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Investing in Institutions for Cooperation

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Investing in Institutions for Cooperation

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Abstract
We studied public goods using an economic experiment. Subjects invested in the productivity of the public good as a group, and voluntarily contributed to provision as individuals. Investment was near the socially optimal level, but contributions were too low.

Executive Summary

In recent years, environmental quality has attracted more and more attention from the public. Everyone enjoys the benefit of having a cleaner environment, but individual efforts are needed in order to maintain the environmental quality. In economics, such goods are called Public Goods. They are non-rival—the consumption of one individual does not reduce the benefit of others, and non-excludable—no one can be excluded from consuming the good.

In many cases, both institutional and individual efforts are required to provide a public good. Looking back at the example of environmental quality, institutions such as the Environmental Protection Agency (EPA) are established to design policies. The policies alone will not improve our environmental quality unless everyone cooperates, and that is where individual contributions come in. Therefore, the effectiveness of policies depend on the level of individual cooperation, and also on the strength of the EPA—how many people are working for it, and how much money does it get each year from the federal government. Those two factors both depend on the general population. People working for the agency come from the general population, and funding for the EPA is from taxation, which is collected from everyone living in the country. Therefore, it can be argued that the productivity of the public good (environmental quality) depends on individual "investments".

In the past, economists have studied about the provision of public goods a lot. However, the focus has mostly been on voluntary contributions. There are very few studies that incorporate the effect of an institution, and most of them used institutions as a medium for sanctioning. No previous study has modeled individuals "investing" in the productivity of public goods as a group, which is what we study in this project. We study how well people make the tradeoff between investing in the productivity of the public good as a group, and contributing voluntarily as individuals, given fixed endowments.

We conducted economic experiments in the Social Science and Policies Studies Department's Experimental Economics Laboratory. Subjects in our study were recruited from introductory economics classes at Worcester Polytechnic Institute. Participation in the study was voluntary. Subjects were divided into fixed groups of four and played a repeated gamefor ten periods. To capture both the investment and contribution aspects, we divided each period of the game into two stages—the investment stage and the contribution stage.

Each period of the game started with the investment stage. Each subject received an endowment, and voted on how much they wanted to invest in the productivity of the public good. More investment would result in a more productive public good, but the marginal return from investment was decreasing as investment got higher. After all group members had voted, the group investment level was determined using the median vote. This mechanism allowed us to exclude outliers in voting. After the investment stage was the contribution stage, where subjects contributed to the provision of public good voluntarily. Subjects could only contribute from the money left after the investment stage, so higher investment, although resulting in a more productive public good, would leave less money for the subject to contribute. After the subjects had made their contribution decisions, their payoffs for the round were calculated and displayed.

The four most important variables that we examined were vote, investment, absolute contribution and percentage contribution. Both vote and investment started at a high level that was above optimal, but declined over time. Their values were very close to each other during the initial periods, but by the later rounds, a gap opened up between the values of those two variables. By the final period, average investment was very close to the optimal level of investment, but average vote was not. Therefore, we conclude that the median vote rule for determining the investment level worked well.

Both average absolute contribution and percentage contribution decreased over time, but the decline in average absolute contribution is not statistically significant. There was a highly significant relationship between relative contributions and investment, so higher investment does promote contributions. Based on our results, we have proposed a few recommendations including:

1. Let people choose the productivity of their public goods, and
2. Use the median voter rule to determine investment level.

This study will be an important contribution to the public goods literature. It provides a method for studying investment in the productivity of public goods, and an understanding of the relationship and dynamics between group investment and individual contributions.

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Chapter 1: Introduction

Economists define public goods as goods that are non-rival and non-excludable. Non-rival means that consumption by one individual does not reduce the benefit for others. Non-excludable means that no one can be excluded from consuming the good. Some real world examples of public goods are a clean environment and a safe neighborhood. Every one living in the same the same city enjoys the same environment—no one can be excluded, and the neighborhood is equally safe whether it consists of ten or twenty families.

Both examples require institutional effort as well as individual contributions. A clean environment needs policies enforced by governmental agencies such as the Environmental Protection Agency, as well as individuals' effort from everyday activities. Let us take an example: reducing air pollution from mobile sources. The EPA has a policy called the Clean Air Act (CAA) for this purpose. The CAA was a mix of controlling emissions at the point of manufacture (refiners and importers) and with vehicle use. For example, the EPA regulated lead as well as other fuel addictives used in gas. From the individual perspective, instead of driving private cars, people can take public transportation, car pool, or simply walk to their destinations if the distance is not too far. All these actions reduce the use of private cars, and therefore reduce air pollution.

Another example is that a good police department is essential for a safe neighborhood, but the crime rate will be low only if the residents cooperate with the police. This means that people should obey the law and report suspicious activities that they have seen. In order to establish the institutions, the government needs to make investments. The decisions about whether to invest are made by the President, Senators and Representatives from the House, who are elected by the general population. Money for investment is from tax revenue, which is collected from all individuals enjoying the benefit of the public good. The individual contributions, however, are not mandated from everyone. For example, someone who always drives his own car might be able to enjoy the benefit of clean environment because everyone else is taking public transportation. This kind of behavior is referred to as “free-riding”, and is very prevalent in public goods games.

The provision of public goods is a major topic that has been studied by many economists and psychologists. However, all previous studies investigate only the *individual contribution* aspect, not the *group investment* part of establishing institutions. Group investment is an essential part of the scenario, because the investment amount will directly affect the amount of benefit that the public good can generate. The productivity of the public good is often captured by the parameter marginal per capita return (MPCR) in public goods experiments.

In a standard public goods experiment, each subject is given an endowment, and is offered the choice of contributing to a group account versus a private account. Subjects earn a fixed return from the private account, but their earnings from the public account dependents on the contributions from other group members—they will be the product of the MPCR and the total group contribution. All group members receive earnings from the public account regardless of their contributions. The MPCR is a number between zero and one, so subjects will benefit from the public account only if multiple group members contribute to it.

Although the effect of the MPCR on contributions has been a popular theme in previous studies, in most cases the value of MPCR was exogenously determined by the experimenter. To our knowledge, Isaac and Norton (2010) is the only study that has examined the effects of an endogenously determined MPCR. In this study, subjects were divided into groups of five, consisting of one “manager” and four “customers”. The “manager” was able to choose the MPCR to be either a high MPCR or a low MPCR (exact values were set by the experimenters) during every decision period. A detailed description of this experiment will be provided in Chapter 2, but one important thing to note is that the manager’s choice of MPCR is one of only three discrete values (high, low, and zero— closing institution) and is not directly related to group investment. This design is not capturing the real world scenario very well, and we will be improving on it in our experimental design.

In our study, the experiment was designed to capture both the *group investment* and *individual contribution* aspects of public good provision. In addition to the *contribution stage* (parallels the *individual contribution* scenario) for traditional public goods experiments, we added an *investment stage* in every period. During the *investment stage*, subjects invested in the productivity of the public good for the following *contribution stage*. A mandatory investment was made based on members' votes. The design allowed us to study people's behavior in a more realistic environment. The voting feature mimics the real world voting for political representatives, and the mandatory investment captures the fact that everyone is required to pay tax, which will then turn into governmental investments.

Our analysis investigates the voluntary contribution of money in the presence of an investment stage. The trends of average investments and contributions are studied, as well as the relationship between MPCR and contribution rate in each game period. In previous studies, contributions have been found to be higher when MPCR was high (Isaac, Walker and Thomas, 1984; Marwell and Ames, 1981). In our study, we found that the percentage of contribution out of remainder (money left after investment) was higher with a high MPCR, but in terms of absolute contributions, there was no significant relationship between the variables. Usually, both investment and contributions were high at the beginning of experiment, but fell over the periods. We also looked at the data from each individual group to find observations that are interesting and worth discussing.

Our study allows a better understanding of human behavior in public good scenarios that require institutional investment. It will also contribute to the public goods literature, especially that on endogenously determined MPCRs.

Chapter 2: A Background on Public Goods Experiments

Public goods experiments have long been an important topic for experimental and behavioral economists. This chapter gives a background on various versions of public goods experiments.

2.1 The Basic Game

2.1.1 Design of the Experiment

In a standard public goods experiment, subjects are voluntarily recruited from undergraduate students in a university. Subjects are assigned to groups—usually of size four or five—and are told that they will participate in a decision making game. They are given endowments of money and asked to divide their endowments between a private account and a public account in any way that they wish. The private account has a fixed return for each token contributed (usually one cent), while the return from the public account depends upon the contributions of all members in the group.

In order to calculate the return from the public account, we multiply the total contribution from the group by the marginal per capita return (MPCR). MPCR is a constant. It has the following properties: if a subject is the only person contributing to the public account, his/her return will be strictly less than that from contributing to the private account for any value of M < 1. If, however, all members of the group fully contribute to the public account, everyone will get a higher payoff than from everyone contributing to the private account.

The payoff of each member in each period can be calculated according to the following equation:

$$\pi_i = \omega_i - c_i + M \sum_{j=1}^{n} c_j$$

where

π = payoff for the period;

ω = endowment for the period;

M = MPCR;

n = number of subjects in each group;

c = contribution to the group account.

2.1.2 Predictions and Hypotheses

If the ability to make rational decisions and maximize personal payoffs is common knowledge among all members, the Nash equilibrium of the game is zero contributions to the public account. However, the highest payoff for a single subject is achieved when he/she contributes all of his/her endowment to the private account, and all other group members contribute fully to the public account. This situation creates an incentive for group members to free-ride—that is, not contribute to the public account, despite the fact that he/she will still get paid from the public account if anyone else has contributed. The optimal outcome in terms of efficiency, however, is full contributions to the public account. The group will earn the highest collective payoff if all members contribute fully to the public account, but each member will earn the highest individual payoff by free-riding. This makes the result of the game unpredictable.

Let us consider an example. Suppose we have a group of 4 subjects. Each subject receives an endowment of 10. Each subject contributes 5 to the group account, and M is 0.3. In this case, each subject will receive a payoff of 10 – 5 + 0.3 (5 + 5 + 5 + 5) = 11. If the subjects kept all their endowments and contributed nothing to the group account, each one of them would receive a payoff of 10.

A real world example of the public goods game could be the problem of environmental protection. A better environment will benefit everyone, but protecting the environment is costly. It is more profitable for everyone to do activities without caring about pollution. For example, hybrid cars cost more than regular cars that burn gas only; using the public transportation takes longer, and is less convenient than driving your own car. We have to make decisions like these every day.

The basic public goods experiments mainly focus on testing the empirical validity of the 'free-riding hypothesis', which has two versions—the strong version (stating that on a voluntary basis, nothing will be contributed to be public good), and the weak version (stating that voluntary contributions to the public good will be suboptimal). Several important studies of this are Marwell and Ames (1979; 1980; 1981) and Isaac, Walker and Thomas (1984).

2.1.3 Results and Findings

There are several common findings from the studies above. The weak version of the free-riding hypothesis received more support than the strong version across all studies (the average contribution in most studies is around 40%). In repeated games, a general decrease of contributions to the public account over time has been observed (Isaac, Walker and Thomas, 1984). This 'decay' of contribution over time has been observed in many other studies as well. Contributions usually start around 50-60% in period one, and fall to around 20% in the last period. Some studies even observed zero contributions in the last period (Andreoni, 1988; 1995; Andreoni, Harbaugh, and Vesterlund, 2003; Isaac and Walker, 1988).

From the decay pattern, it seems that people are learning the dominant strategy (which is zero contributions to the group account) through the learning process, but the pattern might also be due to the strategic play of subjects (Andreoni, 1988). Further research on this matter will be discussed in Section 3. The experiments reported nontrivial contributions to the group account even in the final periods. This indicates that people are not acting completely selfishly.

2.2 Changing the Basic Game

2.2.1 A Higher MPCR Results in Higher Contributions

Marwell and Ames (1979; 1980) conducted two studies exploring the effects of different parameters in public goods games, including group size, MPCR, endowments, provision points, stakes, and experience. They had several hypotheses:

1. Members with higher MPCRs contribute more to the public account;
2. Small groups invest more because actions in small groups are more perceptible;
3. Provision points (points at which the return from the public account increases dramatically) increase contributions;
4. Higher stakes result in more free riders;
5. Experienced subjects are more likely to free ride.

The studies were conducted so that contact between experimenters and subjects happened through mail and phone calls. High school students between the ages of 15 and 17 were used as subjects. They were randomly assigned to groups, and the decision making process was single-shot. The treatment of unequal MPCR was constructed so that one member of the group received 45% of the group's earnings, while other members each received 18.33%. To conduct an experiment without a provision point, the growth of MPCR was kept constant. Higher stakes were created by increasing the return from private accounts. Experienced subjects were students who had participated in the previous study; and among those experienced subjects, there were high contributors as well as low contributors. One thing to note is that people who are told they were in large groups were deceived—they were, in fact, also in groups of four— just like the small group members.

The divergence from the standard experiment was most significant in small groups with unequal MPCRs: the member with the high MPCR contributed all or nearly all of his/her endowment 75% of the time. In large groups with unequal MPCRs and unequal endowments, however, the people with higher MPCRs and higher endowments only contributed about the same amount as others. Neither the change of the provision point, stakes or experience had an effect on the outcome of the experiment. Experienced subjects behaved similarly to the way that they did in the previous experiment—high contributors again contributed more, and low contributors contributed less. This implies that people's behaviors are often consistent, probably due to preferences and moral beliefs.

In both studies, many subjects reported caring about the 'fairness' of group contributions. That is, they believed that there is a "fair amount" when contributing to the public good. Many thought that half or more of their tokens was a fair amount to contribute. This, according to the authors, might have been caused by early training, which tells people that group welfare is just as important as personal welfare. Therefore, free riders are not prevalent in this study.

2.2.2 Effects of High Stakes, Non-Divisible Payoffs, and Different Subject Pools

Marwell and Ames (1981) also changed the parameters of the basic public goods game. Three changes were found to have significantly different results from the standard experiment (around 50% contribution of endowments).

The first example is when high stakes are used—returns from both individual and group accounts were raised to five times as much as before. This resulted in a significant decrease in group contributions. One group had 35% contributions while the other group had 28% contributions. Note that although these are significantly lower contributions than in the standard experiment, they are still much higher than the Nash Equilibrium of zero contributions.

The second case is when a non-divisible good was used as a payoff to the group. Some college freshmen living on the same dorm floor were chosen as subjects for the experiment, and they were informed that their earnings from the group account could only be used to purchase something for their floor. This resulted in a significant increase in contributions to about 80%. This is contrary to what the experimenters expected.

The third case is when graduate economics students were used as subjects. Those subjects, on average, contributed only 20% of their endowments, which is 40% of the average contribution. The low contribution results of this group might be caused by the way that those students have been trained—they may tend to think more self-interestedly than normal people, therefore choosing the single period dominant strategy.

2.2.3 Effects of Group Size and MPCR

Isaac and Walker (1988) constructed a study to analyze the effect of group size and marginal return on group contribution, both separately and jointly. The hypothesis was that a higher MPCR and smaller group size would result in more contributions to the group account.

The experiments used a standard subject pool, but all subjects were experienced—they had all participated in similar economic experiments before. The games were repeated, and each set of experiments consisted of two series of ten period decision trials—one trial with a low MPCR and the other with a high MPCR. Each group had either four or ten subjects (small and big groups). With this design, the experimenters were trying to examine

1. The effect of changing MPCR under constant group size,
2. The effect of changing group size under constant MPCR, and
3. The combination effect of changing both MPCR and group size.

Groups with lower MPCR had significantly more free riding. On the other hand, a higher MPCR led to higher group contributions. The effect of group size, however, is uncertain. If the size is increased with constant MPCR, more group contributions occur, because the total resource available to the group is increased. But if the MPCR is lowered together with an increase in group size, lower group contributions and more free riding is observed. We can tell from these results that MPCR, as well as total resource in the group, is very important in determining group contributions.

Isaac, Walker and Thomas (1984) also studied the effect of group size and MPCR on outcomes. However, their results were a little bit different from that the ones described above—more free-riding was observed when group size was increased with a constant MPCR. This study found MPCR to play a very important role. When the MPCR is higher, there is a greater incentive for members of the group to contribute, resulting more contribution and higher efficiency.

2.3 Analysis of Cooperation and Free-riding

Why do some people free-ride, while others cooperate? Two works of James Andreoni have focused on this question. Both studies were repeated games and used standard subject pools.

2.3.1 Causes of Free-riding

Andreoni (1988) investigated the cause of decay (decreasing contributions), or the convergence to free-riding behavior over time—in repeated public good games. Two hypotheses are:

1. The learning hypothesis—subjects learn the dominant strategy (contributing zero) over time, and
2. The strategies hypothesis—subjects invest more in the beginning as a way to conceal the fact that they are self-interested.

To test the hypotheses, Stranger groups and Partner groups were formed. 20 subjects were assigned to Stranger groups and 15 subjects were assigned to Partner groups. Both settings allowed subjects to play a ten period repeated game followed by three additional periods (these additional periods were not known by the subjects beforehand). Subjects in Stranger groups were randomly assigned to groups of five after each period, but subjects in Partner groups were in the same groups throughout the experiment. Since the groups for Partners were fixed throughout the game, they might have contributed to the group account even knowing that contributing zero is the dominate strategy, because this can give other members an impression of them being cooperative. If other members contribute to the group account consistently, subjects can earn higher payoffs by free-riding in the final periods. Therefore, the experimenters expected more cooperation in Partner groups than in Stranger groups, but the results were exactly the opposite. Partner groups contributed consistently less, and showed more free riding than in Stranger groups. These results clearly reject the strategies hypothesis—if people were playing strategically, they would have contributed more in Partner groups, but very small amounts, if any, in Stranger groups.

In periods 11-13 (the additional periods), Partner group subjects contributed similar amounts as in periods 1-3. This indicates that the decay is not a learning process either—if so, contributions in periods 11-13 would have been the lowest among all periods.

The author suggested that nontrivial contributions to the group account might be caused by pleasures that people receive from cooperation. These pleasures may not be related to monetary payoffs. The decay might also indicate a group's struggle to establish norms of higher contribution—higher contributions to the group account are punished by lower total payoffs, so everyone contributes less as the periods proceed.

2.3.2 Causes of Cooperation

In Andreoni (1995), the cause of cooperation in public goods games was studied. Two hypotheses are stated. One hypothesis attributes cooperation to kindness, while the other attributes it to confusion.

During the experiment, all communication between subjects and experimenters was through paper. Subjects were instructed to sit at numbered desks in a room. Instructions and decision forms were put into the packet that each subject received. For each period, the experimenter collected the decision forms, calculated each subject's payoff using a computer and provided an earnings report for each subject. The decision process was repeated for ten periods.

The experiment was designed to separate the two causes of cooperation—kindness and confusion. Three types of treatments were designed to identify the cause for cooperation: Regular, RegRank, and Rank. Regular groups were just like regular public goods experiments. The Ranks groups were the same as Regular groups, except that subjects in these groups were paid according to their rank of earnings—the highest ranking in each group received the highest payoff. Individuals received information on their Ranking with each period's earnings report. If there were ties, the subjects who tied split the pay-offs. Since the Rank treatment not only reduced the incentive for kindness, but also increased the possibility of confusion in the game (being more complicated than the Regular treatment), another treatment, RegRank, was added. In the RegRank treatment, subjects had information about their ranks in the group—like in the Rank treatment, but were paid according to their experimental earnings—like in the Regular treatment.

The results suggest that cooperation is caused half by kindness and half by confusion. In addition, Regular groups were observed to have the most cooperation and least free-riding, while Rank groups had the least cooperation and most free-riding. Confusion was observed to fall steadily over the periods (from one to ten), but there is no systematic pattern for the change in kindness.

We can tell from these results that kindness and confusion play equally important roles for causing cooperation. Kindness incentives might be very hard to remove from people, since they are related to personalities, social norms, etc. We are, however, able to reduce the effect of confusion. It is important to reduce confusion as much as possible when conducting an experiment, so that we can have more accurate data and have more confidence in our experimental results.

4. Communication

Sally (1995) found communication to have a greater impact on cooperation than any other parameter in public goods games. However, the strength of the effect varies in different settings and among different forms of communication.

2.4.1 Face to Face Communication

Isaac and Walker (1988) examine the effect of face-to-face communication. The hypothesis is that communication reduces free riding and increase contributions in a multi-period voluntary contribution environment.

The experiment used a standard subject pool, but all subjects were experienced—they had all participated in some 'trainer experiments' before the formal ones took place. However, groups were distinct between the 'trainer experiments' and formal experiments. Three different designs were used to examine the effect of communication in different settings. The initial design compared three different decision environments where the only difference was the communication. Subjects all had equal distributions of resources and complete information about the experiment. Let us denote periods with communication with C and periods without communication with NC. The three different treatments in the experiments can then be represented as NC/NC, NC/C, C/NC. The observed result is that communication reduces free riding significantly, even when following NC periods of substantial free riding. However, if communication is allowed only in the first period, second period contributions do not grow higher. In the four C/NC experiments, three used communication successfully without occurrences of free-riding. In the one group where defection did occur, group contributions dropped quickly from 100% to 47% of optimal following the observed defection.

The second design of the experiment introduced asymmetric distributions of endowments and incomplete information about endowments. Four groups, each with different treatments, were used to test the effect of information completeness and distribution of resources thoroughly. All four groups, however, were C/NC groups. Contributions were significantly higher in the first period for all four groups (during which communication was allowed). Cross group comparisons show that contributions by symmetric endowment groups tend to dominate those of asymmetric groups, and contributions by complete information groups tend to dominate those with incomplete information. Groups with asymmetric endowments had a harder time agreeing upon 100% contributions to the group account.

The third design was a more complex one with larger groups (eight people). Decay was very obvious in this set of experiments. Communication did not work as well in these bigger groups (resulting in lower contributions), because agreements were usually less explicit, and people tend to rationalize noncooperation in bigger groups. It is also harder for subjects to understand the nature of this more complex game.

Overall, communication reduces free riding and increases group contributions significantly. Communication has served as a tool for subjects to learn the implication of group profit, as well as building credibility among members. When the communication mechanism is taken out of the experiment, credibility ceases quickly if any defection occurs. This explains the decay pattern in most no-communication trials. Successful communication is usually a combination of explicit agreement and learning of the optimal strategy.

2.4.2 Different Mediums of Communication

Bochet, Page and Putterman (2006) compared three different forms of communication—face-to-face, online chat room, and numerical cheap talk—and their effectiveness in promoting cooperation. The effect of punishment on top of these treatments was also studied, and those results will be discussed in Section 5.

The experiment had eight types of treatments: baseline (B), face-to-face communication (FF), online verbal chat room (CR), numerical cheap talk (NCT), and each of the above with punishment (R, FFwR, CRwR, NCTwR; R stands for reduction, a more neutral way to say punishment). Baseline treatments are just like the standard public goods game. The MPCR was set to 0.4 for all sessions. The experiment used a standard subject pool, and subjects played repeated public goods games in groups of four. Except for the FF sessions, all interactions between subjects occurred over the computer network, and anonymity was preserved throughout the experiment.

In FF sessions, subjects in each group were allowed to talk for five minutes after the introduction of the experiment. Threats and offers of side payments were not allowed in these talks, but everything else could be discussed freely. Subjects, therefore, were aware of who their group members were. However, it was impossible for them to identify each member during the experiment, since subjects were coded with letters that changed each period.

In CR sessions, subjects could communicate through an online chat room before periods 1, 4, and 7. Restricted messages (regarding threats, side-payments, and revealing of personal identity) were blocked. The length of chat was not specified in the paper. Signaling emotional state is more difficult in the CR treatment, and that was what the researchers believed would make a difference in the level of cooperation.

In NCT sessions, a “communication stage” was added at the beginning of each period. In this stage, subjects were able to instantly overtype their intended contribution amount in response to others’ messages for a fixed amount of time (length is not specified in the paper). In NCTwR treatments, subjects could also type in possible punishments together with contributions. Frequent responses and revisions of messages were observed.

Face-to-face communication was found to cause a dramatic increase in contributions—full contribution in periods 1-4, 6, and 7, over 90% in periods 5, 8, and 9, and nearly 80% in period 10. 25/32 subjects contributed fully even in period 10. These results are inconsistent with predictions based on payoff maximizing behavior.

The effect of chat room communication in increasing cooperation is less than face-to-face communication, but it still caused a significant increase compared to the baseline treatment. Most messages in CR treatments were mainly about figuring out the best strategy to maximize payoffs, while others were stating commitments to the group strategy.

NCT did not increase efficiency over all. Some groups did succeed in establishing high cooperation and payoffs using the tool provided. Payoffs from these groups were much higher than baseline treatments. However, there were also other groups where members created free-riding opportunities for themselves using misleading messages. Payoffs from those groups were much lower than baseline treatments. Offsetting each other, the overall payoffs from NCT treatments were mostly the same as the baseline treatment.

Open-end communication seemed to have greater effects on the level of cooperation, since verbal communication allows explicit commitments to a common agreement. NCT lacks a tool for members to proclaim commitments.

5. Punishments and Rewards

2.5.1 Punishment Only—By Punishment Points

Fehr and Gächter (2000) tried to identify the impact of 'punishment' in public good games. There were two main aims in this paper: one was to show that cooperators are willing to punish free-riders even if it is costly for them to do so; the other was to test whether punishment will reduce free-riding behavior. In this experiment, cooperators were defined as those subjects contributing to the public good, and free riders were defined as subjects who do not contribute.

The hypothesis has not been clearly stated, but if we assume, as the author did, that subjects are rational, selfish, and able to use backward induction, no contribution and no punishment should take place at all.

The experiment used a standard subject pool. It was designed for five sessions, testing the effect of punishment in both Stranger and Partner groups. Subjects in Stranger groups were reassigned to new groups in each decision period, while subjects in Partner groups remained in the same groups throughout the experiment. Each session of the experiment contained two sequences of decision making consisting of ten periods each. Of those two sequences, one was with punishment, and the other was without. To enable subjects to punish each other, the concept of "punishment points" was introduced. Each subject was able to assign at most ten punishment points to other subjects, each costing them a certain amount of resource (the cost for each point was different, and was given in a table provided to subjects during the experiment). For subjects receiving punishment points, each point would reduce their payoffs by 10%.

The result showed that punishments raised contributions significantly. Without punishments, the average contribution was close to full free-riding (zero contribution), while with punishments, the average contribution was above 50% of subjects' endowments. In Partner groups without punishments, full free-riding emerged to be the dominant strategy; with punishments, however, full contributions emerged to be the dominant strategy because subjects who contributed below the group average were punished heavily. Also worth mentioning is that Partner groups with punishments were able to establish a common standard of group contribution; therefore, punishments were less prevalent in the later periods of these treatment groups—after all members of the group had conformed their contributions close to the group standard.

We can tell from this paper that punishment increases group contributions and reduce free-riding behavior significantly. There were cases in this experiment where the same group contributed nearly all of their endowments in the punishment condition, but fully free-rided in the no-punishment condition. Also, most people had a tendency to punish free-riders (or low contributors as compared to the group average) even at a cost. This is irrational, but generally, it leads to higher payoffs by the end of ten decision periods. The need for punishment ceases when contributions rise to the group standard. Without the cost of imposing punishments, the payoffs for each subject rise even higher.

2.5.2 Punishment Only—By Expulsion from Group

Cinyabuguma, Page and Putterman (2005) studied the behavior of people in a varied public goods game, where the expulsion of group members is possible at a cost.

The hypothesis is that, since expulsions are costly, rational profit maximizing subjects will not use them. Knowing this, and using backward induction, rational players will contribute zero to the public account.

The experiment used a standard subject pool. Subjects were assigned to groups of 16, and each group played two sets of 15-period repeated games. Subjects did not learn about the second set of games until the first set was finished. Two kinds of treatments were used: the baseline treatment (same as the standard game), and the expulsion treatment (expulsion of group members was possible). The voting procedures for expulsion will be discussed in detail in Section 6.

All members start as members of the Green group. Expelled members were moved to the Blue group, where members received endowments of only five dollars each period, compared to ten dollars for Green group members. There were no voting stages in the Blue groups; all other aspects were the same for both groups. There was the BE game—a baseline treatment followed by an expulsion treatment, and the EE game—one expulsion treatment followed by another one.

There were several findings from this experiment. Contributions were significantly higher in expulsion treatments even when we include the Blue groups. Green groups usually ended up having very high contributions by the end of each game. Blue groups, however, usually had zero contributions because there were never enough subjects in these groups to make the public good profitable. Also, contributions rose, rather than fell (as they did in the baseline treatments) over time—except for in the last period, where the contribution fell sharply. They also observed that expulsion votes served as a warning to group members: if votes were cast to expel some members without succeeding, those members increased their contributions as a response.

The expulsion mechanism can be one way to foster cooperation within groups. However, there is a “dark side” associated with this method: subjects might rely too much on expulsion— if this mechanism is taken away, contributions fall sharply—as it did in the final periods.

2.5.3 Punishment Only—By Formal Sanction from Institution

Putterman, Tyran and Kamei (2011) studied behavior related to formal sanctions in public goods games. Formal sanctions are defined as the “application of sanctions by a central authority or by a group acting collectively”. In this experiment, formal sanctions were imposed by the institution constructed voluntarily by subjects within each group.

In the experiment, standard subjects were pooled and formed into groups of five. Games were repeated for 24 periods. A fixed endowment of 20 was given to each subject in each period, and groups were fixed throughout the experiment. There were two kinds of treatments in this study: the Baseline treatment (standard public goods game), and the Penalty treatment. In the Penalty treatment, two important parameters were determined: *a* and *b*. *a* was the maximum level of penalty, and *b* was the ‘exemption level’—members were free from punishment if they contributed to the group account at level *b* or higher.

In order to construct the formal sanction scheme, a voting period was added every 4 periods. Each four periods is referred to as a phase. During the voting period, members of each group voted on:

1. Whether to punish contributions to the ‘private accounts’ or to the ‘public account’ (majority of vote);
2. The maximum penalty level a (median value voted);
3. The exemption level b (median value voted).

In Penalty treatments, subjects voted almost uniformly upon punishing contributions to private accounts. Compared to the baseline treatments, penalty schemes were able to increase contributions almost immediately. Also, contributions rose over time. Factors like IQ, political orientation, and gender had effects on the use of punishments—participants who were male, more cooperatively oriented, had a higher IQ, and lower political conservatism tended to use more punishments.

The effect of formal sanctions was significant. The schemes were able to increase contributions immediately, and help group members overcome declines in contributions. Contributions rose over time when sanctions were present.

2.5.4 Punishment Only—In Communication Settings

Bochet, Page and Putterman (2006) studied the effect of punishment in different communication settings, as I have mentioned before.

First of all, findings in R treatments (no communication) were similar to those from previous research—higher initial contributions, no decline until end periods, and an absence of overall monetary gains (higher contributions, but payoffs drop due to the cost of punishment). They also found that some uses of punishment were not strategic, such as punishments in period 10, the last period. These actions only decreased subjects' payoffs, resulting in no future benefits.

As found in Fehr and Gächter (2000), punishment can increase the level of cooperation, but is costly to individuals. By introducing communication to the experiment, the experimenters expected to reduce the demand for punishment, which would reduce overall cost, and increase efficiency. This was found to be exactly the case.

Comparing treatments B and R, they observed an increase in cooperation, mainly due to the elimination of contributions declining over time. The paper argued that punishments induce higher contributions by creating fear of group members. However, in groups where verbal communication was available, subjects may have suffered from a guilty conscience if they did not commit to their group agreements. This 'self-punishment' seems to be more effective than material punishments. This is probably why punishments did not do much in FF and CR treatments, since high cooperation in these groups were mainly achieved through friendly agreements, not threats.

2.5.5 Punishments and Rewards—Proposer and Responder Game

Andreoni, Harbaugh and Vesterlund (2003) examined punishments and rewards separately and jointly in a series of two-person games. Groups of two people were used to avoid "free-riding on punishments by others". Many people expected punishments and rewards to work as substitutes, but, as seen from results of this study, this is not exactly the case.

The experiment used a standard subject pool. Each session had ten periods of decision making. Subjects were reassigned to new groups in each period, so no two subjects met more than once. Four different treatments were used in the design of experiment—Dictator (no reward or punishment), Carrot-Stick (both rewards and punishments available), Carrot (rewards only), and Stick (punishments only). In each treatment with rewards or punishments, the responder was able to, at a cost of one cent, change the proposer's payoff by five cents. The only restriction on the amount of change was that the proposer's payoff could not be reduced to a negative number.

The highest offers from proposers were found in the Carrot-Stick treatments, followed by the Carrot treatments; offers in Dictator treatments were the lowest. There was no trend of decline in the amounts offered, so the one-shot nature of this game was clearly understood by the subjects. Responders in Carrot treatments spent the most changing proposers' payoffs, followed by Carrot-Stick; responders in Stick treatments spend the least.

The results suggest that rewards alone are not effective for promoting cooperation. Punishment alone increases the level of cooperation to a modest level. The combination of punishments and rewards have very strong effects—offers from proposers reach as high as 240 (full endowment) in Carrot-Stick treatments, compared to a mode of 40 (the smallest amount possible as specified in the design of experiment) in Dictator treatments. The demand for punishment seems to be unaffected by the availability of reward, but the demand for rewards is greater in the absence of punishment. Therefore, the relationship between punishments and rewards is not merely substitutes. Punishments are rewards work together to promote cooperation—punishments can move offers away from the perfectly selfish point, while rewards can encourage further cooperation.

6. Voting and Institutions

Voting and the formation of institutions is a very important part of our study. This section discusses some previous work that either focused on, or incorporated voting mechanisms or institution formation.

2.6.1 Voting for Expulsion

Cinyabuguma, Page and Putterman (2005) included voting mechanisms in the design of their experiment. In order to expel members, a second stage following the contribution stage was introduced in each, except for the last, period. The following procedures were used for expulsion of group members: all subjects of a group start as members of the Green group, if half or more votes are cast to expel a member (or some members), they will be no longer in the Green group for the rest of the game. Instead, they will be moved to the Blue group.

In this study, expulsions, despite being costly, were used in most sessions, and a majority of subjects voted to expel group members at least once during the game. As we can tell from this result, the voting expulsion mechanism was useful for most people.

2.6.2 Voting for Institution Formation

Kosfeld, Okada and Riedl (2009) studied the endogenous formation of sanction institutions within groups. Three important hypotheses are stated in this paper:

1. There exists an organizational equilibrium (forming an institution) if the number of organization members is greater than or equal to the minimum number that will make the institution profitable; there exists a status quo equilibrium (not forming an institution) for any number of group members;
2. If subjects all have a preference to maximize material payoffs, the number of institution participants (s) would be the same as the minimum size of the institution ($s*$) necesssary to make profit;
3. The grand organization—institution that consists all members of the group—might be the strict organizational equilibrium under certain conditions.

In the experiment, standard subjects were used. Subjects were assigned into groups of four, which were fixed for 20 periods of decision making. Three stages occur during each period of the experiment:

1. Participation stage: group members vote for whether they would like to participate in an institution, members who would like to participate will be referred to as participants;
2. Implementation stage: subjects are informed the number participants, and each participant chooses whether they would like to implement the institution or not. The institution will only be implemented if all participants agree to do so;
3. Contribution stage: if an institution was implemented, the participants would be forced to contribute their full endowments automatically, non-participants could contribute freely to the group account; if no institution was implemented, all group members contribute freely to the group account;

There were two control treatments and two experimental treatments. In the control treatments, subjects played the standard public goods game without an opportunity to form institutions: PG40

(MPCR = 0.4) and PG65 (MPCR = 0.65); in the experimental treatments, the formation of institutions was possible: IF40 (MPCR = 0.4, s^* = 3), and IF65 (MPCR = 0.65, s^* = 2). The cost of implementing an organization was 2, and was split among participants.

There was almost always at least one member who would initiate an institution, but implementation was successful only about half of the time. A large majority of the institutions implemented were grand organizations. There were very rare cases where $s < s^*$. The number of institutions formed increased significantly over time, and those increases were driven exclusively by implementation of grand organizations. There is evidence that subjects were aiming at grand organizations—the implementation rate was high only when all members of the group participate (over 90%, compared to 23%-38% when $s = s^*$). The implementation rate was also higher when a higher MPCR was used. Compared to the control treatments, efficiency was higher and more stable in the experimental treatments.

Overall, institution formation was an effective way to promote cooperation and increase efficiency. However, success of implementation is not guaranteed—a large number of institutions fail even when $s > s^*$.

2.6.3 Voting on Formal Sanction Schemes

Voting mechanisms were also used in Putterman, Tyran and Kamei (2011). As described in the previous section, subjects voted on parameters for the sanctioning scheme. In most sessions, subjects voted for the option that would increase cooperation and efficiency (punish contributions to the private account), but there were also cases where subjects voted for the opposite. Since the overall result of the sanctioning treatment was better than the baseline treatment, we can conclude that voting on formal sanctioning schemes is useful for promoting cooperation and efficiency. However, it is also important to note that it may not succeed all the time.

2.6.4 Institution Formation—'Manager' and 'Customers'

Norton and Isaac (2010) studied the formation of institutions that consisted of 'customers' and 'managers'. The experiments modeled REMs—retained earning maximizing non-profit organizations. These organizations operate just like normal profit-maximizing firms, but all their earnings are donated to charitable organizations and activities.

In the experiment, subjects were assigned to groups of five. Each group consisted of four customers and one manager. Both the customers and managers received 50 token endowments for each period. From the customers' perspective, the game was very similar to the standard public goods game. Each customer makes a choice between contributing to a private and public account for 24 periods. The private account returned one dollar for each token contributed, and the return from the public account depended on MPCR and total group contributions. The determination of MPCR for the public account, however, was different from the standard game. The MPCR was chosen by the manager, between 0.3 and 0.75. Choosing MPCR = 0.3 cost nothing to the manager, but choosing MPCR = 0.75 would cost the manager 30 tokens each time. The manager could also choose an 'outside option', which would allow him to 'close the institution' and receive a wage of 25 tokens. The manager could not contribute his/her endowment to the group account, but he/she also benefited from any contributions the customers made. The customers, on the other hand, did not know about the level of MPCR upon making a decision to contribute.

From the customers' point of view, if all subjects are selfish and profit maximizing, the Nash Equilibrium is zero contributions. From the Manager's point of view, the best choice is to:

1. Close the institution and take the outside option if contributions are low;
2. Choose MPCR = 0.75 if contributions are high.

Choosing MPCR = 0.3 is never a profitable decision.

Two types of transparency were important in these institutions: historical records and outside options. In this experiment, historical records refer to the manger's choice of MPCR in past periods. In treatments where historical records were available, customers were told the manager's choices of MPCR every three periods for the previous three periods. This is akin to quarterly reports in the real world. Outside options also served as a type of transparency because by choosing it, the manager reminded the customers of his/her credentials, signaling the customers to increase their level of contributions.

Three treatments were used in the experiment—Baseline (both historical information and outside option is available), No Info (only outside option is available), and No O/O (only historical information is available). In the Baseline treatments, managers usually chose MPCR = 0.75, and the outside option was seldomly used. Contributions were more stable compared to standard public goods games—there was no significant decay of contributions over time. In No Info treatments, the decay of contributions was more significant. Average returns from the Baseline treatments were higher than from the No Info treatments in almost all periods. Managers also chose the 0.75 MPCR less frequently. Results from No O/O treatments were similar to that from No Info.

We can tell that similar effects result when either transparency condition is removed. So adding transparency to the manager's actions will, very likely, increase efficiency. In the real world, however, managers do not always have precise control over the group production technology (modeled by MPCR in the experiment). So revealing both the manager's choice and the actual outcome might be useful.

7. Summary

Let us recap the key points of this chapter:

1. In a basic public goods game, subjects usually make nontrivial contributions to the group account, but optimal, full contributions are rarely observed. There is usually a downward trend of contributions over time.
2. High MPCR, high stakes, and non-divisible payoffs usually result in higher contributions. Graduate economics students were found to contribute less than standard subjects.
3. Free-riding was neither a result of learning nor strategic play. Cooperation could be attributed half to kindness and half to confusion.
4. Verbal communication, including face-to-face communication and online chatting, promoted cooperation and increased efficiency significantly. Numerical cheap talk did not increase overall efficiency.
5. Different forms of punishment were all able to increase contribution, but the higher overall efficiency was not always observed because imposing punishments was costly. When both punishments and rewards were available, very high efficiency levels were achieved.
6. Voting and institution formation mechanisms were often useful, and usually led to higher contributions as well as higher efficiency levels.

In the next chapter we will present the design of our experiment. We will also present some analysis of the game and propose some hypothesis.

Chapter 3: Methodology

This section explains the design of our experiment, as well as provides a basic analysis of the game. Based on the analysis, we propose three hypotheses.

3.1 The Lab Setting

All sessions took place in the Department of Social Science and Policy Studies' Experimental Economics Lab located in Room 223A of Salisbury Labs. During the experiment, subjects were seated at private computer workstations, and all interaction occurred over the computer network. The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher, 2007). All procedures for the experiment were programmed into the software beforehand so that there would be minimal interaction between the experimenters and the subjects. During the experiment, subjects simply followed the instructions on their computer screens and entered their decisions using keyboards and mice. The experimenters were available for help if subjects had any questions during the experiment.

3.2 Subject Recruitment

All subjects were recruited from undergraduate students enrolled in introductory economics classes. Students were informed about the experiments during their lectures. If interested, students could join the mailing list to receive information about upcoming experiments. Once an experiment was scheduled, an email was sent out to the mailing list with the experiment's time and place. Simple instructions for registration were also included in the email.

Registrations were supported by the Regi 25 web application, which is maintained by the Computing and Communications Center of Worcester Polytechnic Institute. Regi 25 offer registrations for events from various departments around campus. To register, students would click on a link included in the email. After logging in using their WPI user name and password, the Regi 25 page would come up and students could register for the session offered. To learn more about Regi 25, please refer to its website: http://www.wpi.edu/webapps/regi/.

Each session was run with eight subjects. However, during registration, one or two extra students were usually invited in case of no-shows. If all students showed up, the ones unable to participate were given a 5 dollar show-up fee, as well as the extra credit points in their economics classes as promised. Students unable to participate were welcome register to future sessions.

3.3 The Experiment

Before the experiment, each student was provided with two copies of the informed consent agreement form. Important information (such as possible risks and benefits) about the study was included in the form. All information related to the experiment was submitted to and approved by the Institutional Review Board of Worcester Polytechnic Institute. Participation in the study was voluntary. If the student agreed to participate in the study, he/she would sign and date the forms. One copy of the form was returned to the investigator, and the other one was given to the subjects for their records. After the consent forms were collected, instructions for the experiment were passed out and explained to the subjects.

The experiment was a repeated voluntary contribution game. Subjects were randomly assigned to groups of four. The groups remained fixed throughout the experiment for ten periods (the last period was known to all subjects). Each period followed exactly the same procedure, consisting of two stages—the investment stage and the contribution stage. At the beginning of each period, each subject was provided with an endowment of 10 Lab Dollars (LD). The conversion rate between Lab Dollars and real money is 1 LD = 0.1 USD.

Starting out with the investment stage, subjects would vote on their group investment in the marginal per capita return (MPCR). All members of a group invested the same amount of money. When all four members of the group had voted, the highest and lowest votes were dropped, and the average of the two middle votes became the investment level for the entire group. Let us denote MPCR by M and investment by I, the MPCR is then calculated as:

$$M = \sqrt{0.1 * I}$$

Below is a graph of M verses I. As we can tell from this diagram, as investment increases, M increases, but the marginal increase in M is smaller as I grows higher. Thus, the *investment* has diminishing marginal productivity.

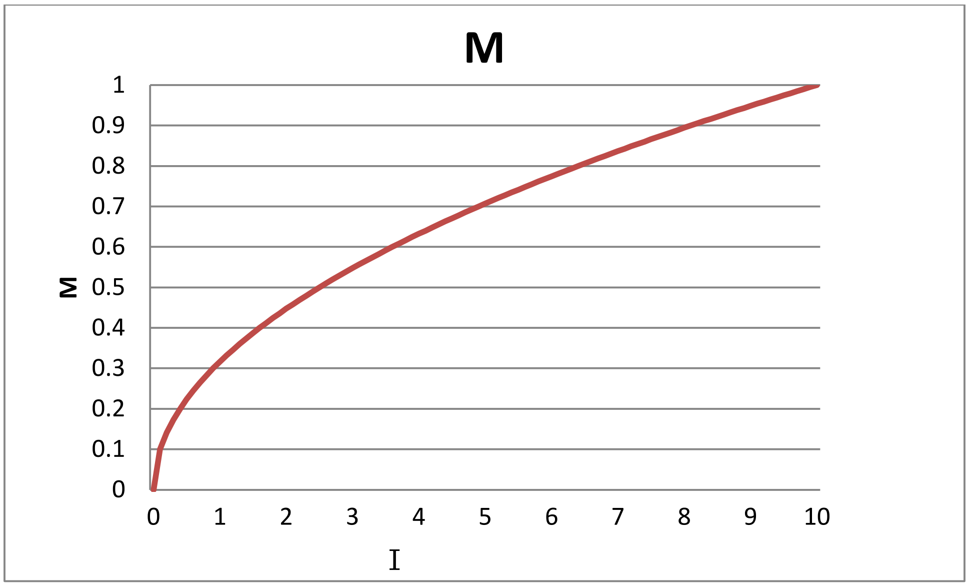

Figure 1. Diminishing Marginal Return of Investment

Also note that there are two special points on this graph:

$$I = 0 \rightarrow M = 0$$

$$I = 10 \rightarrow M = 1$$

This means that, when the group invested nothing, their MPCR would be zero. In this case, anything contributed to the group account would simply disappear, because the group account was unable to generate any benefit—productivity of the public good is zero. On the other hand, if the group invested their full endowments, M would be the highest possible value—one. However, the members would have nothing left to contribute in the contribution stage.

After the value of M was determined, members of each group were informed about that value as well as the group investment level.

The contribution stage follows the investment stage, and proceeds just like a standard public goods game. Each member of a group began the contribution stage with (10 - I) LD. Subjects would decide on how much he/she would contribute to the group account. Payoff of the period for each subject was

$$\pi_s = \omega_s - I - c_s + M \sum_{t=1}^{4} c_t$$

where

π = payoff for the period;

ω = endowment for the period;

I = Investment ;

M = Productivity of the public good;

c = contribution to the group account.

After 10 periods of decision-making, the payoffs for each subject were added up and converted to USD and a $5 show-up fee was added. Subjects were asked to complete a short questionnaire for some basic demographic information. Receipt forms were signed and payments were made in a private manner.

3.4 Analysis of the Game

3.4.1 Nash Equilibrium (NE)

To find the NE for this game, we use backward induction and start by looking at the contribution stage of period 10. Assume all subjects are rational and self-interested, knowing this is the final period of the game, they should play the dominate strategy in a single-shot game—contribute nothing to the group account. Given this, they should also invest nothing during the investment stage of period 10. If no investments and no contributions are made in period 10, same thing should happen in period 9, 8, 7, etc. If all subjects are to follow this logic, no investment or contribution will be made in any period of this game. Therefore, the NE for this game is zero-investment and zero-contribution in all periods.

3.4.2 Pay-off Maximizing Outcome

Find the symmetric maximum value of

$$\pi_s = \omega_s - I - c_s + M \sum_{t=1}^{4} c_t$$

As long as M > ¼, we should have

$$c_s = \omega_s - I$$

$$\sum_{t=1}^{4} c_t = 4c_s$$

We can then simplify

$$\pi_s = \omega_s - a_s - c_s + 4Mc_s$$

$$\pi_s = \omega_s - I - (\omega_s - I) + 4\sqrt{0.1 * I} * (\omega_s - I)$$

Simplify, get

$$\pi_s = 4\sqrt{0.1 * I} * (\omega_s - I)$$

If we plug in $\omega_s = 10$ and solve for π_{max} , we will get

$$\pi_{max} \approx 15.396 \text{ at } I = \frac{10}{3} \approx 3.333$$

Therefore, to maximize payoff, subjects should invest 3.33 LD during the investment stage, and contribute all endowments left (6.67 LD) to the group account in the contribution stage.

3.5 Hypotheses

In this section, we propose several hypotheses about the outcome of our experiment. The investment stage and contribution stage are analyzed separately.

3.5.1 Investment Stage

Since the investment level is the same for all members of a group, subjects are investing in the institution collectively during the investment stage. Thus, from the perspective of an individual, there is no way to "free-ride" in this part of the game. In situations similar to this (members of a group has to make a collective decision), subjects have been found to vote for the option that would promote both cooperation and efficiency most of the time (Putter, Tyran and Kamei, 2011). However, without doing any calculation, it is hard to find the optimal level of investment, but it is very likely that subjects will learn the optimal level through repeated games over periods. We thus propose the following hypothesis:

H1: Group investment will start somewhere between 0 and 10 LD, and approach the optimal level (3.33 LD) over the 10 periods.

3.5.2 Contribution Stage

In this stage, subjects are contributing voluntarily as individuals. According to our self-interested assumption, everyone will try to earn the highest payoff by contributing nothing, while hoping everyone else will contribute fully, so that he/she can free-ride on the contribution of others. If everyone is following the same logic, then contribution will be zero.

However, this is not what has been observed in previous studies (Isaac, Walker and Thomas, 1984). As we have stated before, the contribution stage is exactly the same as a standard public goods game. It is, therefore, appropriate for us to expect similar observations. Because weak free-riding was observed most of the time, we construct our second hypothesis as:

H2: Contributions will be above zero, but below optimal (full contribution) in the contribution stages.

Another important finding from previous studies was the relationship between MPCR and contribution—higher MPCR values often lead to higher contributions (Isaac, Walker and Thomas, 1984; Marwell and Ames, 1981). We incorporate these findings into our third hypothesis:

H3: The percentage of contribution out of remainder (amount of endowment left after investment) will be higher when M is high and lower when M is low.

Since the MPCR in previous studies were not determined by endogenous investment, the maximum amount each subject could contribute was their full endowment. In our experiment, however, subjects could not contribute up to their full endowment because some of their money would be consumed as investment. The maximum limit for their contributions, then, is the remainder. That is why we use the percentage (of contribution out of remainder) as a measure of cooperation level.

In the next chapter, we report the findings from our experiment. Behavior is mostly consistent with our hypotheses. Several interesting facts at the individual level will also be reported.

Chapter 4: Results

4.1 Overview

Eleven sessions were conducted. Eight subjects (divided into two groups) participated in each session. Therefore, we have a total of 880 observations at the individual level, and 220 observations at the group level. Overall, the average investment level was 4.068 (std. dev. 1.414) and the average contribution was 2.939 (std. dev. 1.849). Average percentage contribution—the ratio of contribution over remainder, while remainder is endowment minus investment—was 0.517 (std. dev. 0.313), and the average payoff was 10.308 (std. dev. 2.218). Average earnings were $15.308 (std. dev. 1.490). A summary of the key variables is shown in Table 1.

Variable	Obs.	Max	Min	Mean	Std Dev.
Vote	880	10	0	4.239	2.425
Investment	220	9	0.75	4.068	1.414
M	220	0.949	0.274	0.627	0.117
Contribution	880	9.05	0	2.939	1.849
Percentage Contribution	880	1	0	0.517	0.313
Payoff	880	16.854	2.372	10.308	2.218
Total Earnings	88	19.841	11.490	15.308	1.490

Table 1. Summary of Key variables

4.2 Trends

In this section, we graph the trends of vote, investment, M, contribution, and percentage contribution.

4.2.1 Vote, Investment and M (Marginal Per Capita Return)

Figure 2 presents the average vote and average investment by period. Both variables have a downward trend. They both start above optimal, and their values fall over time, converging to amounts very close to the optimal investment level. Notice that average investment is consistently below average vote. This means that the highest voter in each group was often an outlier, and our mechanism for determining investment (using the median vote instead of mean vote) works well by excluding outliers in votes. Two lines labeled 98%max(+/-) are added to this graph to indicate the range of values such that, under full contributions, subjects would receive more than 98% of the maximum payoff. We can see that starting in period 7, average investment is consistently within the 98%-optimal range. By period 10, the average investment level is very close to the optimal level.

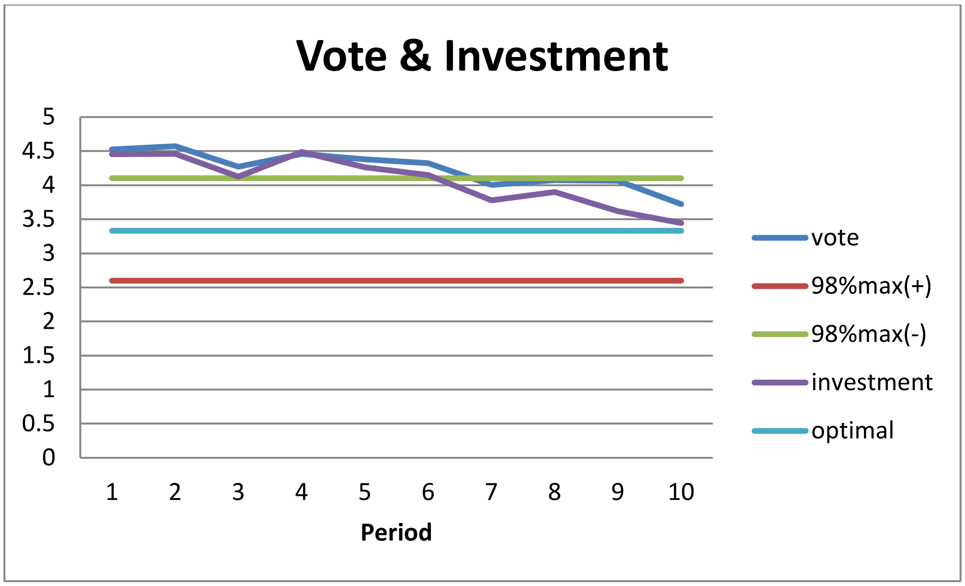

Figure 2. Trends of Vote and Investment

Figure 3 shows average M over time. Since M is only a function of investment, the trend of M is very similar to that of investment. However, because the relationship between M and investment is non-linear, there is less volatility in M. In previous studies, the marginal per capita return is usually chosen to be 0.3 – 0.4. A high MPCR generally refers to a value of 0.6 or higher (Ledyard, 1995). In our experiment, the average resulting M value had an initial value of about 0.68, and reached around 0.58 by period 10. Therefore, we can see that subjects have been choosing high MPCRs, which means higher return from the public good. Note that the lines indicating 98%-optimal range have been used again in this graph.

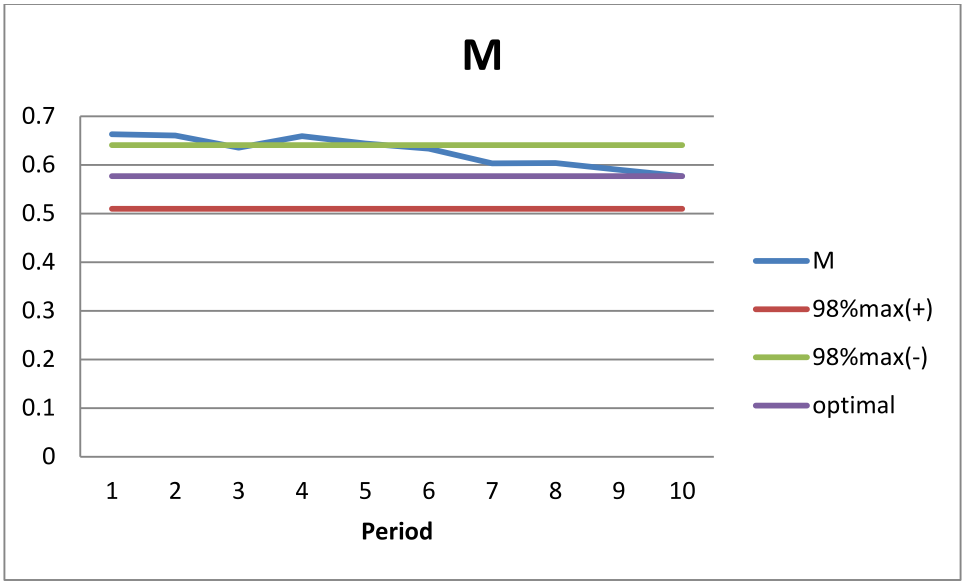

Figure 3. Trend of M

4.2.2 Contribution and Percentage Contribution

Figures 4 and 5 show average contribution and average percentage contribution over time. Both of them have a downward trend, consistent with the findings from previous studies (Isaac, Walker and Thomas, 1984). There is more volatility in the trend of percentage contribution compared to that of absolute contribution. This is due to way percentage contribution is calculated; even if absolute contribution was constant over time, percentage contribution would be changing if investment level is changing.

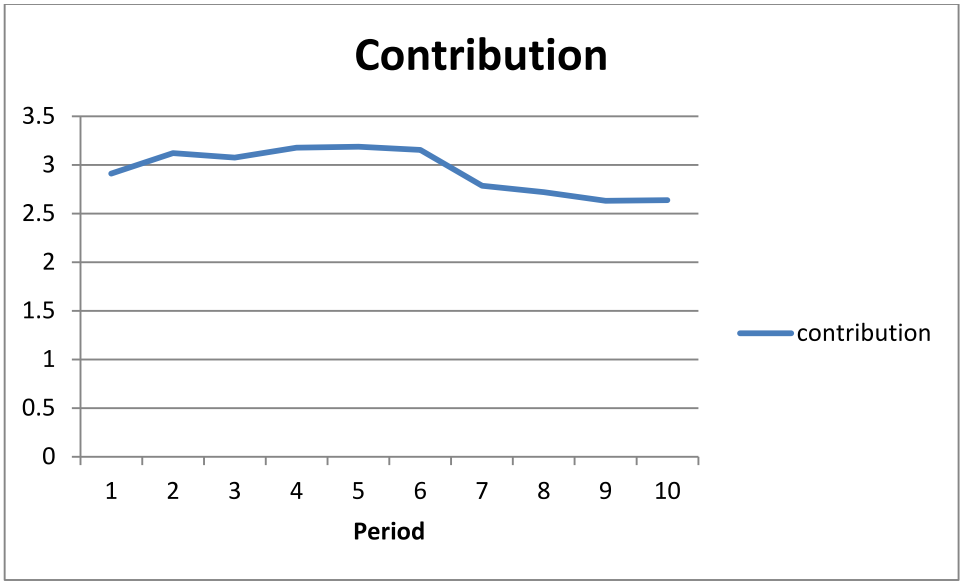

Figure 4. Trend of Contribution

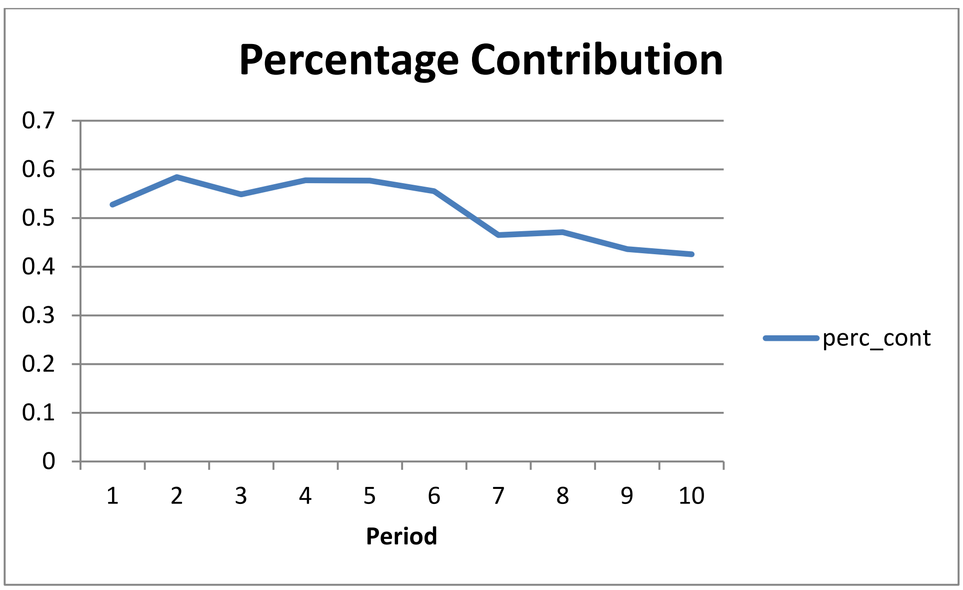

Figure 5. Trend of Percentage Contribution

4.3 Convergence Regression Results

The first sets of regressions are convergence regressions. We adopted the method from (Ashenfelter et al, 1992; Plott et al, 2005; Eckel and Grossman, 2005). For each regression, we regress the trending variable of interest on two constructed variables—*beta_int_var* and *beta_con_var*. The first one, *beta_int_var*, represents the average initial value of the trending variable. On the other hand, *beta_con_var* represents the predicted asymptotic value of the variable if the game was to continue for an infinite number of rounds. Detailed regression results can be found in Table 2.

	(I)	(II)	(III)	(IV)
dependent variable:	ave_vote	investment	ave_cont	ave_perc_cont
beta_int_var	4.683***	4.666***	3.080***	0.576***
	(0.186)	(0.237)	(0.171)	(0.026)
beta_con_var	4.055***	3.820***	2.881***	0.492***
	(0.119)	(0.142)	(0.120)	(0.020)
subjects	-	-	-	-
groups	22	22	22	22
rounds	1-10	1-10	1-10	1-10
n	220	220	220	220
R^2	0.9305	0.895	0.868	0.875

Table 2. Convergence regression results

Figures 6 – 9 graph the convergence regression lines for each key variable with a plot of the actual data points. All the key variables (vote, investment, contribution, and percentage contribution) have downward trends. For both vote and investment, the initial estimate values are above optimal, but their convergence estimates are very close to the optimal level; so subjects were able to learn the best strategy over time. For absolute contribution and percentage contribution, the downward trends are consistent with previous studies (Ledyard, 1995).

If we look at the numerical regression results, we can see that the estimates for initial value of average vote and investment are (difference is less than 0.02). Both of them have a lower convergence estimate, but the difference between those two values is greater—about 0.24. This again confirms the fact that most people are learning to vote at the correct level, while the high outliers are excluded by the voting mechanism. The estimated initial value for percentage contribution is 58%, which is close to what has been found in previous studies (Ledyard, 1995). The convergence estimate for percentage contribution is 49%. Although it is lower than the initial value, is it higher than what have been found in previous studies—usually, people contribute only around 20% by the end of the game.

We also tested each pair of constructed variables to see if they are statistically different from one another. The test was significant for average vote and average percentage contribution at the 5% level, and significant for investment at the 1% level. However, it was not significant for average absolute contribution. As investment falls over time, subjects have higher remainders, so even if percentage contribution declines, absolute contributions can stay pretty level.

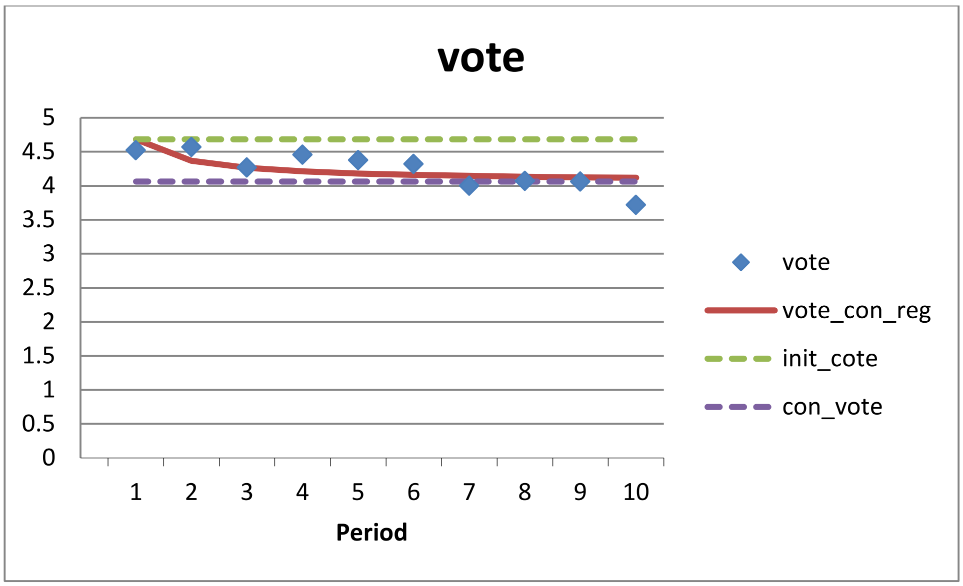

Figure 6. Convergence Regression for Vote

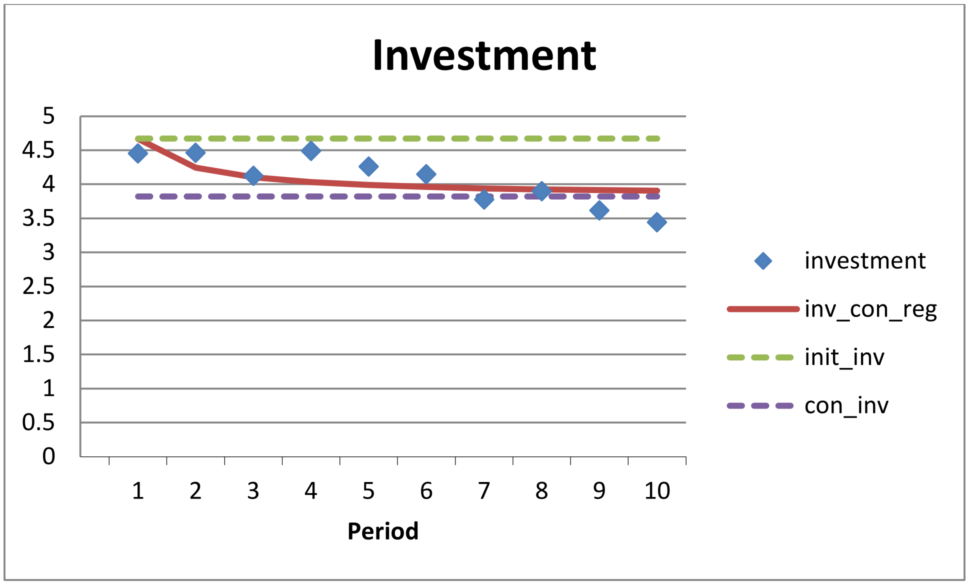

Figure 7. Convergence Regression for Investment

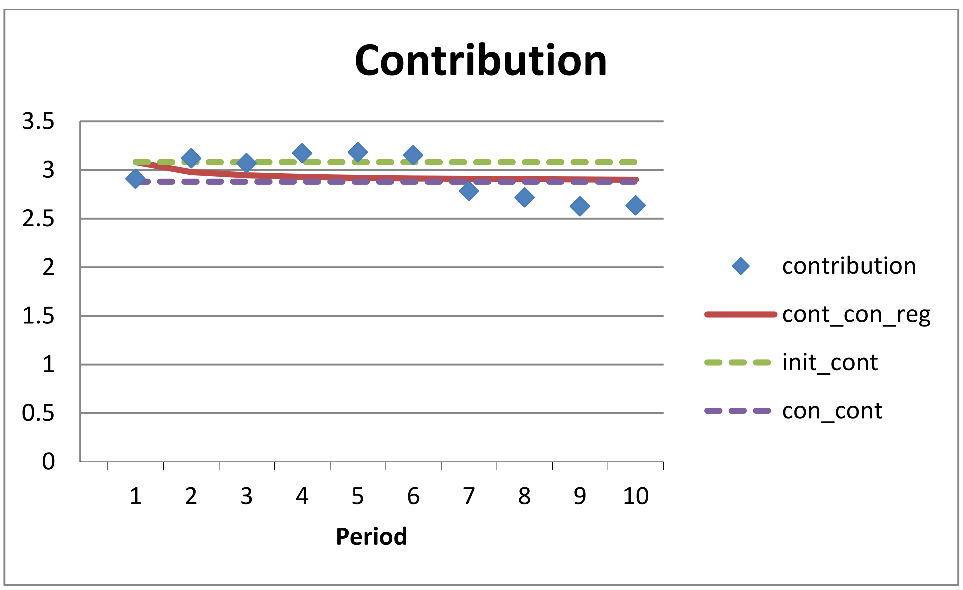

Figure 8. Convergence Regression for Contribution

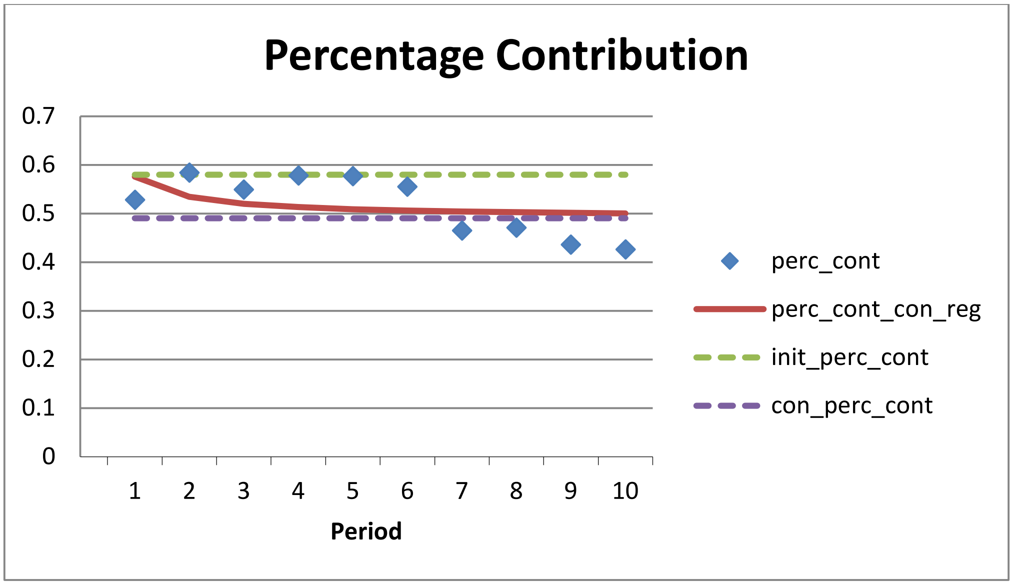

Figure 9. Convergence Regression for Percentage Contribution

The different percentage contributions have different associated maximum payoff functions investment. Figure 10 shows the maximum payoff as a function of investment under two different levels of percentage contribution: the initial value and the asymptotic value. As we can tell from the graphs, as percentage contribution goes down, the top of the payoff function becomes flatter. The investment level which will result in maximum payoff also shifts for different contribution levels.

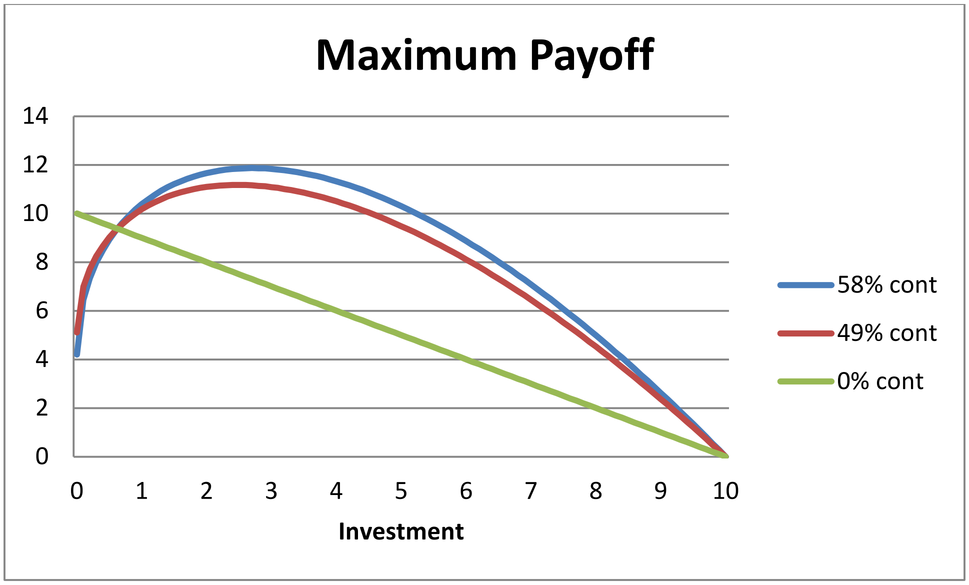

Figure 10. Maximum Payoffs under Different Percentage Contributions

Table 3 shows the payoff change as a result of the change in investment and percentage contribution. As we can see, at the estimated initial investment and contribution level (4.67, 58%), payoff is 10.689 lab dollars. At the convergence level of investment and contribution (3.82, 49%), the payoff is 10.638 lab dollars. Therefore, although investment becomes closer to optimal, the decline in contribution had the dominant effect in terms of change in payoff. As a result, the payoff in final period is on average slightly lower than that of the initial period.

	Percentage Contribution		
Investment	58%	49%	100%
4.67	10.689	9.857	14.570
3.82	11.457	10.638	15.278
3.33	11.731	10.946	15.396

Table 3. Payoff for different investment and contribution levels

4.4 Vote

Vote was regressed on five variables: lagged vote, lagged investment, lagged contribution, lagged profit, and period. We have mainly lagged variables because as explained before, voting is the first stage in every period, so no variables from the current period can affect it.

To summarize, we found that vote is positively related to lagged contribution and lagged investment; it is negatively related to period. The positive relationship between vote and lagged investment is weakly significant in (VII). This means that people tend to vote for values close to the past period's investment—they are trying to reach a consensus on the group investment level. Another weakly significant result is the relationship between vote and period. As described before, vote has a downward trend, and as a result, subjects are moving towards the optimal investment level over time. Vote is positively related to lagged contribution, and this relationship is significant. We believe subjects have viewed declining contributions as a signal of being less cooperative, resulting in fewer votes in the next round.

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
vote -1	0.032	-	-	-	-	0.010	-
	(0.069)					(0.075)	
investment -1	-	0.095	-	-	-	0.094	0.101*
		(0.056)				(0.071)	(0.053)
contribution -1	-	-	0.130*	-	-	0.137**	0.137**
			(0.066)			(0.063)	(0.064)
profit -1	-	-	-	0.015	-	0.044	0.044
				(0.045)		(0.041)	(0.041)
period	-	-	-	-	0.080***	-0.067*	-0.067*
					(0.026)	(0.033)	(0.033)
constant	4.068***	3.814***	3.821***	4.057***	4.679	3.320***	3.332***
	(0.295)	(0.231)	(0.197)	(0.460)	(0.141)	(0.627)	(0.621)
subjects	88	88	88	88	88	88	88
groups	-	-	-	-	-	-	-
rounds	2-10	2-10	2-10	2-10	1-10	2-10	2-10
n	792	792	792	792	880	792	792
R^2	0.185	0.046	0.021	0.010	0.009	0.054	0.045

Table 4. Regression results on vote

4.5 Investment

We regressed investment on lagged investment, lagged sum of contributions, lagged average profit, and period. Note that investment is a group level variable—there are not many group level variables in our study, so there are not many regressions involving investment.

Investment is affected by almost all of the variables mentioned above. It is positively related to lagged investment, lagged sum of contribution, and average profit, but negatively related to period. In our final regression (VI), we did not include lagged average profit, because it is highly correlated with lagged investment and lagged sum of contributions. By doing this, our results turned out to be significant for almost all variables.

Investment is positively related to lagged investment (weakly significant), indicating the direction of change for investment is consistent over periods. The positive relationship between investment and lagged sum of contributions can be explained with a similar story which we have used for vote—lower contributions mean less cooperative group members, so subjects invest less, as a result of less interest in the public good. The story between investment and lagged average profit is similar to that with contribution. Lastly, the negative relationship between period and investment is significant, showing a downward trend.

	(I)	(II)	(III)	(IV)	(V)	(VI)
investment -1	0.132*	-	-	-	0.162**	0.120*
	(0.070)				(0.069)	(0.059)
sumc -1	-	0.069**	-	-	0.027	0.066**
		(0.027)			(0.042)	(0.024)
average profit -1	-	-	0.151**	-	0.132	-
			(0.067)		(0.114)	
period	-	-	-	0.111***	0.092**	-0.096**
				(0.033)	(0.041)	(0.044)
constant	3.480***	3.208***	2.464***	4.680***	2.227**	3.320***
	(0.290)	(0.330)	(0.689)	(0.179)	(0.961)	(0.583)
subjects	-	-	-	-	-	-
groups	22	22	22	22	22	22
rounds	2-10	2-10	2-10	1-10	2-10	2-10
n	198	198	198	220	198	198
R^2	0.225	0.001	0.002	0.051	0.144	0.112

Table 5. Regression results on investment

4.6 Contribution

We regressed absolute contribution on vote, investment, lagged contribution, lagged average contribution of others, lagged profit, and period. As shown in Table 5, there was only one weakly significant result—the negative relationship between absolute contribution and period, which is consistent with our convergence regression. No other significant result occurred. This is because of the complex relationship between absolute contributions and investment—higher investment leads to higher contribution, but it also means less money left available to contribute, which makes the result

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
vote	-0.013	-	-	-	-	-	0.019	-	-0.013
	(0.054)						(0.060)		(0.056)
investment	-	-0.108	-	-	-	-	-0.127	-0.113	-
		(0.105)					(0.098)	(0.091)	
contribution -1	-	-	0.059	-	-	-	0.054	0.056	0.050
			(0.056)				(0.048)	(0.049)	(0.048)
average contribution others -1	-	-	-	0.100	-	-	0.032	0.028	0.013
				(0.082)			(0.196)	(0.194)	(0.201)
profit -1	-	-	-	-	0.036	-	0.028	0.028	0.027
					(0.036)		(0.092)	(0.091)	(0.094)
period	-	-	-	-	-	-0.054*	-0.084***	-0.084***	-0.073**
						(0.029)	(0.029)	(0.029)	(0.029)
constant	2.994***	3.378***	2.768***	2.645***	2.574***	3.235***	3.343***	3.362***	2.970***
	(0.229)	(0.427)	(0.167)	(0.244)	(0.374)	(0.0158)	(0.593)	(0.611)	(0.491)
subjects	88	88	88	88	88	88	88	88	88
groups	-	-	-	-	-	-	-	-	-
rounds	1-10	1-10	2-10	2-10	2-10	1-10	2-10	2-10	2-10
n	880	880	792	792	792	880	792	792	792
R^2	0.005	0.007	0.221	0.041	0.001	0.007	0.105	0.098	0.082

Table 6. Regression results on contribution

ambiguous. In the next section we will introduce regression results for percentage contribution, which has a better control for the offsetting effects of investment.

4.7 Percentage Contribution

We regressed percentage contribution with vote, investment, M, lagged percentage contribution, lagged average contribution of other people in group, lagged profit, and period. All variables except for period have positive coefficients that are significant when included on their own. However, when all the variables are put into one large regression, only investment and period have significant coefficients.

Percentage contribution is positively related to investment. When investment is higher, M is higher, which means there will be higher return from the public good, attracting higher contributions. On the other hand, when investment is lower, the public good is not very productive. The per capita return rate from is low, and people have less incentive to contribute. The significant negative relationship between percentage contribution and period is again consistent with previous findings. The downward trend has already been confirmed many times by regressions in our study.

4.8 Other Findings

One thing we have noticed is a significant drop in contributions in period 7. Figures 4 and 5 are good illustrations of this. Something special must have happened to cause this drop, but we are not sure what it is at this moment. However, we did try running our regressions without data from period seven, which still produced very similar results.

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)	(XI)
vote	0.017**	-	-	-	-	-	-	0.004	-	-	-
	(0.009)							(0.010)			
M	-	0.722***	-	-	-	-	-	-	-	-	-
		(0.178)									
investment	-	-	0.059***	-	-	-	-	0.053***	0.056***	0.056***	0.057***
			(0.013)					(0.013)	(0.011)	(0.011)	(0.011)
percent contribution -1	-	-	-	0.099*	-	-	-	0.041	0.041	0.041	-
				(0.055)				(0.043)	(0.044)	(0.045)	
average percent contribution others -1	-	-	-	-	0.727***	-	-	0.006	0.003	-	0.106
					(0.182)			(0.216)	(0.211)		(0.242)
profit -1	-	-	-	-	-	0.013**	-	0.008	0.008	0.008	0.004
						(0.005)		(0.008)	(0.008)	(0.006)	(0.009)
period	-	-	-	-	-	-	-0.016***	0.014***	-0.014***	0.014***	0.014***
							(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
constant	0.443***	0.064	0.277***	0.464***	0.388***	0.383***	0.607***	0.267***	0.272***	0.272***	0.310***
	(0.036)	(0.112)	(0.054)	(0.029)	(0.032)	(0.056)	(0.026)	(0.087)	(0.089)	(0.086)	(0.084)
subjects	88	88	88	88	88	88	88	88	88	88	88
groups	-	-	-	-	-	-	-	-	-	-	-
rounds	1-10	1-10	1-10	2-10	2-10	2-10	1-10	2-10	2-10	2-10	2-10
n	880	880	880	792	792	792	880	792	792	792	792
R^2	0.053	0.086	0.083	0.256	0.066	0.002	0.023	0.148	0.142	0.142	0.111

Table 7. Regression results on percentage contribution

Chapter 5: Conclusions and Recommendations

5.1 Summary of Method and Key Results

In traditional public goods experiments, subjects are divided into groups of four or five. They start each period with a fixed amount of money, and decide how much to contribute to the group account. The payoff from the group account is the marginal per capita return (MPCR), which is an exogenously determined number between zero and one. Each individual personally gets less money back if he/she contributes to the group account, but everyone in the group benefits from each contribution. As a result, the optimal outcome for the group is for everyone to contribute fully to the group account. After the contribution, subjects are informed about their payoffs for the period, and the same process continues for a fixed number of periods (e.g. 10).

In our study, we changed the game by allowing subjects to determine the MPCR. We added an investment stage prior the contribution stage. In the investment stage of each period, subjects voted on their desired investment level. After all votes had been cast, the investment level was determined by the mean of the two middle votes. The MPCR, which we call M in this experiment, was then calculated as $\sqrt{0.1 * investment}$. We decided to calculate M this way because it shows the diminishing marginal return to investment. All group members were then informed about the value of M. The contribution stage followed the same process as in traditional public goods games. There is one difference though: the endowments of subjects are not fixed, since they can only contribute from what was left after the investment stage. After all contribution decisions had been made, subjects were informed about their payoffs for the period, and the same process continued for ten periods.

There are several key findings from our study. First of all, all of our key variables—votes, investment, absolute contributions, and percentage contributions—have downward trends. Investment is consistently lower than average vote, meaning that there is usually a high voter in each group acting as an outlier. Vote and investment usually start at a high level, but then converge to optimal. We believe this trend is a result of the decline in contribution—members view low contributions as signs of non-cooperativeness, causing them to invest less in subsequent periods. Decline in investment is a good thing, while it brings the investment level closer to optimal; the decline in contributions, although consistent with previous studies' findings, is something worth paying attention to, since it decreases payoffs significantly.

From data analysis, we have found that the effect of declining contributions dominates that of investment. The average payoff in final the period is slightly lower than in the initial period. This means that we should put more effort on encouraging contributions. On the other hand, if we consider results from previous studies, the payoff in the final period is usually a lot lower than that in the initial period. If we look at our result from this viewpoint, we can tell that having an endogenously determined MPCR is beneficial overall.

5.2 Recommendations

From our experimental results, we would like to offer three recommendations for real world policies:

1. **Let people choose the productivity of their public goods.**

As we have stated in the previous section, a voting mechanism was used to endogenously determine the MPCR of public good. This worked well, since it alleviated the decline in payoff. In policy designs, we suggest more use of endogenously determined MPCR. For example, the government could have more consultation with the public through surveys, meetings, councils, committees, and referenda to determine investment in the productivity of the public goods. Apparently more money spent on the agency will make it more productive—more research can be done, and more policies can be made to improve the environmental quality. However, if no one cooperates with the policies (which analog to not contributing to the public good) all the investment will be wasted. Therefore, it is better to invest at the level people want.

2. Use the median voter rule to determine investment level

Regarding the determination of investment, we have found that there is usually a high outlier in each group. Therefore, if the voting mechanism is going to be used in the real world, outliers need to be detected and excluded. Using the EPA example again, there might be some people who are very rich, and are very concerned about the current environmental issues. Those people would probably want to investment millions of dollars, but such amount is unreasonable to most ordinary people. There might also be people who do not care about the environment at all—they would probably vote for investing zero. Both cases should be taken out of our consideration when determining the actual investment level.

3. Promote individual contributions

Contributions have a dominant effect on the resulting payoffs. Therefore, designing policies to encourage contributions is very important. Since higher MPCRs result in higher contributions, making the public good more productive can be a good way of attracting contributions. Again, consider the example of protecting environmental quality. If people are more familiar with the benefit of every small action (thus, perceive the MPCR to be higher), such as taking public transportation instead of driving private cars, they will have a higher incentive to contribute.

5.3 Future Work

In the future, we plan to further study subjects' behavior with endogenously determined MPCRs. This study is only our first step. There is already another study underway, which incorporates income inequality. We have outlined three other suggested topics for future research.

Our first suggested topic is to have comparison of different group sizes. In real life public game scenarios, the group size is usually very large and coordination is much harder. Testing the same problem with larger group size makes the experiment a more realistic model. Our second suggestion is to include punishment and/or reward in the experimental design. Allowing the institution or group members to have the ability to punish low contributors and/or reward high contributors might be able to increase the contribution level significantly. Our third suggestions are to include of communication in the experiment. Communication has been proved to improve cooperation significantly. We are interested we see if it is still a useful tool in this more complicated setting.

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Appendix A: Experiment Instructions

Instructions

This is an experiment in decision-making. Decisions result in monetary payoffs to be paid in cash at the end of the experiment. Payments are considered compensation for the time and effort put into making decisions. The experiment lasts a total of about 45 minutes.

Please refrain from speaking with others during the experiment. If you have any questions, raise your hand and an experimenter will assist you.

You will be randomly assigned to a group of 4 people. Since the assignment occurs over the computer network, you will not know which other people in the room have been assigned to the same group as you.

The experiment consists of 10 rounds of decision-making. Each round has 2 stages: the investment stage and the contribution stage. I will start by explaining the contribution stage and then come back to the investment stage in a few minutes. The contribution stage proceeds as follows:

1. Each person begins the contribution stage with a certain amount of money (denoted in lab dollars; LD). The exact amount will be explained in a few minutes.
2. Each person must decide how much of his/her money to contribute to the "group account." Contributions may include up to 2 digits after the decimal point. Any amounts not contributed to the group account are simply kept by the person.
3. The contributions of your 4 group members will be added up and each person will receive M times the sum of the 4 contributions. Therefore, the payoffs of each person in each round will be: $amount\ kept + M * (sum\ of\ contributions)$. So let's say that each person begins the stage with 8 LD, each person keeps 4 LD and contributes 4 LD, and M is 0.5. Each person's payoff will be $4 + 0.5 * (4 + 4 + 4 + 4) = 12$ LD.
4. M is a number between 0 and 1, so for each LD that you contribute to the group account, you personally will get less than 1 LD back. However, each other person in your group will also receive M LD as a result of your contribution. Similarly, you will benefit from the contributions that your group members make. This is the incentive to make contributions.

The contribution stage occurs after the investment stage. The purpose of the investment stage is to determine the value of M in the contribution stage. The investment stage proceeds as follows:

1. Each person receives 10 LD.
2. Each person votes on how many LD each person in his/her group will invest in M. Each person in your group will invest the same amount. M is determined according to the following equation: $M = \sqrt{0.1 * investment}$ where $investment$ is the amount invested by each person. So if the investment amount is 2.5 LD, M will be $\sqrt{0.1 * (2.5)} =$

$\sqrt{0.25} = 0.5$. If the investment amount is 4.9 LD, M will be $\sqrt{0.1 * (4.9)} = \sqrt{0.49} = 0.7$. Two special cases are that $investment = 0 \rightarrow M = 0$ and $investment = 10 \rightarrow M = 1$.

3. Here's how the voting works: Each person enters an investment amount between 0 LD and 10 LD (inclusive; up to 1 digit after the decimal point is allowed). The highest and lowest votes are dropped and the investment amount is the average of the 2 middle votes. Thus, if the votes are 1, 2, 3 and 4, the investment amount will be 2.5 LD. If the votes are 0, 4, 4 and 7, the investment amount will be 4 LD.
4. The investment amount is subtracted from each person's 10 LD, and he/she begins the contribution stage with the amount that remains. If the investment amount is 3 LD, each person will begin the contribution stage with 7 LD. If the investment amount is 10 LD, each person will have 0 LD left, and will have no money left to contribute in the contribution stage.

Each of the 10 rounds follows exactly the same process. The groups of 4 are fixed for the whole sequence of 10 rounds. At the end of the 10 rounds, payoffs from the 10 rounds will be added up and converted to real money at a rate of 1 LD = 0.1 USD. This amount will be added to a $5 show-up fee to determine your final earnings.

You will be asked some demographic questions and also to provide some contact information. Payments will be made in a private manner.

Let me briefly summarize the experiment in the order that each stage will occur:

1. You will be randomly and anonymously assigned to a group of 4 over the computer network.
2. You will complete 10 rounds of decision-making in these groups.
3. You start each round with 10 LD.
4. In the investment stage, you vote over how much each member of your group will invest in M.
5. Your group's investment in M determines M in the contribution stage.
6. You begin the contribution stage with 10 LD less the investment level that your group chose.
7. You decide how much to contribute to the group account.
8. The sum of your group members' contributions to the group account are multiplied by M and added to any money that you kept to determine your payoff in the round.
9. After the 10 rounds, payoffs are added up and converted to real money. ☺

Are there any questions?

Appendix B: Experiment Screen Captures

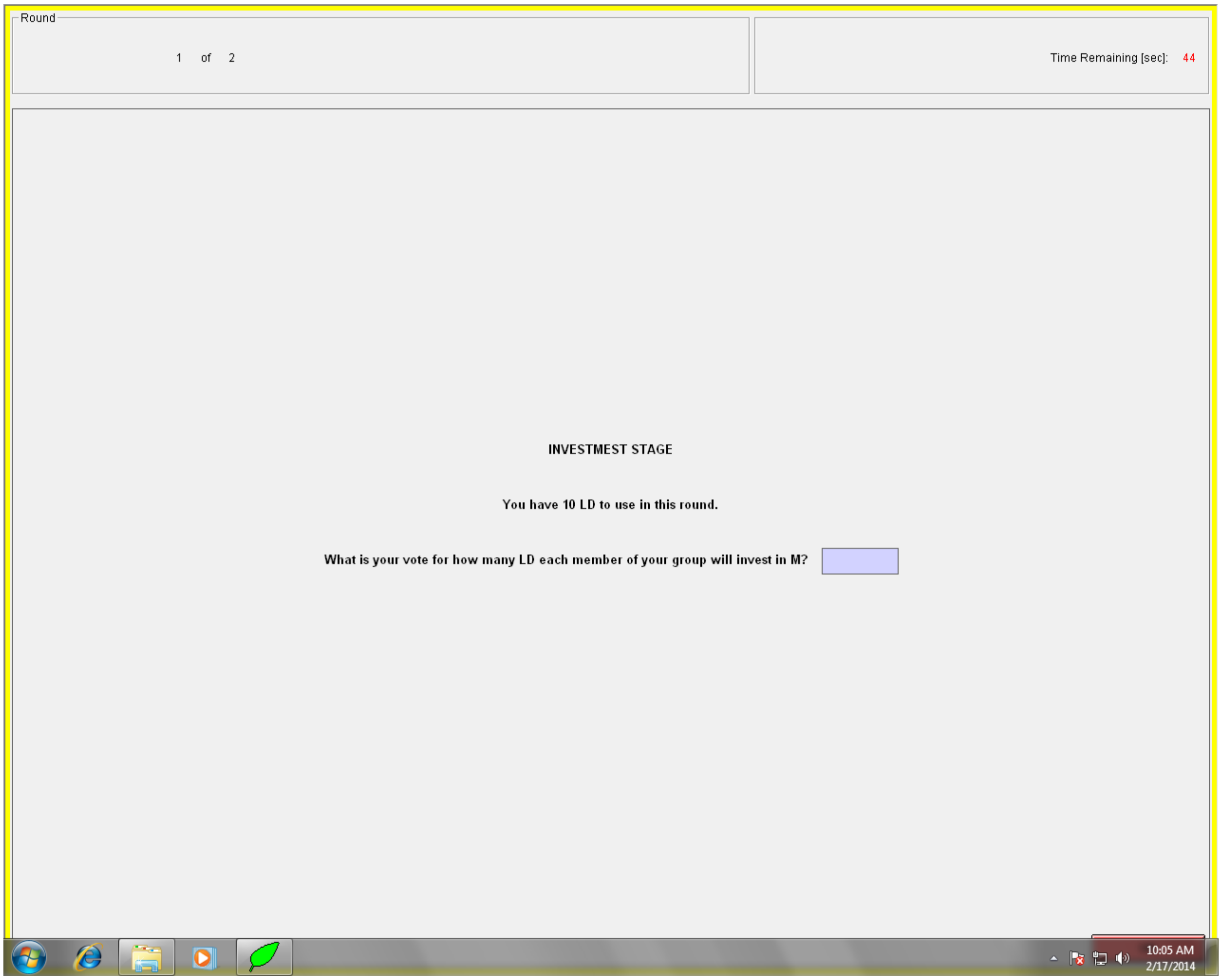

Figure 11: Voting Screen

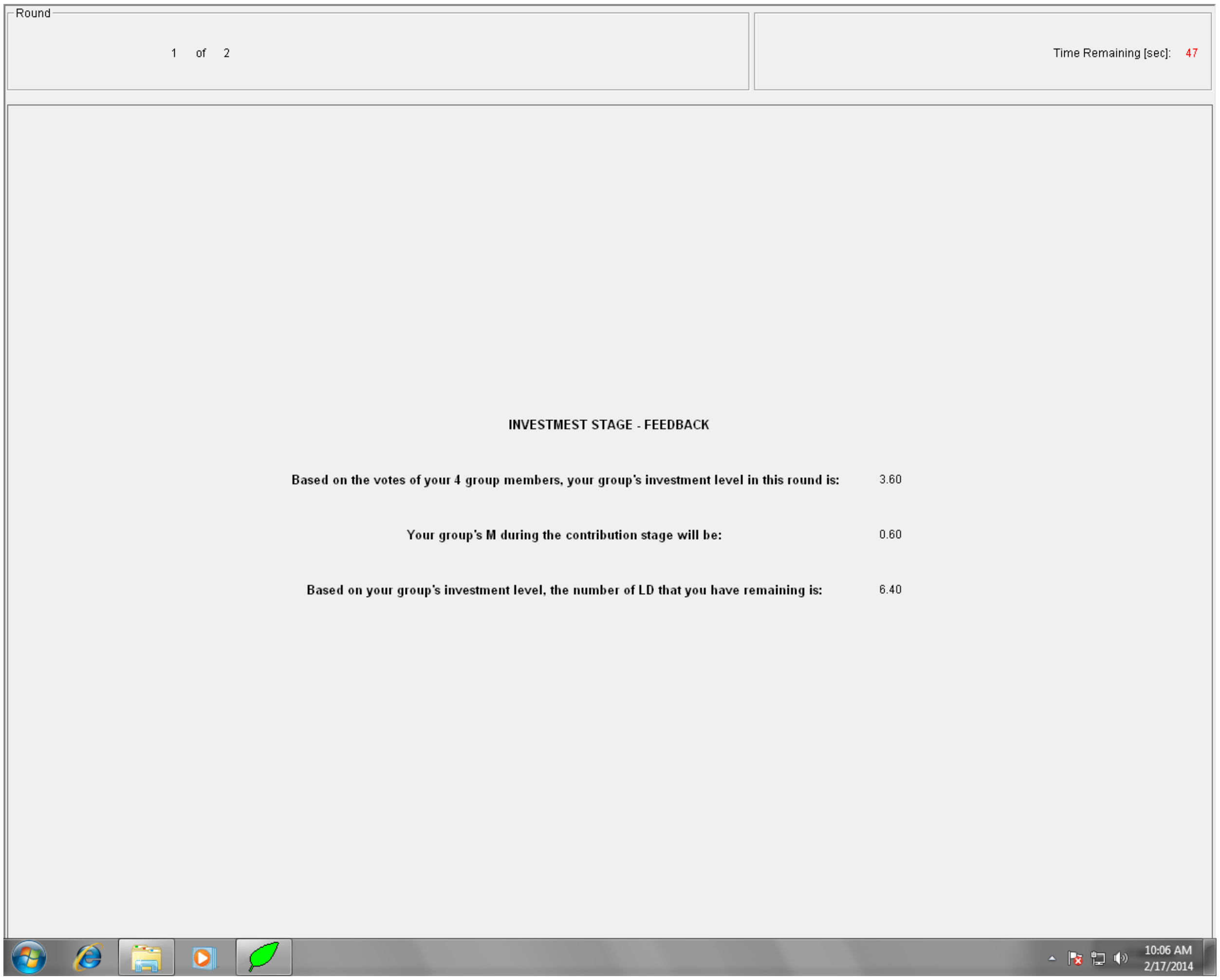

Figure 12: Voting Feedback Screen

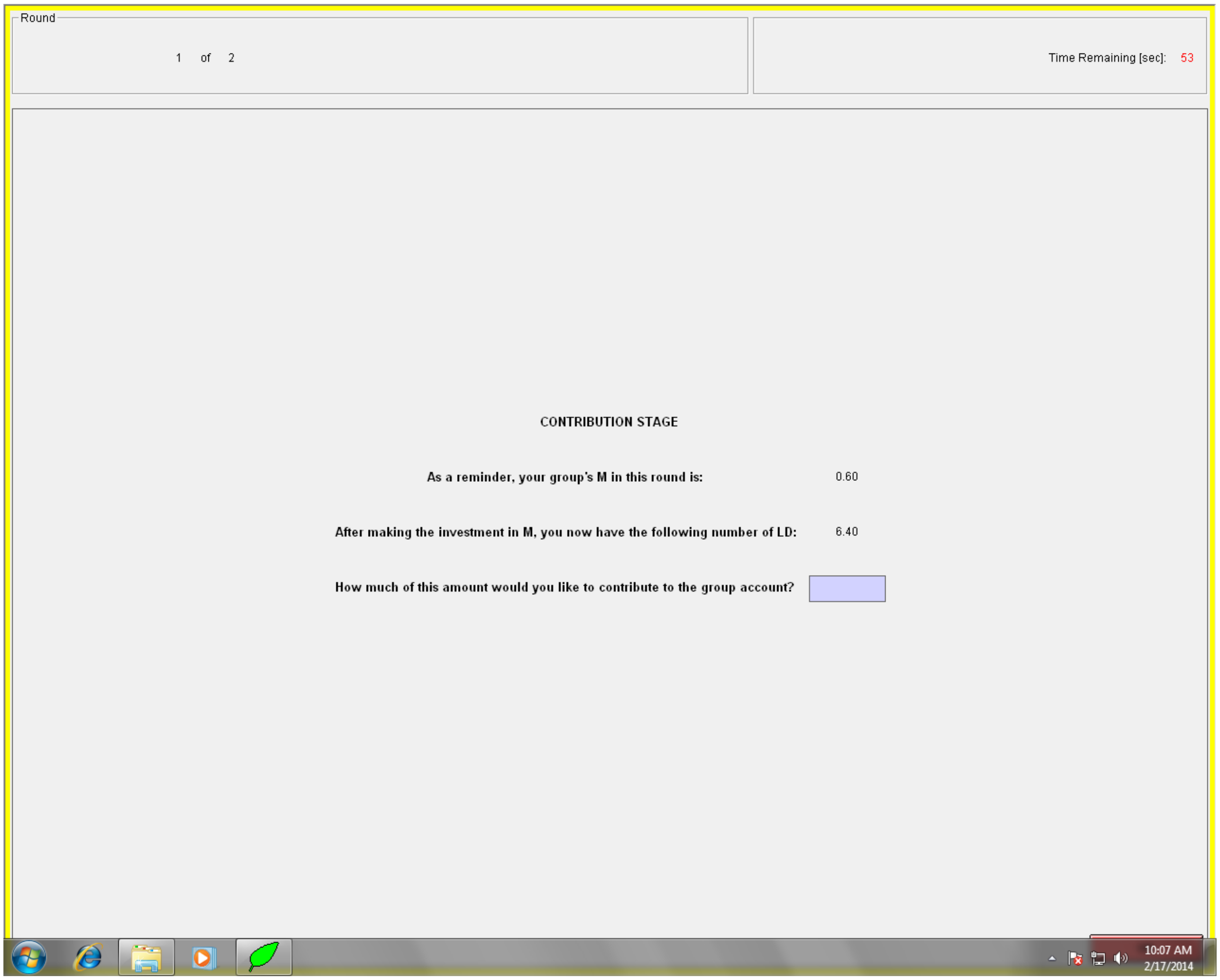

Figure 13: Contribution Screen

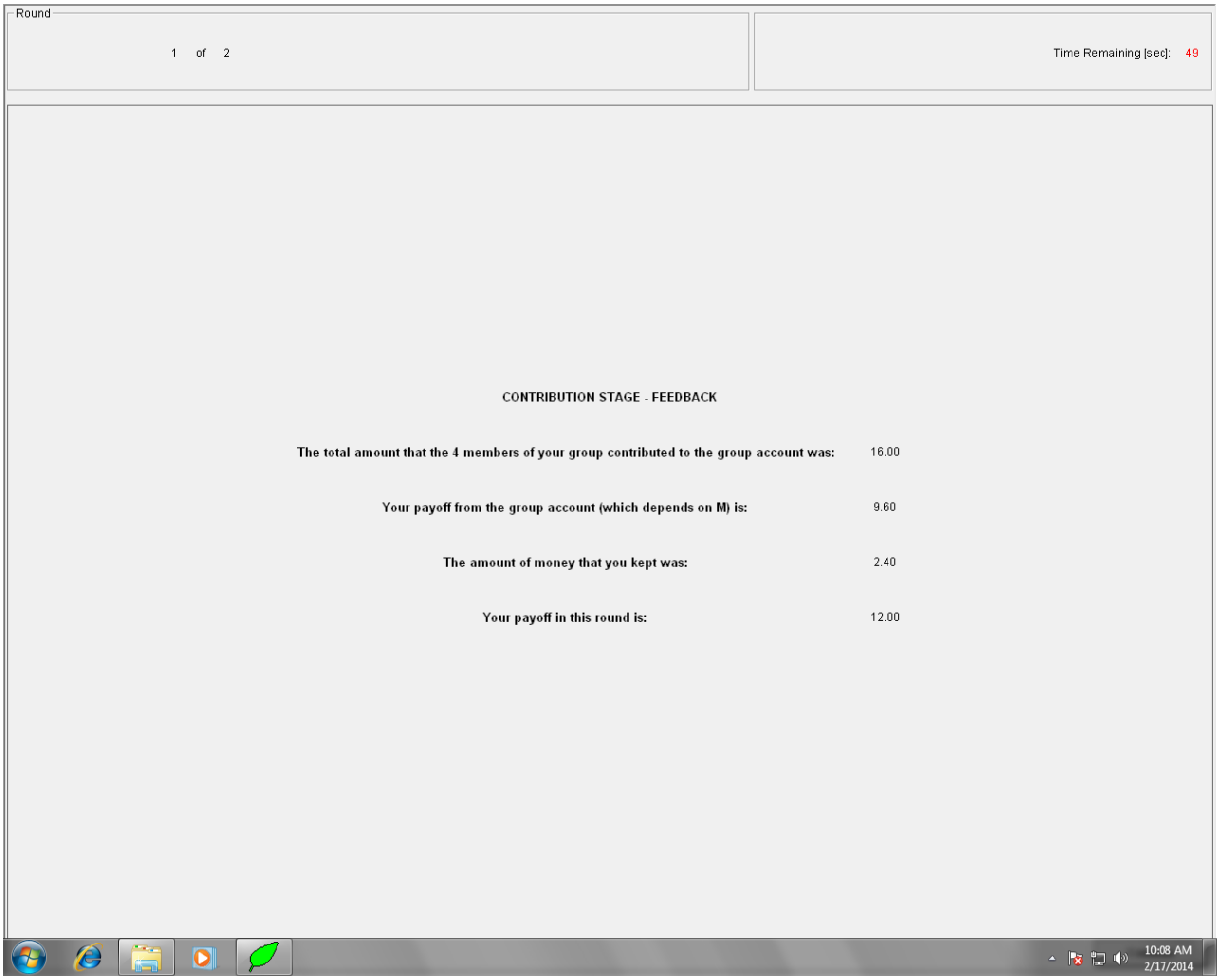

Figure 14: Contribution Feedback Screen