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Threshold Level Public Goods Provision with Multiple Units: Experimental Effects of Disaggregated Groups with Rebates

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Abstract

We introduce two institutions that provide multiple public good units, assuming that a market-maker has the ability to establish groups of contributors. We set up a public good experiment where either all N individuals form one group to provide two units, or divide the N participants into two groups, and each group provides one unit separately, with all individuals benefiting for any unit(s) provided. Our results show that, under certain circumstances, the latter approach provides more of both units, and it encourages more contribution on average. We also explore the performance of two rebate rules under the two grouping approaches.

Keywords: Experimental economics, Grouping approach, Provision point mechanism, Rebate, Environmental economics, Ecosystem Service Markets

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1 Introduction

The problem of public good provision remains an active area of research and often applies experimental methods. In such problems, the result from aggregated individual utility maximization behavior may not coincide with a socially best outcome. This individual and social divergence encourages us to search for mechanisms that enable individuals to act according to their own interests while simultaneously maximizing the total welfare of society. Our paper explores factors that might raise individual contributions substantially compared to traditional voluntary contribution approaches in a multi-units public good context. Our proximate motivation concerns private provision of public goods provided by ecosystems, but our contribution concerns public goods more generally.

This research adds to the current public good literature, addressing the problem of a market-maker or donations-administrator who has the ability to establish groups of donors as a control in the voluntary contribution institutions. We compare two different grouping approaches to provide multiple units of the public good: the aggregated grouping approach, where the market-maker assigns all participants to a single group that is responsible (or able) to deliver multiple units, is compared to the disaggregated grouping approach, where the market-maker assigns participants to separate groups, and each group is responsible for providing one unit, and all participants can benefit from the public good regardless which group provided it.

There are two lines of literature regarding the public good provision game. One is called the "linear" public good provision game (e.g., Andreoni, 1995, Bernheim, 1986, Isaac and Walker, 1988, Palfrey and Prisbrey, 1996). The linear game asks subjects 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 yields a higher rate of return than the public fund for the private investor, but the public fund provides the group with a higher total return. The marginal return for the group fund is set such that the social optimum occurs when individuals give everything to the group fund, while the individual's optimum occurs when one keeps all tokens in their private fund.

The other line of literature uses the provision point mechanism to provide the public good in a discrete unit(e.g., Alboth et al., 2001, Laussel and Palfrey, 2003, Schram et al., 2008). The provision point mechanism evolves from the step-level public good game which asks individuals to make decisions on whether to contribute toward a public good. The provision point mechanism relaxes the dichotomous choice constraint so that each subject can make a continuous offer. The public good is funded if the aggregated offers reach or surpass the predetermined cost, or the provision point. The linear public good game asks participants to take action against their own best interest, at the margin. In contrast, the provision point mechanism, at least in principle, enables participants to contribute toward provision up to their marginal benefit. Thus the provision point mechanism could enable contributors to benefit such that their benefit always equals or exceeds their own cost for contribution. The incentive to free-ride or cheap-ride is then motivated by rent seeking or strategic opportunities to avoid cost partially or entirely.

Our investigation is motivated by the difficulty encountered in developing environmental markets, such as in a U.S.D.A. effort that asked for private contributions to provide ecosystem services (Swallow et al. 2008). Ecosystem services are the benefits that Nature provides to humans (Millennium Ecosystem Assessment 2005), many of which carry public good properties. For example, cultural ecosystem services may include aesthetic goods like the open space of an undeveloped farm or forest landscape, or services of grassland or hayfield habitats supporting aesthetically pleasing wildlife[1]. Using this example, 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. To raise contributions, one might establish groups of residents, with the intent that each group can pay the cost for preserving one field, and residents of the communities benefit from all fields provided (e.g., Swallow et al 2008). This framework is largely in accordance with the provision point mechanism, in that each group addresses a single unit, only here there are multiple units and therefore multiple groups. Swallow(2012) has explored the implications of a market equilibrium built around such an approach in a second-best world extending beyond two units. Our interest is to evaluate relative advantages of the two grouping approaches – the aggregated approach and the disaggregated approach. It is a policy issue – or an issue regarding the pragmatic design of institutions for provision of public goods in a second-best world – which grouping approach performs better in a multiple units' environment.

One of the main questions is which of the two grouping approaches can increase the number of units provided. On the one hand, this disaggregated approach is wasteful, as excess contributions in one group cannot be used to complement contributions in another group. For example, when two public good units are available, if $1,000 is required to provide each unit of the public good, and total contributions are $1,500 in one group and $700 in another, only one unit is provided, although the aggregate contribution is more than that required for the provision of two units. On the other hand, contributors in small groups may become more pivotal, leading to more contributions (cf. Rapoport, 1987); participants in a larger group may contribute more if they are assigned to a smaller group. The multi-units situation characterizes many of the most challenging public good provision problems. The paper provides a starting point where we apply both grouping approaches to a two-unit environment.

Our research also relates to recent public good literature that focuses on the individual behavior and group membership (Charness et al, 2006; Sutter, 2009), only here we mitigate the membership effect by reshuffling the group membership for each experimental period when multiple groups are available, so that the individual will not be attached to a particular group. Also, our research provides some experimental evidence on individual behaviors in the multilevel public goods games with community structures (Wang et al, 2011; Perc et al, 2013). The public good games with community structures consist of different groups where the interaction rate within group is higher than that between groups (Newman, 2006). In our disaggregated approach, since individuals can only benefit from, but have no control over, the provision outcomes of other groups, the between groups interactions only affect the benefit side while the within group interactions enter both individuals' benefit and cost considerations. Broadly speaking, the comparison between the aggregated grouping approach and the disaggregated grouping approach is about assessing the relative advantage of a flat and a hierarchical provision structure wherein individuals voluntarily support multiple units of a public good, which can also be one public good project with discrete configurations. An example is the problem faced by the social planner to build either a new two-lane or a four-lane bridge (or not build a new bridge) that connects two communities across a river and when the cost is to be covered by individual voluntary contributions.

The paper is organized as follows. Section 2 describes the experiment mechanism. Section 3 develops hypotheses. Section 4 describes the experimental designs and procedures. Section 5 presents the experimental results and discusses their implications. Section 6 concludes the paper.

2 Provision Mechanisms

Consider the problem when a finite and fixed number of individuals from two communities (two neighborhoods) are to provide discrete units of a public good, e.g., preserving twenty acres of aesthetic habitat that lies on the boundary of two communities. Suppose there are three possible outcomes: zero acres are perserved, ten acres are perserved and twenty acres are preserved. We envision a case when meaningful increments of habitat require a minium field-size, such as demanded by the breeding requirements of certain grassland-nesting birds. One can also consider the problem of a land trust attempting to preserve two contiguous parcels spanning a community boundary, with each parcel indivisible due to property ownership and zoning rules or excessive transaction cost. The marginal cost of preservation per ten acre parcel is flat. The market maker solicits contributions by asking each individual from the two communities and collects money to provide as many parcels as possible: we assume that residents of either community are indifferent between which parcel is selected if only one is funded. A community could simply be neighborhood within a single town: if the total contributions from the two communities cannot cover the cost of ten acres, zero acres are perserved; if the total contributions can cover the cost of ten acres while falling short of twenty acres, only ten acres are perserved and so on. This grouping structure corresponds to the aggregated grouping approach.

Alternatively, we may require that each community contributes to preserve ten acres at the maximum. Due to the non-exclusive property of the public good, individuals from both communities can benefit from the habitat preservation regardless of which community provides it. Figure 1 depicts the two grouping approaches. The illustration of the disaggregated approach (right side) is adopted from Wang et al (2011)'s sketch for a multiple level of public good's game. In the left figure, the small squares represent individuals from the two communities, their total contributions determine the level of public good provided in the aggregated grouping approach, where each individual needs to offer a contribution knowing the possible outcomes are zero, ten or twenty acres. This approach can be considered as a case within a broader class of public good combinatorial auctions (Day and Raghaven, 2007)[2], or more closely, a private combinational auction with multiple winners (see Cramton, Shoham and Steinberg, 2006), where people place a single bid for multiple units of a discrete public good and everyone benefits from the provision. The right figure represents the group structure in the disaggregated approach: first, individuals from the same community decide whether a public good (in our case, a ten-acre parcel) can be provided; the total quantity of public good provided will depend on the outcome of these two communities, which can be thought of as the simplest, two-level public good game. However, the term "community" shall not limit the ability of the market maker to form different provision structures; we can use the disaggregated approach to construct different numbers or sizes of groups to deliver multiple units of a public good, by using any combination of potential contributors, not necessarily by the similarity in residential locations or other demographic attributes[3].

Other than deciding the way to establish groups of potential contributors, realistically, the market maker has to decide how to address any excess contributions in the event that more money is raised than the provision cost requires. We mainly use two generic classes of rebate rules: one is the no rebate rule where the market maker keeps all the excess contributions, which we call the PPM in the context of the provision point mechanism; the other rule is when all the excess contribution are rebated to the contributors in proportion to their contributions (PR), under which the market maker only collects the money needed to cover the provision cost whenever applicable. Marks and Croson (1998) point out the marginal penalty of offering another dollar under the PR rule is within (-1,0): if an individual contributes one dollar more, conditional on a successful provision without the additional dollar, this individual receives a rebate that is smaller than a dollar . The marginal penalty indicates that instead of getting a rebate from excess contribution ex post, one may acquire a higher profit by lowering the contribution ex ante. Under the perfect information assumption where each individual knows the contributions of the others, the "core" equilibrium is the total contribution just equal to the provision cost, the proportional rebate will not alter the equilibrium core (Bagnoli and Lipman, 1989). When individual values and contributions are private information, past experiment results reveal that the rebate rules have a significant influence on individual contributions (Mark and Croson, 1998; Spencer et al, 2009). However, the influence of rebate in different group structures is unknown; such knowledge is necessary if we are to apply rebate to a wider range of fund raising applications.

Furthermore, depending on the type of public good, individuals may not have a constant marginal benefit curve. It is interesting to see how individuals with a decreasing marginal benefit will respond compared to those with a constant or even an increasing marginal benefit; past public good experiments provide little information in this respect. In the bridge construction example, an individual may have a decreasing marginal benefit since the value for a first-two lane bridge is greater than half of a four-lane bridge if congestion does not always happen. On the contrary, people may have a constant or even increasing marginal value for land preservation if they think a single parcel is not likely to make a "significant" difference either from the scenic views or environmental quality enhancement. Such simplifications can be representative for some real world fund-raising activities and our experiments can shed light on how to better design a decentralized mechanism to supply various kinds of public good.

2.1 Rebate Rules

Next we formally present the rebate rules and grouping approaches when a certain number of individuals are to provide two units of a public good. We briefly introduce two rebate rules, in the context of a one-unit public good, and then characterize the two-units provision game. Let v_i denote the amount of money individual i gets once the total contribution from the group meets or exceeds the provision cost; v_i acts as the individual's private value for the public good. The amount individual i decides to contribute is denoted as b_i. The cost of providing the public good is defined as the provision point (C).

In the PPM rule, individuals get no refund if more money is collected than needed to pay the provision cost.

$$\pi_i = \begin{cases} 0, & \text{if } \sum b_{-i} + b_i < C \\ v_i - b_i, & \text{if } \sum b_{-i} + b_i \geq C. \end{cases} \tag{1}$$

In equations (1), π_i is individual i's profit or net benefit, $\sum b_{-i}$ is the aggregated contribution of others. If the group fails to provide the public good, individual i gets zero benefit; if the group provides the public good, individual i gets a benefit equal to value v_i minus contribution b_i. From the perspective of all contributors, contributing more than the provision point is not optimal since excess funds will be wasted.

The proportional rebate mechanism (PR) differs from PPM in handling excess contributions. In PR, excess contributions are redistributed to individuals in proportion to their own contributions, conditional on a successful provision. Specifically, we have:

$$\pi_i = \begin{cases} 0, & \text{if } \sum b_{-i} + b_i < C. \\ v_i - b_i(1-R), & \text{if } \sum b_{-i} + b_i \geq C, \end{cases} \tag{2}$$

where R is the rebate rate given by $(\sum b_i - C)/\sum b_i$.

2.2 Two grouping approaches

In the disaggregated approach, two groups are created by the market-maker. Since we want to avoid self-selection in group formation, each individual will be randomly assigned to one of the two groups, regardless of their individual values. Each group is responsible for providing one unit of the public good. Both groups can benefit from a successful provision regardless of which group provided it. Contributions from one group cannot support provision of the other unit. If both units are provided, individuals receive the value for two units. Here we only present individual payoff functions for the PPM as an example; assume individual i is assigned to group 1, $\sum b^1$ is the sum of contributions by individual i's group (group 1), while $\sum b^2$ is sum of contributions from the group other than the group to which individual i is assigned (group 2). The marginal benefit for a second unit is proportional to v_i at rate α, and is the same for all individuals.

$$\pi_i^1 = \begin{cases} 0, & \text{if } \sum b^1 < C \text{ and } \sum b^2 < C, (3a) \\ v_i^1 - b_i^1, & \text{if } \sum b^1 \geq C \text{ and } \sum b^2 < C, (3b) \\ v_i^1, & \text{if } \sum b^1 < C \text{ and } \sum b^2 \geq C, (3c) \\ (1+\alpha)v_i^1 - b_i^1, & \text{if } \sum b^1 \geq C \text{ and } \sum b^2 \geq C, (3d) \end{cases} \tag{3}$$

In this case, equation (3a) represents i's payoff if neither group provides a unit; (3b) concerns i's payoff if only her own group provides a unit; (3c) concerns i's payoff if her group fails to provide a unit but the other group succeeds; and (3d) gives the payoff when both groups provide a unit, where αv_i represents the benefit from a second unit for individual i.

In the aggregated approach, the number of participants represents the combined total from the disaggregated groups, assuming the same distribution of individual values. The larger group can provide up to two units of public good. The cost for providing the first unit is C; the cost for providing two units is $2C$, where C is the provision point for one unit. Participants make only a single contribution, which the market-maker uses to provide as many units as possible.

$$\pi_i = \begin{cases} 0, & \text{if } (\sum b_{-i} + b_i) < C, (4a) \\ v_i - b_i, & \text{if } C \leq (\sum b_{-i} + b_i)) < 2C, (4b) \\ (1+\alpha)v_i - b_i, & \text{if } (\sum b_{-i} + b_i)) \geq 2C. (4c) \end{cases} \tag{4}$$

These payoffs are modified under the proportional rebate rule by setting the rebate R equal to $(\sum b_i - C)/\sum b_i$ and $(\sum b_i - 2C)/\sum b_i$ for the one-unit and two-units provision outcomes in (4) and adding $b_i R$ to the payoffs in (4b) and (4c) (analogous to (2)) . Note that though the experiment is limited to a two-units environment, our method can be generalized to providing three or more units. For example, when there are four levels/units of a public good, e.g., providing forty acres of habitat in ten-acre increments, we can either divide the potential contributors into the four groups, each group providing ten acres, or keep all the contributors in the same group where each individual makes an offer for providing up to forty acres; we may even use a "hybrid" approach where we divide the contributors into two groups and each group could provide up to twenty acres. Furthermore, if providing forty acres of habitat is an extremely difficult task based on some prior information available to the market maker, she may only try to provide twenty or thirty acres at the maximum, using just two or three groups, so that each ten-acres has a higher probability of being provided.

3 Hypotheses

This experiment focuses on three treatment variables: the grouping approach (aggregated versus disaggregated), the rebate rule (PPM versus PR) and the second-unit marginal benefit level (α set to the baseline level 0, a decreasing marginal benefit where the value of the second unit is 0.6 (60%) of the first unit, a constant marginal benefit level with α at 1.0 and an increasing marginal benefit level with α at 1.2). The marginal benefit level is largely determined by the type of public good and individual preference, while the rebate rule and the grouping approach are control variables that the market maker can choose. We adopt a subjective expected value model to inform average contributions across different treatment variables (Savage, 1954; Fishburn, 1986). Note that regarding individual behavior, we only assume that subjects are maximizing expected payoffs and make reasonable conjectures based on individuals' belief. We do not assume individuals will necessarily converge to any group equilibrium, due to the level of complexity involved in figuring out an equilibrium contribution strategy under imperfect information and the hierarchic payoff structures. Ample experimental and empirical evidence shows that individuals deviate from equilibrium strategy quite often[4]. Though the assumption that indiviudals are always optimizing utility over a well-defined preference have also been constantly questioned by experimental inquiries (Lichtenstein and Slovic, 1971; Simon, 1955; Smith, Suchanek, and Williams, 1988), the individual expected utility model can still provide useful benchmarks.

In the aggregated approach, each individual makes a single offer to provide both units. One's expected payoff is the net profit from providing one unit times probability that only one unit is provided, plus the net profit from the group providing both units times the probability that both units are provided. Specifically, in the aggregated approach without rebate, the expected profit for a risk neutral individual i if she contributes b_i is:

$$E(\pi_i|b_i) = (v_i - b_i)Pr(C \leq (\sum b_{-i} + b_i) < 2C) + ((1+\alpha)v_i - b_i)Pr((\sum b_{-i} + b_i) \geq 2C). \quad (5)$$

Let $\eta = \sum b_{-i}$, and denote the probability density function over all η ($\eta \geq 0$) by $f(\cdot)$ with $\eta \geq 0$, where $f(\cdot)$ representing individual i's subjective belief of others' total contributions. We can then write equation (5) as:

$$E(\pi_i|b_i) = (\tilde{v} - b_i)(1 - F(C - b_i)) \quad (6)$$

where $F(\cdot)$ is the corresponding cumulative distribution function of $f(\cdot)$ and $\tilde{v} = v_i(1+\alpha\frac{1-F(2C-b_i)}{1-F(C-b_i)})$. When there is a single public good unit, $\alpha = 0$ and $\tilde{v} = v$, then $1 - F(C - b_i)$ is the probability that the public good will be provided if individual i contributes b_i. When the value of the second unit is positive, regardless the level of α, $\tilde{v} > v$ since the probability of providing the first unit and the second unit is always positive.

In the disaggregated approach without rebate, each individual also makes a single offer, but their offer can only influence the provision probability of one unit. Different from the aggregated grouping approach, individuals also need to form a belief regarding the unit by the other group, which one cannot directly influence, in addition to forming a belief regarding the provision probability of one's own group. Thus, the expected profit for individual i if she contributes b_i is:

$$E(\pi_i|b_i) = (1-p) * (v_i - b_i)Pr(\sum b_{-i} + b_i > C) + p * (v_i + (\alpha v_i - b_i)Pr(\sum b_{-i} + b_i > C)), \quad (7)$$

where p is an exogenous variable indicating the subjective probablity that the other group provides one unit. Therefore, equation (7) gives the value of i's decision when i's group is providing the only unit (first term in (7)) or when i's group is providing the second unit (second term in (7)). We can also write equation (7) as:

$$E(\pi_i|b_i) = (\hat{v}_i - b_i)(1 - F(C - b_i)) + v_i p; \quad (8)$$

where $\hat{v}_i = v_i(1 + p(\alpha - 1))$.

Hypothesis 1 : The average contribution in the disaggregated group is higher than the average contribution in the aggregated group.

Since the cost of the public good is fixed, dividing the larger group into two smaller groups will lead to a dramatic increase in the provision difficulty for each unit. In our experiment, the per-unit provision point is set to equal 30 percent of the total expected group values in the aggregated approach, and 60 percent of the total expected group values in the disaggregated approach. This design corresponds to a constant marginal cost of delivery, with the aggregated approach having a group size that is twice the size of the two groups in the disaggregated approach. The influence of the provision point has been investigated in the several experimental studies (Isaac et al., 1989; Suleiman and Rapoport, 1992; Li et al., 2012); results show that people contribute more to the threshold-level public good when the provision point is higher for a group with constant average value, even starting from the first period (Isaac et al., 1989). In our experiment, we hold the provision point per unit constant relative to the aggregate expected benefits to a single group in the disaggregated approach. In the aggregated approach, there are twice the aggregate expected benefits on each unit, because the separate groups are merged but the marginal cost of delivery remains constant while the aggregated, single group is now able to deliver both units. Note that there is also a group size difference between the two grouping approaches[5]. However, we believe the influence of group size will be trivial after we consider the influence of the provision point. Thus, we expected the average contribution in the disaggregated approach to be higher since it has a more stringent per-unit provision point relative to the value induced in the smaller groups. To demonstrate this, we use the baseline case as an example. From equation (6) and (8), when α equals 0, one's expected profits are

$$E^A(\pi_i|b_i) = (v_i - b_i)(1 - F^A(C - b_i)) \tag{9}$$

and

$$E^D(\pi_i|b_i) = (v_i(1-p) - b_i)(1 - F^D(C - b_i)) + v_i p; \tag{10}$$

in the aggregated and disaggregated approaches, respectively. An individual's subjective provision probability of her group providing one unit, conditional on her contributing b_i, is $1 - F^A(C - b_i)$ in the aggregated group, and $1 - F^D(C - b_i)$ in the disaggregated group. Assuming individuals maximize expected payoff, since the perceived provision probability decreases significantly in the disaggregated group approach, optimally, individuals will have to increase contributions to counter the influence of a perceived reduction in provision probability[6]. Note an individual would act as if she has a value of $v_i(1-p)$ in the disaggregated approach in the case where only the first unit, from either group, provides the benefit ($\alpha = 0$). The term $(1-p)$ captures the "free-riding" incentive due to the presence of another group. However, we expect this influence to be small compared to the influence of the reduced provision probability because in the disaggregated-group we conjecture that each individual sees her contribution as more critical to the provision of the first unit.

Hypothesis 2 : The difference in average contribution between the disaggregated group and the aggregated group is smaller when the marginal benefit of a second unit is higher (i.e., when α is high).

When the marginal benefit of a second unit is positive ($\alpha > 0$), individuals may benefit if a second unit is provided in the aggregated approach, and benefit from the provision by the other group in the disaggregated approach. The increase of marginal benefit level brings a mixed influence regarding the optimal choice of contribution in both grouping approaches. On one hand, when the marginal benefit increases, individuals have a higher value on the second unit and thus will increase contribution if everything else is unaffected. On the other hand, if individuals expect the total contribution of others also will increase as the second-unit marginal benefit level rises, they could lower their contribution to take advantage of the higher probability of successfully cheap riding on others. The overall influence on contribution of an increase on the marginal benefit level is unclear. Note that this brings a clear contrast compared to a private good situation where an increase in the marginal value will always lead to an increase in the equilibrium price when the supply is unchanged; in the public good, an increase in the marginal benefit level also brings in a larger "free-riding" possibility.

Nonetheless, there are still some notable differences regarding individuals' valuation on the second unit between these two grouping approaches. In the aggregated approach, individuals can influence the provision probability of the second unit; as the second-unit marginal benefit increases, the relative importance of the second unit increases, which will encourage people to raise contributions to support both units, though such an increase in contribution would lower the expected net utility of the first unit[7] . In the disaggregated approach, each individual receives an exogenous value (the second term in equation (8) which is the provision probability of the other group times individual i's value for one unit), the increase of second-unit marginal benefit (α) only changes the "value" ($\tilde{v}$) they have for the provision of their own unit. However, the increased provision probability will induce a free riding incentive in the disaggregated group; and such incentive is mitigated by the possibility to provide two units in the aggregated group. Therefore, we expect the aggregated group is more sensitive to the change of marginal benefit, as there is less to lose with a higher contribution if a second unit can be provided, and thus the difference between the disaggregated and aggregated group becomes smaller as the marginal benefit increases.

Hypothesis 3 : The PR increases average contribution compared to PPM; the PR has a larger influence in the aggregated group than in the disaggregated group.

According to the PR rule, the market maker redistributes all the excess contributions back to contributors, instead of keeping the excess contributions as under the PPM rule. We expect that the presence of a rebate will increase the average contributions, as anticipated by Marks and Croson (2001) and Spencer et al. (2009). We also expect the rebate has a larger influence in the aggregated grouping approach. Considering equation (6), under the PR rule, individual i will incorporate the possible amount she can get from the rebate once one (or two) units can be provided when making her contribution decision. The amount of rebate increases with one's contribution b_i, which reduces the potential loss when one is trying to provide two units but only one unit is provided as a result; thus, the rebate will encourage contributions and enhance the provision probability of the second unit. In the disaggregated group, however, a rebate likely will only influence the provision probability of one unit; the influence of rebate is limited largely due to the provision structure. In this regard, rebates offer greater assurance against waste of personal resources if total contributions exceed the cost for one unit, while the value of the second unit is still likely to encourage a single higher offer in the aggregated approach. Thus, we expect to see a larger influence of rebate when combined with a high second-unit marginal benefit level (higher α) in the aggregated approach, where, we hypothesize, a higher value on the marginal unit will attract higher contributions compared to the disaggregated approach.

Hypothesis 4 : The provision success is the same in the aggregated-group as in the disaggregated-group.

A more interesting question to the market maker is whether dividing the potential contributors into groups, that can each provide a separate unit of the public good, can increase the number of units provided. Our experiment presents the simplest version of this idea by dividing the contributors equally into two separate groups. In a multi-units environment, the market-maker may need to optimize the number of groups, or the size of the group in order to increase the provision probability. Average contribution per individual and the provision mechanism jointly determine the provision success. From the above discussion, we expect that the disaggregated approach may increase the average contribution, however the disaggregated approach would waste a portion of the contribution since the excess of contribution of one group cannot be used for the other group. The overall outcome regarding the provision success in largely unknown; thus, we propose the above null hypothesis regarding the group provision success. We expect to reject this null hypothesis because, by disaggregating the group, the provision point for the first unit becomes more difficult to achieve and one group might free or cheap ride on the other group; however, the provision probability for a second unit, under certain circumstances, might be larger since in the disaggregated group, the provision probability of each unit is almost equivalent while in the aggregated group, the provision probability for the second unit is much lower than the first unit.

4 Experimental design and procedure

We conducted eight experiment sessions in the Policy Simulation Lab, at the Department of Environmental and Resource Economics, University of Rhode Island (URI). Subjects were recruited primarily through an email list that consists of undergraduates from various academic majors who have indicated a willingness to participate in economic experiments. A small proportion of subjects were recruited directly from undergraduate classes at URI. We checked the participants' names and email addresses, before confirming their attendance, to ensure each subject participated only once in this sequence of experiments.

We conducted experiments through networked computer terminals[8]. Inter-participant communications during the experiment were prohibited and subjects could not observe each other's choices. Subjects were told that they had already earned a $5 show-up fee before we proceeded to the instructions. Experiment instructions were read aloud. Subjects were paid in cash after all treatments were finished. One experimental session usually lasted about one hour and twenty minutes with an average individual payoff around $35. We controlled the total number of subjects to between 10 and 14 for each session with variation arising from individuals who failed to arrive at the time of the session, despite careful confirmations and reminders.

Table 1 presents the experimental design and parameters. We implemented a within-subject design on the two grouping approaches and a between-subject design on the two rebate rules, each varied by a different marginal benefit level. The experiment included four PPM and four PR sessions. In each session, subjects were asked to make decisions in three treatments. Treatment 1 was a single-unit provision point public good experiment using PPM, while treatments 2 and 3 in each session involved one of the grouping approaches. In treatment 1, we separated all the subjects into two groups with each group able to provide one unit of the public good, and individuals could not benefit from the outcome of the other group. After each decision period, we randomly re-assigned each individual to a new group. Treatment 1 was intended as a test treatment that allowed subjects to become familiar with the experimental environment. There were 10 decision periods in treatment 1. The payoffs subjects collected in this treatment were counted toward their final payoffs. The data from treatment 1 was not used in our analysis.

Both treatment 2 and treatment 3 have four sub-treatments. Each sub-treatment consisted of ten decision periods with a different marginal benefit for the second unit (denoted as αV, as above). We chose four different levels of α: 0, 0.6, 1.0 and 1.2. Treatments 2 and 3 are set up for the two different grouping approaches: the disaggregated and the aggregated approach. For a session beginning with the aggregated approach, in treatment 2, all individuals were kept in a single group; each individual was asked to make a single offer for two units of the public good. In treatment 3, individuals were divided equally into two groups; we reshuffled the group composition after each decision period to prevent individuals from developing a strong group membership. We implemented a counterbalancing experiment design to mitigate order effects by including sessions wherein treatment 2 was implemented with the disaggregated approach (Table 1).

At the beginning of each decision period, individuals were told their induced values, which simulate the valuations for the public good. Induced values followed a uniform distribution on the interval [3.95,12.05) and are rounded to one decimal place. Subjects know the value distribution and their own induced values, but not the induced value of the others. The induced values were constant for ten decision periods, but changed at the beginning of a new treatment or a new sub-treatment. The unit cost, C, was public information. We set the provision cost for one unit equal to 30% of the expected induced value for an individual ($\boldsymbol{E}v_i$) times the number of all individuals in a session; the cost for two units was twice as much as for one unit. Therefore, when $\alpha \leq 0.3$, it was socially optimal to provide 1 unit; when $\alpha > 0.3$, it was socially optimal to provide 2 units in both grouping approaches. A total of 98 subjects participated in the experiment, producing 7840 individual level observations and 640 group level observations suitable for regression analyses. In this study we only use group level observations, mostly the last five periods experiment data for interpretation, in order to avoid adjustment and learning variations in early periods.

5 Experiment Results and Discussion

We provide a multivariate assessment on the influences of the experiment variables using a random effects model using group-level observations. The random effects model controls for the dependence of group outcomes within a session. The dependent variable is the average contribution (AC), which is the total contribution divided by the total number of individuals. We summarize the average individual contribution across different treatment variables in Table 2. The independent variables include the PR rebate (PR), which is a dummy variable and equals 1 if individuals can get a proportional rebate; the disaggregate approach (DisAgg) and the three marginal benefit levels ($\alpha_D = 0.6$; $\alpha_C = 1.0$; $\alpha_I = 1.2$), where the zero marginal benefit is the baseline:

$$\begin{aligned} AC_{ij} =& \beta_0 + \beta_1 PR + \beta_2 DisAgg + \sum_{k=D,C,I} \beta_{3k}\alpha_k + \beta_4 PR \times DisAgg + \sum_{k=D,C,I} \beta_{5k}\alpha_k \times DisAgg \\ &+ \sum_{k=D,C,I} \beta_{6k}\alpha_k \times PR \times DisAgg + \xi_i + \epsilon_{ij}. \end{aligned} \tag{11}$$

In the above model, ξ_i is the session-specific random effect and ϵ_{ij} is the usual error term for each group level outcome. We include several interactions terms in the above regression model (11): we expect the some of the interaction effect to be significant as outlined in Hypotheses 2 and 3. We run the regression model for observations in the first 5 periods and the last 5 periods separately. We mainly focus on the coefficient estimates from last 5 decision periods; nonetheless, the regression results from the first 5 periods can provide insights regarding the group dynamics and the influence of a particular treatment variable through learning. Table 3 shows the regression results. A log-likelihood ratio test between the random effects model and the linear regression result provides justification for the use of a random effects model (Model 1: χ^2=67.99, p<0.01; Model 2: χ^2=78.32, p<0.001).

5.1 Differences between Two Grouping Approaches

From the Table 3, we find that compared to the aggregated approach, the average contribution is significantly higher in the disaggregated approach (p<0.01); the effect is observed not only in the last five periods but also apparent in the first five periods, only to a lesser, but still significant, extent (p<0.01). Figures 2 and 3 show the predictions of the average contributions from the fitted model, combined with the PPM or the PR rule. The predicted contribution is computed at the average of the sessional effect. We conducted two statistical tests to detect possible differences between the aggregated and disaggregated approaches: other than the statistical test from regression result, we also apply the Wilcoxon rank-sum (or the Mann-Whitney) method as a complementary nonparametric test.

Overall, we find the Wilcoxon rank-sum test results match with the parametric test results well. We use the p value based on the random effects model for comparison.We find support for Hypothesis 1: in all cases, the average contribution is higher in the aggregated approach. Also, this difference is significant at all marginal benefit levels with PPM rule, and at the decreasing marginal benefit level with PR rule. This result suggests that subdividing the larger group into smaller groups can significantly increase contributions, especially when no rebate is available; also, our result is consistent with the findings on the influence of the provision point on individuals' contributions (Isaac et al., 1989; Suleiman and Rapoport, 1992). The subjective expected value model may well explain such changes by attributing the causes to the changed perceptions on the provision probability.

From Table 3, we find the interaction terms $DisAgg \times CMB$ and $DisAgg \times IMB$ are negative and significant, and the term $DisAgg \times DMB$ is positive but insignificant compared to the baseline marginal benefit level. These results suggest that a positive influence on contributions resulting from subdividing the group is, at least partially, offset by the increase of the marginal benefit level. We can also confirm this difference from Figure 2, as the contribution difference between these two grouping approaches seems to "shrink" as the marginal benefit level increases, though not in a monotonic manner; the difference appears to be the smallest under the constant marginal benefit level. Under the PR rule, we find that the difference between the two grouping approaches is not significant at the constant and increasing marginal benefit levels, though at the baseline and at a decreasing marginal benefit levels, the average contribution in the disaggregated approach is still higher. These results show some support for our Hypothesis 2, which implies that the difference in contributions between the aggregated and disaggregated approaches can be offset by, or less substantial under a higher, positive marginal benefit level; rebate of excess of contributions also makes such differences smaller (the interaction term $DisAgg \times PR$ is negative and significant in Table 3).

To summarize, we find that the disaggregated approach can encourage individuals' contributions substantially, which is consistent with effects of a higher the perceived provision difficulty in the disaggregated grouping approach. We also find negative interaction effects regarding the disaggregated approach with PR and a constant or an increasing marginal benefit level ($DisAgg \times PR$, $DisAgg \times CMB$ and $DisAgg \times IMB$). The broad implication is that the disaggregated approach increases contributions, but when marginal benefits are non-decreasing, the proportional rebate may provide a sufficient incentive so that the disaggregation of groups has little additional effect. Yet, typically one expects decreasing marginal benefits, and this situation still shows a large positive effect from disaggregating groups.

5.2 The Influence of the Rebate

We expect the rebate of excess contribution will generally encourage contributions compared to no rebate under otherwise identical situations. From Table 3, we see a positive and significant influence of rebate; the influence of rebate is similar in the regression results for the last 5 periods ($\beta_{PR} = 1.103, p < 0.01$) and first 5 periods ($\beta_{PR} = 1.178, p < 0.01$). Figures 4 and 5 show the predicted average contributions from the fitted model, arranged so that we can compare the difference between PPM and PR directly, either in the aggregated approach or the disaggregated approach. As before, predicted contributions are computed at the average of the sessional effect.

We use the p value based on the random effect model for comparison since the two test results are conformable. We find that in general, the PR rule raises contributions significantly above contributions under the PPM rule. The average contribution, calculated from the regression model, is higher under the PR treatment than the PPM treatment except in the disaggregated approach under the a baseline marginal benefit level; however that difference is not significant (p=0.664). Also, from Figures 4 and 5, we observe that the influence of rebate is larger in the aggregated approach, and the difference between PPM and PR grows as the marginal benefit level increases. This result confirms the importance of rebate when we using a decentralized approach to provide public goods, while also showing that the influence can also be moderated by other treatment variables such as grouping structure and marginal benefit, although we note that marginal benefit is innate to individuals' preferences for the public good.

Such observations are supported by the regression model. In Table 3, as we already discussed, the interaction term $DisAgg \times PR$ is negative and significant, which shows the reduced influence of rebate when combined with the disaggregated approach; also, the interaction term $PR \times IMB$ is positive and significant ($p < 0.01$), which indicates, in the aggregated approach, that PR has a higher influence when the marginal benefit is increasing. In contrast, the coefficient estimates for the interaction terms $PR \times DMB$ and $PR \times CMB$ are negative and positive, respectively, both of which are not significant. In the disaggregated approach, however, we find that the largest effect observed for the average contribution is between the baseline and the decreasing marginal benefit level from the regression model. In comparison, an increasing in the marginal benefit level, even under a rebate, is unlikely to lead individuals to make a substantially higher contribution. Thus, our results generally support Hypothesis 3. Another interesting observation is that we find, among the four marginal benefit levels, the predicted contribution is highest with the constant marginal benefit level, even higher than the contribution with the increasing marginal benefit level, regardless of the grouping approach or the rebate rule.

The most important insight might be that when the market-maker decides to rebate excess contributions, and when the second unit has a higher marginal value, the aggregated approach induces significantly more contribution compared to the baseline; when the second unit has a positive but relatively low marginal value, the disaggregated approach might be a better choice since individuals are more likely to be pivotal than if they were placed in a single, aggregated group. Of course, while we know that the disaggregated approach makes it harder to fund the public good, especially for the first unit, it is still obscure to us which approach is better in terms of provision success, as the disaggregated approach always raises more contribution per capital in our experiment. In the next section we will see whether the increased provision difficulty is dominated by (or dominates) the incentive to contribute more in the disaggregated grouping approach by comparing the provision frequencies.

5.3 Can the disaggregated-group potentially provide more of both units?

From the Figure 2 and Figure 3, we observe that the average contribution is always higher in the disaggregated-group. However, as we discussed, the disaggregated approach is less effective in public good provision when the excess contribution of one group cannot be used for the other group. Therefore, the overall provision success is uncertain. In Table 4 we provide the provision frequency statistics using the data from the last 5 periods. We find that under the decreasing marginal benefit level ($\alpha = 0.6$), the frequency of providing both units is slightly higher, but insignificantly so, in the disaggregated-group (odds ratio test: $p=0.279$); under the increasing marginal benefit level ($\alpha = 1.2$), the frequency of providing both units is equal for the two grouping approaches with no rebate, and the provision frequency of both units is much higher in the aggregated-group with rebate under all marginal benefit levels (odds ratio test: $p<0.001$).

The rebate of excess contribution reduces the provision failure (providing 0 units) to zero in the aggregated-group; however, in the disaggregated approach, provision failure is not significantly reduced with rebate. At the decreasing marginal benefit level ($\alpha = 0.6$), complete provision failure is even higher with the PR rule (probability of providing zero units, PPM : 20%, PR : 40%, odds ratio test: $p = 0.174$). These results imply the rebate can effectively mitigate the free or cheap riding within a group but may not sufficiently reduce the incentive to gain costless benefit from the provision of other groups. Therefore, when a rebate is not available, the disaggregated approach can be a potential improvement over the aggregated approach as it may increase the provision frequency of both units; from our experiment, the disaggregated approach even has a lower provision failure at the low marginal benefit level, though the difference is small. When a rebate is employed, especially in a population with a high marginal benefit level, the aggregated approach provides a better outcome.

Our results suggest that the disaggregated approach encourages higher contributions than the aggregated approach. We also find that the disaggregated approach outperforms the aggregated approach in certain circumstances in terms of provision success, particularly when individuals have a decreasing marginal benefit toward an incremental unit of public good. Note that of all cases in Table 4 (or all positive marginal benefit levels α), the social benefit of providing the second unit is always higher than the social cost since the unit cost is only 30% of social benefit.

For comparison, consider the provision frequencies that result from the first five periods, summarized in Table 5. Results generally conform to our observations for the last 5 periods, although the PR leads to a notable improvement in provision success over PPM in these early decisions.

In Table 6, we compare the provision frequencies in the aggregated approach with a counterfactual situation where we use the individual contribution in the disaggregated approach to calculate provision frequencies as if those contributions had been made in an aggregated group. First, we note that if contributions in an aggregated group could have been raised to those made by individuals in disaggregated groups, this would have been sufficient to eliminate provision failure, particularly under PPM (in the absence of a rebate). Second, we note that higher contributions from the disaggregated approach would have matched or raised the frequency of provision of both units, if obtained in the aggregated group, in nearly all cases (the exception being under PR with increasing marginal benefit, or $\alpha = 1.2$). In particular, with decreasing marginal benefits ($\alpha = 0.6$), the contributions obtained under PPM and, especially, PR would have enabled provision of both units nearly a third to a half of the time, rather than zero times, had these contributions occurred in the aggregated group. These results suggest the disaggregated group approach could be used, perhaps with a bit larger membership per group, to produce provision outcomes equivalent to those seen in the current-size aggregated group.

Our experiment used a population of N potential contributors in a single, aggregated group, as compared to the disaggregated group with $0.5N$ contributors. In the PR with increasing marginal benefit, if we increased the disaggregated groups to $0.5N + 0.5$, which is equivalent to adding one more person to the aggregated group, provision results would have nearly matched results in the aggregated group if average contribution remained unchanged from the disaggregated group (see last row in Table 6). Alternatively, we increase the size of the disaggregated group by 0.5 of an average contributor[9] and compare the result with the orignal outcome from the aggregated group (Table 4, hypothetical provision success in parentheses for the disaggregated-group). We find that by adding 0.5 contributor to each of the disaggregated group, the disaggregated approach would outperform the aggregated approach, with the one exception being under the PR with increasing marginal benefit. Theses results suggest there is a potential to mix the effects of group size with the stringency of provision for disaggregated groups relative to a given provision point (per unit); adjusting these factors could provide a more effective provision process for multiple units.

6 Conclusion

This research explores the public good provision game under a two-units environment using two grouping approaches, combined with two rebate rules. Our results suggest noticeable differences between the aggregated and disaggregated grouping approaches. In our experiment, though the unit cost is fixed for both grouping approaches, the aggregated approach actually has a lower *relative* provision point (for *one* unit), because the disaggregated approach relies on a smaller group to deliver a single unit. However, distinct from experiments that focus on the influences of different provision points, this study utilizes the influence of provision point to examine institutions that might balance the total revenue and the provision success.

Our experiment does not focus on incentive compatibility and thus individuals are unlikely to reveal full induced value (Day and Raghavan, 2007). Past experimental evidence also shows that even when the mechanism is incentive-compatible (such as the pivotal mechanism), individuals may not reveal their full value in public good provision experiments (Kawagoe and Mori, 2001). At the same time, a group or community-based approach has been developed to support multi-units of public good under a hierarchy structure. Our experiment compares two broad approaches and experimentally investigates which approach might be more desirable in a two-units environment. As the number of units grows, the market-maker has a larger flexibility both in designing the auction rule and in forming the group structure. Further theoretical and experimental studies in this area can be crucial to establish a functional, decentralized market to provide public goods.

Compared to traditional threshold provision games, this study opens the door to allowing the market-maker to have the ability to establish different grouping approaches. Thus, other than exploring different provision mechanisms, empirically, the market-maker may need to optimize the number of groups to increase the provision probability. Our study provides some insights on how such groups can be constructed. Furthermore, in actual applications, the market-maker might not only decide how many groups to define, but she might also alter the total population to which she markets; our unit cost was scaled relative to expected value of a fixed population in the experiment, but future research could explore the influence of group division when the total population is a variable allowing the market-maker to control the aggregated benefits of group or sub-group relative to the unit cost. These considerations may be necessary to facilitate support for providing multiple-units of a public good.

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Notes

[1] In addition to cultural services, the MEA's categories include provisioning services (such as seafood or wood); regulating services (such as flood or storm protection by wetlands); supporting services (ecosystem structure and

function necessary to provide final goods or services).

[2]Combinatorial auctions are auctions where bidders place offers on "packages" of items. Cramton, Shoham and Steinberg (2006) provide a comprehensive introduction to this emerging auction approach. This auction approach has been widely applied to areas such as allocating radio spectrum for mobile phones or assigning airport arrival and departure slots. Combinatorial auctions mainly address multiple items with complementarities, which is similar to the increasing marginal benefit case in our experiment: e.g., individuals have a higher value for two parcels than twice their value for a single ten-acre parcel.

[3]There is also a growing literature on the endogenous formation of groups before individuals choose to contribute to public good projects. We avoid this source of "self-selection" bias by assigning the group membership exogenously in the disaggregated approach. Results show that if groups are formed endogenously, people exhibit homophily: individuals with similar valuation are likely to join the same group (Baccara and Yariv, 2013). The influence of endogenous group formation is out of the scope for this research, but can be an interesting direction for future experimental investigation.

[4]Crawford, Costa-gomes and Iriberri (2013) conducted a comprehensive literature review on the non-equilibrium strategy modeling.

[5]Issac and Walker (1988) and Issac et al (1994) report experimental results on the influences of group size in a linear public good provision experiment. It is hard to make direct comparison with their results since we are using a different class of provision mechanism. In the threshold-level provision experiment, when the cost is fixed, different group sizes will naturally lead to different provision points when individual values are drawn from the same distribution. Of course, in the natural setting, the provision point is tied to the delivery cost of a real public good

[6]The difference in the perceived provision probabilities captures the arguments on the influence of provision point; in the disaggregated group, since the group size is reduced in half, the perceived provision probability is reduced, thus, $1 - F^A(C - b_i) > 1 - F^D(C - b_i)$. Take the first order derivative w.r.t b_i for equations (9) and (10), we can get $b_i^A = v_i + \frac{1-F^A(C-b_i^A)}{f^A(C-b_i^A)}$, and $b_i^D = v_i(1-p) + \frac{1-F^A(C-b_i^D)}{f^A(C-b_i^D)}$. To compare these two terms b_i^A and b_i^D, we need to make additional assumptions on the two probability distributions and p; however, we hypothesize that the difference in the perceived provision probability will override other influences and thus individuals will contribution more in the disaggregated approach.

[7] In the aggregated approach, when $\alpha = 0$, assume that individual i chooses b_i^* to maximize expected profit. Thus, we have $b_i^* \in arg\max{(v_i - \tilde{b_i})}(1 - F(C - b_i)$; we can also write equation (6) as: $E(\pi_i|b_i) = (v_i - b_i)(1 - F(C - b_i)) + \alpha v_i(1 - F(2C - b_i))$, compared to $\alpha = 0$, an increase in b_i^* reduces the value of the first term and increases the value of the second term.

[8]Experiments are designed based on the z-tree software package (Fischbacher, 2007).

[9]A bit less than a 10% increase in average size of the disaggregated groups.

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Table 1. Experimental Sequences and Parameters

Session	Rebate Rule	Experimental Sequence (Grouping Approach, Marginal Benefit Level Order)			N[a]	Value[b]	Unit Cost[c]
		Treatment 1	Treatment 2	Treatment 3			
PPM1	PPM	PPM (test)	Disaggregated-Group 1.0-1.2-0.6-0	Aggregated-Group 1.0-1.2-0.6-0	14	[4,12]	33.6
PPM2	PPM	PPM (test)	Aggregated-Group 0-0.6-1.2-1.0	Disaggregated-Group 0-0.6-1.2-1.0	14	[4,12]	33.6
PPM3	PPM	PPM (test)	Disaggregated-Group 1.0-0-1.2-0.6	Aggregated-Group 1.0-0-1.2-0.6	10	[4,12]	24
PPM4	PPM	PPM (test)	Aggregated-Group 0-1.2-0.6-1.0	Disaggregated-Group 0-1.2-0.6-1.0	12	[4,12]	28.8
PR1	PR	PPM (test)	Disaggregated-Group 1.0-1.2-0.6-0	Aggregated-Group 1.0-1.2-0.6-0	10	[4,12]	24
PR2	PR	PPM (test)	Aggregated-Group 0-0.6-1.2-1.0	Disaggregated-Group 0-0.6-1.2-1.0	10	[4,12]	24
PR3	PR	PPM (test)	Disaggregated-Group 1.0-0-1.2-0.6	Aggregated-Group 1.0-0-1.2-0.6	10	[4,12]	24
PR4	PR	PPM (test)	Aggregated-Group 0-1.2-0.6-1.0	Disaggregated-Group 0-1.2-0.6-1.0	14	[4,12]	33.6

[a] N is the number of individuals in each experimental session, representing a fixed population.

[b] Individuals were randomly assigned to induced value in the range of [3.95,12.05) and rounded to the nearest tenth.

[c] Unit cost was calculated as 30% of the sum of expected induced values of all individuals.

Table 2. Summary of the Average Individual Contribution

Grouping Approaches	Second-Unit Marginal Benefit Level (α)	Rebate Rules	Mean	Median	Std. Dev	Min	Max	No. of Observations
The Aggregated-Group	Baseline (0)	PPM	2.73	2.65	0.473	1.77	3.91	40
		PR	3.87	3.93	0.987	1.97	6.06	40
	Decreasing (0.6)	PPM	2.59	2.53	0.431	1.72	3.47	40
		PR	3.97	4.03	0.766	2.52	5.81	40
	Constant (1.0)	PPM	3.79	3.48	1.36	1.32	6.43	40
		PR	5.45	4.99	1.16	3.84	8.55	40
	Increasing (1.2)	PPM	3.28	3.19	0.895	1.80	5.95	40
		PR	5.02	5.17	0.629	3.89	6.05	40
The Disaggregated-Group	Baseline (0)	PPM	3.99	3.82	1.09	2.56	9.45	40
		PR	4.26	4.30	0.713	2.35	5.66	40
	Decreasing (0.6)	PPM	4.25	4.17	0.612	2.94	5.50	40
		PR	4.91	4.65	0.736	3.74	6.33	40
	Constant (1.0)	PPM	4.46	4.38	0.579	3.28	5.67	40
		PR	5.40	5.03	1.22	3.55	7.90	40
	Increasing (1.2)	PPM	4.32	4.24	0.611	3.28	5.77	40
		PR	4.99	4.53	1.12	3.81	7.45	40

Table 3. The Random Effects Model Regression Result

Dependent Variable: Average Individual Contribution	(1) Last 5 periods	(2) First 5 periods
PR	1.103***	1.178***
	(0.4006)	(0.4455)
DisAgg	1.715***	0.8431***
	(0.2295)	(0.2431)
DMB (alpha=0.6)	0.01366	-0.2968
	(0.2295)	(0.2431)
CMB (alpha=1.0)	1.084***	1.047***
	(0.2295)	(0.2431)
IMB (alpha=1.2)	0.3905*	0.7076***
	(0.2295)	(0.2431)
DisAgg×PR	-1.277***	-0.4785
	(0.3246)	(0.3438)
PR×DMB	-0.09742	0.5917*
	(0.3246)	(0.3438)
PR×CMB	0.4631	0.5589
	(0.3246)	(0.3438)
PR×IMB	0.8335***	0.3906
	(0.3246)	(0.3438)
DisAgg×DMB	0.1017	0.6784**
	(0.3246)	(0.3438)
DisAgg×CMB	-0.7688**	-0.4102
	(0.3246)	(0.3438)
DisAgg×IMB	-0.5394*	0.1039
	(0.3246)	(0.3438)
DisAgg×PR×DMB	0.8993*	-0.5723
	(0.4591)	(0.4862)
DisAgg×PR×CMB	0.4269	-0.1154
	(0.4591)	(0.4862)
DisAgg×PR×IMB	0.2686	-0.6948
	(0.4591)	(0.4862)
Constant	2.552***	2.904***
	(0.2833)	(0.3150)
Number of Observations:	320	320
Log restricted-likelihood:	-366.5	-384.3
LR test vs. linear regression:	p<0.0001	p<0.0001

Standard errors are in parentheses. Random effects model controls for variation across sessions. The dependent variable is the average individual contribution, which equals the sum of the contributions divided by the number of people. Asterisk(*) indicates significance at 10%; double asterisk(**) indicates significance at 5%; triple asterisk(***) indicates significance at 1%.

Table 4. Provision Frequencies in the Last 5 Periods [a]

Grouping Approaches	Second-Unit Marginal Benefit Level (α)	Rebate Rules	Frequency of Provision: 0 Units	1 Unit	2 Units
The Aggregated-Group	Decreasing (0.6)	PPM	30%	70%	0%
		PR	0%	100%	0%
	Constant (1.0)	PPM	20%	55%	25%
		PR	0%	30%	70%
	Increasing (1.2)	PPM	25%	70%	5%
		PR	0%	40%	60%
The Disaggregated-Group	Decreasing (0.6)	PPM	20% (5%)[c]	70% (60%)[c]	10% (35%)[c]
		PR	40% (0%)[c]	50% (45%)[c]	10% (55%)[c]
	Constant (1.0)	PPM	50% (0%)[c]	45% (45%)[c]	5% (55%)[c]
		PR	10% (0%)[c]	70% (35%)[c]	20% (65%)[c]
	Increasing (1.2)	PPM	45% (15%)[c]	50% (60%)[c]	5% (15%)[c]
		PR	30% (0%)[c]	55% (60%)[c]	15% (40%)[c]

[a]We do not include the baseline level 0 since it is not socially optimal to provide both units; the cost of providing the second unit outweighs the benefit. There are 20 group level observations in each row. We only use the experiment outcome in the last five periods of each treatment.
[b]Couterfactual result when 0.5 person (with average performance in that environment) is added to the each of the disaggregated group.

Table 5. Provision Frequencies in the First 5 Periods

Grouping Approaches	Second-Unit Marginal Benefit Level (α)	Rebate Rules	Frequency of Provision 0 Units	1 Unit	2 Units
The Aggregated-Group	Decreasing (0.6)	PPM	35%	65%	0%
		PR	0%	70%	30%
	Constant (1.0)	PPM	15%	55%	25%
		PR	0%	30%	70%
	Increasing (1.2)	PPM	25%	70%	5%
		PR	0%	25%	75%
The Disaggregated-Group	Decreasing (0.6)	PPM	65%	25%	10%
		PR	5%	85%	10%
	Constant (1.0)	PPM	50%	35%	15%
		PR	10%	65%	25%
	Increasing (1.2)	PPM	40%	55%	5%
		PR	20%	60%	20%

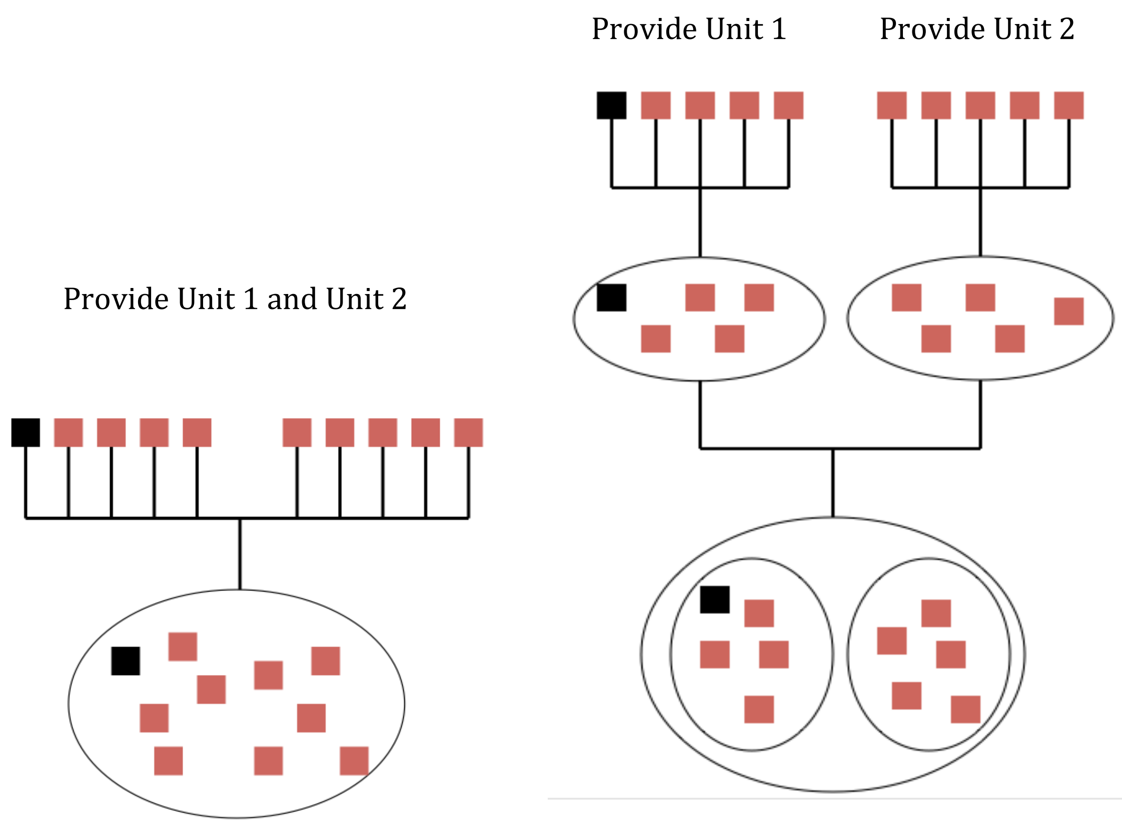
Table 6. Counterfactual Provision Frequencies if public good are provided by the aggregated-group approach, using the contribution outcomes from the disaggregated groups, in the Last 5 Periods[a]

Grouping Approaches	Second-Unit Marginal Benefit Level (α)	Rebate Rules	Frequency of Provision		
			0 Units	1 Unit	2 Units
The Aggregated-Group (Using Contributions From the Disaggregated-Groups)	Decreasing (0.6)	PPM	0% (30%)	70% (70%)	30% (0%)
		PR	0% (0%)	55% (100%)	45% (0%)
	Constant (1.0)	PPM	0% (20%)	75% (55%)	25% (25%)
		PR	0% (0%)	30% (30%)	70% (70%)
	Increasing (1.2)	PPM	0% (25%)	85% (70%)	15% (5%)
		PR	*0% (0%)*	*70% (40%)*	*30% (60%)*
		PR[b]	0% (0%)	42.5% (40%)	57.5% (60%)

[a]The actual provision frequencies from the aggregated-group approach are in parentheses. These numbers are the same as the provision frequencies in Table 4 for the aggregated group.

[b]Couterfactual result when one more people (with average performance in that environment) is added to the hypothetical aggregated group, which is equivalent to adding 0.5 people with average performance to each of the two disaggregated group. Results show that the provision successes are almost equivalent between these two grouping approaches.

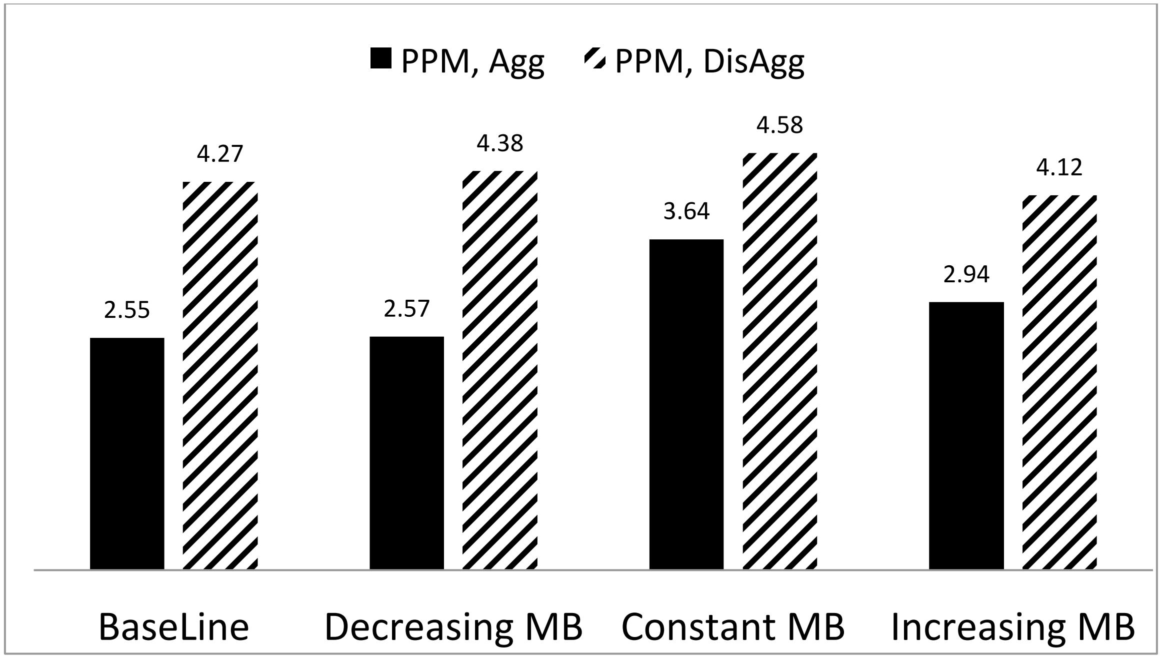
Figure 1. Aggregated grouping approach (left); Disaggregated grouping approach (right).



Left **Right**

The small squares represent individuals and the circles represent the way individuals are formed into different group structures. In the aggregated grouping approach (left), all the individuals form a large group, which can provide up to two units of a public good. In the disaggregated grouping approach (right), individuals are equally divided into two smaller groups, where each group can provide one unit of a public good (level 1); the outcome of the two smaller groups will jointly determine the number of units that can be provided by these individuals (level 2).

Figure 2. Differences between two grouping approaches under PPM, depending on last 5 periods.

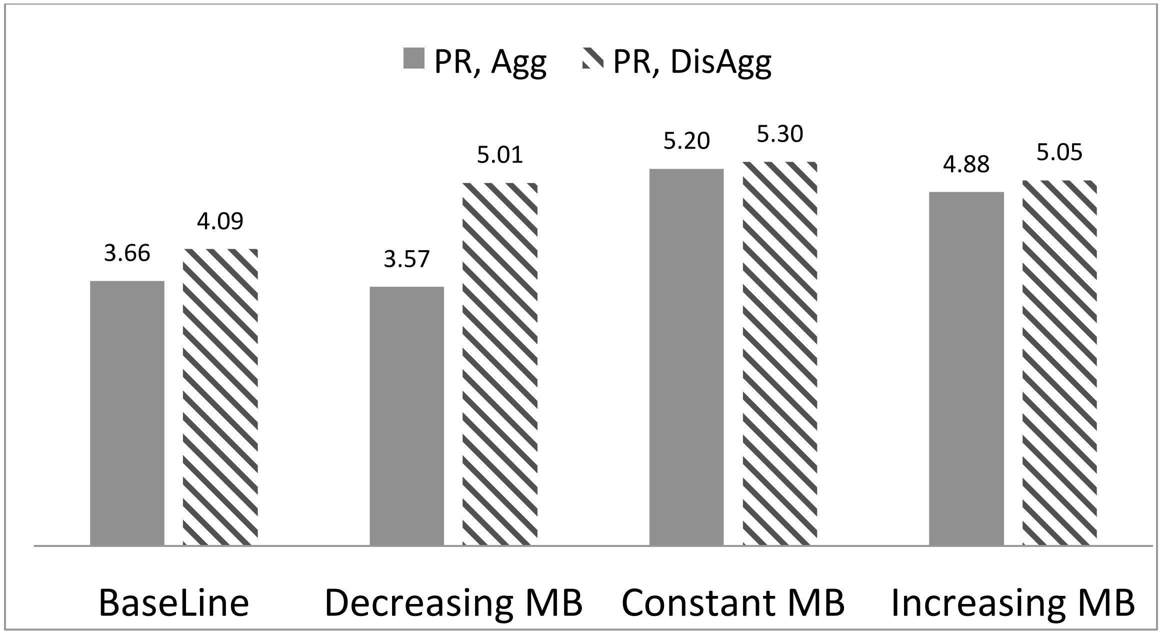


The predicted average contribution is based on the regression model of the last 5 period contributions, and calculated at the mean of the sessional effect.

BaseLine: the marginal benefit level equals 0; Decreasing MB: the marginal benefit level equals 0.6; Constant MB: the marginal benefit level equals to 1.0; Increasing MB: the marginal benefit level equals to 1.2.

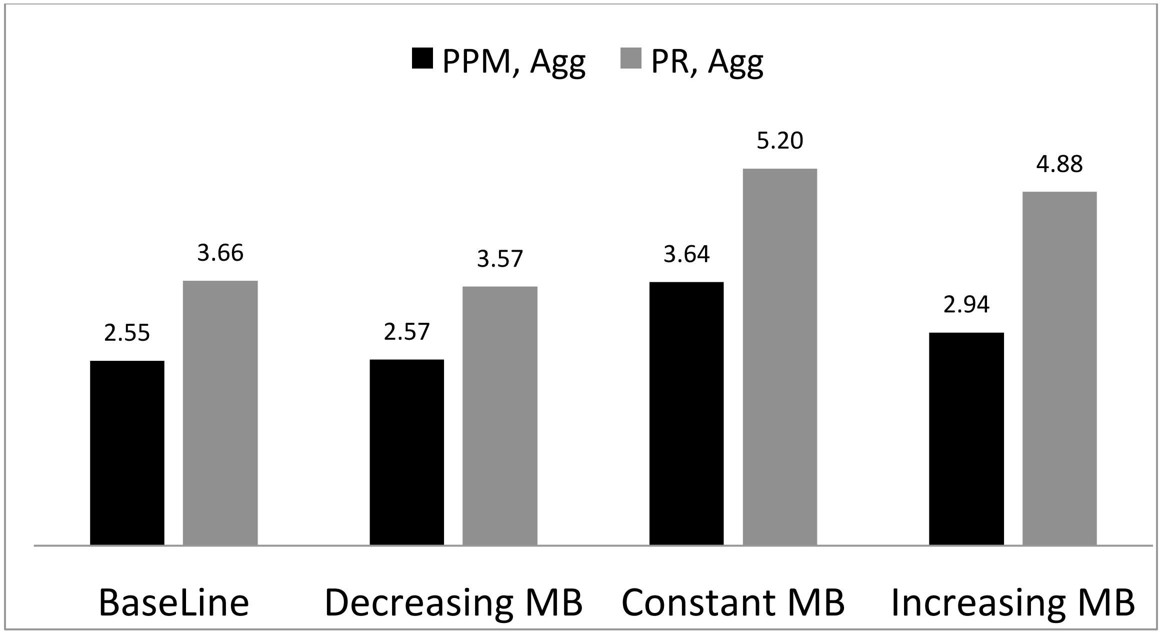
We use both the regression results and the nonparametric two-sample Wilcoxon rank-sum (or the Mann-Whitney), using the original experimental data, to test whether the difference in the contribution is significant at the same marginal benefit level. The first significant value, p_1, is based on the results from the regression model; the second significant value, p_2, is based on the result from the rank-sum test. Baseline: $p_1<0.001(z=7.47)$, $p_2<0.001(z=5.38)$; Decreasing MB: $p_1<0.001(z=7.91)$, $p_2<0.001(z=5.41)$; Constant MB: $p_1<0.001(z=4.12)$, $p_2=0.028(z=2.19)$; Increasing MB: $p_1<0.001(z=5.12)$, $p_2<0.001(z=4.72)$.

Figure 3. Differences between two grouping approaches under PR, depending on last 5 periods.



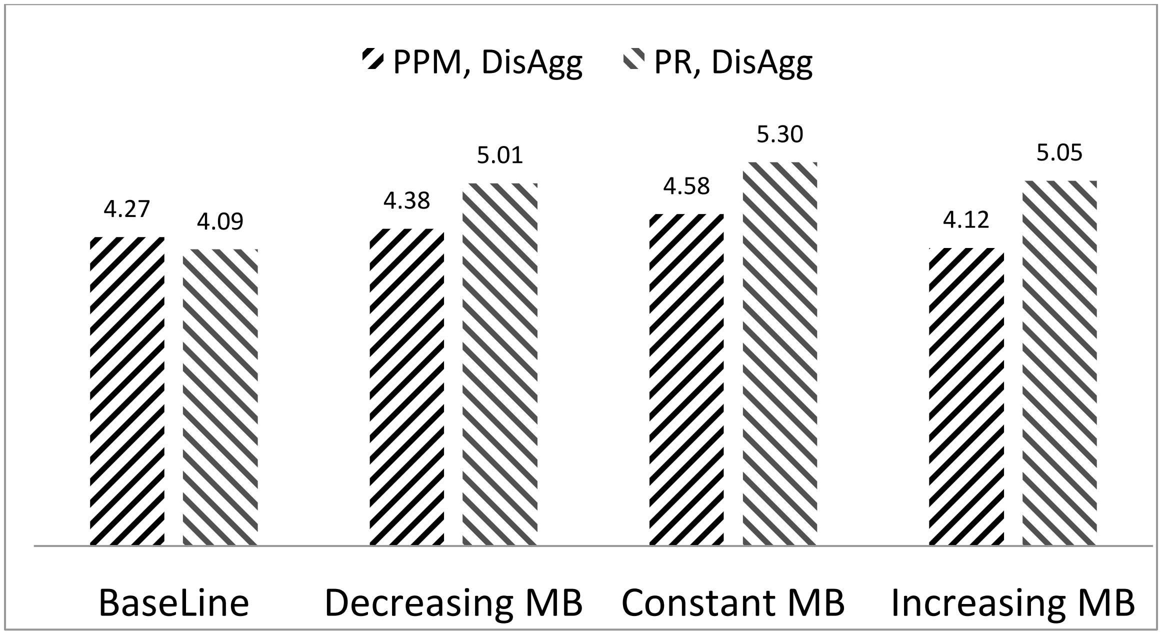
We use both the regression results and the nonparametric two-sample Wilcoxon rank-sum (or the Mann-Whitney) to test whether the difference in the contribution is significant at the same marginal benefit level. The first significant value, p_1, is based on the results from the regression model; the second significant value, p_2, is based on the result from the rank-sum test. *Baseline*: $p_1 = 0.057 (z=1.91)$, $p_2 = 0.047 (z=1.99)$; *Decreasing MB*: $p_1 < 0.001 (z=6.27)$, $p_2 < 0.001 (z=4.463)$; *Constant MB*: $p_1 = 0.677 (z=0.42)$, $p_2 = 0.935 (z=0.081)$; *Increasing MB*: $p_1 = 0.468 (z=0.73)$, $p_2 = 0.622 (z=0.5338)$.

Figure 4. Differences between rebate rules in the aggregated grouping approach, depending on last 5 periods.



We use both the regression results and the nonparametric two-sample Wilcoxon rank-sum (or the Mann-Whitney) to test whether the difference in the contribution is significant at the same marginal benefit level. The first significant value, p_1, is based on the results from the regression model; the second significant value, p_2, is based on the result from the rank-sum test. *Baseline*: $p_1<0.001(z=2.75)$, $p_2<0.001(z=4.27)$; *Decreasing MB*: $p_1=0.012(z=2.51)$, $p_2<0.001(z=4.87)$; *Constant MB*: $p_1<0.001(z=3.91)$, $p_2<0.001(z=3.79)$; *Increasing MB*: $p_1<0.001(z=4.83)$, $p_2<0.001(z=4.90)$.

Figure 5. Differences between rebate rules in the disaggregated grouping approach, depending on last 5 periods.



We use both the regression results and the nonparametric two-sample Wilcoxon rank-sum (or the Mann-Whitney) to test whether the difference in the contribution is significant at the same marginal benefit level. The first significant value, p_1, is based on the results from the regression model; the second significant value, p_2, is based on the result from the rank-sum test. *Baseline*: p_1=0.664(z=-0.43), p_2=0.7952(z=-0.25); *Decreasing MB*: p_1=0.117(z=1.57), p_2=0.010(z=2.57); *Constant MB*: p_1=0.074(z=1.79), p_2=0.111(z=1.60); *Increasing MB*: p_1=0.020(z=2.32), p_2=0.005(z=2.84).