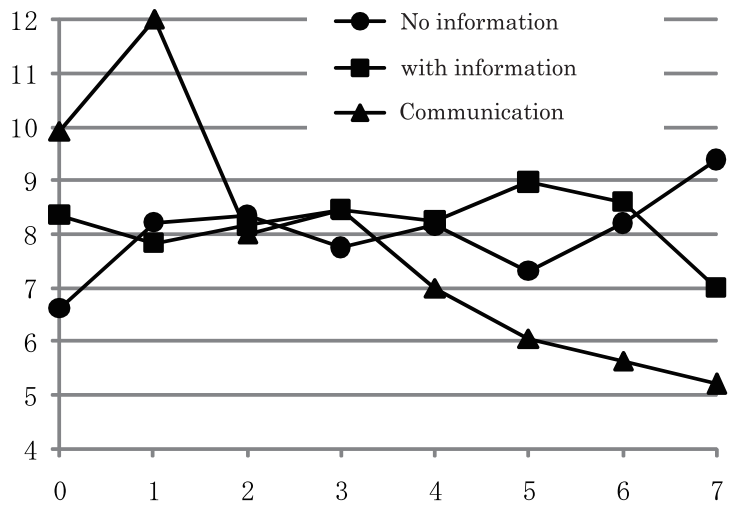

Figure 4: Expectation and Investment

The results are slightly different between two groups.

We can see that the two groups differently behave around the Nash equilibrium. That is, Group 1 has an inclination that their investments increase as the expectations of the investment of others increase. Inversely, for Group 2, we see that their investments decrease as the expectations of the investment of others increase. Though Group 2 has the trend of increase after that the expectation exceeds the 5 players and this trend is equivalent to Group 1, the investment levels are low. As a whole, we can confirm that the players in Group 2 inversely response their number of expectation.

4 Roles of information and expectation for cooperation

4.1 Information and the reality of Nash equilibrium

The information used in our experiments is just the fact how other players behave. Thus it is neutral in the sense that the information does not necessarily or directly cause both positive attitude and negative attitude towards the investment. However it does affect the investment behavior

Information affects the players who invest excessively to lessen and it makes the players who invest somewhat less to increase some extent. We can interpret this fact as the players behave so as not to be different from others. It may be caused by the consciousness that they are in a community. However, the most important point for us is that it makes their investment level to be near by the Nash equilibrium. The Nash equilibrium plays an attractor and it has affirmative reality.

In this experiments, we can see the Nash equilibrium from the return table as follows. Table 6 shows a part of that table. Now, suppose that a player invest nothing and the other players invest 8 point that is the Nash equilibrium. Then, he will have 60 points that are return only from Market 1. His return increases as he increases the investment Market 2 as shown in the number below arrows. He attains the maximum return at the cell he invests 8 points. This means that if the other players invest 8 point, his optimal investment is also 8 point. This is the symmetric Nash equilibrium.

The possibility that the players had understood this equilibrium seems to be low. They should vaguely have understood this fact. In the comment after the experiments, a player wrote "Though in the beginning, the levels of investment are fluctuate largely, in course of time, the investment levels is approaching 7 or 8 points where the returns are not so largely changed, So I also invest 8 or 9 point."

It has important implications that the information enhances the reality of the Nash equilibrium. As knowing how the other people utilize CPM (say the environment), if people think that they use CPR less

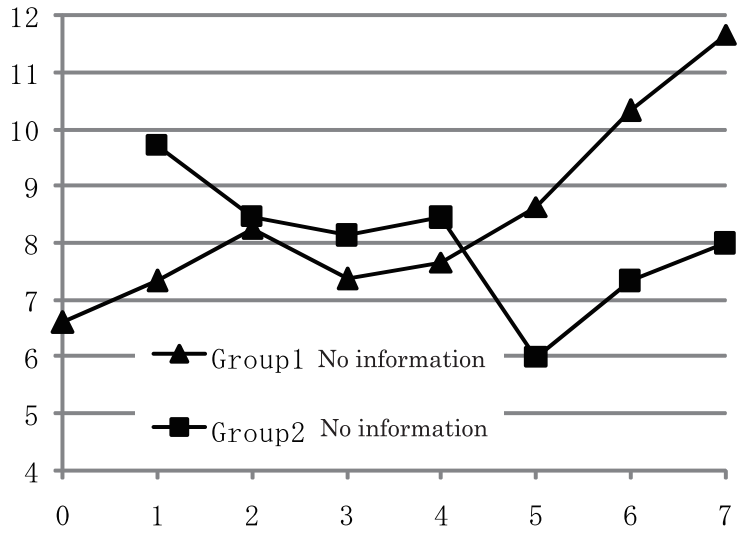

Figure 5: Expectation and Investment: without information

総利得表

G総投資	平均投資	個人の市場2への投資額 0	1	2	3	4	5	6	7	8	9	10	11	12
54	6.8	60.0	64.5	69.0	73.5	78.0	82.5	87.0	91.5	96.0	100.5	105.0	109.5	114.0
55	6.9	60.0	64.3	68.5	72.8	77.0	81.3	85.5	89.8	94.0	98.3	102.5	106.8	111.0
56	7.0	**60.0**	64.0	68.0	72.0	76.0	80.0	84.0	88.0	92.0	96.0	100.0	104.0	108.0
57	7.1	60.0	**63.8**	67.5	71.3	75.0	78.8	82.5	86.3	90.0	93.8	97.5	101.3	105.0
58	7.3	60.0	63.5	**67.0**	70.5	74.0	77.5	81.0	84.5	88.0	91.5	95.0	98.5	102.0
59	7.4	60.0	63.3	66.5	**69.8**	73.0	76.3	79.5	82.8	86.0	89.3	92.5	95.8	99.0
60	7.5	60.0	63.0	66.0	69.0	**72.0**	75.0	78.0	81.0	84.0	87.0	90.0	93.0	96.0
61	7.6	60.0	62.8	65.5	68.3	71.0	**73.8**	76.5	79.3	82.0	84.8	87.5	90.3	93.0
62	7.8	60.0	62.5	65.0	67.5	70.0	72.5	**75.0**	77.5	80.0	82.5	85.0	87.5	90.0
63	7.9	60.0	62.3	64.5	66.8	69.0	71.3	73.5	**75.8**	78.0	80.3	82.5	84.8	87.0
64	8.0	60.0	62.0	64.0	66.0	68.0	70.0	72.0	74.0	**76.0**	78.0	80.0	82.0	84.0
65	8.1	60.0	61.8	63.5	65.3	67.0	68.8	70.5	72.3	74.0	**75.8**	77.5	79.3	81.0
66	8.3	60.0	61.5	63.0	64.5	66.0	67.5	69.0	70.5	72.0	73.5	**75.0**	76.5	78.0
67	8.4	60.0	61.3	62.5	63.8	65.0	66.3	67.5	68.8	70.0	71.3	72.5	**73.8**	75.0
68	8.5	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0	70.0	71.0	**72.0**
69	8.6	60.0	60.8	61.5	62.3	63.0	63.8	64.5	65.3	66.0	66.8	67.5	68.3	69.0
70	8.8	60.0	60.5	61.0	61.5	62.0	62.5	63.0	63.5	64.0	64.5	65.0	65.5	66.0
71	8.9	60.0	60.3	60.5	60.8	61.0	61.3	61.5	61.8	62.0	62.3	62.5	62.8	63.0
72	9.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0

Figure 6: Read Nash Equilibrium in Return Table (Part)

than its average, they are prompted to use more and if they use it excessively, they decrease the level of utilization. The results are the same, that is, inefficient use of CPR over the optimal level.

For example, people in Japan with high economic growth for 1960's or in current developing countries with high economic growth felt or feel the environmental degradation seriously and excessive utilization of the environment. They naturally behave to avoid those environmental degradations. On the other hand, in case of the global warming issues, people are apt not to be able to realize the environmental degradation. Then, over use of the environment (e.g. increase emission of global warming gasses) is prompted.

Economic growth and the higher income as the result of it brings high availability of information with developed mass media inclusive of Internet. Prevalence of democracy as a political system makes societies transparent and many chances are given to people to have information of other people's behaviors. Those mean that in developed countries people tend to contribute to form Nash equilibriums other than efficient states.

Communication disrupts the Nash equilibrium. It enhances the consciousness of communities and generates the motivations to reduce the utilization of CPR. As the scale of community to be larger, the costs to realize it increase sharply. Furthermore, the prevalence of market economies and the liberalism as the basis of the market tend to prevent from forming the consciousness of community. We cannot easily expect that the communication has the power to disrupt the Nash equilibriums.

4.2 Effects of Expectation of Cooperative Behaviors

In this experiments, we have to admit that the expectation of cooperative behavior affects player's investment as the clear direction of increase or decrease. It inversely proofs the strength of the Nash equilibrium. Players, however, decrease their investment under the communication. It means that they expect many other players behave cooperatively. The expectation of cooperative behavior actually functions.

Our result shows that the expectation operates in two directions depending on the characteristics of groups. One is to increase the investment to CPR, and the other is to decrease it. This can be interpreted along the environmental issues as follows. The first one is "If the other people behave so as to protect the environment, I will also do it." The other is "If the others behave so as to protect the environment, I do not necessarily have to behave so as to protect the environment." People who behave with the former concept seem to have confidence on the cooperative behavior of the other people. It may say that they have altruistic tendency. On the other hand, people who behave with the latter concept are said to be individualistic. In our experiments,

We have to mention to the research by Hirose 1995, which treats the environmental problem as a kind of the social dilemmas. He shows that if the increase of the expectation of other's cooperative behavior brings the increase of the players who choose the cooperative strategy. His experiment is based on the frame work that player choose one in the two options, which is different from the experiments we performed for this paper. Moreover, he employed the concrete CPR problem whether a player increase cows he browses or not. The result his experiment is one direction that the increase expectation of cooperative behavior motivates cooperative behavior[3].

5 Concluding Remarks

We have shown preliminary results for the role of information and expectation by players. Information enhances the reality of Nash equilibrium. The direction of the effects for the expectation is not clear. It suggests, however, that a opposite tendencies appear depending on whether people are altruistic or individualistic. We do not repeat those details. Instead, let us show the subjects we should challenge.

(1) How much can we simulate actual CPR problem with the investment markets we have employed in our experiments? It is true that the market structure theoretically simulates economic mechanism. This economic structure is given by replace the natural resource with the pure monetary value. Even if the CPR is a simple pasture, it is a kind of ecosystem supported by numerous living creatures. If we look at CPRs as the environment, people must have more complex feelings. Therefore, this aspect of the relationship between

[3]Hirose 1995 pointed out that this result accords with the Schelling's concept of "Critical Mass". This is important point we should explore further.

a investment structure and a CPR problem is closely related to the environmental economic valuation, which becomes one of major field of environmental economics. As the environmental economic valuation has some difficulties, the replacement CPR problems with a type of investment problems.

(2) How large scale are economic experiments required to have unbiased results. As the experiments performed for this research, the number of players who joins experiments is not so large. They are dozens of players at most. Based on the statistical point of view, the biases are inevitable. Especially, for the CPR problem, players in small scale group behave differently from those in the large scale group. This is because of the smallness of influences of individual player to collective results. Then, the tendency that he only considers his costs and his own returns becomes stronger. The difference between the results of individual actions and those of collective actions become frequently major issues.

References

[1] Yukio Hirose, 1995, Kankyo to shohi no shinrigaku — koueki to shieki no dilemma, Nagoya Univ. Press. (広瀬幸雄, 1995, 『環境と消費の社会心理学—共益と私益のジレンマ—』, 名古屋大学出版会.)

[2] Keser,C., and Gardner,R., 1999, "Strategic behavior of experienced subjects in a common pool resource game," *International Journal of Game Theory*, 28:241-252.

[3] Thoru Mori, 1996, Kokyozai kyokyu no mechanism — Jikken Keizaigaku teki approach, Taga shuppan. (森徹, 1996, 『公共財供給メカニズムの有効性 — 実験経済学的アプローチ』, 多賀出版.)

[4] Ostrom,E., Gardner, R., and Walker,J., 1994, *Rules, Games, and Common-Pool Resources*, The University of Mishigan Press.

[5] Schelling,Thomas C., 1978, *Micro Motives and Macro Behavior*, W.W.Norton&Company, New York.