Assurance Payments for Multi-Unit Public Goods Provision: Experiments Motivated by Ecosystem Service Markets

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Abstract

In provision point mechanism, the cost threshold for provision introduces incentives for individuals to contribute toward the public good and, in general, the Pareto efficient outcome is a subset of equilibrium outcomes. However, the threshold cannot eliminate the pure free-rider equilibrium unless refinements are used. In this paper, we examine a set of assurance payment schemes for multi-unit public good provision using individualized price auction (IPA). We find assurance payment significantly eliminates non-provision equilibria, and reduces the multiplicity of provision equilibria suffered by most discrete public good provision games, especially in a multi-unit setup. The assurance payments could be useful in establishing markets for a previously non-marketable good, and thus improve the efficiency regarding the provision of various types of public good currently funded only by government or through traditional non-profit donations.

1 Introduction

In discrete public goods provision games (e.g., provision point mechanism), the cost threshold for provision introduces incentives for individuals to contribute toward the public good and, in general, the Pareto efficient outcome is included in the set of equilibrium outcomes. However, the threshold cannot eliminate the pure free-rider equilibrium unless refinements are used (Bagnoli and Lipman, 1989). Tabarrok (1998) introduces a so-called dominant assurance contract which could successfully eliminate the non-provision equilibria and shows that contributing to the public good becomes a dominant strategy under the assurance contract with complete information. The key idea is to encourage commitments to pay for public good provision by offering compensation (an assurance payment) to would-be contributors if, in the end, the group fails to provide the public good. When an individual commits to pay into the public good fund, they become eligible for a compensation payment from the market-maker in the event the good is not provided. Different from public good provision experiments using penalties (Masclet et al., 2003), the assurance contract mechanism tries to achieve efficient provision by rewarding “good people” rather than penalizing free or cheap riders. To our best knowledge, this potentially powerful, but still theoretical, idea has not been experimentally tested for public good provision, which motivates this paper.

Based on the assurance-payment idea, we examine a set of assurance payment schemes for multi-unit public good provision in a framework proposed by Smith and Swallow (2013) and Swallow (2013). The motivation for multiple units is twofold. Empirically, with the vision of setting up a market for ecosystem services, the public goods are naturally multiple discrete units, for example due to multiple parcels of farms or the minimum requirements that a target species requires for meaningful units of habitat conservation. Theoretically, multi-unit public goods provision is much more challenging than one unit good provision due to an increased multiplicity of equilibria. Bagnoli and Lipman (1989) use a stronger refinement to eliminate those non-provision equilibria in a multi-unit provision point mechanism, which is not as well observed in the corresponding experiment in Bagnoli et al. (1992) as in the one-unit case in Bagnoli and McKee (1991). If assurance payment can significantly eliminate the inefficient equilibria without refinement, it may improve the multi-unit provision. Therefore, we apply the assurance payment idea to this more challenging multi-unit case.

We show that assurance payment does reduce the multiplicity of the non-provision Nash equilibria in a multi-unit environment. Furthermore, from a computerized lab experiment, we find that the a positive assurance payment always performs better than no assurance in terms of provision rate, group value revelation and realized social surplus.

The rest of the paper is organized as follows. Section 2 defines the baseline mechanism and describes the assurance payment schemes. Section 3 characterizes the Nash equilibira of one- and two-unit cases with and without assurance payments. Section 4 explains the experimental design and procedures. Section 5 discusses the observed results. Section 6 concludes.

2 Baseline Mechanism and Assurance Payment Schemes

Assume there are N individuals who are asked to support a total of J units public good with constant marginal cost C through voluntary contributions; each individual is indexed by $i \in \{1,\ldots,N\} \equiv \mathcal{I}$, and each unit of the public good is indexed by $j \in \{1,\ldots,J\} \equiv \mathcal{J}$. Individuals are asked to make a contribution or bid toward each unit of a public good simultaneously. Let v_i^j be the individual i's value toward Unit j, and b_i^j be the individual i's bid on Unit j. Individual

i's payoff is denoted as π_i. Thus, we can express the total bids on j as $B_j = \sum_{i \in \mathcal{I}} b_i^j$, where $j \in \mathcal{J}$. Let $\Theta_j \equiv [\underline{v}_j, \overline{v}_j]^N$ denote the individual value support for j=1 and J. Each individual's value v_i^j (individual i on Unit j) is independently and randomly drawn from $[\underline{v}_j, \overline{v}_j]$ for j=1 and J, and v_i^j for j=2,…, $J-1$ is determined by $v_i^j = v_i^1 - (j-1)(v_i^1 - v_i^J)/(J-1)$, assuming $\underline{v}_1 \geq \overline{v}_J$.

2.1 Individualized Price Auction (IPA) Mechanism for Multi-Unit Public Good Provision

The baseline mechanism we use is called individualized price auction (IPA) mechanism, which is a Lindahl-based pricing mechanism. IPA includes two components: 1) the market clearing rule g and 2) the pricing rule t.

The market clearing rule determines the number of public good provided based on individuals' bids. In IPA, we compare the total bids from a group of individuals with the cost of the public good, starting from the first unit. If individuals' total bids on the first unit are higher or equal to the cost of the first unit, we continue to compare the total bids on the second unit with the cost of the second unit, and so on. We will stop at the first time the total bids for a unit is smaller than the unit cost. For example, if the total bids on the first unit, second unit and third unit are all higher than the cost, but the total bids on fourth unit are smaller than cost of the fourth unit, we will provide three units in total. Therefore, the market clearing rule in IPA can be expressed as

$$(1) \qquad g(B_1, \ldots, B_J) = \begin{cases} 0 & \text{if } B_1 < C \\ \max\{j \in \{1, \ldots, J\} : \min(B_1, B_2, \ldots, B_j) \geq C\} & \text{otherwise} \end{cases}$$

where $B_j = \sum_{i \in \mathcal{I}} b_i^j$.

The pricing rule determines how much each individual has to pay based on his and the others' bids. In IPA, each individual pays the same price for all the units provided, and the price equals to one's bid on the last unit that the group can collectively deliver, i.e.,

$$(2) \qquad t_i(B_1, \ldots, B_J) = \begin{cases} 0 & \text{if } g(\cdot) = 0 \\ g(\cdot) b_i^g & \text{otherwise} \end{cases}$$

Therefore, in IPA the payoff function for *i* is[1]

(3) $$\pi_i(B_1,\ldots,B_J)=\sum_{j=1}^{g(\cdot)} v_i^j - t_i(\cdot)$$

2.2 Assurance Payment Schemes

Assurance payment is a predetermined compensation fee to whoever bids higher than a pre-specified minimum offer in the event of provision failure. For example, let the minimum offer be 10 for a compensation fee of 10 on the first unit. Then if an individual bids 11 on the first unit and the total group bids are below the cost of the first unit (nothing will be provided in this case), this individual will receive an assurance payment of 10.

Different assurance payment schemes can vary in terms of the minimum offer and the compensation fee on different units. The original assurance contract in Tabarrok (1998) specifies the number of people to accept the contract for providing the good. In this paper, we deviate one step away from the mechanism without assurance and only consider the case where the minimum offer equals the compensation. We focus on the effects of various patterns of the assurance payment over multiple units; particularly, we compare the following four payment schemes: 1) no assurance payment, as a baseline; 2) the same assurance payment for the first several units, i.e., partial assurance; 3) decreasing assurance payments for the first several units, i.e., the fist unit has a higher assurance payment than the second unit, and so on; 4) the same assurance payment for the first unit that *cannot* be provided, with the assurance payment applicable to all units, i.e., conditional assurance.

Let AP_j denote the assurance payment, which is also the minimum offer, for Unit *j*, then the payoff function for *i* in IPA with assurance payment is

(4) $$\pi_i(B_1,\ldots,B_J;AP_1,\ldots,AP_J)=\begin{cases}\sum_{j=1}^{g(\cdot)} v_i^j - t_i(\cdot) & \text{if } g=J \text{ or } b_i^{g+1}<AP_{g+1} \text{ for } g<J\\ \sum_{j=1}^{g(\cdot)} v_i^j - t_i(\cdot)+AP_{g+1} & \text{if } b_i^{g+1}\ge AP_{g+1} \text{ for } g<J\end{cases}$$

[1] The initial endowment is omitted here for simplicity. And $\sum_{j=1}^{0} v_i^j = 0$.

Note that the assurance payment is applicable only if one's bid is at or above the minimum offer on the first unit that the group *fails* to provide.

3 Nash Equilibria of IPA with Assurance Payment

In this section, we characterize the Nash equilibria of IPA with assurance payment under complete information.[2] First, we show the Nash equilibria of IPA with assurance payment for one-unit public good provision; then we extend the argument to a 2-unit case. To simplify the discussion, we assume the assurance payment is greater than or equal to C/N and is much less than C.

3.1 One-Unit IPA with Assurance Payment

One-unit IPA without assurance payment is equivalent to the provision point mechanism (PPM) characterized by Bagnoli and Lipman (1989), who show that the provision point is exactly met in the undominated perfect equilibria. However, in PPM without the refinement, any strategy profile that leads to a group contribution less than the difference between the provision point and the highest induced value in the group is a Nash equilibrium, in which the good is not provided. We show below a simple assurance payment can eliminate most and in some cases all of the non-provision equilibria without refinement in the one-unit case.

3.1.1 $v_i > AP$ for all i

If the induced values in a group are all greater than the assurance payment, denoted by $v_i > AP$ for all i, the Nash equilibria of one-unit PPM with assurance payment can be characterized as follows.

E3.1.1.1 Any strategy profile $\{b_i\}_{i\in\mathcal{I}}$ *s.t.* $\sum_{i\in\mathcal{I}} b_i \neq C$ is not a Nash equilibrium;

E3.1.1.2 Any strategy profile $\{b_i\}_{i\in\mathcal{I}}$ *s.t.* $\sum_{i\in\mathcal{I}} b_i = C$ but $b_k > v_k - AP$ and $b_k > AP$ for some k is not a Nash equilibrium;

[2] Complete information here means that the following information is common knowledge: the provision cost for each unit, the group size, and the induced value of each unit for each individual.

E3.1.1.3 Any strategy profile $\{b_i\}_{i\in\mathcal{I}}$ *s.t.* $\sum_{i\in\mathcal{I}} b_i = C$ with either $b_k \le v_k - AP$ or $b_k \le AP$ for any *k* is a Nash equilibrium.

E3.1.1.1 consists of two cases. 1) $\sum_{i\in\mathcal{I}} b_i < C$ is not an equilibrium outcome. $\sum_{i\in\mathcal{I}} b_i < C$ implies the existence of at least one individual *m* bidding $b_m < C/N \le AP$, but *m* would be better off to bid AP, earning a positive payoff of either AP or $v_m - AP$, instead of 0. 2) Obviously, $\sum_{i\in\mathcal{I}} b_i > C$ is not an equilibrium outcome, either. In **E3.1.1.2**, some individual *k* with $b_k > v_k - AP$ and $b_k > AP$ would be better off to reduce the bid to AP since $AP > v_k - b_k$, i.e., the assurance from failure is greater than the payoff from provision. In **E3.1.1.3**, individual *k* bidding below or at AP will not reduce the bid since $0 < v_k - b_k$; individuals bidding below or at $v_k - AP$ will not deviate since $\max(AP, 0) \le v_k - b_k$. Note that the strategy profile $b_i = C/N, \forall i$, is an equilibrium.

These results show when all induced values in a group are higher than the minimum payment and hence on aggregate are higher than the provision cost, all Nash equilibria lead to the provision of the public good, and no assurance payment will be paid in equilibrium.

3.1.2 $v_i \le AP$ for some *i*

When some individual has an induced value less than the assurance payment, it is easy to verify that the statements in **E3.1.1.2** and **E3.1.1.3** still hold. However, there may exist some equilibria supporting the non-provision outcome, which are characterized as follows.

E3.1.2.1 Given $v_i \le AP$ for some $i \in \mathcal{I}$, any strategy profile $\{b_i\}_{i\in\mathcal{I}}$ *s.t.* $\sum_{i\in\mathcal{I}} b_i < C$ is a Nash equilibrium if

1) $AP \ge \max(v_k, C - \sum_{i\ne k} b_i)$ for all $k \in \{i \in \mathcal{I}: b_i < AP\}$; and
2) $AP \ge v_k - b_k - (C - \sum_{i\in\mathcal{I}} b_i)$ for all $k \in \{i \in \mathcal{I}: b_i \ge AP\}$.

These two conditions eliminate the incentive to deviate for individuals bidding below the assurance payment and those bidding above, respectively. If 1) does not hold, individual *k* would be better off to bid either *AP* if $AP < C - \sum_{i \neq k} b_i$ or $C - \sum_{i \neq k} b_i$ if $AP < v_k$ to earn a positive payoff, instead of 0; if 2) does not hold, individual *k* would be better off to increase the bid to provide the good.

Further, these two conditions significantly reduce the non-provision equilibrium set compared to that in PPM without assurance payment. In PPM, the condition for a non-provision equilibrium is $\sum_{i \neq k} b_i + v_k \leq C$ for all $k \in \mathcal{I}$. While in PPM with assurance payment, we need both $\sum_{i \neq k} b_i + v_k \leq C + AP$ for all $k \in \{i \in \mathcal{I}: b_i \geq AP\}$ (condition 2) and $\sum_{i \neq k} b_i \geq C - AP$ for all $k \in \{i \in \mathcal{I}: b_i < AP\}$ (condition 1). Note that, although the former allows higher total contributions, the constraint $\sum_{i \in \mathcal{I}} b_i < C$ makes the increased upper bound have little effect on the equilibrium set. However, the latter constraint on the lower bound eliminates a substantial subset of the equilibria supporting non-provision outcomes, especially when *AP* is much less than *C*, meaning that even in a non-provision equilibrium outcome, the group contribution is still close to the provision cost.

Thus, the non-provision equilibrium set is much tighter than that in PPM without assurance, and in some cases the set could be empty. Let n^+ denote the number of individuals with induced values greater than the assurance payment. Then **E3.1.2.1** implies that all these n^+ individuals will bid at or above the assurance payment. Therefore, if $n^+ \geq C/AP$, non-provision will not be supported in Nash equilibrium, which explains the results in Section 3.1.1. Note that if $AP < C/N$, then $C/AP>N$, and non-provision outcomes cannot be eliminated in equilibrium, which is why we assume $AP \geq C/N$. Moreover, if $AP> C/N$, $C/AP <N$, and hence if *AP* is not too high, it may become easier to have $n^+ > C/AP$, and all non-provision equilibria can be eliminated. But if *AP* is too high, we may not have enough number of individuals with induced values higher than *AP*. So, given a value distribution and a provision point level, there could exist an optimal assurance payment level at which the non-provision equilibrium set can be reduced the most. Let $\mathrm{n}(v)=|i: v_i>v|$. If there exists a v such that $C/v<\mathrm{n}(v)$, then there always exists an *AP* such that no equilibrium supports a non-provision outcome, for example $AP=C/\mathrm{n}(v)$.

3.2 Two-Unit IPA with Assurance Payment

For more than one unit, the Nash equilibrium set of IPA is slightly different from that of PPM which is easy to obtain by generalizing the argument for one-unit PPM. We first characterize the Nash equilibria of two-unit IPA without assurance payment by modifying the equilibria set of two-unit PPM, and then show the Nash equilibria of two-unit IPA with assurance payment.

3.2.1 Two-Unit IPA without Assurance Payment

Since we are essentially considering a one-shot game with simultaneous moves, the Nash equilibria of two-unit PPM are simply a generalization of those of one-unit PPM in Bagnoli and Lipman (1989) and are characterized as follows.

In PPM with J=2, any strategy profile $\{b_i^j\}_{i\in\mathcal{I},j\in\mathcal{J}}$ is a Nash equilibrium if it satisfies one of the following three conditions:

E3.2.1.1 $\sum_{i\in\mathcal{I}} b_i^1 < C$, $\sum_{k\neq i} b_k^1 + v_i^1 \le C$ and $\sum_{j\in\mathcal{J}} [v_i^j - (C - \sum_{k\neq i} b_k^j)] \le 0$ for all $i \in \mathcal{I}$;

E3.2.1.2 $\sum_{i\in\mathcal{I}} b_i^1 = C$, $b_i^1 \le v_i^1$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, and $\sum_{k\neq i} b_k^2 + v_i^2 \le C$ for all $i \in \mathcal{I}$;

E3.2.1.3 $\sum_{i\in\mathcal{I}} b_i^j = C$, $b_i^2 \le v_i^2$, and $\sum_{j\in\mathcal{J}} (v_i^j - b_i^j) \ge 0$ for all $i \in \mathcal{I}$.

The argument for each case is straightforward and hence is omitted here.[3] Note, the three types of equilibria respectively result in the provision of 0, 1, and 2 units of the good.

The key difference between IPA and PPM is the pricing rule: In PPM, each individual's payment per unit provided is their bid on each unit; in IPA, however, the payment or price for each unit provided is equal to their bid on the last unit provided. In other words, the payoffs across the units are independent in PPM, while correlated in IPA. The correlation of payoffs across units introduces two new incentives in IPA. First, if an individual increases her bid on the first unit that is not currently provided such that her payment to provide this unit is sufficiently low, the individual may be overall better off by providing the additional unit. Second, if an individual decreases her bid on the last unit currently provided such that her payment to the second-to-last

[3] The idea is to eliminate the incentive to deviate to each possible case. For example, in E3.2.1.1, for providing 0 units to be an equilibrium, the payoff to provide 1 or 2 units should not be greater than zero.

unit is sufficiently low, the individual may be overall better off by not providing the last unit. With these two new incentives, the Nash equilibria of two-unit IPA are characterized as follows.

In IPA with J=2, any strategy profile $\{b_i^j\}_{i\in\mathcal{I},j\in\mathcal{J}}$ is a Nash equilibrium if it satisfies one of the following four conditions:

E3.2.1.4 $\sum_{i\in\mathcal{I}} b_i^1 < C$, $\sum_{k\neq i} b_k^1 + v_i^1 \le C$, $\sum_{j\in\mathcal{J}} [v_i^j - (C - \sum_{k\neq i} b_k^j)] \le 0$ for all $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{k\neq i} b_k^1 + v_i^1 = C$, $\sum_{k\in\mathcal{I}} b_k^2 = C$, and $\sum_{j=1}^{2} v_i^j - 2b_i^2 > 0$;

E3.2.1.5 $\sum_{i\in\mathcal{I}} b_i^1 = C$, $b_i^1 \le v_i^1$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, and $\sum_{k\neq i} b_k^2 + v_i^2 \le C$ for all $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{k\neq i} b_k^2 + v_i^2 = C$, and $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\neq i} b_k^2] > v_i^1 - b_i^1$;

E3.2.1.6 $\sum_{i\in\mathcal{I}} b_i^j = C$ for $j \in \{1,2\}$, $b_i^2 \le v_i^2$, $\sum_{j\in\mathcal{J}} (v_i^j - b_i^j) \ge 0$, for all $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{j=1}^{2} v_i^j - 2b_i^2 < v_i^1 - b_i^1$;

E3.2.1.7 $\sum_{i\in\mathcal{I}} b_i^1 = C$, $b_i^1 \le v_i^1$ for all $i \in \mathcal{I}$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, $\sum_{k\neq i} b_k^2 + v_i^2 > C$ for some $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\neq i} b_k^2] > v_i^1 - b_i^1$.

The first three conditions in IPA are obtained by just adding some additional constraints on the corresponding conditions in PPM, and hence are reduced equilibrium sets of PPM. Specifically, **E3.2.1.4** shrinks the PPM equilibrium set in which no public good is provided at all; **E3.2.1.5** eliminates some equilibria in PPM that provide only one unit and collapses them to the equilibria of providing two units; and **E3.2.1.6** eliminates some of the most efficient equilibria where two units are provided in PPM, and collapses them to the equilibria of providing one unit, among which some are captured by **E3.2.1.5**, and the others form a new type of equilibria characterized by **E3.2.1.7**. Note that all the additional constraints added in the four conditions can be summarized as follows: In IPA, individuals have incentive to lower per-unit price by either increasing or decreasing the number of units provided.

3.2.2 Two-Unit IPA with Assurance Payment

To characterize the equilibrium set of two-unit IPA with assurance payment, we need to add the equilibrium condition of one-unit IPA with assurance payment as additional constraints to the equilibrium conditions of two-unit IPA without assurance payment. The interaction between the two sets of equilibrium conditions results in the equilibrium set of two-unit IPA with assurance payment.

As in the one-unit IPA, we will show how the assurance payment eliminates some of the equilibria of two-unit IPA in two cases depending on whether or not all the induced values for each unit are greater than the assurance payment. In each case, we will discuss two types of assurance payment schemes: 1) only the first unit has an assurance payment; 2) both units each have an assurance payment. These two schemes represent partial and conditional assurance.

3.2.2.1 $v_i^j > AP_j$ for all i, and j =1, 2

If for each unit the induced values in a group are all greater than the assurance payment, denoted by $v_i > AP_j$ for all i, and j =1, 2, the Nash equilibria of two-unit IPA with assurance payment can be characterized as follows.

Two-unit IPA with an assurance payment *AP* only for the first unit

First, any strategy profile resulting in the non-provision of the first unit is not an equilibrium due to the condition **E3.1.1.1**. Second, any equilibrium belonging to **E3.2.1.5** to **E3.2.1.7** is eliminated if the bidding strategy profile for the first unit satisfies **E3.1.1.2**. Thus, we have the following equilibrium conditions.

In IPA with assurance payment on the first unit and J=2, any strategy profile $\{b_i^j\}_{i\in\mathcal{I},\, j\in\mathcal{J}}$ is a Nash equilibrium if it satisfies one of the following three conditions:

E3.2.2.1.1 $\sum_{i\in\mathcal{I}} b_i^1 = C$ with either $b_i^1 \le v_i^1 - AP$ or $b_i^1 \le AP$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, and $\sum_{k\ne i} b_k^2 + v_i^2 \le C$ for all $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{k\ne i} b_k^2 + v_i^2 = C$, and $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\ne i} b_k^2] > v_i^1 - b_i^1$ or equivalently $b_i^1 > v_i^2$;

E3.2.2.1.2 $\sum_{i\in\mathcal{I}} b_i^j = C$ for $j \in \{1,2\}$, $b_i^2 \le v_i^2$, $\sum_{j\in\mathcal{J}} (v_i^j - b_i^j) \ge 0$, for all $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{j=1}^{2} v_i^j - 2b_i^2 < v_i^1 - b_i^1$; and no individual with $b_i^1 > AP$ *s.t.* $\sum_{j=1}^{2} v_i^j - 2b_i^2 < AP$;

E3.2.2.1.3 $\sum_{i\in\mathcal{I}} b_i^1 = C$ with either $b_i^1 \le v_i^1 - AP$ or $b_i^1 \le AP$ for all $i \in \mathcal{I}$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, $\sum_{k\ne i} b_k^2 + v_i^2 > C$ for some $i \in \mathcal{I}$, and there is no individual $i \in \mathcal{I}$ *s.t.* $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\ne i} b_k^2] > v_i^1 - b_i^1$.

In **E3.2.2.1.1** and **E3.2.2.1.3**, the constraint from **E3.1.1.3** eliminates the incentive to reduce the bid on unit 1, and the constraint from **E3.2.1.5** eliminates the incentive to increase the bid on unit 2. In **E3.2.2.1.2**, the constraints from **E3.1.1.3** and **E3.2.1.6** eliminate the incentive to reduce the bid on unit 1 and unit 2, respectively. Under the three conditions, a great amount of equilibria in the two-unit IPA without assurance payment are eliminated, and the remaining ones always provide 1 or 2 units of the good.

<u>Two-unit IPA with assurance payment for each unit</u>

With an assurance payment on each unit, AP_j for j =1, 2, **E3.1.1.1** and **E3.1.1.2** can be applied to all the equilibrium cases in IPA without assurance, where 0, 1, and 2 units are all supported.

It is easy to see that any strategy profile resulting in 0 units is not a Nash equilibrium due to the same reason for **E3.1.1.1**, and hence the whole equilibrium set specified by **E3.2.1.4** is eliminated. Also, it is impossible that $\sum_{i\in\mathcal{I}} b_i^2 < C$ and $\sum_{k\ne i} b_k^2 + v_i^2 \le C$ for all $i \in \mathcal{I}$ with assurance on unit 2, since if $\sum_{i\in\mathcal{I}} b_i^2 < C$, there must exist some i such that $b_i^2 < AP_2$ and $\sum_{k\ne i} b_k^2 + AP_2 \ge C$ (otherwise i will bid AP_2), and then we have $\sum_{k\ne i} b_k^2 + v_i^2 > C$ given $v_i^2 > AP_2$. Therefore, the whole equilibrium set specified by **E3.2.1.5** is eliminated as well, and we only need to check how **E3.1.1.1** and **E3.1.1.2** affect the equilibria in **E3.2.1.6** and **E3.2.1.7**, where 2 units and 1 unit are provided. The equilibrium conditions are as follows.

In IPA with assurance payment on each unit and J=2, any strategy profile $\{b_i^j\}_{i\in\mathcal{I},j\in\mathcal{J}}$ is a Nash equilibrium if it satisfies one of the following two conditions:

E3.2.2.1.4 $\sum_{i\in\mathcal{I}} b_i^j = C$ for $j\in\{1,2\}$, $b_i^2 \le v_i^2$, $\sum_{j\in\mathcal{J}}(v_i^j - b_i^j) \ge 0$, for all $i\in\mathcal{I}$, and there are no strategies by individual $i\in\mathcal{I}$ belonging to any of the following three cases:

1) $b_i^2 > AP_2$ and $\sum_{j=1}^{2} v_i^j - 2b_i^2 < v_i^1 - b_i^1 + AP_2$;
2) $b_i^2 \le AP_2$ and $\sum_{j=1}^{2} v_i^j - 2b_i^2 < v_i^1 - b_i^1$;
3) $b_i^1 > AP_1$ and $\sum_{j=1}^{2} v_i^j - 2b_i^2 < AP_1$.

E3.2.2.1.5 $\sum_{i\in\mathcal{I}} b_i^1 = C$ and $b_i^2 \le v_i^2$ for all $i\in\mathcal{I}$, $\sum_{i\in\mathcal{I}} b_i^2 < C$, $\sum_{k\ne i} b_k^2 + AP_2 \ge C$ for any $i\in\mathcal{I}$ with $b_i^2 < AP_2$, and there are no strategies by individual $i\in\mathcal{I}$ belonging to any of the following four cases:

1) $b_i^2 \ge AP_2$ and $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\ne i} b_k^2] > v_i^1 - b_i^1 + AP_2$;
2) $b_i^2 \ge AP_2$, $b_i^1 > AP_1$, and $AP_1 > v_i^1 - b_i^1 + AP_2$;
3) $b_i^2 < AP_2$ and $\sum_{j=1}^{2} v_i^j - 2[C - \sum_{k\ne i} b_k^2] > v_i^1 - b_i^1$;
4) $b_i^2 < AP_2$, $b_i^1 > AP_1$, and $AP_1 > v_i^1 - b_i^1$.

With an assurance payment on each unit, there are more types of incentives to deviate and hence both equilibrium sets of providing 1 and 2 units without assurance are significantly reduced. However, the equilibrium set of providing only 1 unit is still not empty even with assurance payment on each unit. Specifically, there exists a type of strategy profiles providing only the first unit that are Nash equilibria but involve strategies on unit 1 violating **E3.1.1.2** and those on unit 2 violating **E3.1.1.1**. The reason is that a relatively high price on unit 2 could make the payoff from providing one unit more attractive. For example, some individual k with $b_k^1 > v_k^1 - AP_1$, $b_k^1 > AP_1$, and $b_k^2 \ge AP_2$ would earn both a positive payoff from unit 1 and the assurance payment from unit 2 by providing only one unit, and hence could be better off compared to both of earning only the assurance payment by providing 0 units and earning some small payoffs from providing two units, which justifies the violation of **E3.1.1.2** on unit 1. Similarly, individual l with $b_l^2 < AP_2$ could earn a sufficiently high payoff from unit 1, but would be worse off to provide both units by bidding AP_2 due to an overall higher unit price. This type of equilibria can be either totally new or from the equilibrium set of IPA without assurance, but does not belong to the equilibrium set of two-unit IPA with assurance only for unit 1.

Comparing two-unit IPA with partial and full assurance (3 types vs. 2 types of equilibria), although generally full assurance could eliminate more non-provision or non-efficient provision equilibria and potentially make the efficient provision easier to implement by reducing the equilibrium selection problem, it may also increase the probability of paying more assurance payments.

3.2.2.2 $v_i^j \leq AP_j$ for some i, and j =1, 2

When some individual has an induced value less than the assurance payment, there may exist some equlibria providing 0 units. Since **E3.1.2.1** for the non-provision equilibria is just another constraint, we can adjust the conditions in Section 3.2.1 in a way similar to that in Section 3.2.2.1. However, as discussed in Section 3.1.2, the non-provision equilibrium set is really tight if not empty, and there is an equilibrium selection problem regarding who will be the one or the few individuals earning nothing. So the existence of non-provision equilibria would not change either the significant positive effect of assurance payment on inducing provision or the comparison between partial and full assurance. For simplicity, we will rely on the discussion in Section 3.2.2.1 for this case, only keeping in mind that non-provision is supported by a very tight set of equilibria.

3.3 Summary

The main message from the above equilibrium analysis is that with assurance payment, the multiplicity of equilibrium s is greatly reduced, and in some cases non-provision is not an equilibrium outcome. The assurance payment may improve public good provision, especially for multi-unit public goods where only strong refinements could lead to efficient outcomes.

Specifically, we have shown that in general the non-provision Nash equilibrium set if not empty is much tighter in one-unit IPA with assurance than that without assurance. If the assurance payment is greater than or equal to C/N, there may exist an assurance payment level higher than but not too far away from C/N such that the non-provision Nash equilibrium set is empty. When all individual values are greater than C/N, an assurance payment equal to C/N can eliminate all non-provision equilibria. In two-unit IPA, both partial and conditional assurance payment schemes make the equilibrium set (either provision or non-provision) tighter than that without assurance payment, and can eliminate 0-unit provision equilibria when all individual values are greater than C/N. Conditional assurance scheme has fewer categories of less efficient equilibrium set than partial assurance scheme and could potentially provide more units, although it also increases the probability of paying more assurance payments.

4 Experimental Parameters, Conjectures and Implementation

4.1 Experimental Parameters

We use the following parameters in our lab experiments. A maximum of 6 (=J) units of a discrete public good are available. Individuals' induced values for the public good follow a linearly decreasing marginal benefit curve. The induced values for Units 1 and 6 for each individual are randomly drawn from the uniform distributions over [15, 25] and [5, 15], respectively. The induced values for Units 2 to 5 are interpolated linearly based on those for Units 1 and 6. The average individual cost for each unit is 10, and hence the provision point for each unit in a group of size N is $10*N$. The value distribution, group size, and the provision point for each unit are common knowledge.

To test the effects of various assurance payment schemes over multiple units, we have the following six treatments:

A0) No assurance;

A1) The same assurance payment 10 for the first three units;

A2) The same assurance payment 14 for the first three units;

A3) Decreasing assurance payments 18, 14, and 10 for the first three units, respectively;

A4) The same assurance payment 10 for the first unit that cannot be provided;

A5) The same assurance payment 14 for the first unit that cannot be provided.

Treatment A0 is the baseline. A1 to A3 are partial assurance, while A4 and A5 conditional assurance. We use 10, 14, and 18 to represent low, medium, and high assurance payments.

4.2 Experimental Conjectures

Based on the previous equilibrium analysis, we have the following conjectures, where we use provision (success) rate to measure the performance of the schemes.

Conjecture 1 (A0 vs. A1-A5): Assurance payment improves provision rates on all assured units;
Conjecture 2 (Partial Assurance): A1 to A3 improve provision rates for the first three units, and there is no different between any pair of A1 to A3;
Conjecture 3 (Conditional Assurance): A4 to A5 improve provision rates for all the six units, and A5 is better than A4.
Conjecture 4 (A1-A3 vs. A4-A5): A4 to A5 result in higher provision rates for the last three units than A1 to A3.

In **Conjecture 2**, we expect no difference among A1 to A3 since all induced values in the first three units are higher than 10. In **Conjecture 3**, the reason that A5 is expected to be better than A4 is in the last three units, it is possible that induced values of some individuals are lower than 10, and hence it may be easier for a subset of the group members with induced values above 14 biding 14 to provide Units 4 to 6 than for all group members bidding 10 to provide the last three units. The other conjectures are straightforward.

4.3 Experiment Implementation

We conducted 6 sessions of lab experiments on networked computer terminals, each with 3 treatments in different orders (Table 1). Each session has 10 to 14 subjects in total, split into two groups of 5 to 7. At the start of each treatment, the experimenter read the instructions aloud as subjects read along. In the end of the instruction and before actual decisions were made, some quiz questions were given to control subjects' understanding. Each treatment has 15 decision periods. In each period, subjects were randomly matched into one of the two groups and were assigned induced values for each unit as described in Section 4.1. Then they submitted their bids to each unit simultaneously. At the end of each period, subjects were informed how many units are provided, and their per-unit payment, earnings, and assurance payment if any. At the end of a session, earnings were totaled across all periods.

Subjects were recruited through university-wide daily digest email server (mainly for undergraduates) and from an email list of students who expressed interests in participating in experiments at University of Connecticut. A total of 74 subjects participated in the six complete sessions, generating 3330 (=74*15*3) independent individual decisions with 19,980 (3330*6) individual level observations. The software z-Tree (Fischbacher, 2007) is used for the program.

Table 1 Treatment Arrangement of Experimental Sessions

Session	Treatment 1	Treatment 2	Treatment 3	Number of Subjects
1	A0	A1	A2	5*2
2	A1	A0	A3	6*2
3	A2	A3	A1	6*2
4	A3	A2	A0	7*2
5	A0	A4	A5	7*2
6	A0	A5	A4	6*2

5 Results

We compare the assurance payment schemes in terms of provision rate, group value revelation, and realized social surplus. In our setup, it is always socially optimal to provide the first three units, so the provision rate of each unit reflects the probability of an efficient decision being made. Group value revelation is important for non-market valuation studies. Realized social surplus measures the social efficiency by combining surpluses (or deficits) from both consumers and the producer.

Figure 1 gives an overview of group contributions (total bids) scaled (i.e., divided) by group size for each unit in each period by session. In Figure 1, two vertical dash lines separate the three treatments in each session. Different colors represent contributions on different units. A unit is provided if a scaled group contribution is greater than or equal to 10 which is highlighted by a black horizontal line in each panel of the figure. In Sessions 1 to 4 where the no assurance scheme A0 is paired with the partial assurance ones A1 to A3 with assurance on the first three units, their main differences in contributions are on the first three units, since the contributions for the last three units are almost all below the provision point. In Sessions 5 to 6 where A0 is paired with the conditional assurance schemes A4 and A5, their differences show up on all units. In addition, the contributions are generally stabilized after 5 periods, so we focus on the last 10 periods in the following analysis.

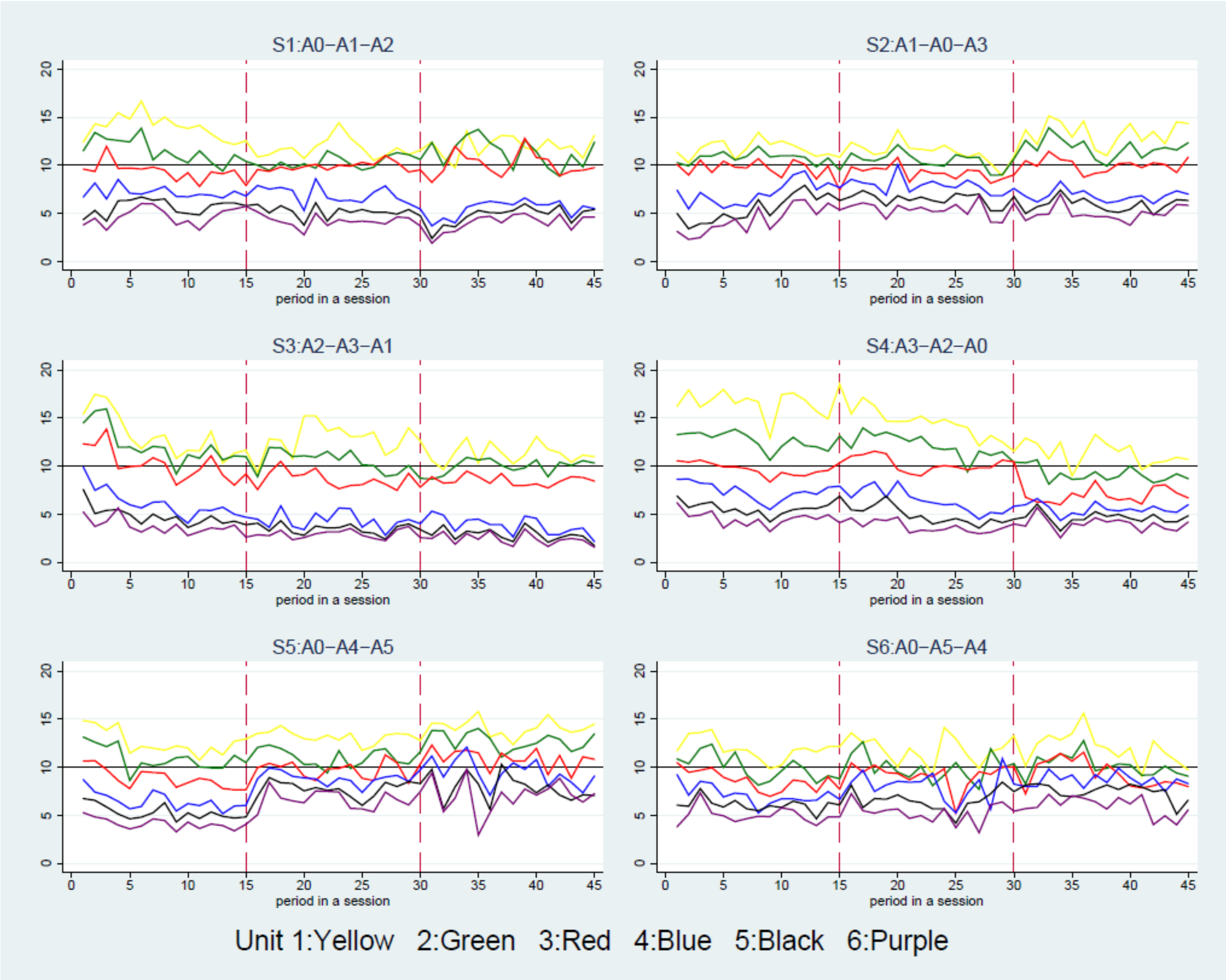

Figure 1. Group Contribution/*N* for Each Unit by Session

4.1 Provision (Success) Rate for Each Unit

Figure 2 shows the ex post provision rate for each unit by assurance scheme.[4] Provision rate decreases over units. Without assurance, provision rate drops quickly from 0.80 at Unit 1 to 0.13 at Unit 3 and close to zero thereafter. With assurance, provision rate decreases slower for higher assurance payment (A2 and A3 at Units 2 and 3) and stays positive longer for conditional (full) assurance payment (A4 and A5 at Units 4 and 5). Since the expected total induced values are

[4] Ex post here means that if it is not efficient to provide a unit given the realized total induced value, we will exclude that observation when calculating the provision rate. In our data, this happens only for Units 5 (15 out of 720 observations) and 6 (340 out of 720 observations).

equal to the provision point at Unit 6, Unit 6 is never provided in any schemes. Corresponding to our conjectures, we have the following observations.

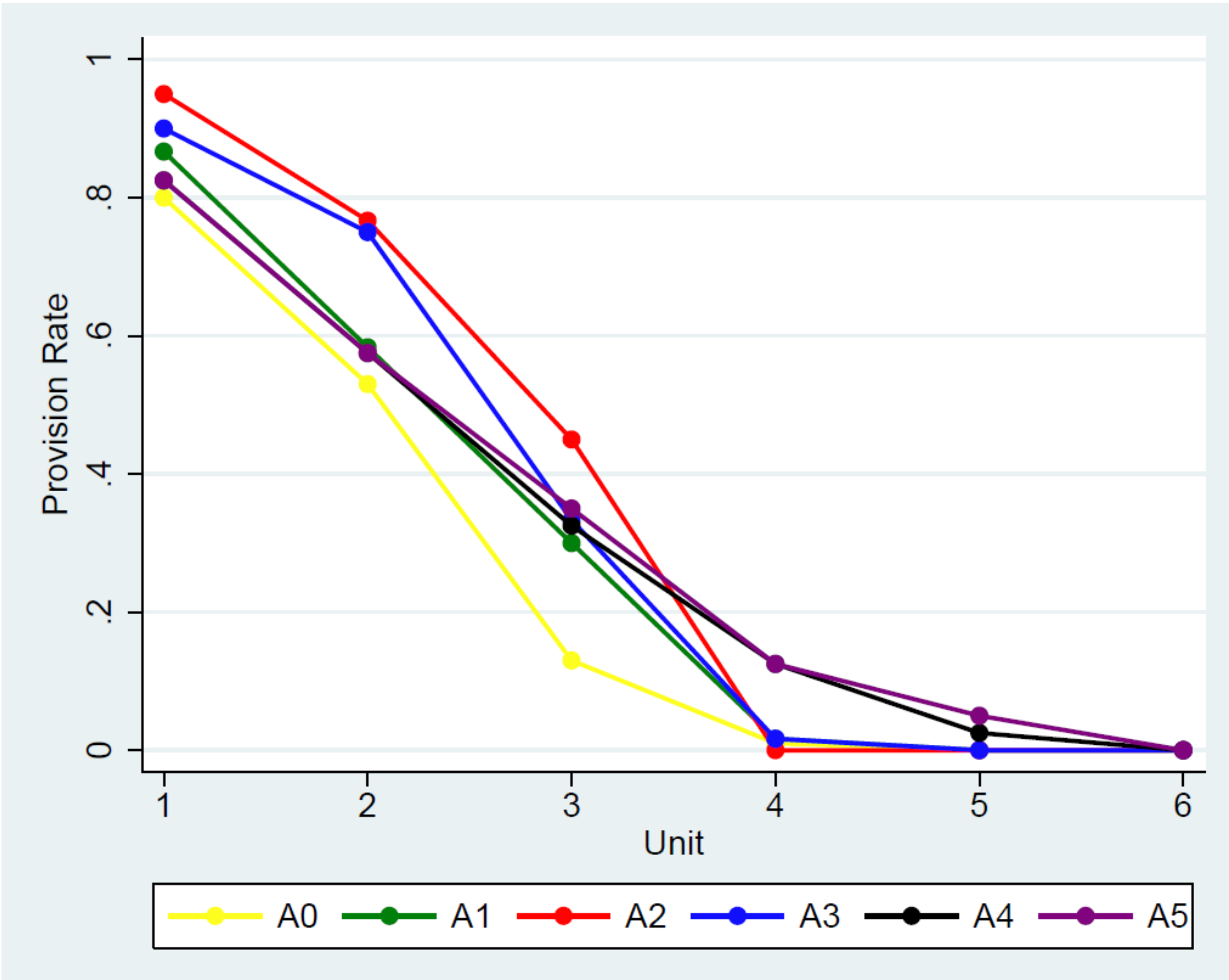

Figure 2. Provision Rate for Each Unit by Assurance Scheme

Observation 1 Provision rates are improved at all units with assurance payment, especially at units greater than 2.

The no assurance scheme A0 has the lowest provision rates at all units but Unit 4, from 0.80, 0.53, 0.13, to 0.01 for Units 1 to 4, and 0 for the last two units. The partial assurance scheme A2 with an assurance payment 14 on the first three units has the highest provision rates 0.95, 0.77, and 0.45 for the first three units. The conditional assurance scheme A5 with an assurance payment 14 for the first unit not provided has the highest provision rates for Units 4 and 5, which are 0.13 and 0.05 respectively.

To test **Conjecture 1**, we use the test of proportions to compare A1-A5 with A0 for each unit. Assurance works the best at the unit where the provision rate without assurance drops dramatically: At Unit 3 where the provision rate of A0 drops from 0.53 to 0.13, A1 to A5 are all significantly higher than A0 all with $p<0.01$. Partial assurance scheme with medium and high payments induces higher provision rates even for the first two units assured: At Units 1 and 2, A2 and A3 have significantly higher provision rates than A0 (p=.0088 and .0969 at Unit 1; p=.0028 and .0057 at Unit 2). Conditional assurance scheme generates higher provision rates at units beyond partially assured: At Unit 4, A4 and A5 are significantly higher than A0 both with p=.0024; at Unit 5, A5 is significantly higher with p=.0265.

Observation 2 In the partial assurance schemes, the level of assurance payment matters in some cases; in our setup, the medium assurance payment results in the highest provision rate. In the conditional assurance schemes, medium and low assurance payments result in similar provision rates.

In **Conjecture 2**, we expect that there is no significant difference between any pair of A1 to A3. However, the medium assurance payment results in the highest provision rate in the partial assurance schemes: A2 has significantly higher provision rates than A1 at Units 1 to 3 (p=.0568 one-tailed, .0320 and .0897 two-tailed); A3 with an assurance payment 14 on Unit 2 is significantly higher than A0 at Unit 2 as well (p=.0528); A2 is also higher than A3 at Unit 3 where the assurance payment in A3 is 10, although the difference is not significant (p=.1905). The reason may be that a relatively higher assurance payment is more robust to deviations below the minimum payment: With an assurance payment of 10, one deviation below 10 may result in non-provision if the others bid just 10; while with a medium assurance 14, fewer bids at or above 14 are needed to provide a unit. A much higher assurance may not perform better than a medium one at a provision rate level that is already quite high (such as 0.9 at Unit 1), which may explain why A2 and A3 are not significantly different at Unit 1.

Different from the partial assurance scheme, medium and low assurance payments result in similar provision rates at all units in the conditional assurance scheme. The difference between partial and conditional schemes may be due to different equilibrium selections. The partial assurance on a fixed number of units may be closer to the case of two-unit IPA with assurance only on the first unit, while the conditional assurance may be closer to that on each unit. And hence the former has the advantage of providing the first three units, while the latter in some sense spreads out the equilibria over all units. Additionally, for Units 4 and 5, since the realized induced values were almost all greater than 10, it is expected that A4 and A5 have similar provision rates, which does not contradict **Conjecture 3**.

Observation 3 Provision rate is sensitive to the existence of assurance payment.
Partial assurance schemes A1-A3 do not cover Units 4 and 5 where they all have provision rates as close to zero as does A0, while conditional assurance schemes A4 and A5 potentially cover every unit and hence they both have a significantly higher provision rate than A0-A3 at Unit 4 with both $p<0.05$, and A5 is also significantly higher than A0 ($p=.0265$) and A1-A3 all with $p<0.09$.

4.2 Group Value Revelation for Each Unit

To further understand the patterns of provision rate across assurance payment schemes, we investigate the group value revelation for each unit. Figure 3 shows the ex post group value revelation (group contributions divided by realized group induced values) for each unit by assurance scheme. Without assurance, group value revelation decreases linearly from 0.59 (Unit 1) to 0.52 (Unit 3), and stays around 0.46 for Units 4 to 6. With assurance, group value revelation varies with the level of assurance payment. With constant assurance, group value revelations are stable at units with the same assurance payment, for example, at Units 1 to 3 under A1 and A2, and at all units under A4 and A5. This group value revelation pattern is useful to explain the observed patterns of provision rates. Since the total induced values decrease with the unit number and the unit cost is constant, a constant group value revelation results in a decreasing provision rate over unit as in A4 and A5, and a decreasing group value revelation results in the provision rate decreasing even faster over unit in A0 than in A1 to A5.

With decreasing assurance, group revelation decreases significantly: Under A3 with high (18), medium (14), and low (10) assurance payments respectively at Units 1 to 3, group revelations decrease from 0.72 at Unit 1 to 0.63 at Unit 2, and 0.58 at Unit 3. At the same unit, the previous argument holds across assurance schemes: At Unit 1, group revelation is higher under A3 with a high assurance 18 than A2 and A5 with 14 which both are slightly higher than A1 with 10. At the extreme, since A1 to A3 have no assurance payment at Units 4 to 6, group revelations drop from around 0.6 at Unit 3 to around 0.4 at Units 4 to 6.

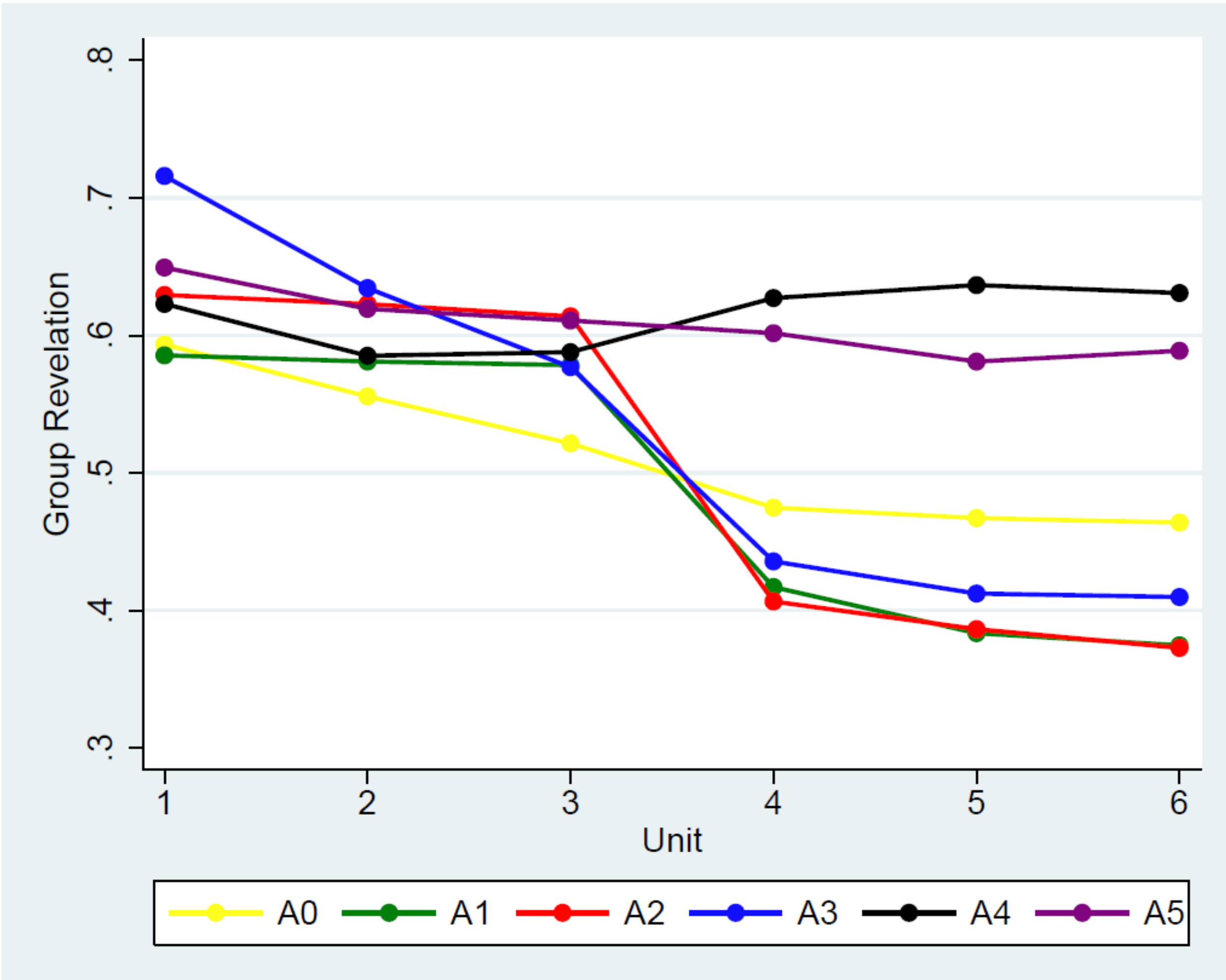

Figure 3. Group Revelation for Each Unit by Assurance Scheme

To test statistically how group value revelations vary with assurance payment and assurance schemes, we run a 2-factor (group- and period-specific) random effects regression for each unit, focusing on the observations from the last 10 periods as shown in Table 2.[5] At each unit, A0 is the baseline scheme, then dummies for assurance payments 10, 14, and 18 if any are added, where the conditional assurance schemes are the default and the dummies for the partial assurance schemes are interacted with the assurance payment dummies to identify the difference

[5] We exclude the observations from the first five periods to isolate potential mechanism-learning or order effects in the early periods.

between conditional and partial assurance schemes. We have the following observations which are generally consistent with the observations of provision rate.

Table 2 Two-factor Random Effects Models of Group Value Revelation for Each Unit

Group Value Revelation	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
AP10 (A4)	0.0373*	0.0332**	0.0696***	0.167***	0.179***	0.189***
	(0.0197)	(0.0169)	(0.0159)	(0.0213)	(0.0205)	(0.0242)
AP10*A1	-0.0244	0.000917	-0.00725			
	(0.0251)	(0.0214)	(0.0204)			
AP14 (A5)	0.0638***	0.0673***	0.0925***	0.141***	0.123***	0.147***
	(0.0197)	(0.0169)	(0.0159)	(0.0213)	(0.0205)	(0.0242)
AP14*A2	-0.0331	0.0103	0.0220			
	(0.0251)	(0.0214)	(0.0204)			
AP18 (A3)	0.137***					
	(0.0171)					
AP14*A3		0.0214				
		(0.0214)				
AP10*A3			0.00828			
			(0.0204)			
A1				-0.0321*	-0.0616***	-0.0826***
				(0.0185)	(0.0178)	(0.0210)
A2				-0.0144	-0.0205	-0.0426**
				(0.0185)	(0.0178)	(0.0210)
A3				-0.00104	-0.0115	-0.0189
				(0.0185)	(0.0178)	(0.0210)
Constant (A0)	0.587***	0.550***	0.512***	0.452***	0.444***	0.444***
	(0.0178)	(0.0143)	(0.0151)	(0.0260)	(0.0274)	(0.0283)
Log-likelihood	228.1	255.0	268.2	216.7	224.1	194.3
Chi-square	84.98	57.90	101.8	76.46	95.48	88.19
R^2 overall	0.251	0.183	0.230	0.405	0.453	0.431
Number of Observations	180	180	180	180	180	180
Number of Periods	10	10	10	10	10	10

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1;
AP10, AP14 and AP18 denote dummies for assurance payments of 10, 14 and 18, respectively; A0 to A5 are assurance scheme dummies; the variables in the parentheses are the baseline schemes.

Observation 4 Assurance payment significantly increases group value revelations at all units. At Units 1 to 3, all assurance payment schemes results in higher group value revelation than A0 with a significance level of at least 0.1, except for A1 at Unit 1. At Units 4 to 5, A4 and A5 are not only statistically but also economically higher than A0 both with $p<0.01$.

Observation 5 At Units 1 to 3, a higher assurance payment results in a higher group value revelation; at Units 4 to 6, the relationship switches.

At Unit 1, an assurance payment 18 generates significantly ($p<0.01$) higher group value revelation than 14 and 10; at Units 2 and 3, an assurance payment 14 generates significantly higher group value revelation than 10 with *p*=0.054 (two-tailed) and 0.082 (one-tailed). At Units 4 to 6, however, an assurance payment 10 has higher group value revelations than 14 with *p*=.241, .008, and .089 for Units 4 to 6 respectively. This group value revelation pattern is consistent with Observation 2 for provision rate.

Observation 6 At each unit, group value revelations are similar across assurance schemes with the same assurance payment.

This observation is supported by the fact that all the interaction terms between assurance payment level and assurance scheme are not significant. Only a few exceptions exist at Units 4 to 6 when there is no assurance payment. At Units 4 to 6, although A1 to A3 all have zero assurance payment, they generally induce lower group revelation than A0, and the differences are significant for A1 at Units 4 to 6 and A2 at Unit 6. The reason may be that the assurance payments on the first three units discourage the value revelation on the last three units that are not assured. **Observations 5** and **6** together highlight the key role of assurance payment in value revelation.

4.3 Social Efficiency and Surplus Allocation

So far, the results from assurance payment in terms of provision rate and group value revelation are quite promising, which supports our expectation of the advantage of assurance payment. It seems that a sufficiently high assurance payment may improve both provision rate and value revelation significantly. However, if the provision rate is not 100%, the assurance payment indeed has to be paid by the producer for the first unit assured but not provided. Although the actually assurance paid is simply a *surplus transfer* from the producer to consumers from a societal perspective, this transfer could be costly and inconvenient in reality and hence disadvantages the assurance payment scheme. In this section, we summarize the experimental results from the social planner's perspective; particularly we are interested in the realized social surplus, as well as its allocation between consumers and the producer, which will give us an aggregate comparison of the assurance payment schemes, including the effect of assurance transfer.

Table 3 Realized Average Social Surplus and Its Allocation*

Treatment	Potential Maximum Social Surplus	Realized Consumer Surplus	Realized Producer Surplus	Realized Social Surplus
A0	100	39	5	44
A1	100	61	-11	50
A2	100	62	1	63
A3	100	64	-6	58
A4	100	70	-17	53
A5	100	60	-8	52

*: The numbers are essentially in percentage, which is based on a maximum social surplus assumed to be 100.

Table 3 shows the realized social surplus and its allocation between consumers and the producer. The potential maximum social surplus equals the sum of the realized induced values of all units minus the total provision cost; the realized social surplus equals the sum of values on each unit provided minus the total cost for providing these units; the consumers' surplus equals the sum of values on each unit provided minus their contributions, and *plus* assurance payment if any; the producer's surplus equals consumer' contributions *minus* the provision cost and the assurance payment if any, or equivalently the realized social surplus minus consumers' surplus. Since the realized maximum social surplus varies across treatments and the group size varies across sessions, we scaled the individual-averaged realized maximum surplus to 100, and proportionally adjusted the surpluses in the other categories. By rank-sum tests, we have the following observations.

Observation 7 All assurance schemes improve the realized consumer surplus significantly.
In Table 3, A1 to A5 all have higher realized consumer surpluses than A0, which are all significant with $p<.001$ by rank sum test. A4, the conditional scheme with an assurance payment of 10 results in the highest consumer surplus 70 compared to 39 of A0, which is consistent with that A4 has a higher provision rate at Unit 4.

Observation 8 All assurance schemes result in a significantly lower realized producer surplus than A0; all but A2 have a negative producer surplus.
A0 has the highest realized producer surplus 5, which is significantly higher than those from A1 to A5 all with $p<.001$. This makes sense since all the assurance schemes involve the assurance payment, which can be considered as the cost to improve the realized consumer and hence

societal surplus. It is worth noting that in A2, the producer still sustains a positive surplus, indicating that A2 is the least costly assurance scheme on average.

Observation 9 All assurance schemes improve realized social surplus; A2 with an assurance payment 14 on the first three units has the highest realized social surplus, which is significantly higher than that in A0.

In Table 3, A1 to A5 all have higher realized social surpluses than A0, in which A2, A3, and A4 are significantly higher with p<.0001, p=.0069 and .092, respectively. Although A2 does not have a consumer surplus as high as A3 or A4, A2 involves a relatively smaller assurance payment and hence a much higher producer surplus than A3 and A4. Therefore, on aggregate, A2 stands out as the best assurance scheme in our tested schemes, which has the highest social surplus level. This result may imply the existence of an optimal assurance scheme resulting in the highest efficiency gain with the lowest assurance payment.

6 Conclusions

This paper builds on the assurance contract idea introduced by Tabarrok (1998) and develops an assurance payment hopefully to improve the public good provision compared to the traditional threshold public good game. Both theoretically and experimentally, we examine a set of assurance payment schemes for multiple-unit public good provision using the individualized price auction (IPA) mechanism, and seek to establish whether an assurance payment generally makes a significant improvement on public good provision, and if so, which scheme is better. We first characterize the Nash equilibira of one- and two-unit IPA with and without assurance payment. Then we design 6 treatments of assurance payment schemes and run lab experiments to test the effects of the existence, the level, and the completeness of assurance payment on provision rate, group value revelation, and the social efficiency. The key message is that assurance payment works in the expected directions in our setup.

Assurance payment significantly eliminates non-provision equilibria, and reduces the multiplicity of provision equilibria suffered by most discrete public good provision games, especially in a multi-unit setup. This theoretical advantage is supported by our lab experiment results: A positive assurance payment always performs better than no assurance in all the measures of provision rate, group value revelation, and realized social surplus. Nonetheless, it is possible for the producer to incur a deficit if the assurance scheme is not chosen properly, though the total social surplus can still be higher using assurance payment.

Furthermore, the level and the completeness of the assurance payment do matter. In our setup of a maximum of 6 units of discrete public good available and the last unit with a zero net gain from provision, a higher assurance payment generally generates higher provision rates and group value revelations at the first three units under the partial assurance schemes with assurance on the first three units, but this cannot be generalized to the conditional schemes for the last three units. Partial and conditional schemes seem to work differently: A sufficiently high assurance payment on the first three units generally performs better at those three units than a conditional scheme with the same assurance payment, although the conditional scheme induces higher provision rates and group revelations in the last three units. The tradeoff between the number of units covered and the provision rate at each unit implies that we may choose different schemes based on different goals.

The inconsistent results between partial and conditional assurance schemes indicate some future research directions. Recall that in out setup, a partial scheme with a medium assurance payment results in the highest social surplus. Then the questions would be how to choose the most efficient assurance payment level and the number of units covered, and whether these parameters can be determined in theory. Experiments designed specifically to answer these questions would be helpful as well.

Lastly, our results have two important policy implications. First, the provision-point based mechanism with assurance payment provides a powerful tool for non-marker valuation, since the assurance payment could significantly reduce the free-riding incentive and induce a more accurate preference measure. Second, it may provide a feasible framework to establish a decentralized ecosystem service market, backed by a relatively high provision rate, which can be further optimized by flexible payment schemes. This is especially true if we are in a market lack of valuation information, in which multiple rounds of assurance payment contract would reveal much of the information and improve the contract design with the development of the market.

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