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Assessing a Provision Game for Two Units of a Public Good, With Different Group Arrangements, Marginal Benefits, and Rebate Rules: Experimental Evidence

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Working Paper

ASSESSING A PROVISION GAME FOR TWO UNITS OF A PUBLIC GOOD, WITH DIFFERENT GROUP ARRAGEMENTS, MARGINAL BENEFITS, AND REBATE RULES: EXPERIMENTAL ENVIDENCE

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1. Introduction

The problem of public good provision remains an active area of economic research and one of the several areas that massively apply experimental methods in deriving analytical data. In such problems, aggregated individual utility maximization behaviors would not necessarily coincide with a socially best outcome. Thus, a possible solution shall reconcile this individual and social divergence, which encourages us to search for a set of mechanisms that enable individuals to act according to their own best interests while simultaneously maximize the total welfare of society. When providing public good through private fund, people tend to rest on the contributions of others to cover some cost of the goods, which is often referred a "free riding" problem. The efficient allocation of a public good happens when the sum of marginal benefits across people (or the sum of the heights of people's demand curves) equals the marginal cost of public good provision. If individual each pays his/her marginal benefit, these individualized price levels would constitute the necessary condition for Lindahl equilibrium. This Lindahl pricing system would establish a Pareto optimal provision of the public good, however this system is rather unattainable even in carefully controlled experimental settings (R. Mark Isaac and James M. Walker, 1988, R. Mark Isaac et al., 1985): people quickly decrease their contribution in a voluntary environment as experience grows. This paper compare several elements (including alternative rebate rules) that are often seen in the public good game, in hope of finding a better way to raise individual contribution substantially compared to traditional volunteer contribution.

There are two lines of literature regarding the public good provision game in a lab environment. One is called the "linear" public good provision game (James Andreoni, 1995, B. Douglas Bernheim, 1986, R. Mark Isaac and James M. Walker, 1988, Thomas R. Palfrey and Jeffrey E. Prisbrey, 1996). Subjects are asked to allocate a certain amount of tokens between a private fund that benefits only the individual investor and a group fund that generates profits for everyone. The private fund would yield a higher return rate than the public fund for the private investor, but total return is higher for the group from the public fund. The marginal return for the group fund is set such that it is socially optimal to give everything to the group fund, while it is individually optimal to keep all the tokens in the private fund. Theoretically, individuals would contribute nothing to the public fund. However, experimental evidence shows that we do not have to be "so pessimistic". Subjects contribute significantly positive amount while nonetheless the amount is still far lower than the group optimum (R. Mark Isaac and James M. Walker, 1988, R. Mark Isaac et al., 1984). Andreoni (1990) shows how altruism may explain the positive donations, and proposes a warm-glow effect to explain substantive contributions observed under a voluntary environment.

The other line of literature uses a provision point mechanism (Dirk Alboth et al., 2001, Didier Laussel and Thomas R. Palfrey, 2003, Arthur Schram et al., 2008). The provision point mechanism evolves from the step-level public good game, where individuals are asked to make dichotomous choices on whether to contribute or not toward a single unit public good. When a certain portion of subjects chooses to contribution, that unit is provided. The provision point mechanism relaxes the dichotomous constraint so that each subject can make continuous offers. The public good is funded if the aggregated offers reach or surpass the predetermined cost, and the cost is also called the provision point. Two difficulties arise from this approach. One is the incomplete information problem. Individuals do not know others' valuations toward a particular public good. This may deepen the free riding problem since one may reasonably expect some "high" value people are there and expect them to contribute more than people with low values. Laussel and Palfrey (2003) provide a nice theoretical paper on how to deal with the private (incomplete) information problem. The other difficulty, which is more focused in this paper, is the strategic complexity of the provision point mechanism. Compared with the linear public good game, where the dominant strategy for each individual is to contribute nothing to the group, the provision point mechanism has multiple Nash equilibria (Melanie Marks and Rachel Croson, 1998). Individuals, as well as the whole group, are very unlikely to identify the best outcome, as we would envision due to its complexity and relative short time available in the experiment. One interesting thing to test is which equilibria they are attaching to, in a multiple equilibria background.

This paper implements the provision point mechanism to investigate the public good provision problem in a carefully controlled experimental environment. This experiment originates from a real world difficulty we encounter while carrying out a project that asks for private contribution to provide ecosystem services. To raise contributions, we group people through a stratified random sampling method and test whether each group can sufficiently provide the cost for protecting one "field", which serves as the carrier for ecosystem service; here, one field, or one unit of the public good is like a single farm-field providing wildlife habitat of aesthetic value to non-farm residents of a rural or urban-fringe community. The framework is largely in accordance with the provision point mechanism expect multiple fields, instead of one, are available in real world situation, even in a small community. Therefore, the free riding problem can be multi-dimensional: not only can individuals free ride within a group, but also one group can free ride on other groups. Thus, we might the free riding problem to be more severe in the multiple group situations. On the other hand, since each group have no control on the provision success of other groups, provision of other fields just enter individual's benefit function as positive externalities, and may encourage each group to contribute more. We are interested to compare the magnitude of these two countervailing effects, and also it is a policy issue – or an issue regarding the pragmatic design of institutions for provision of public goods in a second-best world - whether we should ask each group to provide one field or aggregate all contributions together and calculate how many fields they can provide in total.

Alternative rebate rules have been proposed to reduce the free riding problems (Melanie Marks and Rachel Croson, 1998, Michael A. Spencer et al., 2009). In this paper, we compare three different rules to address the excess contributions (the amount beyond the cost). The first rule uses the provision point mechanism with no rebate regarding excess contributions (PPM). Under PPM, the market-maker or "broker" keeps any excess contributions once the total contribution exceeds the provision threshold. We also explored the proportional rebate rule (PR), where excess contributions are refunded to individuals in proportion to their contribution if the threshold is reached. Another rebate rule we tested is the uniform price contribution (UPC). In this rule, a maximum price is calculated so that the market-maker just collects the cost. If the individual's contribution is higher than the maximum price, he or she pays only the maximum price, the rest is rebated; if a contribution is lower than the maximum price, he or she pays only the amount contributed.

We set up a two unit's public good game under the provision point mechanism framework. We do not hope to draw a general conclusion regarding multiple-unit public good problems: they are too complex and there are still several gaps toward a general solution from the current literature. The two-units is just a starting point. Bagnoli *et al* (2003) investigated the multiple units provision problem through voluntary provision, where subjects have to make a contribution for each unit of the public good. In our experiment, subjects only need to make one offer for the two units of a public good. Additionally, we notice that in the multiple units' case, people may not hold constant value for every unit. We test how different marginal value may, or may not change individual contribution behavior.

The reason for including different marginal value is two folded. On one hand, we try to mimic the real word situation when we need to provide multiple public good units. We may generally expect a decreasing marginal value for additional unit. Nonetheless, there are circumstances where the marginal benefit is constant or even increasing. Consider the wetland conservation; two acres of wetland can provide more than twice the ecosystem value as one acre because of increasing returns to scale. The second reason is we are interested in the connection between marginal benefit and the provision cost. As will be discussed later, different marginal benefits would result different convergence outcomes. We want to test whether, or to what extent, the lab experiment can produce convergence results as predicted.

The paper is organized as follow. Section 2 discusses the theoretic framework for different experiment mechanisms. Section 3 describes the experiment design and procedure. Section 4 presents the experimental results and implications. Section 5 concludes the paper.

2. The two unit provision game and rebate rules

This section describes the basic theoretical model behind the experiment. We designed two different group arrangements for the public good game. In the first arrangement we assign people into two separate groups; each group is responsible for providing one unit of the public good. All individuals can benefit from the successful provision of any unit(s). Compared to the standard provision point mechanism, here the successful provision of one group will have a positive externality on the other group, because both groups can benefit simultaneously. Under the second group arrangement, all individuals are put in a single group, which can provide up to two units of public good. We then compare how the Nash equilibria differ under these two different grouping approaches, adding different rebate rules and marginal values.

A standard provision point mechanism public good game is usually set up like this: assume a group size of N, where each individual receives a private value V_i. The value V_i is the amount of money individual i can get once the total contribution from one group meets the provision cost. The amount individual i decides to contribute to the public good is denoted as C_i. The cost of providing the public good is defined as the provision point (PP). When the aggregated contribution meets or exceeds the provision point, which is $\sum C_i \geq PP$, the public good unit is provided[1]; otherwise the public good unit is not provided, individuals will not receive their induced values. One common assumption is that individual will never contribute more than his value V_i, because such behavior would result non-positive benefit. This version of provision point mechanism is slightly different from the one described in Melanie Marks and Rachel Croson's paper (1998), where an individual receives an endowment rather than a value. In the endowment situation subjects allocate money between a public good and a private account. If the group fails to provide the public good, individuals can still have the full endowment. In our framework, individuals can benefit only if the public good is successfully provided. We use the "value" idea to simulate the ecosystem service provision: the ecosystem service can only be provided if the market-maker collects sufficient money from participants to implement the project, otherwise the participants get no benefits.

2.1 Two groups, each responsible for one unit of public good

The mechanism for the two-group case is largely explained above except now there are two groups, each responsible for one unit of public good. Both groups can benefit from the public good regardless

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[1] We are also assuming $\sum \mathrm{V_i} \geq \mathrm{PP}$, which means it is always beneficial for the group to provide the public good as a whole.

which group provided it. If both units are provided, individuals will get value for tow units. In the following we present payoff functions separately for three rebate rules, with the two-group premise.

2.1.1 No rebate provision point mechanism (PPM)

$$\pi_i = \begin{cases} 0 & if \sum C_i < PP \; and \; \sum C_j^o < PP & \dots (1a) \\ V_i - C_i & if \sum C_i \geq PP \; and \; \sum C_j^o < PP & \dots (1b) \\ V_i & if \sum C_i < PP \; and \; \sum C_j^o \geq PP & \dots (1c) \\ (1+\alpha)V_i - C_i & if \sum C_i \geq PP \; and \; \sum C_j^o \geq PP & \dots (1d) \end{cases}$$

In the above equations, π_i is individual i's profit, V_i is individual i's induced value for the first unit of public good, C_i is individual i's contribution and $\sum C_i$ the total contribution from individual i's group; $\sum C_j^o$ is the total contribution of the other group. Alpha (α) is the ratio of the benefit from the second unit relative to the first unit. Under provision point mechanism with no rebate (PPM), if both groups fail to provide the public good, individual i gets zero benefit (see equation 1a); if both groups provide the public good, individual i will get a benefit amounts to the value for two units, minus his contribution (see equation 1d); if only one group provides the public good, individual i will get his value for one unit, and minus the contribution if it is his group that provided the unit (equations 1b, 1c). A group contributes more than the provision point is not optimal since excess fund will be wasted. Whenever the provision point is surpassed, at least one person can be better off by contributing less while still holding the total group contribution above or equal to the provision point.

Multiple Nash equilibrium solutions exist in this scenario, and the solution sets differ as alpha changes. When $\alpha \sum V_i > PP$, the benefit from providing an additional unit is larger than the cost, there are four Nash equilibrium solutions: an efficient and three inefficient Nash equilibria. The condition needed for the efficient Nash equilibria is $\sum C_i = PP \; and \; \sum C_j^o = PP$, which says the aggregate contribution for both group equal to the provision point. The efficient Nash equilibrium condition guarantees a Pareto optimal outcome: no one can do better without negatively influencing the profit of others. The inefficient Nash equilibrium combinations are: 1) $\sum_{i' \neq i} C_{i'} + V_i < PP \; and \; \sum_{j' \neq j} C_j + V_j < PP$, 2) $\sum C_i =$

$PP\ and\ \sum_{j'\neq j} C_j + V_j < PP$, 3) $\sum_{i'\neq i} C_{i'} + V_i < PP\ and\ \sum C_j^o = PP$, for $i, j = 1,2 \ldots .n$. In the above equations, $\sum_{i'\neq i} C_{i'}(\sum_{j'\neq j} C_j)$ is the aggregated group contribution minus individual i's (j's) contribution. Under these three conditions, no one can be better off by changing contribution unilaterally. They are inefficient in the sense that the group can still increase total benefits by providing more units. It is not difficult to show that among these inefficient Nash equilibrium conditions, the first solution yield least total net social benefit (zero benefit), while total benefit of the other two are between the zero and the optimal level. Note that these results are built on the premise that individuals are "rational" in a sense that no one would accept a negative benefit even if the overall group benefit can be maximized. This assumption also holds throughout our analysis.

When $\alpha \sum V_i = PP$, people would be indifferent to providing one unit or two units since the marginal benefit equals to the marginal cost for the second unit. The efficient Nash equilibrium solutions are: 1) $\sum C_i = PP\ and\ \sum C_j^o = PP$, 2) $\sum C_i = PP\ and\ \sum_j C_j < PP$, 3) $\sum_i C_i < PP\ and\ \sum C_j^o = PP$. All of these solutions will yield a Pareto optimal outcome. The inefficient Nash equilibrium solution is $\sum_{i'\neq i} C_{i'} + V_i < PP\ and\ \sum_{j'\neq j} C_j + V_j < PP$. When $\alpha \sum V_i < PP$, it is not beneficial to provide the second unit since the marginal cost surpasses the possible benefit for the additional unit. In this case, providing just one unit in total is optimal, and the efficient Nash equilibria are: 1) $\sum C_i = PP\ and\ \sum_j C_j < PP$, 2) $\sum_i C_i < PP\ and\ \sum C_j^o = PP$; the condition $\sum C_i = PP\ and\ \sum C_j^o = PP$ is not a Nash equilibria since one decrease contribution such that only one unit can be provide; the one that yields zero social benefit is $\sum_{i'\neq i} C_{i'} + V_i < PP\ and\ \sum_{j'\neq j} C_j + V_j < P$.

It should be clear by now how the provision point and marginal benefit ratio (alpha) are related to the Nash equilibrium solutions. Individual induced value acts as a constraint on the maximum amount one might possibly offer. Additionally, our analysis identifies a range regarding the inefficient Nash equilibrium solutions, under which no one want to change unilaterally. Nonetheless, Pareto improvement is possible by deviating from the inefficient equilibrium though collaborating.

2.1.2 Proportional rebate mechanism (PR)

The proportional rebate mechanism (PR) differs from PPM in handling excess contribution. In PR, the excess contribution is redistributed to individuals in proportion to their contribution. Specifically, we have:

$$\pi_i = \begin{cases} 0 & \text{if } \sum C_i < PP \text{ and } \sum C_j^o < PP & \dots (2a) \\ V_i - C_i + \frac{C_i}{\sum C_i}(\sum C_i - PP) & \text{if } \sum C_i \geq PP \text{ and } \sum C_j^o < PP & \dots (2b) \\ V_i & \text{if } \sum C_i < PP \text{ and } \sum C_j^o \geq PP & \dots (2c) \\ (1+\alpha)V_i - C_i + \frac{C_i}{\sum C_i}(\sum C_i - PP) & \text{if } \sum C_i \geq PP \text{ and } \sum C_j^o \geq PP & \dots (2d) \end{cases}$$

Under the proportional rebate rule, all the excess contributions are refunded to each individual proportionally. When $\sum V_i > PP$, the necessary and sufficient condition for a Pareto optimal outcome is $\sum C_i \geq PP \; and \; \sum C_j^o \geq PP$. However this is not sufficient for a Nash equilibrium solution; at least one people can slightly reduce his contribution to get a higher individual benefit. The penalty of over contribution is zero for a group level but positive individually. Suppose person 1 contributes C_1 and $\sum C_i > PP$, he can reduce his contribution to reap more profit as long as $\sum C_i - PP \geq 0$. The total group benefit stays the same but the distribution of refund, as well as individual profit, are altered. Thus, each person has the incentive to reduce contribution when total contributions excess the cost. The efficient Nash equilibrium is $\sum C_i = PP \; and \; \sum C_j^o = PP$, the same as the PPM.

To demonstrate the positive penalty associated with an individual's excess, we use the method proposed by Mark and Croson (1999). We can derive the marginal penalty associated with excess contribution:

$$-1 < \frac{\partial \pi_i}{\partial C_i} = -1 + \frac{1}{(\sum C_i)^2}[(\sum C_i)^2 - PP(\sum C_i - C_i)] < 0$$

Once the provision point is reached, increase of contribution would reduce one's benefit. The penalty is less than \$1 for each \$1 excess contribution. In a dynamic environment, people may continue to reduce contributions until excess contributions dissipate entirely, which would eventually lead to a Nash equilibrium solution. There are also three inefficient Nash equilibrium solutions under PR: 1) $\sum_{i' \neq i} C_{i'} + V_i < PP$ and $\sum_{j' \neq j} C_j + V_j < P$, 2) $\sum C_i = PP \; and \; \sum_{j' \neq j} C_j + V_j < PP$, 3) $\sum_{i' \neq i} C_{i'} + V_i < PP$ and

$\sum C_j^o = PP$. They are identical to the PPM. For situations when $\alpha \sum V_i = PP$ and $\alpha \sum V_i < PP$, the Nash equilibrium solutions are the same as under PPM. The marginal penalty for PR will not change as alpha changes.

2.1.3 Uniform price contribution mechanism (UPC)

The uniform price contribution mechanism (UPC) also refunds all of any excess contribution. If the total contributions surpass the provision point, a minimum price (UP) is calculated to ensure just enough funds are collected to cover the cost. If one's contribution is below the uniform price, only the contribution amount is collected; if one's contribution is above the uniform price, only an amount equal to the uniform price is collected and any remainder of the contribution above the uniform price will be refunded to that person. Individual benefit can be written as:

$$\pi_i = \begin{cases} 0 & if\ \sum C_i < PP\ and\ \sum C_j^o < PP & \dots (3a) \\ V_i - C_i & if\ \sum C_i \geq PP, \sum C_j^o < PP, C_i < UP & \dots (3b) \\ V_i - UP & if\ \sum C_i \geq PP, \sum C_j^o < PP, C_i \geq UP & \dots (3c) \\ V_i & if\ \sum C_i < PP\ and\ \sum C_j^o \geq PP & \dots (3d) \\ (1+\alpha)V_i - C_i & if\ \sum C_i \geq PP, \sum C_j^o \geq PP, C_i < UP & \dots (3e) \\ (1+\alpha)V_i - UP & if\ \sum C_i \geq PP, \sum C_j^o \geq PP, C_i \geq UP & \dots (3f) \end{cases}$$

Under the UPC, all the excess contributions will be redistributed back to individuals in favor of those who have made higher contribution. When $\sum V_i > PP$, the Pareto optimal outcome is achieved if $\sum C_i \geq PP\ and \sum C_j^o \geq PP$. Same as in the PR, the Pareto optimal outcome is not sufficient for a Nash equilibrium solution. Consider when $\sum C_i > PP$, if one's contribution is higher than or equal to the uniform price calculated, there is some possibility he can reduce his contribution below the uniform price and the group can still provide the public good, and this is not a Nash equilibrium by definition. If one's contribution is below the uniform price contribution, he can always reduce contribution for a higher net benefit. Therefore, the efficient Nash equilibrium that yields a Pareto optimal outcome can only be achieved when $\sum C_i = PP\ and\ \sum C_j^o = PP$, the same as in the PPM and PR; in equilibrium, all individuals would be paying their contribution as the uniform price or their valuations.

To see how the marginal penalty relates to excess contributions under the UPC mechanism, we consider the following three situations. If the individual's contribution is above the calculated uniform price, increased contribution will not bring any negative consequences since any contribution above uniform price will be rebated, and an increased contribution under this situation will not change the uniform price needed for providing the public good. If, however, the individual's contribution is sufficiently below[2] the uniform price, the marginal penalty equals to 1 since all the contribution will be collected, which is similar as in the PPM. If the individual's contribution is sufficiently close[3] to the uniform price, the marginal penalty will be between 0 and 1, the range of which is similar to the PR.

There are also three other Nash equilibrium solutions under UPC: the two Nash equilibria that produce less net social benefits are $\sum_{i'\neq i} C_{i'} + V_i < PP, \sum C_j^o = PP$ and $\sum C_i = PP, \sum_{j'\neq j} C_j + V_j < PP$; the Nash equilibria that yield zero net social benefits is $\sum_{i'\neq i} C_{i'} + V_i < PP, \sum_{j'\neq j} C_j + V_j < P$. When $\alpha \sum V_i = PP$ and $\alpha \sum V_i < PP$, the Nash equilibrium solutions are the same as these under PPM or PR.

2.2 One group provides up to two units of the public good

Assume a single group where each individual receives a private value V_i. The group can provide up to two units of public good. The cost for providing the first unit is PP; the cost for providing two units is 2PP, where PP is the provision point as before. An underlying assumption is that people will never contribute more than their valuation for two units of the public good. Since the implications of different rebate rules have been discussed extensively above, we mainly use the PPM as an example to illustrate the equilibrium conditions under the one-group case. The equilibrium solutions can be found for PR and UPC analogically.

Under the PPM, the individual's benefit function can be written as:

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[2] By sufficient below we mean an increase in the contribution will not put the subsequent contribution above the uniform price needed for covering the cost.

[3] By sufficiently close we mean an increase in the contribution will put the subsequent contribution above the uniform price needed for covering the cost.

$$\pi_i = \begin{cases} 0 & if \sum C_i < PP & \dots(4a) \\ V_i - C_i & if \sum C_i \geq PP \; and \; \sum C_i < 2PP & \dots(4b) \\ (1+\alpha)V_i - C_i & if \sum C_i \geq 2PP & \dots(4c) \end{cases}$$

There are three Nash equilibrium solutions for the one group game[4]. They are: 1) $\sum_{i' \neq i} C_{i'} + V_i < PP$, 2) $\sum C_i = PP$, 3) $\sum C_i = 2PP$. Clearly the first Nash equilibrium solution $\sum C_i = 0$ is the least desirable since it yields zero benefit to all individuals. To see which of the remaining Nash equilibria yields a higher level of net social benefit, we compared the total group benefit under each equilibria. More specifically, the total benefits correspond to 4b and 4c can be written as:

$$\sum \pi_i = \sum V_i - \sum C_i = \sum V_i - PP \qquad \dots(5a)$$

$$\sum \pi_i = \sum (1+\alpha)V_i - \sum C_i = \sum (1+\alpha)V_i - 2PP \qquad \dots(5b)$$

When $\alpha \sum V_i > PP$, the $\sum C_i = 2PP$ solution yields a higher net benefit than $\sum C_i = PP$, thus the $\sum C_i = 2PP$ solution is the efficient Nash equilibrium; when $\alpha \sum V_i = PP$, the two solutions yield identical net benefits, so they are both efficient Nash equilibria; when $\alpha \sum V_i < PP$, the $\sum C_i = PP$ solution yields a higher net benefit and is the efficient Nash equilibria. It is not difficult to draw similar conclusions for PR and UPC rebate rules.

Same as in the two-group case, the efficient equilibrium is dependent on the relative magnitude between α and $\frac{PP}{\sum V_i}$. The marginal penalties for each rebate rule regarding over contribution are similar with the analysis in the two-group case. So far, we have identified the Nash equilibrium solutions for both group arrangements (two groups facing two units and one combined-group providing two units). There are multiple Nash equilibrium solutions under each circumstance, contrasts one equilibrium condition in the linear public good game. Also we found different rebate rules will not change the efficient Nash equilibrium; however, the rebate rules change the marginal penalties for over contribution individually.

[4] Also an unrestrictive assumption for these Nash equilibria to hold is $V_i < PP$, which means a single individual cannot compensate the cost for one unit of public good alone and still benefit from such behavior.

The magnitude of marginal benefit changes the efficient Nash equilibrium in both the two-group and one-group cases. We will utilize these findings as the basic guide for interpreting our experimental results.

3. Experimental design and procedure

We conducted ten experimental sessions in the Policy Simulation Lab, at the Department of Environmental and Resource Economics, University of Rhode Island. Subjects were recruited primarily through an email list that consists undergraduates, from various major backgrounds, who have indicated a willingness to participate in economic experiments. A small proportion of subjects are recruited directly from undergraduate classes at URI. We checked the attendances'' names and email addresses in order to ensure each subject participated in this experiment only once.

We conducted experiments through connected computer terminals. Inter-participant communications during the experiment are strictly prohibited and subjects cannot observe each other's choices. The instructions were read aloud. Subjects were told that they had already earned a $5 show-up fee before we proceeded to the instructions. They were paid in cash after all treatments were finished. One experimental session usually lasts about one hour and twenty minutes with an average total payoff around $35. We controlled the total number of subjects between 10 and 14 for one session: it is difficult to predict exact number of show-ups before each session, even confirmations are made on both sides.

The whole experimental sequence includes four PPM sessions, four PR and two UPC sessions. In each session, subjects are asked to make 90 decisions in three treatments. Treatment 1 is a single-unit provision point public good game under PPM. We separate all the subjects into two groups and each group provides one unit public good. People in different groups cannot benefit from the other group. We randomly change the group arrangement after every decision period, as well as in Treatment 2 and 3. Treatment 1 is intended as a test treatment to allow subjects become familiar with software and to prepare them for more complex games. The payoff subjects collected in this treatment count towards the actual payoff. The data from this treatment is excluded from our analysis. There are 10 decision periods in treatment 1.

Both treatment 2 and treatment 3 have four sub-treatments. Each sub-treatment consists ten decision periods with a varying marginal benefit for the second public good unit (the alpha). We choose four different levels of alphas: 0, 0.6, 1.0 and 1.2. The sequences of alphas are changed symmetrically to eliminate any order effect that may emerge in multiple experimental sessions. Treatment 2 and 3 are set up for the two different grouping approaches: the two-group and the one-group, the sequences of which are also changed systematically. In the two-group treatment, subjects are divided equally into two groups and each group can only provide one unit of the public good, but all subjects can benefit if any public good unit is provided. In the one-group treatment, all subjects stay in a single group that can provide up to two units of the public good.

At the beginning of the each decision period, each individual was told an individual value, which simulates the valuation for the public good. This value is drawn randomly under a uniform distribution from the interval [4,12] and rounded to one decimal place. Different subjects are endowed with different values. Subjects know the value distribution range and individual values differ. An individual value is constant for ten decision periods however changes as the beginning of a new treatment or a new sub-treatment. Subjects do not know the exact value of others. The unit cost is public information and equals 60% of the expected group value under the two-group circumstance. For example, if there are ten participants in an experiment session, under the two-group situation each group will have five participants, the unit cost PP equals 24, which is 60%*8*5, 8 is the average expected value from the given value interval. Table 1 details the experimental design and parameters.

[Table 1]

4. Result

A total of 122 subjects participated in our experiment, producing 9760 observations from treatment 2 and treatment 3. For the two-unit provision game, three outcomes are possible at a group level. The table 2 presents the provision frequency.

[Table 2]

We investigate the contribution data from the group level and the individual level. The group level contribution internalizes all the individual strategic interactions, which provides a more robust response regarding the change of various experimental parameters. Individual-specific attributes are less influential once contribution data is aggregated to a group level. The individual level data is richer in information and more complex due to the possible influence of diversified preferences in subjects' decision choices. It is intuitive to expect higher-value people contribute more, but to what extent remains unknown.

4.1 Group Contribution Behavior

Before going deep into statistical analyses, we first plot the actual average group contribution[6] data against our theoretical prediction. This would provide a general idea on how our results look like and how well the group contribution conform to the efficient Nash equilibrium predictions, under both group arrangements and separated different levels of marginal benefit.

[Figure 1]

We process the group contribution data by focusing on the following three variables: group arrangement, the marginal benefit of an additional unit and the rebate rules, which are of declining priority in our experimental design. Their influences on the convergence outcome also differ, as discussed in the section 2. We first test three hypotheses that we formulated around the influences of these three factors, and then apply a random effect model for more rigorous statistic analyses, on the group contribution data.

4.1.1 Hypotheses testing (Group)

Null Hypothesis 1: The two-group arrangement yield a higher average group contribution compared to one-group arrangement ($AC^2>AC^1$).

Where AC^2 is the average group contribution under two-group arrangement, and one-group arrangement for AC^1. This hypothesis enables us to compare whether the contribution positive externalities in the two-group arrangement overweight the group free riding behavior that may exist in the individual contribution decisions. As noted before, these two countervailing effects primarily decide which arrangement is more effective in raising contribution.

[6] The average group contribution is scaled to be comparable with the 10 subjects experimental session.

Null Hypothesis 2: The average group contribution under alpha 0 equals to the average group contribution under alpha 0.6, while lower than the average contribution under alpha 1.0 or alpha 1.2, for both group arrangements ($AC^{0.6}$=AC^{0}, $AC^{1.0}$>AC^{0}, $AC^{1.0}$>AC^{0}). The average group contribution under alpha 1.0 equals to the average group contribution under alpha 1.2 ($AC^{1.0}$=$AC^{1.2}$).

where the superscripts on *AC* denote different alpha levels. According to our equilibrium analysis, we know that both alpha 1.0 and 1.2 would require a higher total/average group contribution for the efficient equilibria compared to the base case where alpha 0; when alpha equals to 0.6, we assume there is no need to reach for the two units when the provision of one unit has identical maximized benefit; thus, we envision the alpha 0.6 would produce similar contribution outcome as alpha 0. Additionally, although alpha 1.2 would yield a higher total "surplus" to the group, the two has identical equilibrium conditions; we think the average contribution between the two situations would be of no statistical difference. Hypothesis 2 enables us to link our theoretical predictions to actual contribution data and see whether they are consistent with each other.

Null Hypothesis 3: The average group contribution under PR or UPC is higher than PPM for both group arrangements (AC^{PR}>AC^{PPM}, AC^{UPC}>AC^{PPM}). The average group contribution is higher in PR than UPC (AC^{PR}>AC^{UPC}).

where the superscripts denotes different rebate mechanisms. Since we conclude that different rebate schemes would not necessarily alter the convergence outcomes, we might expect the contribution to be indifferent. However this is only true under prefect rationality and complete information. Individual under this context may be more sensitive to the different marginal penalty that associated with rebate rules. We construct this hypothesis based on the fact that PR and UPC impose a less marginal penalty for over contribution compared to PPM. Furthermore, though we do not present a rigorous proof that the marginal penalty associated UPC is between the PR and PPM, we explained it intuitively. We may also expect that AC^{PR}>AC^{UPC}. Therefore, we can rely the hypothesis 3 to see whether individuals respond to different marginal penalties by adjust their contributions.

We use the Wilcoxon signed-rank test for the above three hypotheses to compare the medians of the two populations. Table 3 shows the results.

[Table 3]

The statistical test results generally support our hypotheses, which demonstrate that the three variables are influencing the contribution in a way that is consistent with our initial predictions. The Wilcox-test rejects our null hypotheses twice: $AC^{0.6}=AC^{0}$ and $AC^{1.0}=AC^{1.2}$, both under the two-group arrangement. We test alternative hypotheses and find out $AC^{0.6}>AC^{0}$ and $AC^{1.0}<AC^{1.2}$, significant at a 0.05 level[7]. Though two different alpha levels may share the same efficient equilibrium conditions under the two-group situation, individuals are still sensitive to the magnitude of alpha levels, and higher alpha level unitarily yield a higher group contribution. This might be explained by the positive externality idea we proposed earlier: when the alpha is larger, higher level of positive externality can be generated from one's contribution, which lead to an increased aggregated group contribution. Under the one-group arrangement, we are unable to observe such effects for two comparable alpha levels that have the same efficient equilibrium conditions, and we cannot statically differentiate them by simply comparing the average group contribution. We conclude that the positive externality override the group free riding from *Null Hypothesis 1*, and we are able to attribute the difference reflected in contribution levels to the marginal penalty framework from the test result of *Null Hypothesis 3*.

4.1.2 **Regression Model (Group)**

[7] We test the null hypotheses that $AC^{0.6}<AC^{0}$ and $AC^{1.0}>AC^{1.2}$, the Wilcox-test reject the hypotheses. The p-value are both 0.001.

We provide a multivariate assessment of different parameters using a mixed effects model. The heteroskedastic error between sessions is adjusted by clustering observations within each session. The model is formulated as:

$$y_{it} = \boldsymbol{X}'_{it}\boldsymbol{\beta} + \boldsymbol{Z}'_{i}\boldsymbol{\alpha} + \varepsilon_{it} = \boldsymbol{X}'_{it}\boldsymbol{\beta} + \alpha + u_i + \varepsilon_{it}$$

where explanatory variables are included in $\boldsymbol{X}'_{it}$, group-specific (experimental-session specific) variables are contained in $\boldsymbol{Z}'_{i}$. In our case, group specific variables are unspecified, and we use u_i to capture the group-specific random component. The u_i is similar to ε_{it} except there is only a single value entering the regression for each experimental-session group. Both u_i and ε_{it} are assumed to be uncorrelated with the regressors contained in $\boldsymbol{X}'_{it}$. We use average group contribution per person, for each decision period, as the dependent variable. We first applied an unrestricted model that contains different alphas, rebate rules, group differences, experiment period and their interaction terms. Then we specified four restricted models that eliminate one or all of the interaction variables to test the significance of the interaction terms. The unrestricted model (Model 1) is:

$$y_{it} = \boldsymbol{\beta_1} * \boldsymbol{alpha} + \boldsymbol{\beta_2} * \boldsymbol{Rebate} + \boldsymbol{\beta_3} * \boldsymbol{Group} + \boldsymbol{\beta_4} * \boldsymbol{Period} + \boldsymbol{\beta_5} * \boldsymbol{Group} * \boldsymbol{alpha} + \boldsymbol{\beta_6} * \boldsymbol{Group} * \boldsymbol{Rebate} + \boldsymbol{\beta_7} * \boldsymbol{Group} * \boldsymbol{Period} + \boldsymbol{\beta_8} * \boldsymbol{Rebate} * \boldsymbol{alpha} + \boldsymbol{\beta_9} * \boldsymbol{Rebate} * \boldsymbol{Period} + \boldsymbol{\beta_{10}} * \boldsymbol{Alpha} * \boldsymbol{Period} + \alpha + u_i + \varepsilon_{it}$$

Table 3 explains the meaning of each variable.

[Table 4]

Model 2 is where all the coefficients' interaction terms are restricted to zero ($\boldsymbol{\beta_5} = \boldsymbol{\beta_6} = \boldsymbol{\beta_7} = \boldsymbol{\beta_8} = \boldsymbol{\beta_9} = \boldsymbol{\beta_{10}} = \boldsymbol{0}$). Model 3 restricts the coefficient on the $\boldsymbol{Group}$ vector to zero ($\boldsymbol{\beta_5} = \boldsymbol{\beta_6} = \boldsymbol{\beta_7} = \boldsymbol{0}$). Model 4 and Model 5 restricts the coefficients of $\boldsymbol{Rebate}$ and $\boldsymbol{Alpha}$ to zero ($\boldsymbol{\beta_6 = \beta_8 = \beta_9 = 0, \beta_5 = \beta_8 = \beta_{10} = 0}$), respectively. The regression results of both unrestricted and restricted model are shown in table 4.

[Table 5]

By comparing the log likelihood statistic between two different models, we find each interaction term is significant and statistically different from the Model 1 as a whole. Therefore, we use the regression result from the unrestricted model (Model 1) for interpretation.

From the unrestricted model, we reject the null hypothesis ($\boldsymbol{\beta_3 = \beta_5 = \beta_6 = \beta_7 = 0}$) that the group difference will have no influence on average group contribution (χ^2 = 357.88, df=7, p<0.01). Based on the main effect for OneG variable and its associated interaction terms, we find that the one-group arrangement will generally decrease the average group contribution[8], which is consistent with the nonparametric test result based on *Null Hypothesis* 1. We also tested *Null Hypothesis 2* and were able to get consistent results. Take the one-group arrangement as the example: we cannot reject the null hypothesis that alpha 0.6 has the same influence on the group contribution compared to alpha 0 (χ^2 = 357.88, df=1, p>0.68), while alpha 1.0 and alpha 1.2 significantly increased the average group contribution compared to alpha 0 (alpha=1: χ^2 = 27.97, df=1, p<0.01; alpha=1.2: χ^2 = 15.21, df=1, p<0.01).

From the nonparametric results we find the rebate rules are more effective if they impose a smaller marginal penalty. With the regression results we were able to compare the effectiveness of alternative rebate rules under different grouping schemes. We found that PR and UPC do not statistically increase the contribution compared to the PPM in the two-group case; individuals are apparently more responsive to different alpha levels. However, in the one-group arrangement,

[8] However, since the interaction term with PR offsets OneG variable alone, in the PR case, one-group arrangement will lead a higher aggregated group contribution than two-group arrangement.

the PR significantly increases the contribution (χ^2 = 11.16, df=1, p<0.01) while the effect UPC is not significant (χ^2 = 1.87, df=1, p>0.18) compared to PPM from the model.

Furthermore, we find that under the PR and UPC rebate rule, the average group contribution in the one-group is not significantly different from the two-group case (PR: χ^2 = 1.86, df=1, p>0.17; UPC: χ^2 = 3.37, df=1, p>0.06), while under PPM the one-group arrangement would significantly decrease average group contributions (χ^2 = 16.55, df=1, p<0.01). This result indicates that when excess contribution is refundable, people would contribute at a similar level though in the one-group environment the first unit public good is easier to provide. Therefore, we may provide support the idea that refund mechanism effectively mitigate the free rider behavior and raise more contribution than in the PPM where no rebate is possible.

An ideal rebate mechanism shall encourage individuals to offer their full valuation for the public good and redistribute the excess fund "fairly". The term "fair" is controversial and Pareto optimality is not necessarily a "fair" allocation for everyone involved. Existing mechanisms are still far away from what is perceived to be the "ideal" one. Nonetheless, our results show that PR is the most successful of the three one in raising contributions, subject to our controlled environment.

4.2 Individual Contribution behavior

In this section, we first analyze how the presence of an additional unit influences individuals' contribution behavior by comparing individual contribution ratio (contribution divided by value) under different marginal benefit for the additional unit. Then we use a random effect model to assess the influences of different experimental variables on the individual contribution decisions.

4.2.1 Hypotheses testing

In the experiment, the level of alpha decides the marginal benefit for a second unit. The contribution ratio under zero-alpha case is used as the base line for comparison. We think that individuals would exhibit consistent behavior in their decision making process, that is, the contribution ratio may not change statistically with varying marginal benefit. One difficulty here is how to identify individuals' "reference value" when they make decisions in two-unit environment. The reference value is the denominator of the contribution ratio, the value that individuals think they are bidding on. It can be the value for the first unit, the value for the second unit or the aggregated value of both units. Our initial hypothesis is that when they think they can provide only one unit in the two-unit environment, they would make an offer based on their value for the first unit; when individuals think they can provide two units, they would make an offer as if they are paying for the second. To test this, we developed three hypotheses regarding the individual contribution ratio in the presence of an additional unit:

Null hypothesis 4: When alpha equals to 0.6, people make contribute based on their value for the first unit; the corresponding contribution ratio is not statistically different from the contribution ratio when alpha equals zero. ($\frac{{}^{0.6}C_i}{V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$)

Null hypothesis 5: When alpha equals to 1.0, people make contribute based on their value for the second unit; the corresponding contribution ratio is not statistically different from the contribution ratio when alpha equals zero. ($\frac{{}^{1.0}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$)

Null hypothesis 6: When alpha equals to 1.2, people make contribute based on their value for the second unit; the corresponding contribution ratio is not statistically different from the contribution ratio when alpha equals zero. ($\frac{{}^{1.2}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$)

where $V_i(1)$ is individual i's induced value for the first units, $V_i(2)$ is individual i's induced value for both units; $V_i(2) - V_i(1)$ is individual i's induced value for the second unit; ${}^{0}C_i$ is individual i's contribution when alpha equals to 0, and analogically for the situations when alphas is greater than zero.

If the alpha were small, according to the Nash equilibrium prediction, it may not be wise to support two units. Subjects would think the possibility to reach two units is small, thus they make contributions based on the value for the first unit, and *vice versa* when alpha is large. These two hypotheses can be stated in a unified way: people will contribute the same portion of value for the last unit that they think they can provide, as compared to the situation where an additional unit has no extra value. To test these hypotheses, we also applied a sequence of Wilcox singed-rank tests, the results of which are shown in table 6.

[Table 6]

Two conclusions can be drawn from the test results: 1) The test results provide some support to our initial hypotheses. We cannot reject the null hypothesis 4 that when alpha equals to 0.6, people make contribute based on their value for the first unit and the corresponding contribution ratio is not statistically different from the contribution ratio when alpha equals zero, under both group arrangements (Two-group, p=0.093; One-group, p=0.123). We cannot reject the null hypothesis 6 that people will contribute based on their value for the second unit when alpha equals 1.2 for one-group case (p=0.115), however this hypothesis is rejected under two-group arrangement (p=0.028). We might think that large positive externality pushed up the contribution in the two-group treatment when alpha is high, while such effects are unavailable in the one-group treatment. 2) We reject the null hypothesis 3 under both two-group and one-group arrangements (Two-group, p=0.001; One-group, p=0.001). The test statistics show that when alpha equals to 1, people contribute a significant higher ratio of their value compared to the situation where extra unit has no value. We attribute this result to the mixed expectations that may exist among individuals. Since people have a larger uncertainty (compared to 0.6 and 1.2 alpha level) about the whether the second unit can be provided, they may exhibit less uniformed contribution strategies, and may result a higher contribution variance compared to other situations, which is true according to our test result[10]. However, the provision of a second unit can still yield a positive benefit; a certain portion of people may choose to contribute more to push for the provision of both units. When alpha equals to 0.6 or 1.2, people may have a less diverse opinion on the number of units they think are able to provide, and this may be reason why they exhibit consistence behavior in terms of contribution ratio.

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[10] We used Hartley's F test for the homogeneous of variance assumption. We find that when alpha equals to 1, the variance of two populations differs from each other significantly from each other (p=0.001 for both group arrangements); while alpha equals to 0.6 or 1.2, we cannot reject the homogeneous of variance assumption at 0.05 significant level.

4.2.2 Individual Regression Model

The individual regression model is specified as:

$$y_{it} = \boldsymbol{\beta_1} * \boldsymbol{Value} + \boldsymbol{\beta_2} * \boldsymbol{alpha} + \boldsymbol{\beta_3} * \boldsymbol{Rebate} + \boldsymbol{\beta_4} * \boldsymbol{Group} + \boldsymbol{\beta_5} * \boldsymbol{period} + \boldsymbol{\beta_6} * \boldsymbol{Value} * \boldsymbol{alpha} + \boldsymbol{\beta_7} * \boldsymbol{Value} * \boldsymbol{Rebate} + \boldsymbol{\beta_8} * \boldsymbol{Value} * \boldsymbol{Group} + \boldsymbol{\beta_9} * \boldsymbol{Group} * \boldsymbol{alpha} + \boldsymbol{\beta_{10}} * \boldsymbol{Group} * \boldsymbol{Rebate} + \boldsymbol{\beta_{11}} * \boldsymbol{Group} * \boldsymbol{Period} + \boldsymbol{\beta_{12}} * \boldsymbol{Rebate} * \boldsymbol{alpha} + \boldsymbol{\beta_{13}} * \boldsymbol{Rebate} * \boldsymbol{Period} + \boldsymbol{\beta_{14}} * \boldsymbol{Alpha} * \boldsymbol{Period} + \alpha + u_i + \varepsilon_{it}$$

The result is shown in table 7.

[Table 7]

We go through the same procedures as for the group level data to see if any or all of the interaction terms are significant. Our result shows that the whole interaction component is significant and interactions term of $\boldsymbol{Value}, \boldsymbol{Group}$, $\boldsymbol{Rebate}$ and $\boldsymbol{Alpha}$ is significant individually. Thus, we use Model 6 for interpretation. From the Model 6, we reject the null hypothesis ($\boldsymbol{\beta_1} = \boldsymbol{\beta_6} = \boldsymbol{\beta_7} = \boldsymbol{\beta_8} = \boldsymbol{0}$) that induced value has no impact on the individual contribution level (p<0.01). We can see the induced value significantly increases individual contributions; people tend to contribute more when they have a higher induced value. It is interesting to find out all the interactions terms with the value variables are significant, which means people contribute a different portion of their values as circumstance changes. The regression results shows that compared to alpha equals 0, all the other levels of alphas result mixed influences on the contribution amount for the people with the same induced values on the first unit. The main effects of the alpha variables are all negative and significant, while the marginal effects of alphas are all positive and significant. This indicates that for higher induced value people, the increase of alpha will result in a positive effect on contribution, and for the low induced value people the increase of alpha shall have a negative impact. From the table 7, we find the coefficient for alpha06 is -0.8432, the coefficient for value*alpha06 is 0.1553. If the induced value is lowers than 5.43 (which is 0.8432/0.1553), subjects will contribute less compared the situation when alpha equals 0, and *vice versa*. The increase of alpha brings a mixed influence regarding the individual contribution ratio: low value[11] people would decrease their contribution ratio as alpha increases, and higher value people are likely to increase the contribution ratio. If we assume a higher induced value will increase the contribution linearly, the contribution ratios under different alphas also differ. When the induced value increases by 1, under alpha 0, people will contribute 21.95% of their increased value, and contribute 36.48% under alpha 0.6, 46.00% under alpha 1 and 46.02% under alpha equals 1.2. The regression result also shows that individuals will contribute a significantly larger portion of value under PR and UPC where the extra contribution can be refunded. We find compared to PPM, individuals with the same induced value will contribute a 12.74% higher portion of their valuation on average for PR, and 13.14% higher for UPC. Additionally, we find people contribute 6.72% less of their value in one-group arrangement; the magnitude is small, however it is still significant (p<0.01,table 7).

By comparing Model 6 with Model 1 we can see the effects of other experimental variable on the individual contribution are generally consistent with the regression results for the average group contribution. We used average group contribution per person as the dependent variable for the group contribution model so that the regression results are comparable. We find the estimated coefficient of the same experimental variables (except the intercept) appears to be very close in the two models (Model 1 and Model 6).

5. Concluding Remarks

This research explores the public good provision game under two units environment with different group arrangements, rebate rules and marginal benefits. We test different hypotheses regarding group and individual contribution behaviors. We also tried to analyses the individual as well as the interactions effect among these variables, which may potentially be helpful in selecting an effective, comprehensive mechanism for real world fund raising.

[11] From our regression result, we find if one's induced value is in the lower 22.5(approximately) percentile of the value distribution, he/she is likely to decrease the contribution ratio as alpha increases, and *vice versa*.

The results show significant difference under two different group arrangements. This experimental outcome conforms to the prediction that in the two-group situation, the conditions required for efficiency are more restrictive than in the one-group situation. It is hard to say which group arrangement to provide multiple units' of public good is strictly better than the other. It depends on the objective. If the objective is to encourage people to contribute more and minimize the contribution variance, the two-group arrangement is the better choice. On the contrary, if the objective to increase the provision frequency, the one-group arrangement is more successful. However, our results suggest that a market-maker could utilize the influence of rebate rules, along with group arrangement and the marginal benefit of additional unit (though often exogenous) as a set of controls to develop a market that can efficiently (or Pareto improving) provide public goods, though private, individualized contribution.

The results also reveal that despite all rebate rules yield the same Nash equilibria, the magnitude contribution vary significantly. We attribute this difference to the marginal penalty for excess contributions[12] associated with the different rebate rules. Our experimental results support this conjecture. PR is the most effective rule in raising contributions with the least severe penalty for excess contribution, PPM is the least effective one with the most severe penalty for excess contributions, and UPC is between these two rules in terms of effectiveness and penalty. The marginal benefit of an additional unit is proven to be an important factor in the multiple units' public good game, especially under the two-group arrangement, where positive contribution externalities exist. We may further exam how the marginal value idea can fit into the context of real world public good problem so that we can develop different fund raising designs for specific type public good.

The results provide mixed results on our hypothesis concerning individual contribution behavior in a multi-units provision game. We are expecting that people contribute based on the last unit that they think they will provide. Due to the limitations of our experiment, we only extend the idea to two-unit case, and

12 Marks and Croson (1998) used the term "over contribution" to stand for the extra money that surpasses the provision point. We use "excess contribution" for this while "over contribution" is reserved to indicate the situation where individual contribute more than the possible value he can get when the public unit(s) is(are) provided.

only four specific levels of marginal benefit ratio. It is interesting to apply this hypothesis to three or more units' public good and try more levels of marginal benefit ratio, so that we may identify some general pattern of individual contribution behavior. We may also identify the common ground that exists for private and public good if the marginal value also plays a critical role in multiple-units public good context. We would like to see a system that fully acknowledges the value of the non-private good, such as environmental amenities and ecosystem services, in which people benefit from such goods are also paying their fair shares, and enables a more efficient economy that effectively mitigates externality worries.

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Table 1. Experimental Sequences and Parameters

Session	Rebate Rule	Experimental Sequence			N	Individual Value	Unit Cost
		Treatment 1	Treatment 2	Treatment 3			
PPM1	PPM	PPM (test)	Two Group 1.0-1.2-0.6-0	One Group 1.0-1.2-0.6-0	14	[4,12]	33.6
PPM2	PPM	PPM (test)	One Group 0-0.6-1.2-1.0	Two Group 0-0.6-1.2-1.0	14	[4,12]	33.6
PPM3	PPM	PPM (test)	Two Group 1.0-0-1.2-0.6	One Group 1.0-0-1.2-0.6	10	[4,12]	24
PPM4	PPM	PPM (test)	One Group 0-1.2-0.6-1.0	Two Group 0-1.2-0.6-1.0	12	[4,12]	28.8
PR1	PR	PPM (test)	Two Group 1.0-1.2-0.6-0	One Group 1.0-1.2-0.6-0	10	[4,12]	24
PR2	PR	PPM (test)	One Group 0-0.6-1.2-1.0	Two Group 0-0.6-1.2-1.0	10	[4,12]	24
PR3	PR	PPM (test)	Two Group 1.0-0-1.2-0.6	One Group 1.0-0-1.2-0.6	10	[4,12]	24
PR4	PR	PPM (test)	One Group 0-1.2-0.6-1.0	Two Group 0-1.2-0.6-1.0	14	[4,12]	33.6
UPC1	UPC	PPM (test)	Two Group 1.0-0-1.2-0.6	One Group 1.0-0-1.2-0.6	14	[4,12]	33.6
UPC2	UPC	PPM (test)	One Group 0-1.2-0.6-1.0	Two Group 0-1.2-0.6-1.0	14	[4,12]	33.6

We also did a pilot experiment that mainly tests the functionality of the software, which is not included in the above table.

Table 2. Provision Frequencies of Public Good Unit(s)

		0 Unit	1 Unit	2 Unit
Group Arrangements	Two-Group	0.38	0.50	0.12
	One-Group	0.11	0.64	0.25
Rebate Rules	PPM	0.38	0.54	0.08
	PR	0.17	0.70	0.13
	UPC	0.18	0.61	0.21
Alpha Levels	Alpha 0	0.45	0.52	0.03
	Alpha 0.6	0.37	0.60	0.03
	Alpha 1.0	0.33	0.44	0.23
	Alpha 1.2	0.34	0.45	0.21

Values are rounded up to two decimal place.

Table 3. Wilcoxon signed-rank test (Null Hypothesis 1-3)

	Wilcoxon Signed-rank Test	Group Arrangement	W-statistics	p-value
Null Hypothesis 1	$AC^{2}>AC^{1}$	N/A	107592	0.999
Null Hypothesis 2	$AC^{0.6}=AC^{0}$	Two-Group	6763	***0.001***
	$AC^{1.0}>AC^{0}$		7480	0.999
	$AC^{1.2}>AC^{0}$		6834	0.999
	$AC^{1.2}=AC^{1.0}$		5739.5	***0.037***
	$AC^{0.6}=AC^{0}$	One-Group	4977.5	0.957
	$AC^{1.0}>AC^{0}$		7785	0.999
	$AC^{1.2}>AC^{0}$		7627.5	0.999
	$AC^{1.2}=AC^{1.0}$		5181	0.659
Null Hypothesis 3	$AC^{PR}>AC^{PPM}$	Two-Group	17238	0.999
	$AC^{UPC}>AC^{PPM}$		8253.5	0.999
	$AC^{PR}>AC^{UPC}$		6834	0.847
	$AC^{PR}>AC^{PPM}$	One-Group	21690	0.999
	$AC^{UPC}>AC^{PPM}$		9329.5	0.999
	$AC^{PR}>AC^{UPC}$		8340.5	0.999

Wilcoxon signed-rank test was done in R version 2.12.2.

Table 4. Descriptions Of Explanatory Variables

Variables		Description	Note
Alpha	Alpha0	The ratio of the marginal benefit of the second to the first unit is 0	Reference level
	Alpha06	The ratio of the marginal benefit of the second to the first unit is 0.6	
	Alpha10	The ratio of the marginal benefit of the second to the first unit is 1	
	Alpha12	The ratio of the marginal benefit of the second to the first unit is 1.2	
Rebate	PPM	No rebate provision point mechanism	Reference level
	PR	Proportional rebate provision point mechanism	
	UPC	Uniform price rebate provision point mechanism	
Group	TwoG	Two-group arragement	Reference level
	OneG	Owo-group arragement	
Period		Decision period within each treatment, from 1 to 10.	
Value		Individual induced value for the first unit public good	Only the individual contribution model

Table 5. Mixed Effect Model Regression Result (Group Level)

	Model 1	Model 2	Model 3	Model 4	Model 5
	Coef.(Std.Err.)	Coef.(Std.Err.)	Coef.(Std.Err.)	Coef.(Std.Err.)	Coef.(Std.Err.)
Alpha06	0.348 (0.194)*	0.205 (0.08)***	0.134 (0.195)	0.5 (0.182)***	0.205 (0.076)***
Alpha1	0.653 (0.195)***	1.056 (0.08)***	0.849 (0.195)***	0.935 (0.183)***	1.054 (0.076)***
Alpha12	0.352 (0.194)*	0.832 (0.08)***	0.554 (0.195)***	0.744 (0.182)***	0.832 (0.076)***
PR	0.495 (0.422)	1.062 (0.368)***	0.922 (0.401)**	1.061 (0.368)***	0.854 (0.39)**
UPC	0.361 (0.517)	0.662 (0.451)	0.516 (0.491)	0.662 (0.451)	0.676 (0.478)
OneG	-0.632 (0.155)***	-0.761 (0.056)***	-0.762 (0.056)***	-0.231 (0.15)	-0.544 (0.133)***
Period	0.051 (0.023)**	-0.039 (0.01)***	-0.004 (0.023)	0.029 (0.021)	0.039 (0.017)**
OneG*Alpah06	-0.429 (0.145)**			-0.429 (0.153)***	
OneG*Alpha1	0.377 (0.145)***			0.376 (0.153)**	
OneG*Alpha12	0.405 (0.145)***			0.405 (0.153)***	
OneG*PR	0.844 (0.115)***				0.845 (0.12)***
OneG*UPC	0.31 (0.14)**				0.31 (0.147)**
OneG*Period	-0.112 (0.018)***			-0.112 (0.019)	-0.112 (0.019)***
PR*Alpha06	0.325 (0.162)**		0.325 (0.175)*		
PR*Alpha1	0.6 (0.163)***		0.61 (0.176)***		
PR*Alpha12	0.512 (0.162)***		0.512 (0.175)***		
PR*Period	-0.039 (0.02)**		-0.04 (0.022)*		-0.039 (0.021)*
UPC*Alpha06	0.109 (0.198)		0.109 (0.215)		
UPC*Alpha1	0.215 (0.198)		0.215 (0.215)		
UPC*Alpha12	0.936 (0.198)***		0.936 (0.215)***		
UPC*Period	-0.031 (0.024)		-0.031 (0.026)		-0.031 (0.026)
Alpha06*Period	-0.015 (0.025)		-0.015 (0.027)	-0.015 (0.027)	
Alpha1*Period	-0.013 (0.025)		-0.014 (0.027)	-0.012 (0.027)	
Alpha12*Period	-0.021 (0.025)		-0.021 (0.027)	-0.021 (0.027)	
Constant	3.702 (0.317)***	3.748 (0.272)***	3.766 (0.299)***	3.415 (0.294)***	3.518 (0.284)***
N	800	800	800	800	800
LogLikelihood	-922.897	-977.60621	-977.6676	-956.2759	-945.94565
Chi-Square	714.66***	440.16***	494.83***	552.08***	576.86***

Estimation was done in STATA 11.2. Standard errors are in parentheses. *** Indicates significance at 1% level. ** Indicates significance at 5% level. * Indicates significance at 10% level

Table 6. Wilcoxon signed-rank test (Null Hypothesis 4-6)

	Wilcoxon Signed-rank Test	W-statistics	p-value
Hypotheses:(Two-Group)			
Null Hypothesis 4	$\frac{{}^{0.6}C_i}{V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	773398.5	0.093
Null Hypothesis 5	$\frac{{}^{1.0}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	819935	***0.001***
Null Hypothesis 6	$\frac{{}^{1.2}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	705879.5	***0.028***
Hypotheses:(One-Group)			
Null Hypothesis 4	$\frac{{}^{0.6}C_i}{V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	770968.5	0.123
Null Hypothesis 5	$\frac{{}^{1.0}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	841549.5	***0.001***
Null Hypothesis 6	$\frac{{}^{1.2}C_i}{V_i(2)-V_i(1)} = \frac{{}^{0}C_i}{V_i(1)}$	771567	0.115

Wilcoxon signed-rank test was done in R version 2.12.2.

Table 7. Mixed Effect Model Regression Result (Individual Level)

	Model 6 Coef.(Std.Err.)
Value	0.22 (0.028)***
Alpha06	-0.843 (0.297)***
Alpha1	-1.347 (0.295)***
Alpha12	-1.33 (0.293)***
PR	-0.568 (0.556)
UPC	-0.412 (0.630)
OneG	-0.132 (0.218)
Period	0.03 (0.020)
Value*Alpha06	0.155 (0.031)***
Value*Alpha1	0.24 (0.030)***
Value*Alpha12	0.24 (0.031)***
Value*PR	0.127 (0.025)***
Value*UPC	0.131 (0.028)***
Value*OneG	-0.067 (0.022)***
OneG*Alpah06	-0.233 (0.132)*
OneG*Alpha1	0.386 (0.132)***
OneG*Alpha12	0.258 (0.132)**
OneG*PR	0.933 (0.106)***
OneG*UPC	0.058 (0.122)
OneG*Period	-0.114 (0.016)***
PR*Alpha06	0.066 (0.150)
PR*Alpha1	0.549 (0.150)***
PR*Alpha12	0.346 (0.150)**
PR*Period	-0.023 (0.019)
UPC*Alpha06	0.087 (0.172)
UPC*Alpha1	0.136 (0.172)
UPC*Alpha12	0.653 (0.172)***
UPC*Period	-0.014 (0.021)
Alpha06*Period	-0.007 (0.023)
Alpha1*Period	0.003 (0.023)
Alpha12*Period	-0.023 (0.023)
Constant	2.062 (0.428)***
N	9760
LogLikelihood	-22216.8
Chi-Sqaure	2460.22***

Estimation was done in STATA 11.2. Standard errors are in parentheses. *** Indicates significance at 1% level; ** Indicates significance at 5% level. * Indicates significance at 10% level.

Figure 1. Average Group Contribution (Actual versus Predicted)