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 an experiment where either all* N *individuals form one group to provide two units (aggregated approach), or divide the* N *participants into two groups, and each group provides one unit separately, with all individuals benefiting from any unit(s) provided (disaggregated approach). Our results show that the disaggregated approach produces higher contributions on average. We also find that the rebate of excess contributions has a larger influence in increasing contribution under the aggregated approach.* (JEL D71, H41)

I. INTRODUCTION

Incentives and institutional structure are known to affect the divergence between individual and collective outcomes for public good provision (Andreoni 1988; Issac, Walker, and Thomas 1984; Samuelson 1954), and knowledge of how individuals respond empirically continues to limit the outcomes supported by mechanisms proposed to generate revenues in support of public goods. The divergence between individually and socially optimal outcomes encourages us to develop 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 multiple-units public good context. Our proximate motivation concerns private provision of public goods provided by ecosystems, but our contribution concerns public goods more generally. Our intention is to expand the understanding of factors affecting voluntary contribution and revenue generation in a public good context, and to contribute to the development of market-based approaches to provide public goods through voluntary actions by entrepreneurs or managers.

This research adds to the public goods literature by 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. These factors have been overlooked in the literature on public good provisions, including the literature on charitable giving. There are examples where nonprofit organizations may use a disaggregated approach, such as in fund-raising by Boy or Girl Scout organizations that focus effort on a "unit" in support of a single troop serving children in a large neighborhood, with separate fund-raising efforts focused on the broader scout council scale to support administering programs across troops. In land conservation, localized land trusts typically work independently to fund projects but sometimes work collaboratively on projects of mutual interest when serving complementary missions (preserving open space aesthetics and biodiversity) or when key land parcels transcend jurisdictions (Albers and Ando 2003; Bergmann and Bliss 2004). However, these examples tend to fol-

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low from coincidence of administrative structure or unique opportunity. While our study may identify underappreciated implications of these modes of operation, we approach the context more generally, exploring whether it may sometimes serve fund raisers' objectives to intentionally divide a population of potential donors for the strategic advantage of stimulating higher contributions and delivering more units of public good. Landry et al. (2006) suggest that consideration of attributes of a fund-raising mechanism along with nonmechanism factors has been rare in experiments. We use group configuration as a control that fund-raising could deploy to help focus the advantages of mechanism elements for more effective or beneficial outcomes.

We work within the class of mechanisms designed for goods requiring a threshold level of funding known as the provision point. If we fail to reach the funding threshold, a unit cannot be and is not provided, and contributions are returned to donors. 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 making each responsible for providing one unit, while all participants can benefit from the public good regardless of which group provided it. We also test the influence of rebates in the two grouping structures. Rebates return contributions collected over the mandatory provision point and add a mechanism element to reduce a donor's penalty for overcontributions (Marks and Croson 1998; Spencer et al. 2009). Such knowledge is necessary if we are to apply rebates to a wider range of fund-raising applications and discriminate the effects of rebates as part of a provision point mechanism from the nonmechanism factor of group configuration.

Our specific investigation is motivated by the difficulty encountered in developing environmental markets (Jack, Kousky, and Katharine Sims 2008; Kinzig et al. 2011), such as in an effort initiated under U.S. Department of Agriculture funding 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 2003), many of which carry public good properties. For example, cultural ecosystem services may include aesthetic goods such as 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 nonfarm 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 community benefit from all fields provided. 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 (2013) has conceptually 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 an issue regarding the design of institutions for provision of public goods in a second-best world to know which grouping approach performs better in a multiple units' environment, which is the natural environment (natural setting) where we wish to bring the insights of experimental economic tests of mechanisms to fund public goods.

A primary question is which of the two grouping approaches can increase the number of units provided. On the one hand, this disaggregated approach could be wasteful, as excess contributions in one group cannot be used to complement contributions in another group (allowing cross-group subsidies would

[1] In addition to cultural services, the Millennium Ecosystem Assessment's categories include provisioning services (such as seafood or wood); regulating services (such as flood or storm protection by wetlands); and supporting services (ecosystem structure and function necessary to provide final goods or services).

effectively reunify the groups as one). 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 recognize that they are more likely to be pivotal, thus the disaggregated approach may lead to more contributions and achieve the per-unit provision point more frequently. In the example, a single larger group with increased opportunity to free ride might fall short of $2,000 and thereby also fail to provide two units. The paper provides a starting point where we apply both grouping approaches to a two-unit environment. Readers unfamiliar with experimental economics will note that our public good is generic. Experiments use financial payoffs to mimic the way in which a public good delivers benefits (Smith 1976). Thus, participants in a provision game all are asked to contribute to a group fund that will pay each individual a private value (i.e., an induced value v_i below), under specific conditions, whether or not every individual actually made a contribution to the fund. This establishes the nonexclusion property of a public good that is delivered. Such experiments remove potential confounding factors that may be present in the natural environment, allowing researchers to isolate the effects of factors explored.

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 number of tokens between a private fund that benefits only the individual investor and a group fund that generates profits for everyone. The other line of literature uses the provision point mechanism to provide the public good in a discrete unit (e.g., Alboth, Lerner, and Shalev 2001; Laussel and Palfrey 2003; Schram, Offerman, and Sonnemans 2008). The provision point mechanism evolves from the binary public good game that asks individuals to make decisions on whether to contribute toward a public good. The provision point mechanism can also relax the dichotomous choice constraint so that each subject can make a continuous offer (Cadsby and Maynes 1999). The public good is funded if the aggregated offers reach or surpass the predetermined cost. 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. Bagnoli and McKee (1991) find that a provision point mechanism together with money back guarantee can potentially induce Pareto efficient outcomes in a single-unit provision environment.

Our research also relates to recent public goods literature that focuses on individual behavior and group membership (Charness, Rigotti, and Rustichini 2007; Rapport and Bornstein 1987; Sutter 2009). However, we mitigate the membership effect by reshuffling the group membership for each experimental period so that the individual will not be attached to a particular group. The reshuffling is analogous to the existence of a single community of potential donors who do not know each other's donation behavior well, or who are divided periodically into two groups by random assignment. Also, our research provides some experimental evidence on individual behaviors in the multilevel public good games with community structures (Blackwell and McKee 2003; Wang et al. 2011; Perc et al. 2013). The public good games with community structures usually 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, and have no control over, the provision outcomes of the other group, the between-group interactions affect only the benefit side, while the within-group interactions enter both individuals' benefit and cost considerations. Our results show that, at least in our experimental setting, dividing a population into smaller groups brings the advantage of increased contributions along with a disadvantage of weakly decreased frequency of provision, due to the nature of the provision mechanism. We discuss this trade-off and explore the severity of the disadvantage in a counterfactual numerical exercise.

II. PROVISION MECHANISMS

In this section, we first illustrate the grouping mechanism by using a habitat preservation example. Then we formally introduce the rebate rules and two grouping approaches.

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, for example, preserving 20 acres of esthetic habitat that lies on the boundary of two communities. These communities could be two towns sharing a boundary and operating through a regional land trust, or they could be two neighborhoods in a single town. We envision a case when meaningful increments of habitat require a minimum field-size. 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 10 acre parcel is constant, at half of the total cost. The market-maker, who can either be a private entrepreneur or a social planner who tries to protect habitat through voluntary actions, solicits contributions from each individual in the two communities and collects money to provide as many parcels as possible. We assume that residents of either community are indifferent regarding which parcel is selected if only one is funded. Consistent with what we call the aggregated approach, the market-maker could simply place contributions from any individual in a single fund. In the aggregated approach, if the total contributions cannot cover the cost of 10 acres, zero acres are preserved; if the total contributions can cover the cost of 10 acres while falling short of 20 acres, only 10 acres are preserved; otherwise, the aggregated fund is sufficient to acquire both parcels. Alternatively, the market-maker may take the disaggregated approach and require that each community contribute to its own fund, dedicated to preserve only the 10 acres on its side of the boundary. Each community then funds its parcel or nothing. Due to the nonexclusive property of the public good, individuals from both communities can benefit from the habitat preservation regardless of which community provides it. In other words, the communities may free ride on one another.

In addition to determining the way to establish groups of potential contributors, realistically, the market-maker, by either approach, has to decide how to address any excess contributions in the event that more money is raised than the provision cost requires. We use two common rebate rules. The first is no rebate, whereby the market-maker simply keeps all the excess contributions if the public good is provided. The second rule is the proportional rebate (PR). Under PR, the excess contributions are rebated to the contributors in proportion to their own contribution, and the market-maker retains only the money needed to cover the provision cost whenever applicable. For a single unit with a provision point and assumptions of complete information, the "core" equilibrium produces total contributions just equal to the provision cost; the proportional rebate will not alter the equilibrium core (Bagnoli and Lipman 1989). Past results reveal that the PR rebate rule reduces the contributor's penalty for overcontribution and can have a significant positive influence on individual contributions (Marks and Croson 1998; Gailmard and Palfrey 2005; Spencer et al. 2009). However, the influence of a rebate in different group structures is unknown and remains an open question.

Furthermore, depending on the type of public good, individuals may not have a decreasing marginal benefit curve. For example, 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 for the scenic views or for environmental quality enhancement (Parkhurst et al. 2002; Parkhurst and

Shogren 2007).[2] The above simplifications can be representative for some actual fund-raising activities, and our experiments can shed light on how to better design a decentralized mechanism to supply various kinds of public good.

Rebate Rules

Next we formally present the rebate rules and grouping approaches when a certain number of individuals are asked to provide up to 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. That is, v_i is the individual's private value for the public good; in the parlance of experimental economics, v_i is the induced value for the generic public good. The amount individual i decides to contribute is denoted as b_i. The cost of providing each unit of the public good is defined as the provision cost (C), a constant. Note that C is exogenous to the actual fund-raising process and represents the supplier's opportunity cost of providing the good.

Under the provision point mechanism with money back guarantee (PPM), individuals get no refund if more money is collected than needed to pay the provision cost. Below in equation [1], π_i is individual i's profit or net benefit, and $\sum b_j$ is the aggregated contribution of the group.

$$\pi_i = \begin{cases} 0, \text{ if } \sum b_j < C \\ v_i - b_i, \text{ if } \sum b_j \geq C. \end{cases} \quad [1]$$

[2] Other than the habitat preservation example, the difference in grouping mechanisms is similar to the question of whether it is better for a large charity or several smaller charities with the same or close objectives to provide a discrete public good. The provision cost is similar to the minimum threshold in order for a charity to be effective. Corazzini, Cotton, and Valbonesi (2013) report experiment results on provision of multiple-threshold public goods in relation to the charity donation. Our experiment is different from theirs in several important ways; but our results may reflect some intuition regarding individual's donation behaviors, especially the differences between the donation to a large charity and the donation to several small charities with similar goals.

If the group fails to provide the public good, individual i gets her money back (b_i) and receives zero benefit, but if the group rovides the public good, individual i gets a benefit equal to value v_i minus her contribution b_i. From the perspective of all contributors, contributing more than the provision point is not optimal since excess funds will be wasted. We recognize that donors to real charities could normally assume excess contributions would be put to other good uses. However, this possibility raises questions concerning what the form of such extended benefits (Marks and Croson 1998) might be, which is not readily consistent with our focus on threshold-level public goods provided in discrete units for meaningful benefit. This possibility of such extended benefits remains outside the scope of this paper, as extended benefits would differ in character from the type of good being provided by the main contributions. The issue raises quite a variety of potential forms of benefit that would distract from our focus.

The PR mechanism 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

$$\pi_i = \begin{cases} 0, \text{ if } \sum b_j < C \\ v_i - b_i + b_i R, \text{ if } \sum b_j \geq C, \end{cases} \quad [2]$$

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

Two Grouping Approaches

In the disaggregated approach, two groups are created by the market-maker. Each group is responsible for providing one unit of the public good, and 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; the alternative would be tantamount to reunifying multiple groups as an aggregated entity. If both units are provided, individuals receive their value for two units. Here we present individual payoff functions for the PPM as an example. Assume individual i is assigned to group 1, $\sum b_j^1$ is the sum of contributions by individual i's group (group 1), while k is the 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 this rate is a property of the good that is the same for all individuals. Then the individual's net benefit is as follows:

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

where 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. These payoffs are modified under the proportional rebate rule by setting the rebate rate R equal to $(\sum b_j^1 - C)/\sum b_j^1$ and adding $b_i R$ to the payoffs in [3b] and [3d], analogous to equation [2].

In the aggregated approach, the number of participants represents the combined total from the disaggregated groups. 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 cost for one unit. Participants make only a single contribution, which the market-maker uses to provide as many units as possible. In the aggregated approach with no rebate, i's benefit is as follows:

$$\pi_i = \begin{cases} 0, \text{ if } (\sum b_j^1 + \sum b_k^2) < C, & [4a] \\ v_i - b_i, \text{ if } C \leq (\sum b_j^1 + \sum b_k^2) < 2C, & [4b] \\ (1+\alpha)v_i - b_i, \text{ if } (\sum b_j^1 + \sum b_k^2) \geq 2C. & [4c] \end{cases} \quad [4]$$

These payoffs are modified under the proportional rebate rule by setting the rebate rate R equal to $(\sum b_j^1 + \sum b_k^2 - C)/(\sum b_j^1 + \sum b_k^2)$ and $(\sum b_j^1 + \sum b_k^2 - 2C)/(\sum b_j^1 + \sum b_k^2)$ for the one-unit and two-units provision outcomes in [4b] and [4c], respectively, and adding $b_i R$ to the payoffs in [4b] and [4c], analogous to equation [2].

III. HYPOTHESES

This experiment focuses on three treatment variables: the grouping approach (aggregated versus disaggregated), the rebate rule (no rebate 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). In a real market, the marginal benefit level is 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 develop the following hypotheses mainly based on the results from the experimental literature.

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

Since the cost for each unit of public good is fixed, dividing the larger group into two smaller groups will lead to a dramatic increase in the provision difficulty, at least for the first unit. In our experiment, the per unit cost is constant. In practice, of course, the cost C is exogenous to the fund raiser, and our experiment design is consistent with that stylized fact. We parameterize the experiments so that C equals 30% of the total expected value of the larger group (N individuals) in the aggregated approach. Since the disaggregated approach divides N in half, this implies that C is 60% of the total expected value of participants in one group in the smaller group setting, but C is still the same dollar-value opportunity cost for a single unit. In the aggregated approach, if everyone contributes 30% of the induced value, one unit of public good will be provided. In the disaggregated approach, however, if everyone contributes 30% of the induced value, zero units of public good will be provided. It is in this sense that the constant provision point C makes the provision difficulty more stringent in the disaggregated approach. It is the insight initiated by Bagnoli and Lipman (1989) that we attempt to leverage in the disaggregated approach, as the provision point creates a threshold that a group must cross to add a unit of public good.

The influence of the provision point has been investigated in several experimental studies (Isaac, Schmidtz, and Walker 1989; Suleiman and Rapoport 1992; Li, Anderson, and Swallow 2012). Results show that people contribute more to the threshold-level public good when the provision point is higher for a group with the same average values, thus it is essential that our experiment maintain the ratio of expected benefit to cost as we do by the parameterization of *C*. Specifically, Li, Anderson, and Swallow (2012) find that when the ratio of provision point to expected total benefit increases from 0.3 to 0.6, average individual contribution increases approximately 40% in PPM and 60% in PR. In our experiment, we hold the cost per unit constant. In the aggregated approach, because the separate groups are merged, the aggregated group has double the expected value of a group half its size, so the aggregated group has a less challenging provision difficulty compared to the disaggregated groups. Thus, we expect the average contribution in the disaggregated approach to be higher since it has a higher, more stringent provision point relative to the available donor base.

Note that there is also a group size difference between the two grouping approaches. Issac and Walker (1988) and Issac, Walker, and Williams (1994) report experimental results on the influences of group size in linear public good provision experiments. Particularly, Issac and Walker (1988) find that the an increase in group size (from 4 to 10) has a weak and ambiguous effect and does not necessarily lead to less efficient provision of the public good. Similar results are replicated by Issac, Walker, and Williams (1994). It is hard to make a direct comparison with their results since we are using a different class of provision mechanism. In the threshold provision experiment, when the cost is fixed, different group sizes will naturally lead to different stringency of provision when individual values are drawn from the same distribution but group size creates a scale effect (that our design eliminates) by having a larger number of potential donors holding similar values.

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 (α), individuals may benefit if a second unit is provided in the aggregated approach, and they benefit from the provision by the other group in the disaggregated approach. The increase of marginal benefit level brings a mixed influence regarding the 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 lead to an increase in the equilibrium price when the supply is unchanged.

Nonetheless, there are still notable differences regarding individuals' valuation on the second unit between these two grouping approaches. In the aggregated approach, individuals can directly 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. In the disaggregated approach, each individual may receive an additional benefit (equations [3c] and [3d]) when the other group provides one unit. The potential to receive the additional benefit will induce a free-riding incentive in the disaggregated group, while such incentive is mitigated by the possibility that the individuals' contributions help 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 more to gain 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. Also, in the disaggregated groups, contributors weigh the probability that their group is providing the second unit (the marginal unit). If the benefit of the second unit is low ($\alpha = 0.6$), they may decrease their contribution relative to the case with no benefit from the other group's provision of a unit ($\alpha = 0$). In contrast, if the marginal unit benefit is constant they may contribute the same as when $\alpha = 0$. But if the marginal benefit is increasing ($\alpha = 1.2$), they have an incentive to contribute at least as much as in the baseline case ($\alpha = 0$) or more, because the gain from the second unit is higher.

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 in both aggregated and disaggregated approaches, as anticipated by Marks and Croson (1988) and Spencer et al. (2009). In the aggregated approach, the 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. In this regard, rebates may offer greater assurance against waste of personal resources if total contributions exceed the cost for one unit in the aggregated approach. Thus, we expect to see a larger positive influence of rebate in the aggregated approach. Moreover, if the disaggregation already yields an increase in contributions, the PR would be driving contributions from an already enhanced level, so the positive effect of PR may be less in the disaggregated environment.

In addition to the above hypotheses, the main question for the market-maker is whether dividing the potential contributors into groups, which can each provide a separate unit of the public good, can increase the provision success. Our experiment presents the simplest version of this idea by dividing the contributors equally into two symmetric groups. Average contribution per capita and the provision mechanism jointly determine the provision success. From the above discussion, we expect that the disaggregated approach increases 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 is ambiguous.

IV. 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 had 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. A total of 98 subjects participated in the experiment, producing 7,840 individual-level observations and 640 group-level observations suitable for regression analyses.

We conducted experiments through networked computer terminals.[3] Interparticipant 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 distributed to partici-

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

pants and were read aloud. Subjects were paid in cash after all treatments were finished. One experimental session usually lasted about one hour and 20 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 (α). The experiment included four PPM and four PR sessions. In each session, subjects were asked to make decisions in three treatments. The first treatment was a single-unit provision point public good experiment using PPM, while the second and the third treatments in each session involved one of the grouping approaches. In the first treatment of a session (always a PPM), we separated all the subjects into two groups, with each group able to provide one unit, and individuals could not benefit from the outcome of the other group. This treatment allowed subjects to become familiar with the rules and the experimental setting. There were 10 decision periods in the first treatment. The payoffs subjects collected in this treatment were counted toward their final payoffs. The data from the first treatments were not used in our analysis.

Both the second and the third treatments had four subtreatments. Each subtreatment consisted of 10 decision periods with a different marginal benefit for the second unit (denoted αv_i, as above). We chose four different levels of α: $\alpha = 0$, 0.6, 1.0, and 1.2. The second and the third treatments were set up for the two different grouping approaches: the disaggregated and the aggregated approach. For a session using the aggregated approach in the second treatment, all individuals were kept in a single group and each individual was asked to make a single offer for two units of the public good. This same session then moved to the third treatment, in which individuals were divided equally into two groups. In the third treatment, we reshuffled the group

TABLE 1

Experimental Sequences and Parameters

Session	Rebate Rule	Experimental Sequence (Grouping Approach, Marginal Benefit Level[a] Order)			N^b	Value[c]	Unit Cost[d]
		First Treatment	Second Treatment	Third Treatment			
PPM1	PPM	PPM (test)	Disaggregated-Group 1.0-1.2-0.6-0	Aggregated-Group 1.0-1.2-0.6-0	14	[4.0,12.0]	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	[4.0,12.0]	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	[4.0,12.0]	24
PPM4	PPM	PPM (test)	Aggregated-Group 0-1.2-0.6-1.0	Disaggregated-Group 0-1.2-0.6-1.0	12	[4.0,12.0]	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	[4.0,12.0]	24
PR2	PR	PPM (test)	Aggregated-Group 0-0.6-1.2-1.0	Disaggregated-Group 0-0.6-1.2-1.0	10	[4.0,12.0]	24
PR3	PR	PPM (test)	Disaggregated-Group 1.0-0-1.2-0.6	Aggregated-Group 1.0-0-1.2-0.6	10	[4.0,12.0]	24
PR4	PR	PPM (test)	Aggregated-Group 0-1.2-0.6-1.0	Disaggregated-Group 0-1.2-0.6-1.0	14	[4.0,12.0]	33.6

Note: PPM, provision point mechanism without rebate; PR, provision point mechanism with proportional rebate rule.
[a] The marginal benefit (MB) level is represented by parameter α, representing the proportion of first-unit value that the participant receives from the second unit, and took values 0, 0.6, 1.0, and 1.2 representing, respectively, no second-unit benefit, diminishing MB, constant MB, and increasing MB.
[b] N is the number of individuals in each experimental session, representing a fixed population.
[c] Individuals were randomly assigned to induced value in the range of [3.95,12.05) and rounded to the nearest tenth.
[d] Unit cost was parameterized as 30% of the sum of expected induced values of all individuals.

composition after each decision period to prevent individuals from developing a strong group membership attachment in these smaller groups. Nonetheless, individuals in the small groups had no way of knowing which half of the individuals in the room were in their groups for any decision period. We implemented a counterbalancing experimental design to control order effects by including sessions wherein the second treatment 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 were rounded to one decimal place. Subjects knew the value distribution and their own induced values, but not the induced value of the others. Individual induced values were constant for 10 decision periods but changed at the beginning of a new treatment or a new subtreatment. 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 ($E(v_i)$) times the number of all individuals in a session; the incremental cost for the second unit was the same as the cost of the first unit. Therefore, when $\alpha \leq 0.3$, it was socially optimal to provide one unit; when $\alpha > 0.3$, it was socially optimal to provide two units in both grouping approaches. In this study, we use group-level observations from the last five periods of each treatment for analysis, in order to avoid adjustment and learning variations in early periods.[4]

V. EXPERIMENT RESULTS AND DISCUSSION

To separate the influence of each treatment variable, we provide a multivariate assessment of key variables using a random effects model using the average individual contribution as the dependent variable. The group random effects control for the dependence of group outcomes within a session. The treatment effects on the overall contribution are the focus of this paper; see Liu, Swallow, and Anderson (2011) for details on how individual values affect the contribution. Our 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 for observations in the PR treatment; the disaggregate approach ($DisAgg$) is coded similarly as a dummy variable. The dummy variables $\alpha_{0.6}$, $\alpha_{1.0}$, and $\alpha_{1.2}$ denote the decreasing marginal benefit level ($\alpha = 0.6$), the constant marginal benefit level ($\alpha = 1.0$), and increasing marginal benefit level ($\alpha = 1.2$) for the second unit, respectively, where the zero marginal benefit ($\alpha = 0$) is treated as the baseline. We use the random effects model

$$AC_{ij} = \beta_0 + \beta_1 PR + \beta_2 DisAgg + \sum_{k=0.6,1.0,1.2} \beta_{3,k}\alpha_k + \beta_4 PR \times DisAgg + \sum_{k=0.6,1.0,1.2} \beta_{5,k}\alpha_k \times DisAgg + \sum_{k=0.6,1.0,1.2} \beta_{6,k}\alpha_k \times PR \times DisAgg + \xi_i + \epsilon_{ij},$$

where ξ_i is the session-specific random effect and ϵ_{ij} is the usual error term for each group-level outcome. We include several interaction terms in the above regression model: we expect some of the interaction effects to be significant, as outlined in Hypotheses 2 and 3. 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 ($\chi^2 = 67.99$, $p < 0.01$).

Differences between Two Grouping Approaches

From Table 3, we find that compared to the aggregated approach, the average contribution is significantly higher in the disaggregated approach ($\beta_2 = 1.715$, $p < 0.01$). Figure 1 shows 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 use the t-test from the random effects

[4] Detailed experimental instructions are provided in the online appendix, available at http://le.uwpress.org.

TABLE 2
Summary of the Average Individual Contribution

Grouping Approach	Second-Unit MB Level (α)[a]	Rebate Rules[b]	Mean	Median	Std. Dev.	Min.	Max.	Number 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

[a] The marginal benefit (MB) level is represented by parameter α, representing the proportion of first-unit value that the participant receives from the second unit, and took values 0, 0.6, 1.0, and 1.2 representing, respectively, no second-unit benefit, diminishing MB, constant MB, and increasing MB.
[b] PPM, provision point mechanism without rebate; PR, provision point mechanism with proportional rebate rule.

model for hypothesis testing. We find support for Hypothesis 1: in all cases, the average contribution is higher in the disaggregated approach. Also, this difference is significant at all marginal benefit levels with the PPM rule ($p < 0.001$), and at the baseline ($p = 0.057$) and the decreasing marginal benefit level ($p < 0.001$) with the PR rule. From Figure 1a,[5] the increase is at least 25% and exceeds 70% for the decreasing marginal benefit treatment with the PPM rule, and the increase ranges from about 2% to 40% with PR rule (Figure 1). This result suggests that subdividing the larger group into smaller groups can significantly increase contributions, and the increase is always economically meaningful without PR and still so for at least the decreasing marginal benefit with PR.

From Table 3, we find the interaction terms $DisAgg \times \alpha_{1.0}$ and $DisAgg \times \alpha_{1.2}$ are negative and significant, and the term $DisAgg \times \alpha_{0.6}$ 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 with a relatively high (a constant, $\alpha_{1.0}$ or an increasing, $\alpha_{1.2}$) marginal benefit level for a second unit. We can also confirm this difference from Figure 1, upper panel, as the contribution difference between these two grouping approaches is 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 for the constant and increasing marginal benefit levels, though with the baseline and decreasing marginal benefits, the average contribution in the disaggregated approach is still statistically higher. These results show some support for our Hypothesis 2, which implies that the difference in contributions between the aggregated and disaggregated approaches

[5] The predicted average contribution is based on the regression model of the last five period contributions, and calculated at the mean of the sessional effect. Baseline: the second-unit marginal benefit (SUMB) level equals 0; decreasing MB: the SUMB level equals proportion 0.6 of first-unit MB (FUMB); constant MB: the SUMB level equals 1.0 of FUMB; increasing MB: the SUMB level equals 1.2 of FUMB. The difference between the average contributions at each MB level is assessed by the significant value, p, based on the results from the regression model. *Upper:* baseline, $p < 0.001$ ($z = 7.47$); decreasing MB, $p < 0.001$ ($z = 7.91$); constant MB: $p < 0.001$ ($z = 4.12$); increasing MB, $p < 0.001$ ($z = 5.12$). *Lower:* baseline, $p = 0.057$ ($z = 1.91$); decreasing MB, $p < 0.001$ ($z = 6.27$); constant MB, $p = 0.677$ ($z = 0.42$); increasing MB, $p = 0.468$ ($z = 0.73$).

would be less substantial under a higher, positive marginal benefit level.

To summarize, we find that the disaggregated approach can encourage individuals' contributions substantially, which is consistent with effects of a more stringent provision point relative to a group's expected value. The broad implication is that the disaggregated approach increases contributions, but when marginal benefits are nondecreasing, 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 under PR still shows a large positive effect from disaggregating groups.

The Influence of the Rebate

We expect the rebate of excess contribution will generally encourage contributions compared to no rebate under otherwise identical situations. Figure 2[6] show the predicted average contributions from the fitted model, arranged so that we can compare the difference between PPM and PR directly. As before, predicted contributions are computed at the average of the sessional effect.

We use the *t*-test from the random effects model for hypothesis testing. We find that in general, the PR rule raises contributions significantly above contributions under the PPM rule. The average contribution is higher under the PR treatment than the PPM treatment, except in the disaggregated approach under the baseline marginal benefit level; however that difference is not significant ($p = 0.664$).[7] Also, from Figure 2, we observe that the influence of the rebate is larger in the aggregated approach, and the difference between PPM and PR grows as the marginal benefit level increases. The rebate remains important with the aggregated, larger group, but the influence can be affected by the context created by the grouping structure and marginal benefit function of beneficiaries. Thus, our results generally support Hypothesis 3 that the PR rule increases contribution and has a larger influence in the aggregated approach.

Another interesting observation is that we find, among the four marginal benefit levels,

TABLE 3
Random Effects Regression with Average Individual Contribution as Dependent Variable

	Last Five Periods
PR (= 1 for proportional rebate treatment, = 0 otherwise)	1.103*** (0.4006)
DisAgg (= 1 for disaggregated groups; = 0 otherwise)	1.715*** (0.2295)
$\alpha_{0.6}$ (= 1 for $\alpha = 0.6$; = 0 otherwise)	0.01366 (0.2295)
$\alpha_{1.0}$ (= 1 for $\alpha = 1.0$; = 0 otherwise)	1.084*** (0.2295)
$\alpha_{1.2}$ (= 1 for $\alpha = 1.2$; = 0 otherwise)	0.3905* (0.2295)
DisAgg × PR	− 1.277*** (0.3246)
PR × $\alpha_{0.6}$	− 0.09742 (0.3246)
PR × $\alpha_{1.0}$	0.4631 (0.3246)
PR × $\alpha_{1.2}$	0.8335*** (0.3246)
DisAgg × $\alpha_{0.6}$	0.1017 (0.3246)
DisAgg × $\alpha_{1.0}$	− 0.7688** (0.3246)
DisAgg × $\alpha_{1.2}$	− 0.5394* (0.3246)
DisAgg × PR × $\alpha_{0.6}$	0.8993* (0.4591)
DisAgg × PR × $\alpha_{1.0}$	0.4269 (0.4591)
DisAgg × PR × $\alpha_{1.2}$	0.2686 (0.4591)
Constant	2.552*** (0.2833)
Number of observations	320
Log restricted-likelihood	− 366.5
LR test vs. linear regression	$p < 0.0001$

Note: 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. LR, likelihood ratio.
*Significance at 10%; **significance at 5%; ***significance at 1%.

[6] The predicted average contribution is based on the regression model of the last five period contributions, and calculated at the mean of the sessional effect. Baseline: the second-unit marginal benefit (SUMB) level equals 0; decreasing MB: the SUMB level equals proportion 0.6 of first-unit MB (FUMB); constant MB: the SUMB level equals 1.0 of FUMB; increasing MB: the SUMB level equals 1.2 of FUMB. Rebate rules are provision point mechanism with no rebate (PPM) and with the proportional rebate (PR). The difference between the average contributions at each MB level is assessed by the significant value, *p*, based on the results from the regression model. *Upper:* baseline, $p < 0.001$ ($z = 2.75$); decreasing MB, $p = 0.012$ ($z = 2.51$); constant MB, $p < 0.001$ ($z = 3.91$); increasing MB, $p < 0.001$ ($z = 4.83$). *Lower:* baseline, $p = 0.664$ ($z = -0.43$); decreasing MB, $p = 0.117$ ($z = 1.57$); constant MB, $p = 0.074$ ($z = 1.79$); increasing MB, $p = 0.020$ ($z = 2.32$).

[7] See test statistics and *p*-values in footnote 5, for Figure 2, lower panel.

FIGURE 1
Differences between Aggregated and Disaggregated Grouping Approach, with Differing Marginal Benefit (MB): under Provision Point Mechanism without Rebate (PPM) *(upper);* under Proportional Rebate (PR) *(lower)*

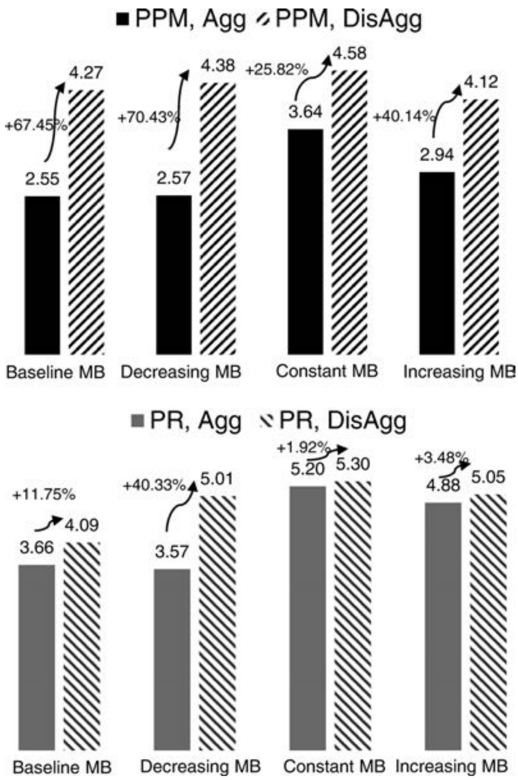
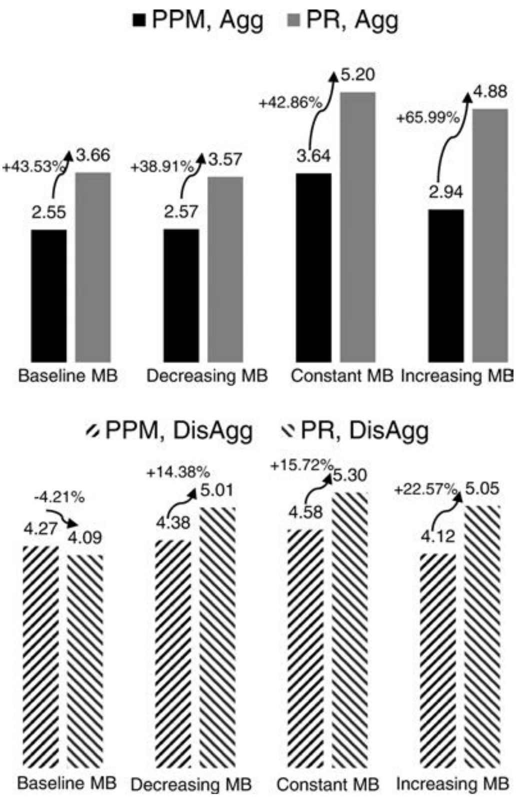


FIGURE 2
Differences between Rebate Rules for Provision Point Mechanism without Rebate (PPM) and Proportional Rebate (PR), with Differing Marginal Benefit (MB): in the Aggregated Grouping Approach *(upper);* in the Disaggregated Grouping Approach *(lower)*



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. This result is different from outcomes observed in the linear public good game with different marginal per capita return or threshold public good games with different step returns (Croson and Marks 2000), where a higher marginal per capita return or a higher step return leads to higher contributions, though we realize there are other differences in the experimental design.

The most important insight might be that when the market-maker decides to rebate excess contributions, and as the value of the second unit increases, the aggregated approach induces significantly more contribution compared to the baseline. When the second unit has a positive but low social value relative to the provision cost, the disaggregated approach might be a better choice. While the disaggregated approach makes it harder to fund the first unit of public good, it is still unclear which approach is better in terms of overall provision success, as the disaggregated approach always raises more contributions per capita 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 disaggre-

TABLE 4
Provision Frequencies in the Last Five Periods

Grouping Approach	Second-Unit MB Level (α)[a]	Rebate Rules[b]	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]

Note: 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 use only the experiment outcome in the last five periods of each treatment.

[a] The marginal benefit (MB) level is represented by parameter α, representing the proportion of first-unit value that the participant receives from the second unit, and took values 0, 0.6, 1.0, and 1.2 representing, respectively, no second-unit benefit, diminishing MB, constant MB, and increasing MB.

[b] PPM, provision point mechanism without rebate; PR, provision point mechanism with proportional rebate rule.

[c] Counterfactual result when 0.5 of a person (with average performance in that environment) is added to the each of the disaggregated group.

gated grouping approach by comparing the provision frequencies.

Can the Disaggregated Approach Potentially Provide More of Both Units?

Despite generating higher contributions, the disaggregated approach has a disadvantage in public good provision, because any excess contributions of one group cannot be used for the other group. Therefore, overall provision success is uncertain. In Table 4 we provide the provision frequency statistics using the data from the last five periods: (1) 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 approach (odds ratio test: $p = 0.279$); (2) 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 at all marginal benefit levels (odds ratio test: $p < 0.001$).

In terms of provision failure (providing zero units): (1) we find the rebate of excess contribution reduces the provision failure to zero in the aggregated group; however, (2) 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 (frequency of providing zero units in the disaggregated groups: 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 strive for 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 frequency of providing both units; from our experiment, the disaggregated approach also has a lower provision failure at the decreasing marginal benefit level. The stringency of the provision cost in disaggregated groups may offset the propensity to donate less, based on the contributors' subjective probability that their group would be providing the second (marginal) unit.

In Table 5, we compare the provision frequencies in the aggregated approach with a counterfactual situation. In this first counterfactual approach, we use the individual con-

TABLE 5

Counterfactual Provision Frequency Outcomes if Contributions in the Aggregated Group Approach Had Reached the Same Average Contribution as Observed from Individuals in the Disaggregated Groups, in the Last Five Periods

Grouping Approach	Second-Unit MB Level (α)	Rebate Rules[a]	Frequency of Provision (%)		
			0 Units	1 Unit	2 Units
The aggregated group	Decreasing (0.6)	PPM	0 (30)	70 (70)	30 (0)
Using average contributions		PR	0 (0)	55 (100)	45 (0)
observed in the disaggregated	Constant (1.0)	PPM	0 (20)	75 (55)	25 (25)
groups		PR	0 (0)	30 (30)	70 (70)
	Increasing (1.2)	PPM	0 (25)	85 (70)	15 (5)
		PR	0 (0)	70 (40)	30 (60)

Note: 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. MB, marginal benefit.

[a] PPM, provision point mechanism without rebate; PR, provision point mechanism with proportional rebate rule.

tributions observed in the disaggregated treatment data to calculate provision frequencies as if those contributions had been made in an aggregated group. First, we note that this counterfactual outcome would have been sufficient to eliminate provision failure (zero units provided) in the aggregated group, particularly under the PPM (the treatment without rebate). That is, if contributions from the disaggregated groups had been merged (contrary to the rules of that approach), at least one unit would have always been provided. Second, we note that higher contributions from the disaggregated approach would have matched or raised the frequency of provision of both units, if such contributions had been aggregated as if from a single group (see last column of Table 5, where the one exception is under PR with increasing marginal benefit, $\alpha = 1.2$). These results show the advantage of higher contributions from the disaggregated group, which are, unfortunately, not realized in the single, aggregated group.

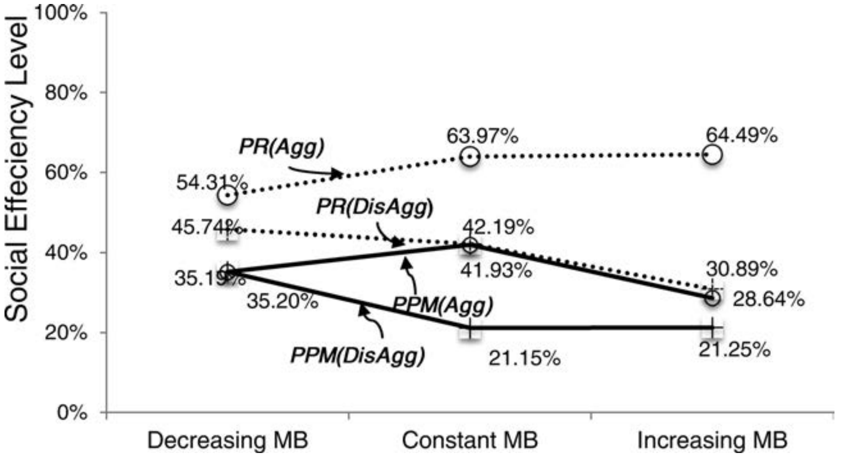
Alternatively, we consider a second counterfactual approach. In this case, we consider directly what outcomes might have occurred in the disaggregated approach if these smaller groups could be increased by just the equivalent of 0.5 of an average contributor. Again, this hypothetical involves a bit less than a 10% increase in the donor base divided between the disaggregated groups. We then compare the result with the original outcome from the aggregated group; see Table 4 for counterfactual provision success, in parentheses, for the disaggregated approach. Under these conditions, we find that the disaggregated approach would outperform the actual aggregated approach, with the one exception being under the PR treatment with increasing marginal benefit.

These counterfactuals suggest that there is potential to balance the effects of group size with the stringency of provision for disaggregated groups relative to a given provision point (i.e., cost per unit). That is, a market-maker could use these factors as controls to optimize the division of a population of potential donors across smaller groups in order to achieve a higher frequency of provision of multiple units. Suppose a market-maker wanted to fund K units with a donor-base of N persons. She could create K groups of N/K (assume N/K people is an integer, in this example). However, the market-maker might do better by forming $K-1$ groups or even fewer. Additional empirical research would then need to evaluate whether the implications identified here can scale up in conditions with a large number of units to be provided, but implications now are that the disaggregated approach appears promising for situations of local-scale public goods where total production might be characterized by a few units.

In terms of overall social efficiency, we summarize the results in Figure 3.[8] We cal-

[8] We plot the social efficiency level for each scenario, depending on the experimental results from the last five periods for different second-unit marginal benefit (SUMB) lev-

FIGURE 3
Overall Social Efficiency, with Differing Marginal Benefit (MB), Depending on Last Five Periods



culate the social efficiency level as the ratio of the realized social surplus and potential social surplus. Note that in the PPM, where there is no rebate, we assume that the excess contributions could be collected by the market-maker, as a profit returning no additional benefit to donors. Our results show that the aggregated approach performs better than the disaggregated approach,[9] except at the decreasing marginal benefit level ($\alpha = 0.6$) with no rebate. It is interesting to see that for this decreasing marginal benefit condition, despite the shortcoming (using the total of contributions less effectively) of the disaggregated provision mechanism, the increased contribution from individuals in the disaggregated approach is able to overcome the restriction preventing cross-group assistance and nonetheless reach a similar efficiency level as with the aggregated approach. We also find that the presence of the rebate helps increase the overall social efficiency, while this influence is larger in the aggregated group with an increasing marginal benefit level.

els. Rebate rules are provision point mechanism with no rebate (PPM) and with the proportional rebate (PR). Decreasing MB: the SUMB level equals proportion 0.6 of first-unit MB (FUMB); constant MB: the SUMB level equals 1.0 of FUMB; increasing MB: the SUMB level equals 1.2 of FUMB.

[9] This statement concerns results based on a fixed *N*, without optimization discussed in the preceding two paragraphs.

VI. SUMMARY AND CONCLUSION

This research explores the public good provision game in a two-units environment using two grouping approaches, across two rebate rules. Our results suggest noticeable differences between the aggregated and disaggregated grouping approaches. The disaggregated approach always encourages a higher average contribution compared to the aggregated approach. However, the difference in average contribution between the two grouping approaches becomes smaller if (1) the proportional rebate is used or (2) individuals hold a relatively high (constant or increasing) marginal value toward the second unit of public good. In terms of overall social efficiency, the aggregated approach performs weakly better than the disaggregated approach for a fixed population of donors divided evenly.

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. For example, when there are four levels (units) of a public good, for example, providing 40 acres of habitat in 10 acre increments, we can either divide the potential contributors into the four groups, each group providing 10 acres, or keep all the contributors in the same group where each individual makes an offer for providing up to 40 acres. We may even use a "hybrid" approach where we divide the contributors into two groups and each group could provide up to 20 acres. Furthermore, if providing 40 acres of habitat is an extremely difficult task based on some prior information available to the market-maker, she may offer for provision only 20 or 30 acres at the maximum, using just two or three groups, so that each 10 acre parcel has a higher probability of being provided. Further 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 begins to illuminate the benefit of allowing the market-maker to establish different grouping schemes. Thus, other than exploring different provision mechanisms empirically, the market-maker may need to optimize the number of groups to increase the provision probability over multiple units. Our study provides some insights on how cross-group incentives affect contributions. 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. Future research could explore the influence of group division when the total target population size is a choice variable, allowing the market-maker to control the aggregated benefits of a group or subgroup relative to the unit cost. These considerations may be necessary to facilitate support for providing multiple units of a public good by private action.

Acknowledgments

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