Supporting Private Provision of Ecosystem Services Through Assurance Contracts in Environmental Markets: Evidence from Lab and Pilot Field Experiments

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January 1, 2020

Abstract

The free riding incentive that exists in public good provision has been a major obstacle to establishing markets or payment incentives for environmental public goods, such as ecosystem services. The use of monetary incentives to induce private provision of public goods has gained increasing support, including from the USDA Office of Environmental Markets, to help to market ecosystem services provided by alternative farmland management practices. Using a series of lab experiments and a pilot field experiment, we explore new ways to raise money from individuals to pay farmers for alternative management practices. In our proposed mechanisms, individuals receive an assurance contract that offers qualified contributors an assurance payment as compensation in the event that total contributions fail to achieve the threshold needed to fund the public good. Contributors qualify by contracting to support provision with a minimum contribution. Our public good involves delaying the harvest of a ten-acre hayfield to allow grassland birds to nest successfully. Evidence from lab experiments shows that the provision probability, consumer surplus, and social welfare significantly increase when the assurance contract is present. Consistent with the theory and the lab experiment, we show that the individual contribution is determined by the value range and the assurance payment level in the pilot field experiment. Our

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proximate motivation is to support wildlife habitats provided by farmland, but our approach contributes to the private provision of ecosystem services and other types of environmental public goods.

Keywords: Assurance Payments, Threshold Public Goods Provision, Ecosystem Services, Lab Experiment, Field Experiment
JEL: Q56, Q57, C72

1 Introduction

In the last fifteen to twenty years, and particularly in the U.S. since the 2008 Farm Bill created the USDA Office of Environmental Markets, environmental policy development has increasingly focused on market-based approaches to the provision of ecosystem services (MEA, 2005; Gómez-Baggethun et al., 2010). Historically, changes in ecosystem services often involved non-market goods, either related to negative or positive externalities, such as excess nutrients discharged to rivers by the point or non-point sources and public goods such as wildlife habitat enhanced or degraded by some agricultural practices. Social institutions and governments have addressed these externalities through command and control regulation, philanthropic or conservation efforts, government payment for ecosystem services (PES), and, increasingly, through market-based approaches such as regulatory-driven cap-and-trade systems (Ferraro, 2008, 2011; Schomers and Matzdorf, 2013). These market-based approaches provide the potential to unleash the cost efficiencies of market incentives to achieve desired environmental outcomes. However, cap-and-trade approaches generally establish a demand for, say, discharge permits by stimulating pollution-regulated parties (firms) to be compliance-buyers. These approaches do not primarily engage the general citizen, although unregulated individuals may voluntarily enter the markets.[1]

Our research addresses the demand side and contributes to understanding alternative mechanisms to engage individuals who value ecosystem services to enter markets or market-like exchanges. While the willingness to pay (WTP) for nature's benefits constitutes a foundation for regulatory, PES, and philanthropic approaches, we contribute to a

[1] For example, websites exist where individuals may buy carbon offsets for personal travel. The ecosystemmarketplace.com provides an overview of alternatives, and a Google inquiry uncovers numerous alternatives (e.g., https://www.terrapass.com).

growing body of effort that strives to improve methods for capturing at least some share of a willingness to pay as revenues that may support private provision of public goods from ecosystem services (Banerjee et al., 2013; Li et al., 2016; Swallow and Liu, 2017; Swallow et al., 2018; Liu and Swallow, 2019). In particular, we focus attention on mechanisms to fund threshold-level public goods, which draws on the literature from charitable giving. Poe et al. (2002) and Rose et al. (2002) provide nice reviews of experimental economics evaluations of threshold-level public goods, for which a provider establishes a provision point defined as a minimum level of funding required to deliver a unit of the public good.

Many conservation-oriented public goods are provided by philanthropic organizations, including bird conservation groups or land trusts. These organizations explicitly solicit donations, but generally for an open-ended purpose, often for the general support of the organization's mission. Even when particular projects or initiatives are the focus of fundraising, common philanthropic practice leads donors to expect that contributions may be redirected broadly within the mission. In contrast, we intend a more market-like approach that connects donations (contributions or purchases) directly to a specific good or service being delivered. For example, funds raised to support a 10-acre field of a bird nesting habitat would only be spent for that purpose; if fundraising fails to reach the provision point, any contributions would be refunded, establishing a money-back guarantee (MBG) in the event of non-provision. In particular, our approach strives to maintain a direct connection between contribution and the goods being delivered, just as markets for private goods connect the payment to units delivered. Unlike markets for private goods, a challenge here is the coordination problem to bring multiple contributors together to simultaneously support a unit of the public good.

Since Bagnoli and Lipman (1989), provision point mechanisms (PPMs) have been well studied, and the money-back guarantee has been associated with increasing contributions relative to the baseline of a more open-ended solicitation for donations (Rondeau et al., 1999, 2005; Poe et al., 2002; Rose et al., 2002). Many of these studies have involved the provision of a single unit, but for a more market-like approach to evolve, we seek a method capable of delivering multiple units. Unfortunately, experimental work has shown that games with multiple units of the public good can yield a multiplicity of equilibria and realize an even a lower percentage of realizable social surplus (Bagnoli et al., 1992). While the MBG reduces the incentive to free ride, it does not necessarily lead to participation or donation consistent with individuals' marginal WTP. For the provision of a single unit, researchers have considered various forms of a rebate of any funds raised over the provision point (Marks and Croson, 1998; Spencer et al., 2009; Li et al., 2016; Liu et al., 2016), showing that rebates also reduce incentives to free-ride or cheap-ride, leading to increases in the rate of provision.[2] Rebates eliminate the possibility that a provider retains surplus generated by the generosity of donations made over the provision point.

This literature has also shown, however, that the provision point, with or without rebates, cannot consistently eliminate free-rider or non-provision equilibria without strong equilibrium refinements (Bagnoli and Lipman, 1989; Bagnoli et al., 1992), particularly in a multi-unit public good setting (Bagnoli et al., 1992). Of course, if the challenges were simple, the public goods problem would have already been settled through the use of, for example, incentive-compatible mechanisms; unfortunately, such mechanisms are usually not budget-balancing and sometimes too difficult for novices to grasp (Clarke, 1971; Groves, 1973; Ledyard, 1995; Attiyeh et al., 2000; Kawagoe and Mori, 2001). Alternatively, some studies have evaluated the potential to use penalties for individuals identified as free-riders or cheap-riders (Falkinger et al., 2000; Masclet et al., 2003). Here, we examine an alternative approach that rewards individuals who commit to contributing to the provision of the public good.

We begin from Tabarrok (1998)'s concept of a dominant assurance contract under which would-be donors, who agree to a pre-specified, minimum contribution, qualify to receive an assurance payment from the market-maker (or the provider of the public good) in the event that fundraising fails to achieve a provision point for a unit of the good. For example, if an individual agrees to donate \$40 or more toward the provision of a unit, but the effort fails to meet the provision point, under that individual's contract the market-maker issues an assurance payment of \$40 in addition to refunding the \$40 donations. Tabarrok (1998) shows that the assurance contact can successfully eliminate the non-provision equilibria when the contribution decision is binary and shows that contributing to the public good becomes a dominant strategy with complete information, at least for a single unit. The key idea is to encourage commitments to pay for the public good provision by offering com-

[2]Here, free-riding occurs when an individual expresses a positive Hicksian willingness to pay (WTP) for a good but does not contribute to provision (zero contribution), while cheap-riding implies this person contributes a non-zero amount to provision but their contribution falls well short of reflecting their Hicksian WTP, at least at the margin.

pensation (an assurance payment) to would-be contributors if, in the end, the group fails to provide the public good. The assurance contract mechanism tries to achieve efficient provision by rewarding committed donors rather than penalizing free or cheap riders. This potentially powerful, but still theoretical, idea has not been well tested experimentally for the public good provision, which motivates this paper. Recently, based on a similar idea in Tabarrok (1998), Zubrickas (2014) and Cason and Zubrickas (2017) discuss a mechanism called PPM with refund bonus in theory and lab experiments, respectively. However, their design is different from ours and they find in general no significant improvements for their mechanism over PPM except for some special environments and experiment periods.[3]

In our laboratory experiment, we expand the assurance contract to address the multi-unit context. We view this as a step toward a market that is open to many providers, i.e., many farms providing hayfields with a single market-maker. Theoretically, we show that the assurance contract eliminates the non-provision equilibrium under certain circumstances. Our results suggest there may be a potential to identify criteria for an optimal assurance payment contract that, overall, enhances the potential for efficient or Pareto improving outcomes. We show that a positive assurance payment always out-performs the baseline without an assurance payment, using criteria such as the rate of provision, the revelation of the group's value, and realized social surplus. However, it remains possible that the provider incurs a deficit if the assurance contract inadvertently leads to frequent non-provision. We follow up on the lab experiments with a discussion of our experience in implementing the assurance contract for a single-unit field experiment to provide a real hayfield to support bobolinks. The experience suggests that future research will require careful consideration of factors affecting participation rates, as well as contributions made by individuals who do respond to a solicitation for donations. While our sample size, in the discussion for a field experiment, is too small to draw definitive conclusions, there are indications that the direction of effect for the assurance payment is encouraging and suggest that future research is needed to enable market-makers to optimize the assurance contract as a tool for practical success.

Before the remainder of the paper presents the theoretical discussion, the laboratory results, and a discussion of a pilot field experiment in successive sections, one note is

[3] Also, in a working paper by Li and Liu (2019), results show that the assurance payment can increase provision rate by about 45% under certain condition for a single unit.

appropriate regarding the potential that an assurance contract scheme may require outside funds to back-up the liability of making assurance payments. We view this need for outside funds as different than, but analogous to, the concept of challenge grants or matching funds already used by philanthropic institutions or some government-managed PES systems. Matching funds have produced mixed results about charitable giving, requiring a balance between stimulating participation and donation while offsetting effects of crowding-out donations partially or wholly for some individuals (List and Lucking-Reiley, 2002; List, 2011). We suggest that one can view the assurance payment fund as an alternative form of a challenge grant, whereby an interested patron offers to pay committed, would-be donors to pursue provision under specified criteria, while the patron's funds have incentivized the donors. From the perspective of government, the assurance payment fund could be identified as a form of subsidy that is only committed in the event private donations meet specified criteria.

2 The Baseline Mechanism and Assurance Payment Schemes

Assume there are N individuals who are asked to support J units of public goods with a constant marginal (per unit) cost C through voluntary contributions. Each individual is indexed by $i \in \mathcal{I} \equiv \{1, ..., N\}$ and each unit of the public goods is indexed by $j \in \mathcal{J} \equiv \{1, ..., J\}$. Individuals are asked to contribute toward each unit of the public goods simultaneously. Let v_i^j and b_i^j be individual i's value and contribution toward unit j, respectively. The total contributions on unit j are $B^j = \sum_i b_i^j$.

2.1 Multi-Unit Public Goods Provision without Assurance Payment

The baseline mechanism is a uniform price (UP) mechanism in a multi-unit setting where an individual pays for the same price for all units provided (Liu and Swallow (2019)). In the UP mechanism, we compare the total contributions from all individuals on each unit with the unit cost of the public good, starting from unit 1. If individuals' total contributions to the first unit are greater than or equal to the cost of unit 1, we move on to the second unit, and so on. This process continues until the total contributions for a unit are less than the unit cost or all available units are provided. For example, if the total contributions on the first, second and third units are all greater than the unit cost, but the total contributions on the fourth unit are less than the unit cost, then only the first three units will be provided. Thus, the market-clearing rule of the number of units provided in UP can be expressed as

$$g = \begin{cases} 0 & if \quad \sum_i b_i^1 < C \\ j & if \quad \sum_i b_i^m \geq C, \, \forall m \leq j \in \{1, ..., J-1\}, \; and \, B^{j+1} < C, \\ J & if \quad \sum_i b_i^m \geq C, \, \forall m. \end{cases} \tag{1}$$

Note that, to provide j units, the total offer on each of the first j units must be at or above the unit cost; otherwise, the process will stop for the first time when the total offer of a unit falls below the cost.

A pricing rule determines how much each individual has to pay in total. In UP, an individual pays the same price for all the units provided, and the price equals one's contribution to the last unit that the group can collectively provide. The pricing rule is given by

$$t_i = \begin{cases} 0 & if \quad g = 0 \\ j * b_i^j & if \quad g = j. \end{cases} \tag{2}$$

Thus, the payoff function π_i for individual i in UP is

$$\pi_i = \begin{cases} 0 & if \quad g = 0 \\ \sum_{j=1}^{g} v_i^j - t_i. & if \quad g = j. \end{cases} \tag{3}$$

2.2 Assurance Payment Schemes

An assurance payment is a predetermined compensation to whoever contributes at or above a pre-specified minimum offer when the provision fails.[4] For example, assume the assurance payment is $10 on the first unit. If the total group contributions are below the cost of the first unit, that is, nothing will be provided in this case, then whoever contributes $10 or above on the first unit will receive an assurance payment of $10, in addition to a full refund of their original contributions (i.e., with money-back guarantee). Those who contribute less than $10 will only receive their refunds but no assurance payment.

[4]As a first step, the assurance payment is set to be equal to the minimum offer in our lab experiment.

The original assurance contract in Tabarrok (1998) includes a binary contribution choice and specifies the number of individuals required to accept the contract to provide the good. In this paper, we allow for continuous contributions in a threshold public good setting with the minimum offer for an assurance payment set to be equal to the assurance payment compensation. Specifically, let AP^j denote the assurance payment for unit j, then the payoff function for individual i is

$$\pi_i = \begin{cases} 0 & if\ b_i^1 < AP^1\ and\ g = 0; \\ AP^1 & if\ b_i^1 \geq AP^1\ and\ g = 0; \\ \sum_{l=1}^{j} v_i^l - t & if\ b_i^{j+1} < AP^{j+1}\ and\ j \in \{1, ..., J-1\}; \\ \sum_{l=1}^{j} v_i^l - t + AP^{j+1} & if\ b_i^{j+1} \geq AP^{j+1}\ and\ j \in \{1, ..., J-1\}; \\ \sum_{l=1}^{J} v_i^l - t & if\ j = J; \end{cases} \tag{4}$$

Note that the assurance payment applies if only if one's contribution is at the minimum offer level or above on the first unit that fails to be provided. In the next section, we describe a series of assurance payment schemes and use lab experiments to investigate the conditions for a potentially optimal assurance contract.

3 Lab Experiments

3.1 Experimental Design and Implementation

In the lab experiment, a maximum of 6 units of a public good is available. Individuals' induced values for the public good follow a linear, decreasing marginal (per unit) benefit function. The induced values for unit 1 and unit 6 are randomly drawn from two uniform distributions over [15, 25] and [5, 15], respectively. The induced values for units 2 through 5 are interpolated linearly based on values on units 1 and 6. The average cost for each unit is set as 10, and hence the provision cost 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 designed the following six treatments: (1) the no assurance baseline, or the treatment $Base$; (2) the same assurance payment 10 for the first three units only, or the treatment

$P10$; (3) the same assurance payment 14 for the first three units only, or the treatment $P14$; (4) decreasing assurance payments 18, 14, and 10 for the first three units, respectively, or the treatment PDe; (5) the same assurance payment 10 for all six units, or the treatment $C10$; (6) the same assurance payment 14 for all six units, or the treatment $C14$. Treatments $P10$, $P14$, and PDe are partial assurance schemes, while $C10$ and $C14$ are conditional assurance schemes as all six units are potentially covered by the assurance payment up to the first unit that fails to be provided.

We conducted two phases of lab experiments on networked computer terminals, with phase 1 including the conditional assurance treatments and phase 2 including the partial assurance treatments (Table 1). The experiment was conducted with students from a major public university in the Northeast U.S. Each session has 10 to 14 subjects in total, split evenly into two groups of 5 to 7, with a small variation due to subjects failing to show up. At the start of each treatment, the experimenter read the instructions aloud as subjects read along. At the end of the instruction and before decisions were made, quiz questions were given to assess subjects' understanding. Each treatment had 15 decision periods. In each period, subjects were randomly matched into one of the two groups to mimic the one-shot game environment and were assigned induced values for each unit as described above.[5] Then they submitted contributions to each unit in a decision period. At the end of each period, subjects were informed how many units were provided, their per-unit payment, earnings, and assurance payments if any.

At the end of a session, earnings were summed up over all periods. The average earning were about $24 with an average time length of 75 minutes. Subjects were recruited through university-wide daily digest email server and from an email list of students who expressed interest in participating in experiments. Our experiment data contains 3330 (=222*15) individual-period level decisions with 19,980 (=3330*6) individual-unit-period level observations. The software z-Tree was used for the program.

3.2 Theoretical Remarks

Our experiment was designed to mimic the real-world scenarios where multiple units of a public good may need to be provided. We focus on the provision success rate and

[5]See Appendix D for sample experimental instructions.

the group value revelation. The provision rate for each unit measures the probability of an efficient decision being made. We look at the provision success when the realized group total values are at or above the provision cost. The group value revelation for each unit is the ratio of group total contributions to the realized group induced values, which represents the demand revelation and is an important measure for non-market valuation studies.

Given our experimental design, the value distribution is determined by the value range in a uniform distribution on a certain value interval, and its relationship with cost C can be presented by the expected value-cost ratio (the expected group value divided by C). Table 2 shows the range and mean of induced values for each unit in the experiment. The expected value-cost ratios are 2, 1.8, 1.6, 1.4, 1.2, and 1 respectively for units 1 to 6 and are denoted as high for units 1 to 2, medium for units 3 to 4, and low for units 5 to 6.

The discussions in Appendix A provide useful theoretical insights. We construct the equilibrium conditions in a multi-unit provision setting with and without assurance contract, developed from Bagnoli and Lipman (1989), Tabarrok (1998), Liu and Swallow (2019), and Li and Liu (2019). Our theoretical analyses show that in a multi-unit setting, the assurance contract changes the equilibrium conditions due to the potential to receive assurance payment compared to no assurance. We find that the assurance contract also changes the upper bound and increases the lower bound of the group contribution in the equilibrium. Particularly, the group contribution is strictly higher than $C - AP_j$ on the jth unit in equilibrium while zero-group contribution in equilibrium when assurance is not available based on the Corollary 1 in the Appendix A.

Furthermore, for a given unit, we find only non-provision equilibria exist when AP is too low, both provision and non-provision equilibria exist when AP is sufficiently high, and only provision equilibria exist when AP is at an intermediate level such that the number of individuals with values at or above AP is greater than C/AP based on the Corollary 2 in the Appendix A. To ensure that the assurance contract performs better, the AP cannot be too low. Therefore, the minimum AP we used in the experiment is 10. We also use a higher level of AP=14 and AP=18. According to Table 2 and Corollary 2, the assurance payment level AP=10 satisfies the boundary condition when non-provision equilibria are eliminated for the first three units ($C/10 = N$), while $AP = 14$ satisfies provision-only equilibria condition for the first two units (when $C/14 < N$) and likely for the third unit[6]. When AP=18, the assurance payment may be too high and the number of individuals with induced values higher than 18 may be smaller than the minimum number to eliminate the non-provision equilibria when the value-cost ratio is low (e.g., at a higher unit). Therefore, we expect assurance payment treatments will outperform the no assurance baseline in general.

4 Experiment Results

In this section, we first compare the assurance payment schemes in terms of the provision rate and group value revelation. Then we analyze individual contribution behaviors. Lastly, we compare the assurance payment schemes according to the realized social surplus as well as the surpluses (or deficits) of consumers and the provider.

Figure 1 gives an overview of group value revelation in each period and five-period-moving-average provision rates, by by AP and unit. Grey lines represent session-specific group value revelations, dark black lines represent averages over sessions, green lines represent five-period moving average provision rates, and red lines indicate average cost-value ratios. [7]

4.1 Provision Success Rate for Each Unit

Figure 2 shows the provision rate for each unit by assurance scheme.[8] The provision rate decreases over units for all schemes from above 80% (unit 1) to 0 (unit 6) as the value-cost ratio decreases, but varies with the assurance payment level on each unit. We have

[6]When the group size is 5, as long as there are 4 subjects with induced value higher than 14, the non-provision equilibria will be eliminated. Our experimental data show that over 90% of the time the provision-only equilibria condition is satisfied when AP=14 for the third unit.

[7]Since the total group values vary with group size and the value realization and we are mainly interested in the effects of the level of AP, we use the ratio of group contributions to total realized group values, that is, the group value revelation, to normalize group contributions, and pool group value revelations based on the assurance payment level. The average ratio of provision cost to the realized group induced value pooling all treatments on each unit is used to provide a baseline comparable across AP levels.

[8]In our analyses, if it is not efficient to provide a unit given the total realized induced value, we will exclude that observation when calculating the provision rate. In our data, the condition where total realized induced value smaller than the cost happens only for units 5 (15 out of 720 observations, or 2.1%) and 6 (340 out of 720 observations 47.2%).

the following results to compare alternative assurance schemes in terms of provision rate.[9]

Result 1. *Assurance payments improve provision rate on units 1 to 5, where the value-cost ratios are greater than 1.*

First note that the no-assurance treatment $Base$ has the lowest provision rate over all units (the black line in Figure 2), while thhe assurance payment AP=14 generates the highest provision rate over all units. Specifically, treatment $P14$ has the highest provision rates of 0.95, 0.77, and 0.45 on the first three units, respectively. Treatment $C14$ has the highest provision rates 0.13 and 0.05 on units 4 and 5, respectively. For the treatment $Base$, the provision rates are 0.80, 0.53, 0.13, and 0.01 for units 1 to 4, and 0 for the last two units.

When the value-cost ratios are relatively high (2 and 1.8) as on units 1 and 2, the medium and high assurance payments improve provision rate significantly. The treatments $P14$ and PDe have significantly higher provision rates than the $Base$ treatment on the first two units (unit 1: 0.95 and 0.90 compared to 0.80, with $p = 0.0088$ and 0.0969; unit 2: 0.77 and 0.75 compared to 0.53 with $p = 0.0028$ and 0.0057).

With a medium value-cost ratio of 1.6 on unit 3, provision rates under all assurance treatments ($P10$, $P14$, PDe, $C10$ and $C14$) are significantly higher than that under the $Base$ treatment (0.58, 0.77, 0.75, 0.58 and 0.58 compared to 0.53, all with $p < 0.01$). Conditional assurance scheme generates higher provision rates on units beyond those only partially assured. On unit 4, provision rates under treatments $C10$ and $C14$ are significantly higher than $Base$ with $p = 0.0024$; on unit 5, $C14$ is significantly higher than $Base$ with $p = 0.0265$.

Note that the treatments $P10$ and $C10$ are not statistically different from $Base$ on units 1 and 2, indicating a drawback of a low AP on units with a high value-cost ratio. When individual values are all higher than the unit cost per capita, the assurance payment AP=10 imposes an upper bound of 10 on contributions for all individuals with v_i below 20 in equilibrium, which limits the capacity of high-value people (e.g., subjects with induced values above 10 but below 20) to offset the influence of individual contributions below 10.[10] For AP=14 and 18, the upper bound is at least 14 or 18, and hence $P14$ and PDe improve provision rates on units 1 and 2 while $P10$ and $C10$ do not. Furthermore, $P14$

[9] All the test statistics reported in this subsection are based on the test of proportions.

[10] On units 1 and 2, the value-cost ratios are relatively high (2 and 1.8) with the lowest induced value 15 and 13 on the first and second units, respectively. The unit cost per capita is 10.

has a significantly higher provision rate than $P10$ on units 2 and 3 ($p = 0.0320$ and 0.0897), and PDe with AP=14 on unit 2 is significantly higher than $P10$ on unit 2 ($p = 0.0528$); $P14$ has higher provision rates than $P10$ on unit 1 and PDe with AP=10 on unit 3, although not statistically significant ($p = 0.1137$ and 0.1905).

We summarize the additional observations above in the following result.

Result 2. *A medium or high assurance payment generally improves the provision rate compared to a low assurance payment. The effect of an assurance payment on the provision rate is the most significant at a medium level of value-cost ratio.*

4.2 Group Value Revelation for Each Unit

To understand the patterns of provision rates across assurance payment schemes, we further investigate the group value revelation rate (i.e., group contributions divided by realized group induced values) for each unit (Figure 3).

A higher assurance payment generally induces a higher group value revelation and the same assurance leads to similar group revelation rates across treatments. The treatment PDe on unit 1 has the highest assurance payment of AP=18, generating the highest group value revelation of 0.72, following which $P14$ on units 1 to 3, PDe on unit 2, and $C14$ on all units 1 to 6 have the same assurance payment of AP=14 and they generate a group revelation around 0.62.

Similarly, $P10$ on units 1 to 3, PDe on unit 3, and $C10$ on all six units have AP=10, resulting in a group revelation around 0.60. Under the treatment $Base$ with $AP = 0$, the group value revelation decreases from 0.59 (unit 1) to 0.56 (unit 2), 0.52 (unit 3) and stays around 0.47 on units 4 to 6, all lower than those with positive assurance payments. This pattern of group value revelation is consistent with the pattern of provision rate over units.

We run a two-factor (group and period-specific) random-effects regression of group value revelation on assurance payment level and treatment dummies for each unit based on data from the last 10 periods (Table 3).[11] The variable $Base$ is the baseline treatment,

[11] The two-factor random effects models are based on the following regression: $y_{it} = X_{it}\beta + \mu_i + v_i + \epsilon_{it}$, where y_{it} represents the group value revelation for group i in period t, with the two random effects denoted by μ_i and v_i, respectively, and X_{it} is a set of regressors including dummies for assurance payment levels and some interaction terms across treatments. The group value revelation of aggregating the two groups, that is, the ratio of the aggregated two-group contributions to the aggregated two-group induced values, is used in the regression to be consistent with the session-group specific effect, since group members are reshuffled

$AP10$, $AP14$, and $AP18$ are dummy variables that represent different assurance payment levels. The conditional assurance schemes are treated as the baselines and the dummies for the partial assurance schemes are interacted with the assurance payment dummies to identify the difference between conditional and partial assurance schemes. In Table 4, we also report results based on individual contributions. Regressions results show that assurance payments induce higher value revelations, consistent with the results of provision rate.

Result 3. *Assurance payments significantly increase group value revelations on all units.*

All assurance payment schemes lead to higher group value revelations on units 1 to 3 with a significance level of at least 0.01, except for $P10$ on unit 1. On units 4 to 5, $C10$ and $C14$ are statistically significant with $p < 0.01$ and increase the value revelations rate by about 12% to 19% compared to the $Base$ treatment.

Result 4. *Group value revelations are statistically indifferent across assurance schemes with the same assurance payment level.*

In Table 3, all the interaction terms between assurance payment levels and assurance schemes are not significantly different. Exceptions exist only on units 4 to 6 when there is no assurance payment. Although the three partial assurance schemes $P10$, $P14$, and PDe all have zero assurance payments on units 4 to 6, they generally induce lower group revelations than $Base$, and the differences are significant for $P10$ on units 4 to 6 and $P14$ on unit 6, implying that the assurance payments on the first three units may discourage the value revelation on the non-assured three units.

Result 5. *A higher assurance payment results in a higher group value revelation with relatively high value-cost ratios on units 1 to 3; a lower assurance payment induces a higher group value revelation with relatively low value-cost ratios on units 4 to 6.*

The highest assurance payment AP=18 generates a significantly higher group value revelation than AP=14 and AP=10 with $p < 0.01$ on unit 1. The assurance payment of AP=14 generates group value revelations higher than that of AP=10 on units 2 and 3, with

among two groups in each period. We exclude the observations from the first five periods to avoid potential learning effects in the early periods. We have run the same model specifications using all 15 periods of data and results are very close.

$p = 0.054$ and $p = 0.164$, respectively. On units 4 to 6, however, the assurance payment of 10 induces higher group value revelations than AP=14 with $p = 0.241$, 0.008, and 0.089, respectively.

Note that the relative magnitude of variables $AP10$ and $AP14$ switches for units 1 to 3 and units 4 to 6: $AP14$ is higher on units 1 to 3, while $AP10$ is higher on units 4 to 6. The switch is consistent with our theoretical insights. The value-cost ratios are relatively high on units 1 to 3, and the effect of AP on the upper bound of individual contributions in provision equilibrium is more significant. With AP=10, the upper bound equals 10 for all individuals with v_i below 20, while for AP=14, the upper bound is 14 for all v_i below 28. As a result, $C14$ with $AP = 14$ generally induces higher group value revelations than $C10$ with $AP = 10$. For units 4 to 6 with low value-cost ratios, however, there are not many high values and the lower bound of group contributions in a non-provision equilibrium $C - AP$ plays a more prominent role, and thus a low AP may induce relatively higher group value revelations.

4.3 Coordination of Contributions by Assurance Payments

The experimental results of provision rate and group value revelation consistently show that assurance payments significantly improve the multi-unit threshold public goods provision and the effects of the assurance do vary with the level of AP and the value-cost ratio. Next we investigate how assurance payments coordinate contributions toward the provision.

First we note that group contributions rarely add up exactly to the unit cost, although it is an equilibrium outcome. The percentage of group contributions being equal to the unit cost is the highest under $AP = 10$ on unit 3, which is 5.5%, followed by 3.1% under $AP = 14$ on unit 2, with all others not greater than 3% among all assurance payment levels on all units.[12] This result is consistent with Li and Liu (2019) where exact group coordinations on the provision cost are rarely observed in the heterogeneous induced value environment. Therefore we will focus on the the coordination of contributions at the individual level.

Result 6. *Assurance payments increase the percentage of individual contributions at or above the equal-cost-share and induce AP as a focal point, especially in the range of induced values at or*

[12]See Table B.1 in Appendix for the percentages of group contributions being equal to the unit cost under each assurance payment level on each unit.

above AP.

All assurance payments significantly increase the percentage of individual contributions at or above the equal-cost-share of 10. Figure 4 shows the cumulative distribution of individual contributions by assurance payment levels, pooling observations on all six units.[13] When AP = 0, 33.8% of individual contributions are not lower than 10, while the percent increases to 73.5%, 62.6%, and 82.6% for AP = 10, 14, and 18, respectively. Furthermore, all assurance payments induce AP as the focal point of individual contributions. The modes are 10 (47.3%), 14 (35.2%), and 18 (39.7%) for AP = 10, 14, and 18, respectively. The equal-cost-share of 10 is the mode (16.6%) when there is no assurance payment, which is much lower than that under AP = 10.

We use the frequency-weighted observed individual contributions at each induced value by the level of assurance payments to identify the driving factor of the coordination (Fig 5).[14] Assurance payments induce contributions from individuals with values at or above AP to be concentrated more on AP, as shown in panels (b) to (d) where the solid lines indicate the assurance payment levels. Under $AP = 0$, however, contributions are mostly below medium and hight assurance payment levels which are indicated by the green and purple dash lines in panel (a) and the percentages of zero-contributions over a large range of values are relatively large, comparable with that of the equal-cost-share of 10 which is a focal level of contributions for individuals with values above 10 (panel a: the red dash line).

When $AP = 10$, the percentage of contributions at 10 conditional on the individuals who have values at or above 10 is 48.4%, while only 19.4% under $AP = 0$. Similarly, the percentages for $AP = 10$ and $AP = 18$ are 39.3% and 47.7%, respectively, while 0.50% and 3.4% under $AP = 0$.[15] The difference between PPM and each corresponding APM treatment is statistically significant with $p < 0.001$ by proportion tests, ranksum tests, and

[13]The cumulative probability curve of AP=10 uses the data of $P10$ on units 1 to 3 and $C10$ on all six units; similarly, the curve of AP=14 uses $P14$ on units 1 to 3 and $C14$ on all six units. The curve of AP=18 uses PDe on unit 1, and all the other observations are used for the curve of AP=0.

[14]In each panel of Fig 5, the horizontal axis denotes the induced values, the vertical axis denotes the observed individual contributions. Both of induced values and contributions are rounded in integer for easier comparisons and demonstration. The area of the circles is proportional to the frequency of the contributions. The colored solid horizontal lines in panels (b) to (d) denote the corresponding assurance payment levels, and the colored dash lines in panel (a) indicate the three assurance payment levels for comparison.

[15]We observe similar patterns for the percentage of individual contributions at or above AP conditional on values above AP. For $AP = 10, 14, 18$, the percentages are 76.5%, 59.7% and 65.0% at or above 10, 14 and 18, respectively, while 40.5%, 19.1%, and 14.3% under $AP = 0$.

random effects probit regressions.

Figures 6 and 7 demonstrate the aggregate effects of the coordination of contributions on the assurance payments by the relationship between the mean and median of individual contributions and induced values (rounded to the nearest integer for easy comparison) with the data of all six units pooled together, where the assurance payment levels of 0, 10, 14 and 18 are denoted by connected black, red, green, and purple lines, respectively. The red, green, and purple vertical dash lines indicate the assurance payment levels of 10, 14 and 18, respectively.[16]

Assurance payments induces higher individual contributions over all values. AP=18 results in the highest contributions overall observed high induced values of 15 to 25. Under AP=10 and 14, contributions are higher than that under AP=0 over the low and medium value range of 5 to 18. Specifically, the contributions under AP=10 are higher than those under AP=10 and 14 in the low value range of 5 to 12, and the contributions under AP=14 become higher than those under AP=0 and 10 for the values of 14 and above. Actually, the red and green dots highlighted in Figure 6 respectively indicate the average contributions with assurance payments of 10 and 14 that generate the largest difference from those without assurance. Note that the values at which the differences are the largest coincide with the assurance payment levels as indicated by the red and blue vertical dash lines.

These observations above well demonstrate the effect of the incentive generated by assurance payments: **individuals with values at or above AP would more likely to contribute at least AP, leading to a higher average contribution for values ranging from AP to above, and the effect is the most significant for those with values just around AP which results in the largest contribution improvement**. This effect is more obviously exemplified by the median of individual contributions over induced values (Figure 7), where the median contribution jumps up when the induced value increases to the assurance payment level, which works for each of AP=10, 14, and 18. We summarize this result as follows.

Result 7. *Assurance payments induces higher individual contributions for values at or above the assurance payment level, and the effect is the most significant at values around the assurance payment level.*

[16]Since the assurance payment level of 18 is used only on unit 1, contributions under $AP = 18$ can be only observed in the value range of 15 to 25. Contributions under other assurance payment levels can be observed in the full value range of 5 to 25.

In addition to induced values, the effects of assurance payments on coordinating contributions towards provision also depend on the value-cost ratio, as suggested in Results 1, 2, and 5. The main logic is that when the value-cost ratio is high, the provision equilibria may dominate and the the effect of AP on the upper bound of individual contributions in provision equilibrium is more significant; when the value-cost ratio is low, there are not many high values and the role of the lower bound $C - AP$ of group contributions in non-provision equilibria becomes more prominent. The former implies under a higher AP there would be more contributions at or above a higher assurance payment level which may result in higher provision rates and group value revelations, while the latter implies under a lower AP the group contributions would be lower than but closer to the provision cost, resulting in higher group value revelation. These effects can be shown by contrasting AP=10 with AP=14.

Figure 8 shows the cumulative distribution of group contributions normalized by the group size N under AP=10 and 14 on each unit in two sets. Panel (a) is for units 1 to 3 and panel (b) for units 4 to 6, representing high and low value-cost ratios, respectively. The vertical grey line at 10 represents the group-size normalized unit cost.[17] In panel (a) with high value-cost ratios (2 to 1.6), the percentages of group contributions greater than the cost are large (i.e., more provision outcomes) and group contributions under AP=14 are significantly higher than those under AP=10, indicating a better performance (provision rate and group value revelation) of a higher assurance payment with a relatively high value-cost ratio. In panel (b) with low value-cost ratios (1.4 to 1), however, the percentages of group contributions greater than the cost are much smaller (i.e., more non-provision outcomes), and the cumulative distribution curve under AP=10 is narrower (more concentrated) around a contribution level less than the provision cost than that with AP=14, indicating a relatively higher group value revelation of a lower assurance payment with a low value-cost ratio.[18] The discussion above may also explain that the effect of an assurance payment on the provision rate is the most significant at a medium level of value-cost ratio (Result 2), since the effects of assurance payments on the upper and lower bounds of contributions are balanced. We summarize these observations in the following result.

[17]See Figure B.1 in Appendix for the cumulative distribution of group contributions normalized by the group size N for different assurance payment levels on each unit.

[18]the contribution variance under AP=10 is significantly less than that under AP=14 on all but the first unit. By variance ratio test, the p-values for the comparisons that AP=10 induces a smaller variance than AP=14 are 0.180, 0.0036, 0.0461, 0.0749, 0.0009, and 0.0338 for units 1 to 6, respectively.

Result 8. *Higher assurance payments generally perform better under a high value-cost ratio in terms of provision rate and group value revelation, and lower assurance payments induce higher group value revelations under a low value-cost ratio,*

4.4 Social Efficiency and Surplus Allocation

Our results show that assurance payment can significantly increase provision rates and group value revelations. A carefully chosen assurance payment level may improve both the provision rate and value revelation significantly. However, if a provision fails, the provider may incur a budget deficit by paying out assurance payments. Although the payment is simply a surplus transfer from the provider to consumers from a societal perspective, this transfer could be costly to the provider and inconvenient in reality. Thus, below we compare the realized social surplus across treatments, as well as the allocation of social surplus between consumers and the provider.

Table 5 presents the realized social surplus and allocation between consumers and the provider. 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, plus an assurance payment if any. The provider surplus equals consumers' contributions minus the provision cost and the assurance payment if any, or equivalently, the realized social surplus minus consumers' surplus. The maximum potential social surplus is normalized to 100 to provide a benchmark across different treatments.

Result 9. *All assurance schemes improve the realized consumer surplus significantly. All assurance schemes result in a significantly lower realized provider surplus compared to the $Base$ treatment; all but treatment $P14$ have a negative provider surplus. All assurance schemes improve the realized social surplus.*

First, note that all have higher realized consumer surpluses than $Base$, which are all significant at $p < 0.001$ by rank-sum test. The conditional scheme $C10$ (with an assurance payment of 10) results in the highest consumer surplus 70 compared to 39 in the treatment $Base$ and the treatment $C10$ also has the highest provision rate on unit 4. Second, treatment $Base$ has the highest realized provider surplus, which is significantly higher than those from $P10$ to $C14$ all with $p < 0.001$. It is worth noting that in $P14$, the provider still maintains a *positive* surplus, indicating that $P14$ is the least costly assurance scheme to the provider. Lastly, all treatments $P10$ to $C14$ all have higher realized social surpluses than the $Base$ treatment, in which $P14$, PDe, and $C10$ are significantly higher with $p < 0.001$, $p = 0.0069$ and 0.092, respectively.

Although $P14$ does not have a realized consumer surplus as high as PDe or $C10$, $P14$ involves a relatively smaller assurance payment and hence a much higher provider surplus than PDe and $C10$. Therefore, $P14$ stands out as the "best" assurance payment scheme in our tested schemes, which has the highest social surplus level and a positive provider surplus. This result implies a budget-balancing assurance scheme is potentially possible, at least based on our experimental data with multiple provision outcomes.

5 Discussion of a Pilot Field Experiment

In this section, we briefly discuss results from a pilot field experiment using the assurance contract. The detailed procedure is described in Appendix C. Our motivation is to construct a field test based on the theoretical and lab experiment results. However, we encountered several major challenges in designing the field experiment, including finding a real public project where people are willing to contribute, estimating the potential number of donors and contributions relative to the project cost, and estimating our liability for providing assurance payments when provision fails. Despite these difficulties, we managed to conduct a pilot field experiment as a first field-test of the assurance payment concept. This section intends to serve as a proof of concept for future studies.

The field experiment was conducted in April and May 2014. We chose Jamestown and Aquidneck Island, Rhode Island, as the study area. We tested the following five treatments in the experiment:

- Treatment $D1$: Donation (MP=40), where residents were first asked whether they are willing to donate at least \$40 (MP). If they answered yes, they were asked whether they are willing to contribute more and specify the amount. If they answered no, they were asked whether they were willing to contribute less and were directed to specify the amount.

- Treatment $D2$: Donation (MP=60), everything else is the same as in Treatment D1, except residents were asked whether they were willing to donate at least \$60.

- Treatment $A1$: Assurance (MP=40, AP=20), the assurance contract approach, where residents were first asked whether they were willing to donate at least \$40 (MP). If they answered yes, they were eligible for the assurance payment, \$20 (AP), and they were asked whether they were willing to contribute more and were directed to specify the amount. If they answered no, they were not eligible for the assurance payment, but they were asked whether they were willing to contribute less and were directed to specify the amount.

- Treatment $A2$: Assurance (MP=40, AP=40): everything else was the same as in Treatment $P10$, except residents who were willing to contribute at least \$40 were eligible to receive a \$40 assurance payment if the provision failed.

- Treatment $A3$: Assurance (MP=60, AP=40): everything else was the same as in Treatment $P14$, except residents who were willing to contribute at least \$60 were eligible to receive a \$40 assurance payment if the provision failed.

Note that in all treatments, if the provision failed, contributions were returned to residents according to our money-back guarantee; the assurance payment was given to those who contributed an amount at least equal to the minimum price. For example, under Treatment $A3$, if one contributed \$60 and we failed to provide a 10-acre field for grassland nesting birds, she would receive \$100 including the original donation \$60 plus \$40 assurance payment.

We collected \$4377 in total with an average contribution of \$65.33. A total of 67 residents responded to our mailing materials and made donations. One individual donated zero dollars and requested to be removed from any future mailings. Thus, 66 residents contributed a positive amount. Recall that we sent out 2,000 solicitations; however, only 75.8% of the letters were deliverable, and about 24.2% were non-deliverable. We find that \$1,842, or about 42% of the donations came from past donors, while more than half of the money came from first-time donors. Due to the high incidence of zero donations, we implement a double hurdle model to address the non-participation issue (Jones, 1989; Labeaga, 1999; von Haefen et al., 2005). See detailed regression results in Appendix, Table

C.2. We find that in terms of participation rate, neither MP nor AP makes a significant difference. Our regression results suggest that a higher MP discourages participation. The presence of assurance payment encourages participation while a higher assurance payment has a larger effect on participation.

Different from the lab experiment, in the field experiment, we do not have information on individuals' true values. Therefore, we assume a previous donor has a high value for the Bobolink Project while those who have not donated before are classified as low-value individuals. Note that this classification is imperfect, though this is the best indicator available in terms of individuals' true types. Based on the contribution equation, we find that both a high MP and a low AP (20) increase contributions among low-value individuals. When MP increases from 40 to 60, the average increase is around 29, higher than the increase in the MP. Also, the observation that a low AP (20) increases contributions from low-value people is consistent with our theoretical and lab results. We also find that a low AP significantly decreases contributions among high-value individuals ($p = 0.07$), which further supports our prediction on the effect of a capped maximum individual contribution level.

In addition, in the field experiment, we find that a high assurance payment (AP=40) generally decreases the contribution. For high-value individuals, a high AP increases contributions, consistent with our theoretical prediction and lab results. The net effect of a high value and a high AP is positive (about $12.66), although the effect is not significant at a 10% level. Consistent with our theoretical results for high-value individuals, a low AP decreases contribution significantly at a 10% level ($p = 0.091$) and a high $AP = 40$ increases contribution. However, a high MP (60) combined with a high AP (40) decreases contributions in our field experiment, which may result from small sample size and needs further investigations.

Our overall message is largely consistent with our theoretical and lab experiment results that the provision rate is mainly determined by the interactions between the value range and assurance payment in equilibrium. Thus, it is promising that once we have better information on the individual value range and the provision cost, an optimal assurance level can be calculated to improve the provision rate.

6 Conclusions and Future Research

We address the need to develop mechanisms that encourage voluntary, private contributions to support public goods provision. This paper builds on the assurance contract introduced by Tabarrok (1998) and the multi-unit public good provision framework in Liu and Swallow (2019) to improve the provision of public goods. Under this approach, a market-maker rewards a would-be donor for committing to a minimum contribution; if a provision fails to occur, the market maker nonetheless pays the committed donor an assurance payment as a reward, while also refunding their contribution under a money-back guarantee.

In the baseline treatment of an economic laboratory setting, an individual pays the same price for all units provided with no assurance available. Conditional assurance and partial assurance schemes are then compared to the baseline treatment. We seek to establish whether an assurance payment generally makes a significant improvement on the public good provision. We characterize the Nash equilibria with assurance payment and compare them with those without assurance payment in the Appendix A. Then we design six assurance payment schemes and experimentally test the effects of assurance payment on the provision rate, the group value revelation, and social efficiency. Our laboratory experiments show the assurance payment works in the expected directions, improving the prospect for real fundraising activities.

We find a well designed positive assurance payment always performs better than no assurance payment using measures such as the provision rate, group value revelation, and realized social surplus. Nonetheless, the provider may incur a deficit if the assurance scheme is not chosen properly, though the total social surplus is higher using an assurance payment. Furthermore, the level of the assurance payment and the value-cost ratio (total expected values divided by the cost) together determine the performance of an assurance payment. In our laboratory experiments with a maximum of six units, a sufficiently high assurance generally improves both of the provision rate and group value revelation more than a low assurance on units (the first three) with relatively high value-cost ratios, but a low assurance generates a higher group revelation with a smaller variance on units (the last three) with low value-cost ratios, although a high assurance still induces higher provision rates on the last three units.

The various interactions between assurance payments and value-cost ratios indicate some future research directions. Recall that in our setup, a partial scheme with a medium assurance payment results in the highest social surplus. Further research could identify how to choose the most efficient assurance payment level based on the likely values of potential donors (i.e., the expected value-cost ratio) and the number of units covered, and whether these parameters can be predicted by theory or empirical, experimental or field-work.

Our results have important policy implications. First, the provision-point based mechanism with assurance payments could provide a powerful tool for non-market valuation, since the assurance payment could significantly reduce the free-riding incentive and induce a more accurate preference measure. However, this potential is not straightforward: while the assurance contract approach can lead to a higher revelation of gross social value by a group, the approach can incentivize individuals to strategize between the net benefit of provision and the net benefit of receiving an assurance payment. Second, this approach may help to facilitate a decentralized ecosystem service market, backed by a relatively high provision rate, which can be further optimized by flexible payment schemes. This implication may be especially important when providers (or market-makers) lack substantial information on valuation, although it comes at the risk of financial liability for assurance payments.

While this research focuses on evaluating mechanisms to leverage the demand for ecosystem services, the service providers (providers) may be identified through various reverse auction mechanisms where, for agroecosystem services, more cost-effective landowners or farmers are the likely winners. Our research assumes a constant opportunity cost, which can be relaxed in future research by assuming an increasing marginal cost to provide an additional unit if the reverse auction is successful in identifying the least costly providers. Also, the implementation of assurance payment in the field requires a third party who can make the assurance payment to eligible contributors in case of potential provision failures. The third-party can be charities, researchers, or government agencies that have established credibility and sufficient funds to cover the assurance payments. However, our theoretical and experimental results imply that a properly chosen assurance payment level can lead to a balanced budget and even leads to a small surplus in the long run. Therefore, we think the assurance contract approach has the potential to mitigate the free riding or the coordination problems in public goods contribution and may serve as a practical method to generate additional revenue streams for landowners or farmers supporting ecosystem services provisions with the help of a third party.

As in many public goods provision schemes, the devil will be in the details. Framing effects may matter to solicitation of contributions. In particular, would-be donors likely will find, as some indicated in side-communications in our field experiment, that the assurance contract is unexpected relative to the common experience of solicitations for open-ended donations to a conservation organization, where such donations are not tied to a specific good (with money-back guarantee), and no one is offering to pay the would-be donor if a project fails to materialize. Individuals may initially question why any charity would offer to pay donors under such conditions. Framing the marketing communications may be critical: for example research to adapt the familiar idea of a philanthropic challenge grant may aid donors to understand that some benevolent patron may seek to encourage participation and donation has therefore offered to pay committed donors to help reach a goal, with payment as a "thank you for helping us try" in the event of non-provision of one or more particular unit(s). Research to evaluate alternative frames may prove critical to assisting the novice-citizen in grasping the concept, as has been seen in research involving novel incentive-compatible mechanisms (Kawagoe and Mori, 2001). By this speculation, we again suggest that the assurance contract approach has practical potentials.

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Table 1: Experiment Treatments and Sessions

Assurance Type	Treatments	No. of Groups	No. of Sessions	No. of Subjects
Partial Assurance	Base	6	3	34
	P10	6	3	36
	P14	6	3	36
	PDe	6	3	38
Conditional Assurance	Base	4	2	24
	C10	4	2	24
	C14	4	2	24

Notes: We test (1) No assurance baseline ($Base$); (1) a constant assurance payment 10 for the first three units ($P10$); (3) a constant assurance payment 14 for the first three units ($P14$); (4) a decreasing assurance payments 18, 14, and 10 for the first three units, respectively (PDe); (5) a constant assurance payment 10 for the first unit that cannot be provided ($C10$); (6) a constant assurance payment 14 for the first unit that cannot be provided ($C14$).

Table 2: Range and Mean of the Induced Values for Each Unit

Unit	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
v_H	25	23	21	19	17	15
v_{Mean}	20	18	16	14	12	10
v_L	15	13	11	9	7	5

Notes: The variable names v_H, v_{Mean} and v_L represent the upper bound, mean, and lower bound of the induced values for the corresponding unit, respectively.

Table 3: Two-factor Random Effects Models of Group Value Revelation for Each Unit

Group Value Rev.	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
AP10	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*P10	-0.0244	0.000917	-0.00725			
	(0.0251)	(0.0214)	(0.0204)			
AP14	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*P14	-0.0331	0.0103	0.022			
	(0.0251)	(0.0214)	(0.0204)			
AP18	0.137***					
	(0.0171)					
AP14*PDe		0.0214				
		(0.0214)				
AP10*PDe			-0.00828			
			(0.0204)			
P10				-0.0321*	-0.0616***	-0.0826***
				(0.0185)	(0.0178)	(0.021)
P14				-0.0144	-0.0205	-0.0426**
				(0.0185)	(0.0178)	(0.021)
PDe				-0.00104	-0.0115	-0.0189
				(0.0185)	(0.0178)	(0.021)
Constant (A0)	0.587***	0.550***	0.512***	0.452***	0.444***	0.444***
	(0.0178)	(0.0143)	(0.0151)	(0.026)	(0.0274)	(0.0283)
Log-likelihood	-228.1	-255	-268.2	-216.7	-224.1	-194.3
Number of Observations	180	180	180	180	180	180
Number of Periods	10	10	10	10	10	10

Notes: 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; $P10$, $P14$, and PDe are the assurance scheme dummies.

Table 4: Two-factor Random Effects Models Based on Individual Contribution for Each Unit

Ind. Con.	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
AP10	4.257*	2.783	2.011	4.383***	0.693	1.895**
	(2.262)	(2.114)	(1.968)	(1.675)	(1.161)	(0.789)
AP10*$P10$	-2.639	-3.539	0.0302			
	(2.527)	(2.349)	(2.182)			
AP14	5.228**	4.995**	-1.868	-0.348	-1.214	1.079
	(2.181)	(2.078)	(1.986)	(1.73)	(1.202)	(0.813)
AP14*$P14$	-2.08	-1.851	7.828***			
	(2.47)	(2.339)	(2.213)			
AP18	4.759**					
	(2.027)					
AP14*PDe		0.915				
		(2.317)				
AP10*PDe			4.283*			
			(2.198)			
$P10$				-2.034	-1.534	-1.460*
				(1.548)	(1.09)	(0.748)
$P14$				0.766	0.194	-0.0136
				(1.536)	(1.055)	(0.71)
PDe				0.266	1.237	0.377
				(0.189)	(0.938)	(0.288)
Value	0.470***	0.457***	0.450***	0.310***	0.346***	0.338***
	(0.0604)	(0.0637)	(0.0677)	(0.0661)	(0.0527)	(0.0413)
Value*AP10	-0.179	-0.126	-0.0578	-0.152	0.124	0.00594
	(0.112)	(0.117)	(0.123)	(0.119)	(0.0952)	(0.0752)
Value*AP10*$P10$	0.123	0.211	-0.00279			
	(0.125)	(0.129)	(0.135)			
Value*AP14	-0.202*	-0.213*	0.214*	0.171	0.233**	0.0613
	(0.108)	(0.115)	(0.123)	(0.122)	(0.0971)	(0.0758)
Value*AP14*$P14$	0.0865	0.126	-0.466***			
	(0.122)	(0.129)	(0.137)			
Value*AP18	-0.0896					
	(0.1)					
Value*AP14*PDe		-0.0191				
		(0.128)				
Value*AP10*PDe			-0.254*			
			(0.137)			
Value*$P10$				0.118	0.0696	0.068
				(0.108)	(0.0878)	(0.0699)
Value*$P14$				-0.0625	-0.0343	-0.0369
				(0.109)	(0.0861)	(0.0675)
Value*PDe				-0.0125	-0.11	-0.0525
				(0.109)	(0.0867)	(0.0677)
Provision Cost	0.0529	0.0339	-0.00683	-0.00704	-0.0189	-0.0185
	(0.0681)	(0.0589)	(0.051)	(0.0555)	(0.0516)	(0.0473)
Constant ($Base$)	-1.073	-0.508	1.363	2.358	2.298	2.132
	(4.458)	(3.885)	(3.386)	(3.609)	(3.304)	(3)
Log-likelihood	-6526.72	-6291.66	-6199.08	-6106.82	-6008.39	-6036.19
Number of Observations	2200	2200	2200	2200	2200	2200
Number of Periods	10	10	10	10	10	10

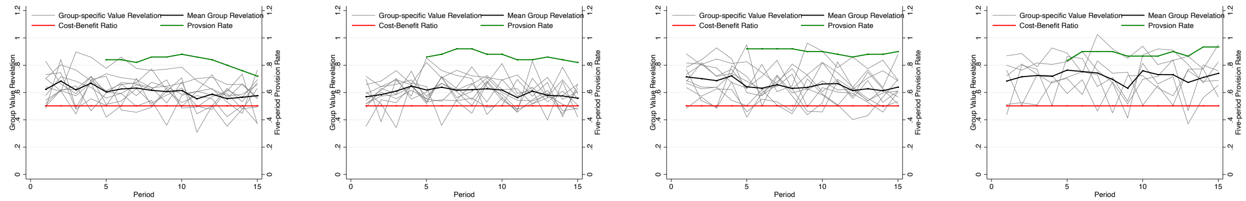
Notes: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; AP10, AP14 and AP18 denote dummies for assurance payments of 10, 14 and 18, respectively; $P10$, $P14$, and PDe are the assurance scheme dummies.

Table 5: Realized Average Social Surplus and Allocation

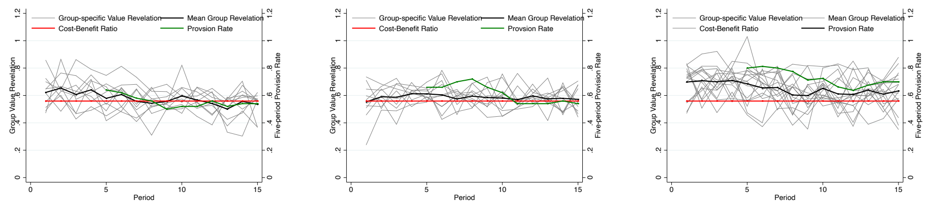
Treatment	Potential Maximum Social Surplus	Realized Consumer Surplus	Realized provider Surplus	Realized Social Surplus
$Base$	100	39	5	44
$P10$	100	61	-11	50
$P14$	100	62	1	63
PDe	100	64	-6	58
$C10$	100	70	-17	53
$C14$	100	60	-8	52

Notes: The maximum social surplus is normalized to 100 across treatments. The Realized Social Surplus equals the sum of Realized Consumer Surplus and Realized provider Surplus. The Realized provider Surplus can be negative with assurance payment when the provider make payments to consumers upon provision failure.

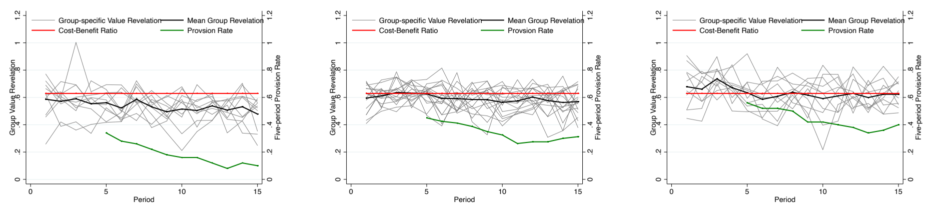
Figure 1: Group Value Revelation in Each Period and Five-Period Moving Average Provision Rate by AP and Unit



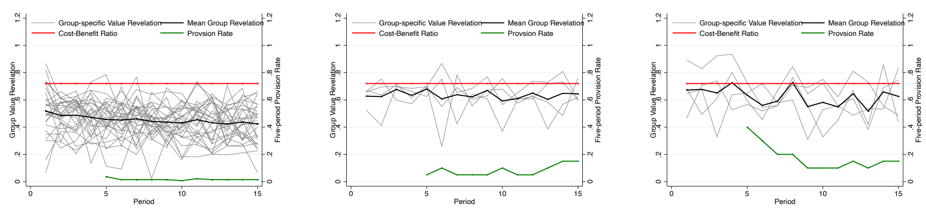
(a) U1 AP0 (b) U1 AP10 (c) U1 AP14 (d) U1 AP18



(e) U2 AP0 (f) U2 AP10 (g) U2 AP14

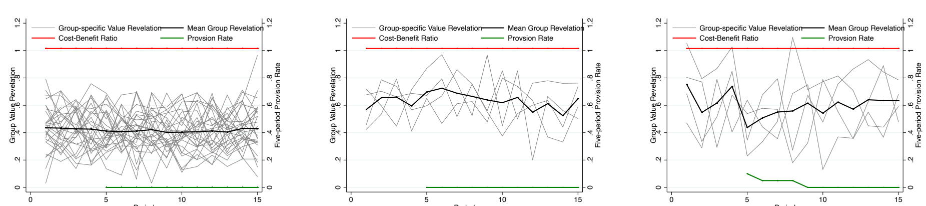


(h) U3 AP0 (i) U3 AP10 (j) U3 AP14



(k) U4 AP0 (l) U4 AP10 (m) U4 AP14

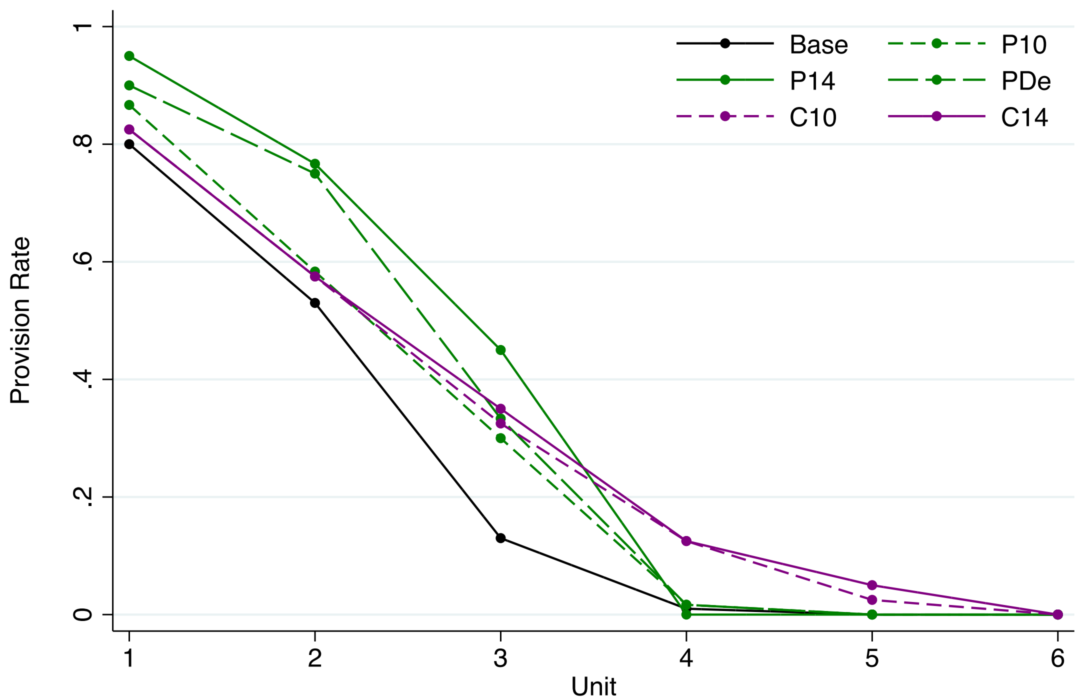
(n) U5 AP0 (o) U5 AP10 (p) U5 AP14



(q) U6 AP0 (r) U6 AP10 (s) U6 AP14

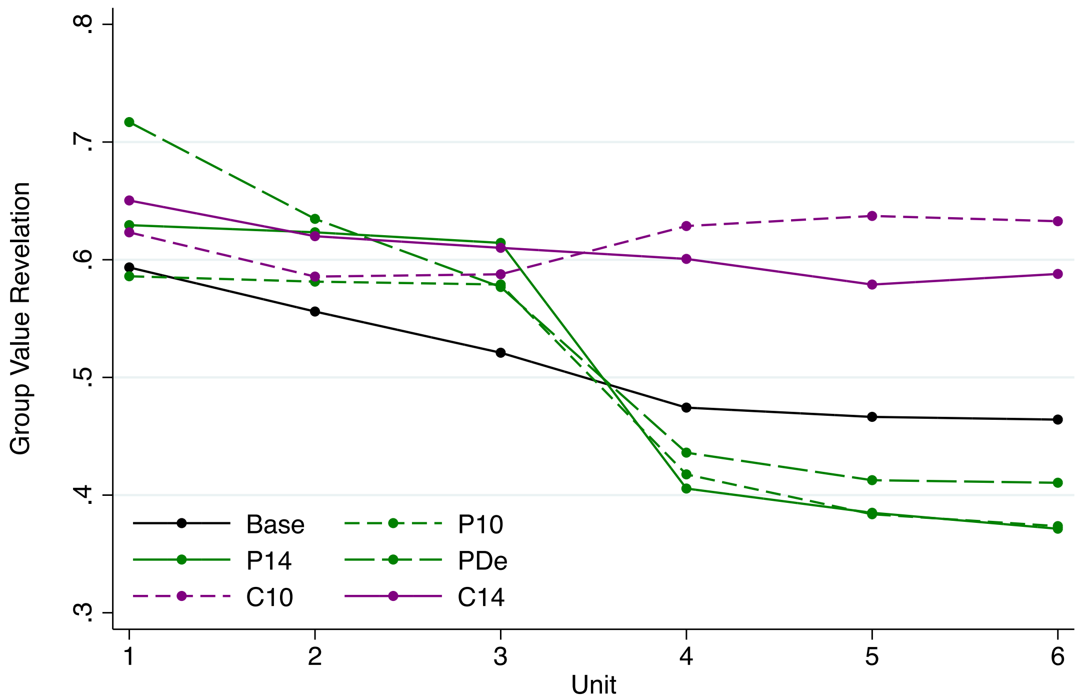
Notes: Panels above show the group value revelation in each period and five-period-moving-average provision rates, by by AP and unit. Grey lines represent session-specific group value revelations, dark black lines represent averages over sessions, green lines represent five-period moving average provision rates, and red lines indicate average cost-value ratios.

Figure 2: Provision Rate for Each Unit by Assurance Scheme



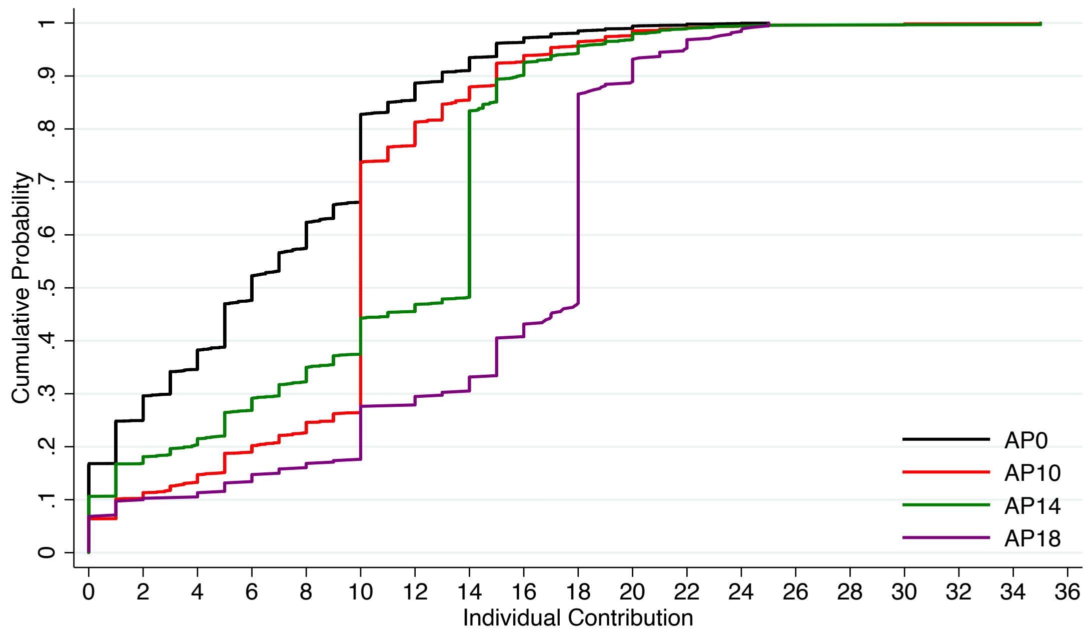
Notes: The above figure shows the provision rate difference among the six assurance payment schemes, including the baseline treatment $Base$ where assurance payment is not applicable for any units.

Figure 3: Group Value Revelation for Each Unit by Assurance Scheme



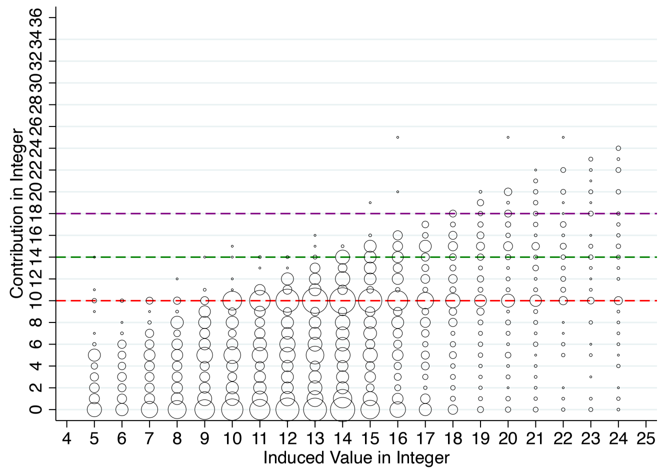
Notes: The above figure shows the group value revelation (contributions divided by induced value) in the six assurance payment schemes, including the treatment $Base$ where assurance payment is not applicable for any units.

Figure 4: Cumulative Distribution of Individual Contribution by Assurance Payments

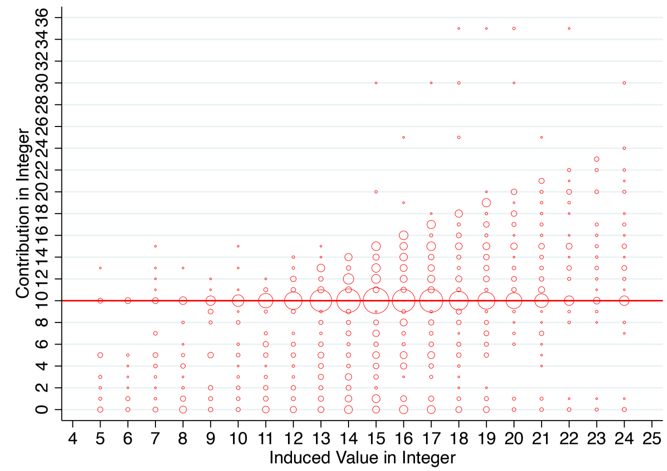


Notes: The above figure shows the cumulative distribution function from the pooled data of individual contributions on all six units.

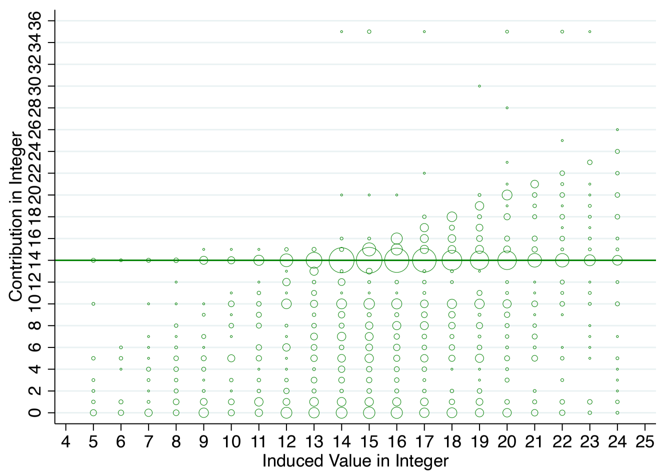
Figure 5: The Influence of Assurance Payments on Individual Contributions



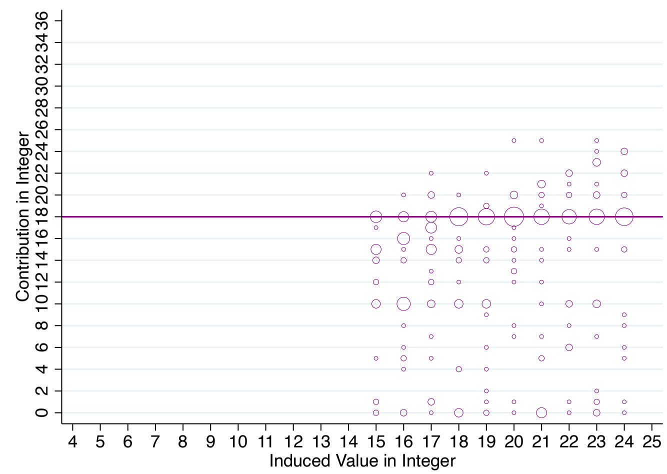
(a) $AP = 0$



(b) $AP = 10$



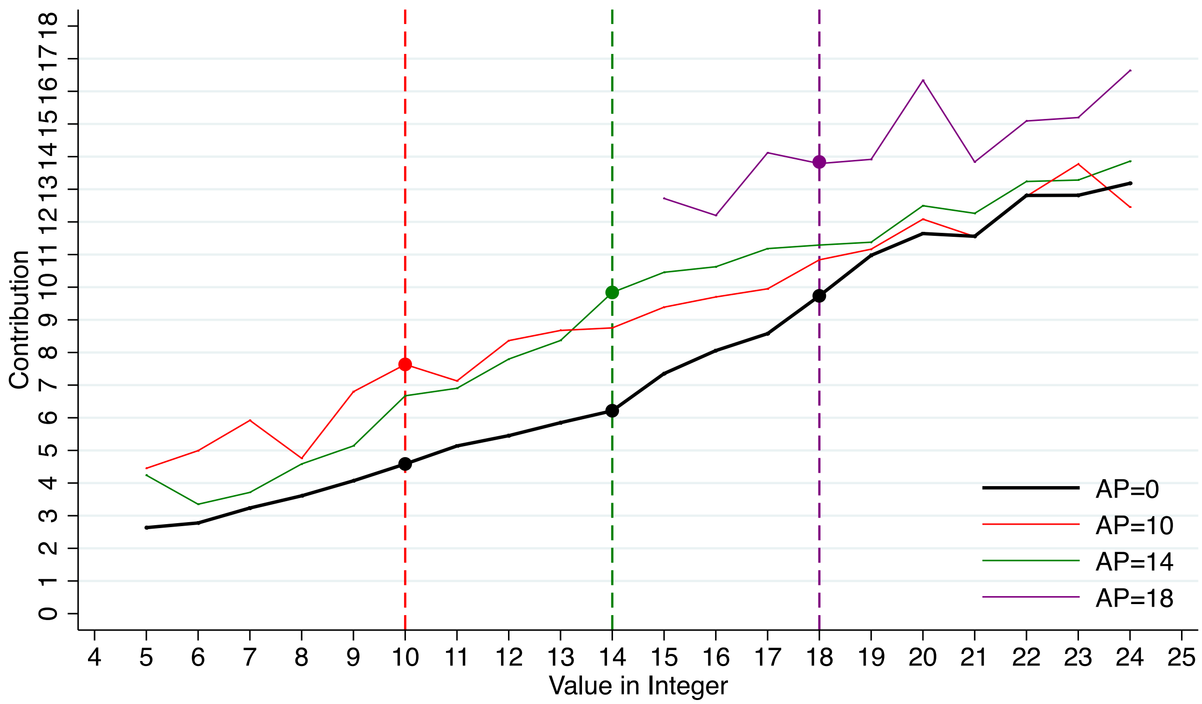
(c) $AP = 14$



(d) $AP = 18$

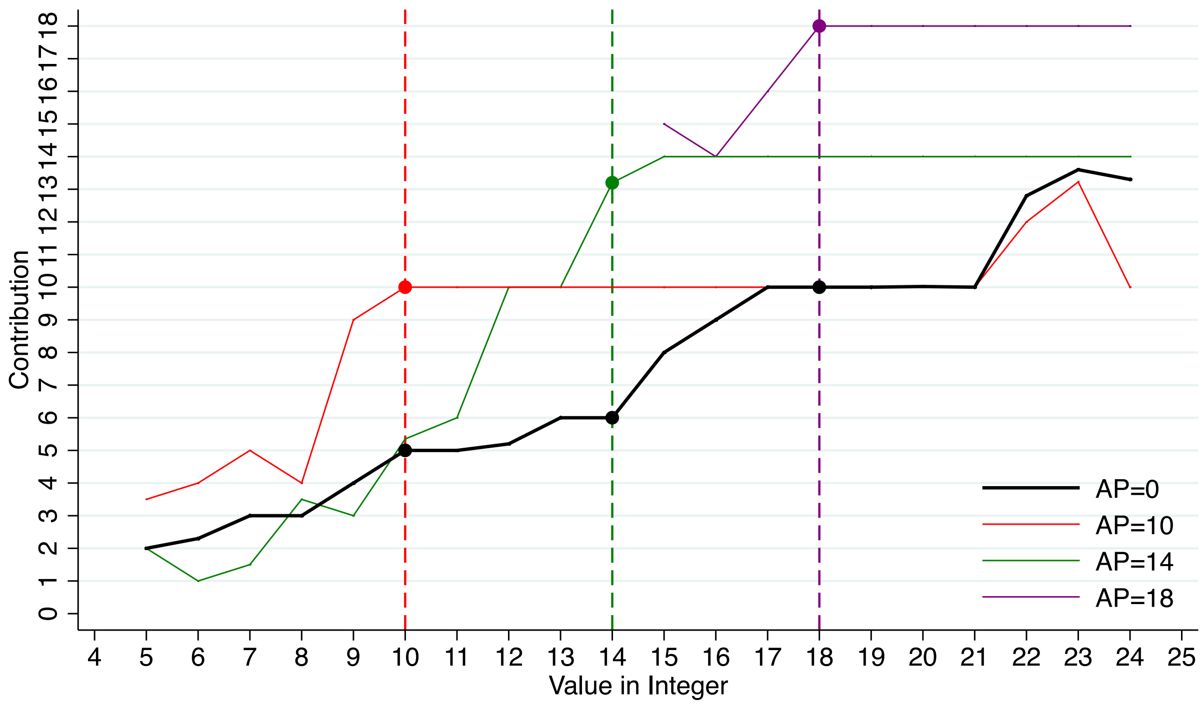
Notes: This figure shows the frequency-weighted observed individual contributions at each induced value by AP. In each panel, the horizontal axis denotes the induced values, the vertical axis denotes the observed individual contributions. Both of induced values and contributions are rounded in integer for demonstration purpose. The area of the circles is proportional to the frequency of the contributions. The colored solid horizontal lines in panels (b) to (d) denote the corresponding assurance payment level, and the colored dash lines in panel (a) indicate the three assurance payment levels for comparison.

Figure 6: Mean Contributions by Induced Value



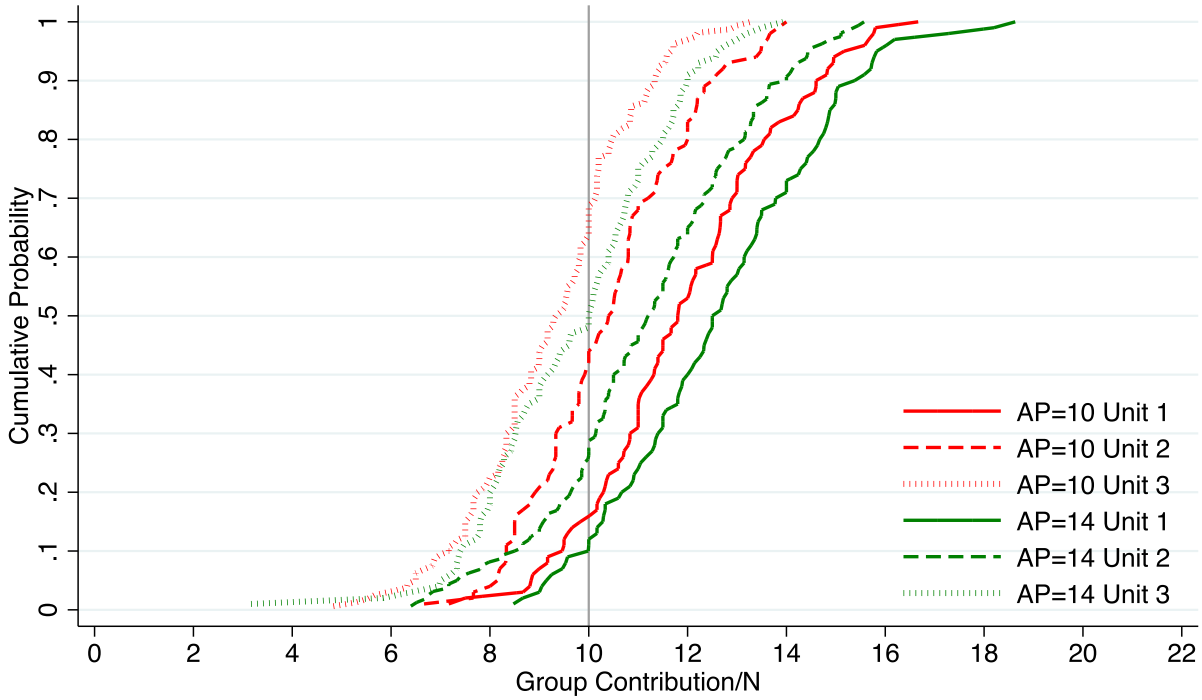
Notes: This figure demonstrates the relationship between average individual contributions and induced values in integer, where the assurance payment levels of 0, 10, 14 and 18 are denoted by connected black, red, green, and purple lines, respectively. The red, green, and purple vertical dash lines indicate the assurance payment levels of 10, 14 and 18, respectively. Since the assurance payment level of 18 is used only on unit 1, contributions under $AP = 18$ can be only observed in the value range of 15 to 25. Contributions under other assurance payment levels can be observed in the full value range of 5 to 25.

Figure 7: Median Contributions by Induced Value

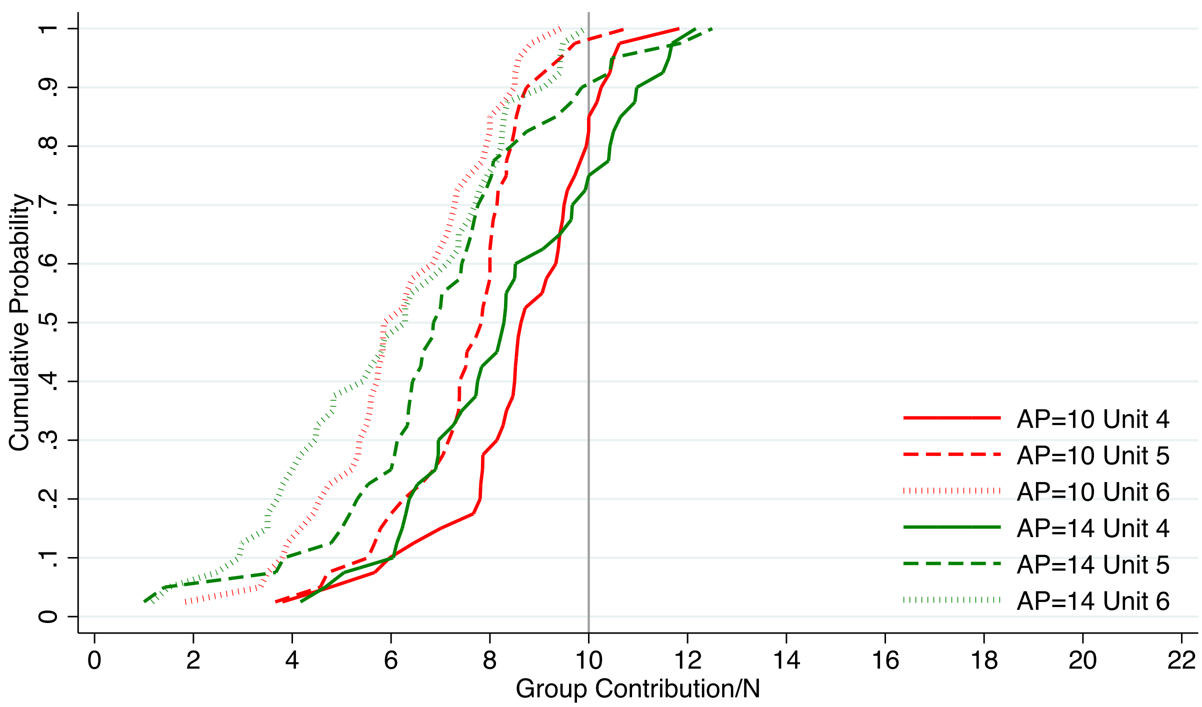


Notes: This figure demonstrates the relationship between median individual contributions and induced values in integer, where the assurance payment levels of 0, 10, 14 and 18 are denoted by connected black, red, green, and purple lines, respectively. The red, green, and purple vertical dash lines indicate the assurance payment levels of 10, 14 and 18, respectively. Since the assurance payment level of 18 is used only on unit 1, contributions under $AP = 18$ can be only observed in the value range of 15 to 25. Contributions under other assurance payment levels can be observed in the full value range of 5 to 25.

Figure 8: Cumulative Distribution of Normalized Group Contributions



(a) $AP = 10$ vs. $AP = 14$: Units 1 to 3



(b) $AP = 10$ vs. $AP = 14$: Units 4 to 6

Note: This figure shows the cumulative distribution of group contributions normalized by the group size N under AP=10 and 14 on each unit in two sets. Panel (a) is for units 1 to 3 and panel (b) for units 4 to 6, representing high and low value-cost ratios, respectively. The vertical grey line at 10 represents the group-size normalized unit cost.

Appendix

A Theoretical Framework and Proof

In this Appendix, we characterize the set of Nash equilibria with assurance payment for the single unit case under complete information.[19] Let v_i and b_i denote individual i's value and contribution. For comparison, the provision and non-provision Nash equilibrium sets for one-unit without assurance payments (or the provision point mechanism with $AP = 0$) characterized by Bagnoli and Lipman (1989) are provided as follows:

Proposition 1. *(provision equilibrium, Bagnoli and Lipman (1989)): Any strategy profile $\{b_i\}_{i \in \mathcal{I}}$ s.t. $\sum_i b_i = C$ with $b_i \leq v_i$, for all $i \in \mathcal{I}$ is a pure-strategy Nash equilibrium under which the good is provided.*

Proposition 2. *(non-provision equilibrium, Bagnoli and Lipman (1989)): Any strategy profile $\{b_i\}_{i \in \mathcal{I}}$ s.t. $\sum_i b_i < C$ and $\sum_{i \neq k} b_i + v_k \leq C$ for all $k \in \mathcal{I}$ is a pure-strategy Nash equilibrium under which the good is not provided.*

Proposition 3. *(Nash equilibrium UP multi-unit, Liu and Swallow (2019)): the strategy profile $\{b_i^1, b_i^2, ..., b_i^J\}$ is a pure-strategy Nash equilibrium if*

- *(a) $\sum_i b_i^l = C, \forall l \leq j$*
- *(b) $v_i^{j+1} + \mathcal{B}_{-i}^{j+1} \leq C, \sum_i b_i^{j+1} < C, \forall i,$,*
- *(c) $v_i^j + \mathcal{B}_{-i}^j \geq C, \forall i.$*

where $\mathcal{B}_{-i}^l \equiv l \sum_{k \neq i} b_k^l - (l-1) \sum_{k \neq i} b_k^{l-1}$.

Proposition 1 states that any contribution strategy profile is a Nash equilibrium where the group contributions exactly add up to the provision cost, and no one contributes above their values. Proposition 2 states that if group contributions are less than the cost, no one

[19] Complete information here means that the following information is common knowledge: the provision cost for each unit, the group size, and the value of each unit for each individual. Theoretical characterization of the equilibrium set of the multi-unit case with assurance payment in an information environment close to the real world is beyond the scope of this paper. Our lab experiments are designed to mimic some real-world scenarios and to provide insights on how assurance payments could improve the private provision of public goods.

can fill in the gap alone without contributing above her value in a non-provision equilibrium. Note that both of the provision and non-provision equilibrium sets include multiple equilibria (or a continuum of equilibria) and the non-provision equilibrium set is never empty. When there are multiple units of a public good, Proposition 3 includes the conditions (b) and (c) which ensure that individual i cannot change bids to acquire a higher profit by providing one more or less unit, respectively.[20] In the following propositionswe show that an assurance contract can change the equilibrium conditions due to the potential to receive assurance payment. The Nash equilibrium sets with assurance contract are characterized as follows:[21]

Proposition 4. *(Nash equilibrium with assurance contract, UP multi-unit): the strategy profile $\{b_i^1, b_i^2, ..., b_i^J\}$ is a pure-strategy Nash equilibrium with $AP \in [C/N, C]$ if the following three conditions are satisfied when j units are provided:*

- *(a)* $\sum_i b_i^l = C$, $\forall l \leq j$
- *(b)* $v_i^{j+1} + \mathcal{B}_{-i}^{j+1} + \mathcal{A}_{j+1} \leq C$, $\sum_i b_i^{j+1} < C$, $\forall i$,,
- *(c)* $v_i^j + \mathcal{B}_{-i}^j + \mathcal{A}_j \geq C$, $\forall i$.

where $\mathcal{B}_{-i}^l \equiv l \sum_{k \neq i} b_k^l - (l-1) \sum_{k \neq i} b_k^{l-1}$, $\mathcal{A}_l \equiv I(b_i^{l+1} \geq AP_{l+1})AP_{l+1} - I(b_i^l \geq AP_l)AP_l$.

Proof. When j units are provided, condition (a) ensures that the total bids on a provided unit just equal the cost, together with $\sum_i b_i^{j+1} < C$ we can conclude that only j units will be provided.

Individual i's profit from providing j units is

$$\pi_i^j = \sum_{l=1}^{j} v_i^l - j(C - \sum_{k \neq i} b_k^j) + I(b_i^{j+1} \geq AP_{j+1})AP_{j+1}, \tag{A.1}$$

where the term $\sum_{l=1}^j v_i^l - j(C - \sum_{k \neq i} b_k^j)$ represents the profit from the public goods without the assurance payment, $I(b_i^{j+1} \geq AP_{j+1})AP_{j+1}$ is the potential assurance payment from the

[20]Liu and Swallow (2019) provide a general condition where the individual cannot deviate from the equilibrium provision by more than one unit. Here we assume that individual cannot obtain a higher profit by deviate from the equilibrium outcome by one unit, similar to the "one-step principle" in the game theory, while our framework in this paper can still be generalized to situation where we allow the outcome to deviate from the equilibrium by more than one unit. Proof can be reconstructed easily from Proposition 4 below.

[21]Here we assume $AP \geq C/N$ to avoid the trivial case in which everyone contributes AP but the good is not provided and everyone earns AP.

$j+1$ unit since the assurance payment is only available on the first unit not provided, which depends on individual i's bid b_i^{j+1} and the assurance payment level AP_{j+1} with $I(\cdot)$ as the indicator function.

To eliminate the incentive to provide one more unit ($j+1$ units), we need to require no individual can obtain a higher profit by providing $j+1$ units. Individual i's profit from providing $j+1$ units is

$$\pi_i^{j+1} = \sum_{l=1}^{j+1} v_i^l - (j+1)(C - \sum_{k\neq i} b_k^{j+1}) + I(b_i^{j+2} \geq AP_{j+2})AP_{j+2}, \tag{A.2}$$

where the term $\sum_{l=1}^{j+1} v_i^l - (j+1)(C - \sum_{k\neq i} b_k^{j+1})$ represents the profit from the public goods without the assurance payment when $j+1$ units are provided. When providing j units are provided, we need $\pi_i^j \geq \pi_i^{j+1}, h > j$ so that no individual can be better by providing $j+1$ units unitarily, which implies,

$$v_i^{j+1} + (j+1)\sum_{k\neq i} b_k^{j+1} - j\sum_{k\neq i} b_k^j - I(b_i^{j+1} \geq AP_{j+1})AP_{j+1} + I(b_i^{j+2} \geq AP_{j+2})AP_{j+2} \leq C, \forall i. \tag{A.3}$$

To eliminate the incentive to provide $j-1$ units, we need to require no individual can obtain a higher profit by providing $j-1$ units. Individual i's profit from providing $j-1$ units is

$$\pi_i^{j-1} = \sum_{l=1}^{j-1} v_i^l - (j-1)(C - \sum_{k\neq i} b_k^{j-1}) + I(b_i^j \geq AP_j)AP_j, \tag{A.4}$$

where the term $\sum_{l=1}^{j-1} v_i^l - (j-1)(C - \sum_{k\neq i} b_k^{j-1})$ represents the profit from the public goods without the assurance payment when $j-1$ units are provided. We need $\pi_i^j \geq \pi_i^{j-1}$ so that no individual can be better by providing $j-1$ units unitarily, which implies,

$$v_i^j + j\sum_{k\neq i} b_k^j - (j-1)\sum_{k\neq i} b_k^{j-1} + I(b_i^{j+1} \geq AP_{j+1})AP_{j+1} - I(b_i^j \geq AP_j)AP_j \geq C, \forall i. \tag{A.5}$$

□

Corollary 1 below shows that an assurance contract can eliminate a substantial subset of contribution profiles supporting non-provision equilibria compared with the baseline case where no assurance is available.

Corollary 1. *The assurance contract changes the upper and increases the lower bound of the group contribution in equilibrium compared to no assurance contract. Without assurance contract, a zero-group contribution is always an equilibrium. With an assurance contract, the group contribution must be higher than $C - AP_j$ on unit j in equilibrium.*

Proof. When providing j units is the equilibrium outcome and assurance is not available, according to Proposition 3, we have

$$\begin{aligned}
&\sum_i \left(v_i^{j+1} + (j+1) \sum_{k \neq i} b_k^{j+1} - j \sum_{k \neq i} b_k^j \right) \leq \sum_i C \\
&\sum_i v_i^{j+1} + (N-1)(j+1) \sum_i b_i^{j+1} - (N-1)jC \leq NC \\
&\sum_i b_i^{j+1} \leq \frac{C(N + j(N-1)) - \sum_i b_i^{j+1}}{(N-1)(j+1)}
\end{aligned} \tag{A.6}$$

When assurance is available, according to Proposition 4, similarly we have

$$\sum_i b_i^{j+1} \leq \frac{C(N + j(N-1)) - \sum_i b_i^{j+1} + N_+^{j+1} AP_{j+1} - N_+^{j+2} AP_{j+2}}{(N-1)(j+1)} \tag{A.7}$$

where we define that $N_-^l = \left|\left\{i : b_i^l < AP_l\right\}\right|$ and $N_+^l = \left|\left\{i : b_i^l \geq AP_l\right\}\right|$. Note that when the assurance payment is constant or decreasing, and since the number of individuals qualify for assurance payment becomes lower at a higher unit as the induced value decreases, the presence of assurance payment will increase the upper bound of the total group contribution in equilibrium when $N_+^{j+1} AP_{j+1} - N_+^{j+2} AP_{j+2} > 0$. Also note that for $i \in N_-^{j+1}$, $C - \sum_{i \neq k} b_k^{j+1} \leq AP_{j+1}$ since otherwise individual i can just contribute AP_{j+1} on the $j+1$th unit to increase the profit by AP_{j+1}, therefore, we have

$$\begin{aligned}
\sum_{i\in N_-^{j+1}}\left(C-\sum_{i\neq k} b_k^{j+1}\right) &\leq \sum_{i\in N_-^{j+1}} AP_{j+1}\\
N_-^{j+1}C-\sum_{i\in N_-^{j+1}}\sum_{i\neq k} b_k^{j+1} &\leq \sum_{i\in N_-^{j+1}} AP_{j+1}\\
N_-^{j+1}C-\left(N_-^{j+1}\sum_i b_i^{j+1}-\sum_{k\in N_-^{j+1}} b_k\right) &\leq N_-^{j+1}AP_{j+1}\\
N_-^{j+1}(C-AP_{j+1})+\sum_{k\in N_-^{j+1}} b_k^{j+1} &\geq N_-^{j+1}\sum_i b_i^{j+1}\\
\sum_i b_i^{j+1}\geq C-AP_{j+1}+\frac{\sum_{k\in N_-^{j+1}} b_k^{j+1}}{N_-^{j+1}} &\geq C-AP_{j+1}
\end{aligned} \tag{A.8}$$

□

Corollary 1 shows that an assurance contract increases the lower bound of group contributions in non-provision equilibria from 0 to at least $C-AP_j$ on unit j. In contrast, a zero-group contribution is always an equilibrium outcome when there is no assurance payment.[22] The assurance payment provides strong incentives of contribution even in the case of non-provision. Compared with Proposition 3, Proposition 4 shows that an assurance contract changes the equilibrium conditions, through the potential of receiving the assurance payment.

Corollary 2. *For any value distribution on unit j with a group of N individuals and a provision cost C, if there exists a $\bar{v}^j$ such that $C/\bar{v}^j \leq n^*$, where n^* is the number of individuals with values greater than or equal to $\bar{v}^j$, then provision is the only equilibrium outcome with $AP_j=\bar{v}^j$ under a monotonic assumption.*

Proof. Here we impose a monotonic assumption so that individual i's bid is not decreasing when induced value increases. As a result, individual i's bid will also non-increasing when induced value is downward sloping as the unit increases, or $b_i^j > b_i^{j+1}$. When equilibrium outcome is j units, we have $\sum_i b_i^{j+1}\leq C$. If $b_i^{j+1}<AP_{j+1}$, then $AP_{j+1}\geq C-\sum_i b_i^{j+1}$

[22]When $AP=0$, the bounds of group contributions under UP with assurance payment coincide with those under UP.

since otherwise individual i can just contribute AP_{j+1} on the $j+1$th unit to increase the profit by AP_{j+1}. Also, since j is not provided, then individual i must receive a smaller profit providing $j+1$ units compared to when providing j units. Let $\tilde{b}_i^{j+1} < C - \sum_i b_i^{j+1}$ be the new bid needed to provide the $j+1$ units. Therefore, $v_i^{j+1} - (j+1)\tilde{b}_i^{j+1} + jb_i^k < 0$, or $v_i^{j+1} < (j+1)\tilde{b}_i^{j+1} - jb_i^k$. According to the monotonic constraint, we have $v_i^{j+1} < (j+1)\tilde{b}_i^{j+1} - jb_i^k \leq \tilde{b}_i^{j+1} = C - \sum_i b_i^{j+1} \leq AP_{j+1}$.

When $j+1$th unit is not provided in the equilibrium and if $b_i^{j+1} < AP_{j+1}$, we find that $v_i^{j+1} < AP_{j+1}$, which implies that if $v_i^{j+1} \geq AP_{j+1}$, then $b_i^{j+1} \geq AP_{j+1}$. When $AP_{j+1} = \bar{v}^{j+1}$, and the number of individuals with values greater than or equal to $\bar{v}^{j+1}$ is great than C/v^{j+1}, the contributions from the set of individuals with values greater than or equal to $\bar{v}^{j+1}$ would be at least C, contradicting with the non-provision condition when the $j+1$th unit is not provided. $\square$

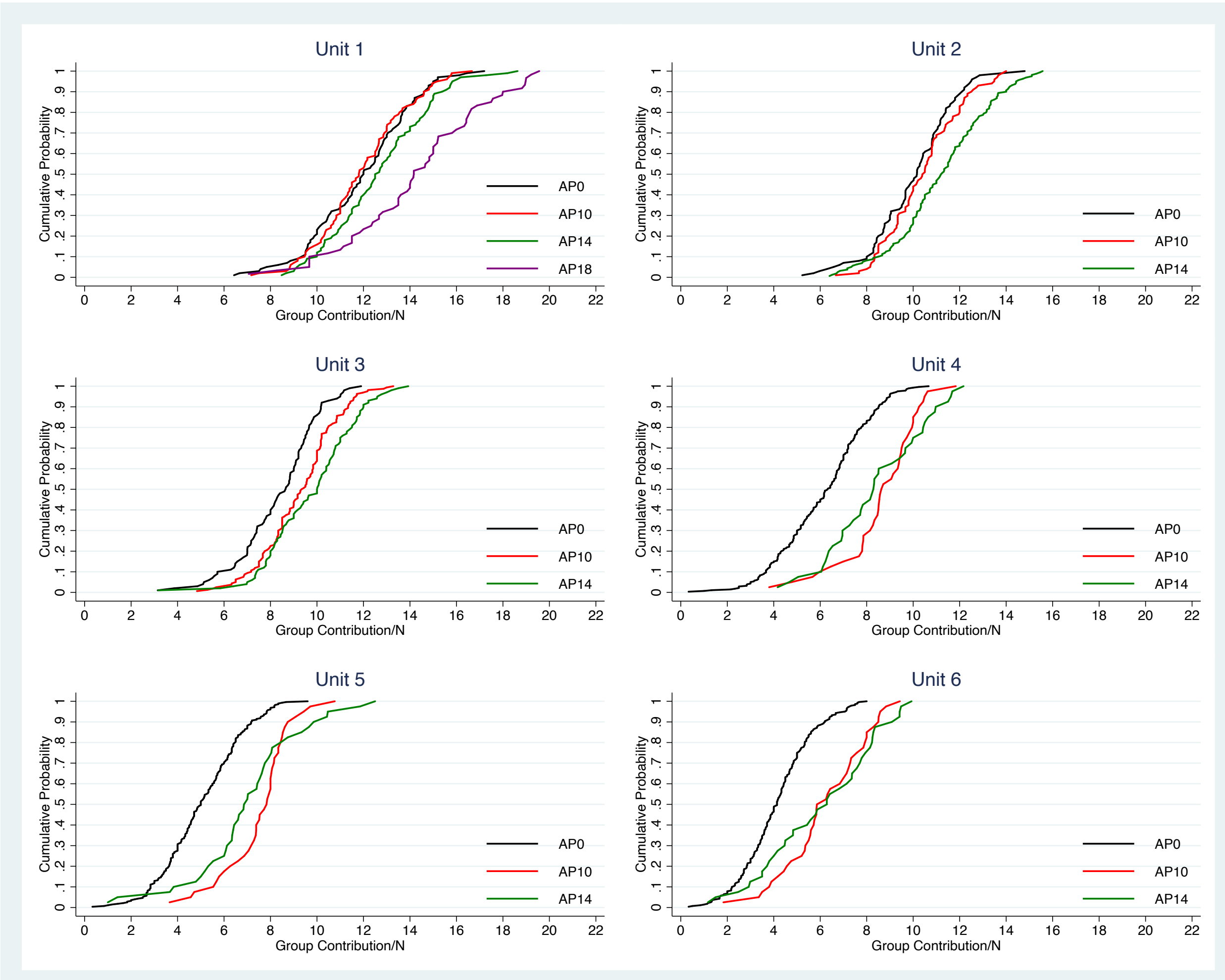
Corollary 2 provides a condition where provision becomes the only equilibrium outcome on a certain unit. When $b_i^{j+1} \geq AP_{j+1}$ for any $v_i^{j+1} \geq AP_{j+1}$ in a non-provision equilibrium, $n^* \geq C/AP_{j+1}$ implies a group contribution not lower than C, contradicting the non-provision condition.

B Supplementary Tables and Figures

Table B.1: The percentage of $B = C$ by AP and unit

AP	0	10	14	18
Unit 1	3.0%	0.0%	2.0%	0%
Unit 2	0.0%	3.0%	3.1%	NA
Unit 3	1.0%	5.6%	3.0%	NA
Unit 4	0.4%	2.5%	2.5%	NA
Unit 5	0.0%	0.0%	0.0%	NA
Unit 6	0.0%	0.0%	0.0%	NA

Figure B.1: Distribution Group Contribution by Assurance Scheme



Note: This figure shows the cumulative probability distribution of group contributions normalized by the group size N at each unit under different assurance payment levels.

C Field Experiment Procedure

In the Appendix, we provide additional materials regarding the field experiment we conducted in Rhode Island. Our pilot experiment is the first to test the assurance contract idea in the field and intends to serve as a proof of concept for future studies. The marketing focus is a migratory songbird called the Bobolink (*Dolichonyx oryzivorus*), as reviewed in the introduction above. It is a protected bird and has been designated as a species of concern due to substantial population declines in the past several decades. The experiment leverages a larger conservation experiment identified as the Bobolink Project that was developing means to generate community contributions to pay farmers for altering farming practices in order to provide better ecosystem and environmental services such as bird habitat.

We conducted the field experiment in April and May 2014. We chose Jamestown, Rhode Island, and Aquidneck Island, Rhode Island, as the study area. The Bobolink Project started in Jamestown in 2007, and since then Jamestown residents have seen several fundraising campaigns. Previous fundraising campaigns used various rebate mechanisms with provision point mechanisms, where a minimum amount of aggregate contributions is required to provide the public good, as detailed in Swallow et al. (2018). The research budget for this pilot experiment enabled an initial mailing of 2,000 fundraising letters in total. Figures D.1 and D.2 in the appendix provide a sample of the survey materials, which include a cover letter and a pledge card. In order to make an offer and be eligible for the assurance contract, we required respondents to mail back negotiable personal checks for the exact contribution amount.

When choosing the treatment parameters, we considered the theoretical and lab experiment results, as well as our previous experience soliciting donations for the Bobolink project. The cost to provide a 10-acre field for Bobolink habit is around $5000 for one year and the average donation is about $40, based on our previous experience with the Bobolink project; thus, approximately 125 contributors are needed to provide a field. Therefore, a response rate of 6.25% (125/2000) would likely be sufficient to deliver one unit. Prior to the field experiment, we also calculated an upper bound of the budget to cover the potential for assurance payments. In the worst-case scenario, if there is no contribution at all from the baseline treatment residents, and no contributions less than $40 from the assurance treatment residents, the maximum total of assurance payments is $4960. Therefore, we set a minimum price (MP, a binding pledge to donate) at $40 in order to qualify for an assurance payment.

To create a list of individuals for the initial mailing, we used all individuals who responded to the Bobolink Project's solicitations in 2013 and obtained a random sample from a commercially available mailing list of individuals who identified their primary residence as Jamestown or Aquidneck Island, Rhode Island, obtaining a total of 2000 addresses (of these, 17% had previously donated to the Bobolink Project). We then randomly assigned these individuals to one of five groups of 400. Table 5 shows the actual number of households who received our mailing, which equals 400 minuses the number of undeliverable letters returned to us by the U.S. Postal Service. We find that demographic variables do not differ significantly across different treatments among the households who received our mailing materials (Table C.1).

Table C.1: Realized Average Social Surplus and Its Allocation

Treatment	Income	Gender	DonExp.	Age	Resi.	Envi.	Dem.	Rep.	Don.	DonProb.	T-test
MP=40, AP=0	N=308										
Mean	138.93	0.53	0.18	59.5	17.82	0.09	0.21	0.1	3.26	0.05	Baseline
(s.d.)	(120.85)	(0.5)	(0.36)	(11.93)	(12.31)	(0.3)	(0.42)	(0.34)	(18.21)	(0.18)	
MP=60, AP=0	N=299										
Mean	141.92	0.52	0.16	60.75	18.04	0.1	0.22	0.13	3.11	0.03	p=0.6107
(s.d.)	(120.85)	(0.5)	(0.36)	(11.93)	(12.31)	(0.3)	(0.42)	(0.34)	(18.21)	(0.18)	
MP=40, AP=20	N=306										
Mean	139.86	0.52	0.16	59.79	18.29	0.11	0.23	0.16	4.05	0.06	p=0.7543
(s.d.)	(119.38)	(0.5)	(0.37)	(12.91)	(13.31)	(0.32)	(0.42)	(0.36)	(19.98)	(0.24)	
MP=40, AP=40	N=309										
Mean	134.44	0.51	0.17	59.83	18.15	0.13	0.22	0.11	3.05	0.05	p=0.9328
(s.d.)	(109.86)	(0.5)	(0.37)	(13.22)	(13.05)	(0.34)	(0.41)	(0.31)	(14.2)	(0.22)	
MP=60, AP=40	N=295										
Mean	141.99	0.52	0.16	59.88	18.39	0.13	0.2	0.09	1.02	0.02	p=0.5741
(s.d.)	(108.62)	(0.5)	(0.37)	(12.86)	(12.84)	(0.34)	(0.4)	(0.28)	(7.22)	(0.15)	
Total	N=1517										
Mean	139.39	0.52	0.17	59.95	18.14	0.11	0.22	0.12	2.91	0.04	
(s.d.)	(115.32)	(0.5)	(0.37)	(12.889)	(12.92)	(0.32)	(0.41)	(0.32)	(15.83)	(0.21)	

Notes: Income variables represents household annual income, in $1,000.?Gender is a dummy variable that equals 1 if male. DonExp. is a dummy variable that equals 1 if an individual has donated previously to the Bobolink Project. DonProb is the number of individuals who donated divided by the net sample (n) of individuals in a group. Age is in years. Resi. Is length of residence in current home, in years. Envi. Is a dummy variable that equals 1 if the individual has previously donated to other environmental groups or purposes. Dem. and Rep. are dummy variables that equal 1 if respondents identify as Democrat or Republican, respectively. Don. Is the dollar amount donated (including zeros). The p-value in this column is a joint test of equality of all covariate means compared to the baseline group where $MP = 40$, $AP = 0$.

We tested the following five treatments in the experiment:

- Treatment D1: Donation (MP=40),
- Treatment D2: Donation (MP=60),
- Treatment A1: Assurance (MP=40, AP=20),
- Treatment A2: Assurance (MP=40, AP=40), and
- Treatment A3: Assurance (MP=60, AP=40).

The five treatments are described in detail in the paper. Because of a high number of zero contributions in the data, we implemented a double hurdle model to address the non-participation issue.[23] The double hurdle model contains two equations and allows the joint identification of a Probit and Tobit estimator. In our case, the decision for individual i to contribute a positive amount is modeled as

$$\tilde{d}_i = Z_i'\alpha + \epsilon_i,$$

where the observed participation choice is indexed by a binary variable $d_i = 1$, corresponding to the latent variable $\tilde{d}_i > 0$ and $d_i = 0$ if $\tilde{d}_i \leq 0$. The vector Z contains treatment and individual attributes that influence the participation decision. Individual i's donation equation is specified as

$$\tilde{y}_i = X_i'\beta + \sigma_i,$$

where the observed donation amount $y_i' = max(\tilde{y}_i, 0)$ for those who decided to contribute (i.e., $d_i = 1$). The vector X_i contains treatment and individual attributes that influence the amount of donation. The error terms ϵ_i and σ_i are assumed to follow a joint normal distribution and the variance of ϵ_i is normalized to 1, thus,

$$\begin{pmatrix} \epsilon_i \\ \sigma_i \end{pmatrix} \sim N \left[\begin{pmatrix} \epsilon_i \\ \sigma_i \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \rho^2 \end{pmatrix} \right]$$

[23]Due to the presence of a large proportion of zero donations (non-compliers), standard treatment effects models that estimate intention-to-treat or the average treatment effects are not significant in the treatment groups. The double hurdle model is better justified in our scenario to detect the influence of assurance contracts ((von Haefen et al., 2005).

The observed donation for all individuals y_i is determined by

$$y_i = d_i y_i'.$$

The log-likelihood function can be written as:

$$LogL = \sum_{i \in \{D_0 | d_i = 0\}} \ln\left(1 - F(Z_i'\alpha)F\left(\frac{X_i'\beta}{\rho}\right)\right) + \sum_{i \in \{D_i | d_i = 1\}} \ln\left(F\left(\frac{Z_i'\alpha}{\rho}\right) f\left(\frac{y_i - X_i'\beta}{\rho}\right)\right)$$

and the estimated coefficients α and β maximize the likelihood function above.

In the regression model, we include a dummy variable, $MP60$, which identifies whether the minimum price suggested was \$60 or \$40 in both traditional donation treatments (D1, D2) and the assurance contract treatments (A1, A2, A3). For assurance treatments, this suggested price is the threshold at or above which an individual's contribution is eligible for assurance payment upon provision failure. The $MP60$ equals 1 if the suggested price is \$60, while treatment using the suggested price of \$40 establishes the baseline ($MP60 = 0$). We include the dummy variables $AP20$ and $AP40$ for different assurance payment levels to contrast with the no assurance payment baseline (donation) treatment where $AP = 0$. The interaction dummy $MP60 * AP40$ is included as well. Individual characteristics include household income (in thousands), gender, donation experience with the Bobolink project before, age, length of current residence, donation experience to environmental organizations and political affiliations (Table C.1). To test the different effects of assurance payments on individual contributions at different values, we treat the variable $Donation\_before$ (donation experience with the Bobolink project before) as an indicator of high-value people and interact it with assurance payment dummies.

Table C.2 shows our regression results using the double hurdle model. Model 1 presents the full specification result, and Model 2 is the restricted model which drops individual characteristics that were not significant at $p < 0.10$ and were irrelevant for interpretations. The discussion in the paper focuses on the estimated coefficients in Model 2.

Table C.2: Two-factor random effects models of group value revelation for each unit

Variables	Model 1		Model 2	
Equation:	Probit	Tobit	Probit	Tobit
MP60	-0.283	37.06	-0.251	29.1
	-0.233	-24.85	-0.22	-24.29
AP20	0.31	21.49	0.195	13.15
	-0.243	-28.3	-0.214	-27.75
AP40	0.836	-105.2**	0.337	-98.40***
	-0.975	-45.51	-0.269	-32.65
MP60*AP40	-0.328	11.51	-0.258	34.25
	-1.113	-64.91	-0.443	-43.63
Income	0.00101	0.135**	0.000973*	0.142***
	-0.000692	-0.0638	-0.000503	-0.0485
Gender	-0.144	-7.11		
	-0.158	-13.64		
Don.before	1.040***	5.196	0.771***	4.672
	-0.232	-26.86	-0.196	-27.02
Don.before*AP20	-0.573	-53.2		-64.13*
	-0.485	-42.61		-35.93
Don.before*AP40	-0.728	117.4**		111.1***
	-1.02	-49.87		-35.47
Don.before*MP60*AP40	-0.312	-58.52		-122.5**
	-1.171	-72.34		-49.96
Age	-0.00335	0.141		
	-0.00748	-0.699		
Len.Res.	0.0263***	-0.171	0.0255***	-0.276
	-0.00652	-0.643	-0.00613	-0.639
Envdonor	0.514**	-22.11	0.540**	-23.09
	-0.229	-18.59	-0.217	-17.16
Democrat	0.0323	-16.69		
	-0.214	-19.12		
Republican	0.156	16.17		
	-0.203	-18.78		
Constant	-2.460***	30.89	-2.605***	42.31
	-0.502	-56.99	-0.243	-35.06
Sigma	42.97***		44.32***	
	-6.326		-6.325	
Number of observations	1517		1517	
Chi-square	19.68		36.33	
Log-likelihood	-545.3		-550.1	

Notes: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

D Lab and Field Experiment Instructions

This is an experiment in the economics of decision-making. During the experiment, you will be asked to make a series of decisions. If you follow the instructions and make careful decisions, you can earn a considerable amount of money.

Experiment Overview

- You will be asked to decide how much money to offer towards the cost of several public goods in discrete units. This cost of the public good is predetermined and known to you.
- You will be randomly assigned to one of the two groups at the beginning. Your group members will change after each decision period.
- All members of your group receive a benefit that depends on the number of units being provided. The number of units provided depends on your decision AND those decisions of the other people in your group.
- Earnings in each decision period are based on how much you are willing to invest, how much you earn (your benefits) if the good is provided and the investment decisions of the others in your group. In some of the treatments, you may also earn extra money by satisfying our assurance contract requirement.

How You Earn Money

At the beginning of each period, you will be told the individual values (benefits) you receive if that unit of public good is provided. The individual value for one unit of public good can be different across people; someone may have a higher value than you, while the others may have a lower value than you. Your individual value will change after each decision period. You will then be asked to make contributions according to our rules. There are six public good units available in total and the cost is same for each unit.

You will be working with experimental dollars. Your initial fund will be 250 experimental dollars, which represents your fee for showing up today. Your earnings for each period will be added to or subtract from this amount. After the experiment, we will convert your earning to cash with a ratio 50:1; that is, if your balance at the end of the experiment is $1000, you will receive $20 in cash. There are three treatments in the experiment. You will be paid as you leave.

Group

Your group is important because the moderator, using a computer program, will evaluate the combined decisions (i.e. contributions) from each member of your group to determine the outcome. In this way, the decisions of every person in your group may impact your profit. You do not know others' contributions or benefits.

Communication

Communication is NOT allowed between participants once we begin today. If you have any questions during the treatments, please raise your hand.

Treatments, Periods

There are 15 decision periods in each treatment. We expect to finish the whole experiment within one hour and thirty minutes or so.

<u>What you need to do?</u>
Once the program is activated, please make a contribution for ***<u>each</u>*** public good unit. There are six units of public good available in total.

<u>Your value</u>

Your value on the first unit is randomly drawn from [15, 25], your value on the sixth (last) unit is randomly drawn from [5, 15]. Others' values are also randomly drawn from the same intervals; thus, someone may have a higher value than you, while some may have a lower value than you. Your value decreases from the first unit to the last unit.

<u>How is your profit calculated?</u>

- Your profit= Your benefit - Your cost.

- Your benefit= sum of your values for all the units that are provided.
  Your benefit depends on the number of units that your group collectively supports. You will receive your value for each unit supported. For example, if your group supported the first three units, and your values for the first three units are \$20, \$15, \$10, your benefit is \$20+\$15+\$10=\$45.

- Your cost=contribution on the last unit provided × number of units provided.
  Your cost also depends on the number of units that your group could collectively support. Your cost is ***your contribution on the last unit provided*** times ***the number of units provided***. For example, if your group supported the first three units, your contribution on the third unit is \$5, then your cost \$5 × 3=\$15.

- Under this situation, your profit=\$45-\$15=\$30.

<u>How to decide if a unit can be provided?</u>

- We will compare the total contribution of your group for each unit with the public good cost for that unit, starting from the ***first unit***. If the group's total contribution on the first unit is higher or equal to the cost for the first unit, we continue to compare the contribution on the second unit with the cost of that unit, and so on.
- We will stop when the total group contribution for a unit is ***smaller*** than the unit cost.

All the numbers used in examples serve only illustrative purpose; please do not try to use these examples to guess what would actually happen in the experiment.

<u>Assurance</u>

In this treatment, we offer an assurance contract for the first three units. Your total profit is whatever you can get from providing the public good, plus any assurance payment whenever applicable. We try to protect you from getting zero benefits when you were willing to contribute above a certain level. That is, if your contribution on the first three units is higher or equals to a certain level, and if that unit is the first unit not provided, then we will compensate you an amount equal to the level we set with the table below, which we call the minimum contribution for assurance. Below is the minimum contribution for assurance you need to reach in order to get an assurance payment in case of provision failure; you may decide to contribute less if you wish, but then you will not be eligible to receive the assurance payment.

Unit	Minimum Contribution	Your Compensation
1	14 experimental dollars	14 experimental dollars
2	14 experimental dollars	14 experimental dollars
3	14 experimental dollars	14 experimental dollars

You receive assurance payment only for the first unit not provided. For example, if your values on the six units are {20, 15, 10, 5, 4, 3}, and contributions on the six units are {15, 14, 10, 5, 4, 2}, with the assurance,

- If 0 units are provided, and we fail to provide Unit 1: Since your contribution on Unit 1 is $15, which is higher than $14, the minimum contribution, you will get a compensation from our assurance, $14. Thus, your total profit is $14. However, if you contributed lower than $14, say $10, your profit is $0.
- If 1 unit is provided, and we fail to provide Unit 2. Since your contribution on Unit 2 is $14, which equals $10, the minimum contribution, you will get a compensation from our assurance, $14. Thus, your total profit is your profit from providing 1 unit, $20-$15=$5, plus the compensation from our assurance, $14; therefore, your total profit is $5+$14=$19. However, if you contributed lower than $14 on the unit 2, say $8, your profit is $5.
- If 2 units are provided, and we fail to provide Unit 3. Since your contribution on Unit 3 is $10, which is smaller than $14, the minimum contribution, you will NOT get a compensation from our assurance. Thus, your total profit is your profit from providing 2 unit, $20+$15-2*$14=$7. However, if you contributed more than (or equal to) $14 on Unit 3, say $15, then your profit is $7+$14=$21, since you get our assurance $14.
- We only provide assurance for the first three units.

<u>Quiz (4 mins):</u>

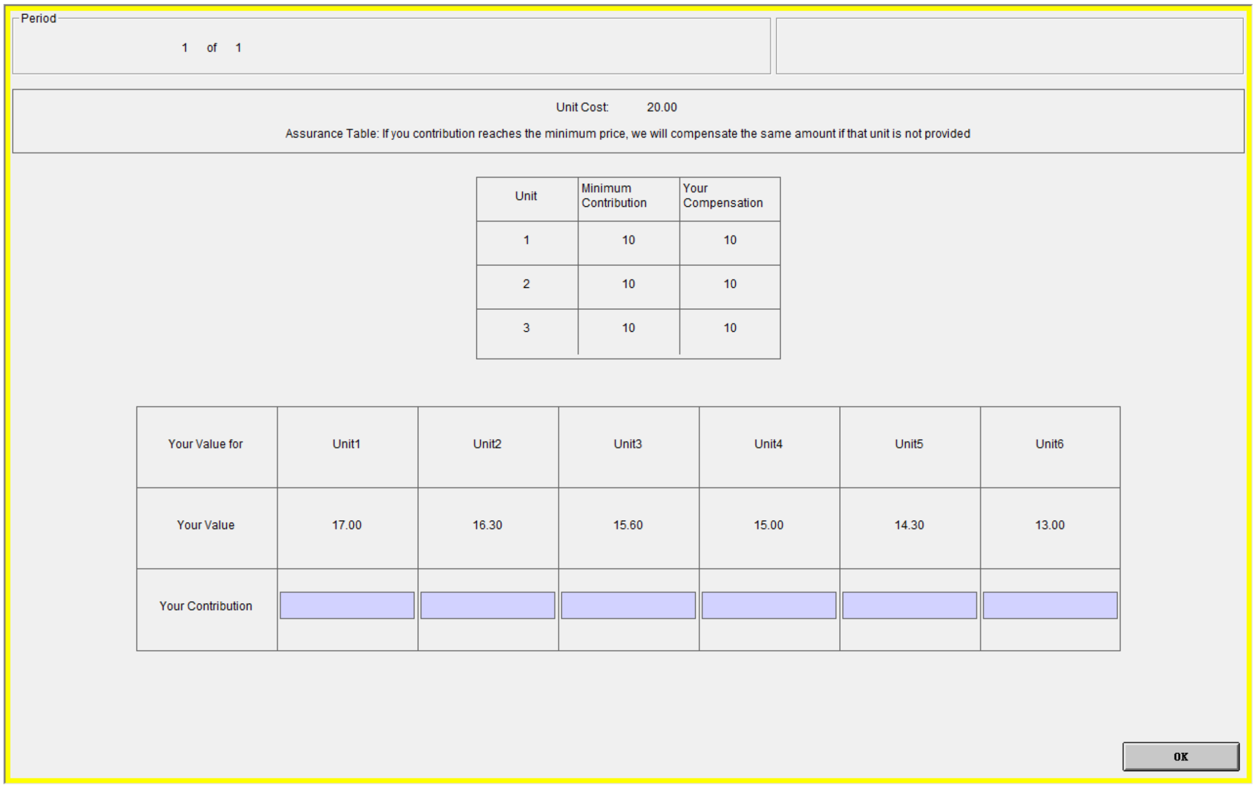
1. If your contributions on the first 4 units are \$15, \$10, \$9, \$6, respectively, and your group provides 2 units, what's your cost in this case?

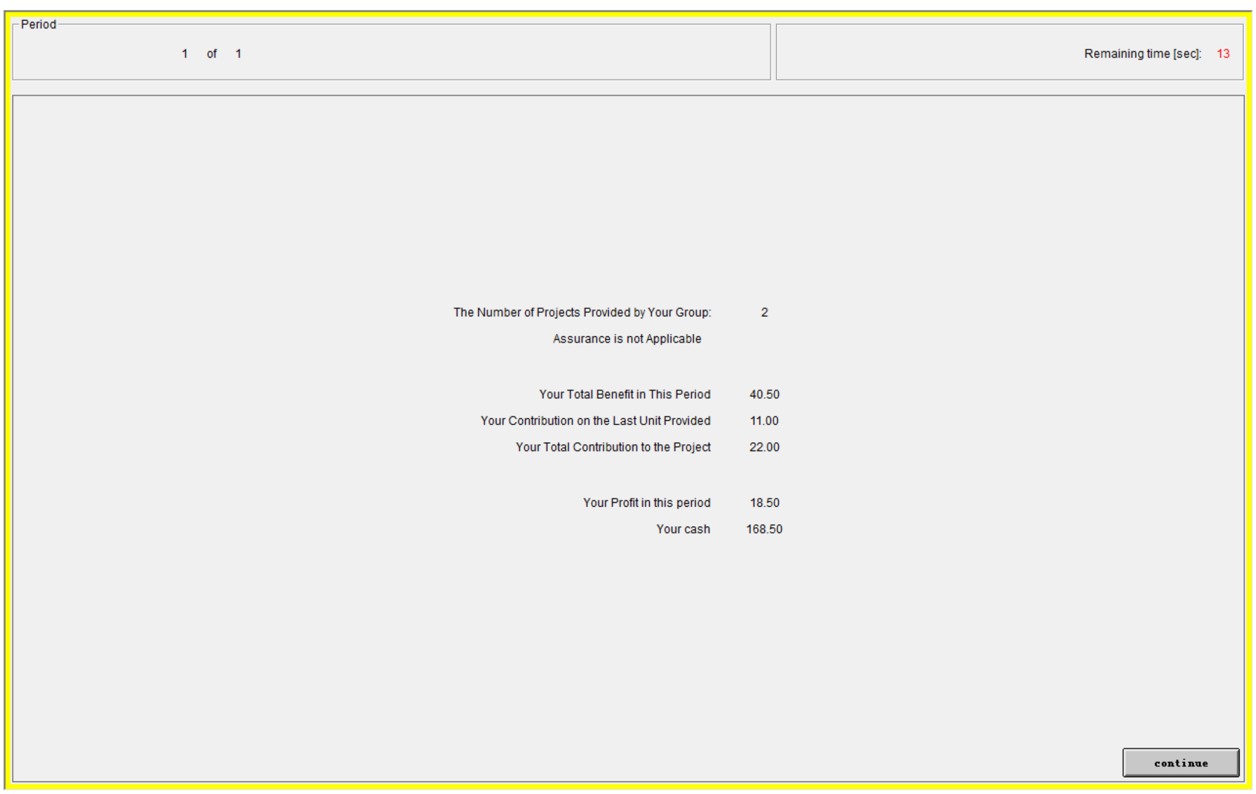
2. If your contributions on the first 4 units are \$15, \$10, \$9, \$6, respectively, your benefits on the first 4 units are \$20, \$10, \$5, \$3, and if your group provides 2 units, what's your profit in this case? What's your profit if your group provided 1 unit? What's your profit if your group provided 0 units?

3. If there are five people in your group, their values are the same for the first five units which are {20, 18, 16, 14, 12}; their contributions on the first unit are {15, 15, 15, 15, 15}, their contributions on the second unit are {13, 13, 13, 13, 13}, their contributions on the third unit are {9, 9, 9, 9, 9}, their contributions on the fourth unit are {5, 5, 5, 5, 5}, and if the provision cost is 50. How many units are provided in total? What's the profit of one people? If only one unit is provided, what's the profit of one people?

At the end of the experiment, your earnings will be totaled across all periods and converted from experimental dollars to real dollars. You will be paid as you leave.

Now please make your decisions!


Period
1 of 1
Unit Cost: 20.00
Assurance Table: If you contribution reaches the minimum price, we will compensate the same amount if that unit is not provided
Unit | Minimum Contribution | Your Compensation
1 | 10 | 10
2 | 10 | 10
3 | 10 | 10
Your Value for | Unit1 | Unit2 | Unit3 | Unit4 | Unit5 | Unit6
Your Value | 17.00 | 16.30 | 15.60 | 15.00 | 14.30 | 13.00
Your Contribution
OK


Period
1 of 1
Remaining time [sec]: 13
The Number of Projects Provided by Your Group: 2
Assurance is not Applicable
Your Total Benefit in This Period 40.50
Your Contribution on the Last Unit Provided 11.00
Your Total Contribution to the Project 22.00
Your Profit in this period 18.50
Your cash 168.50
continue

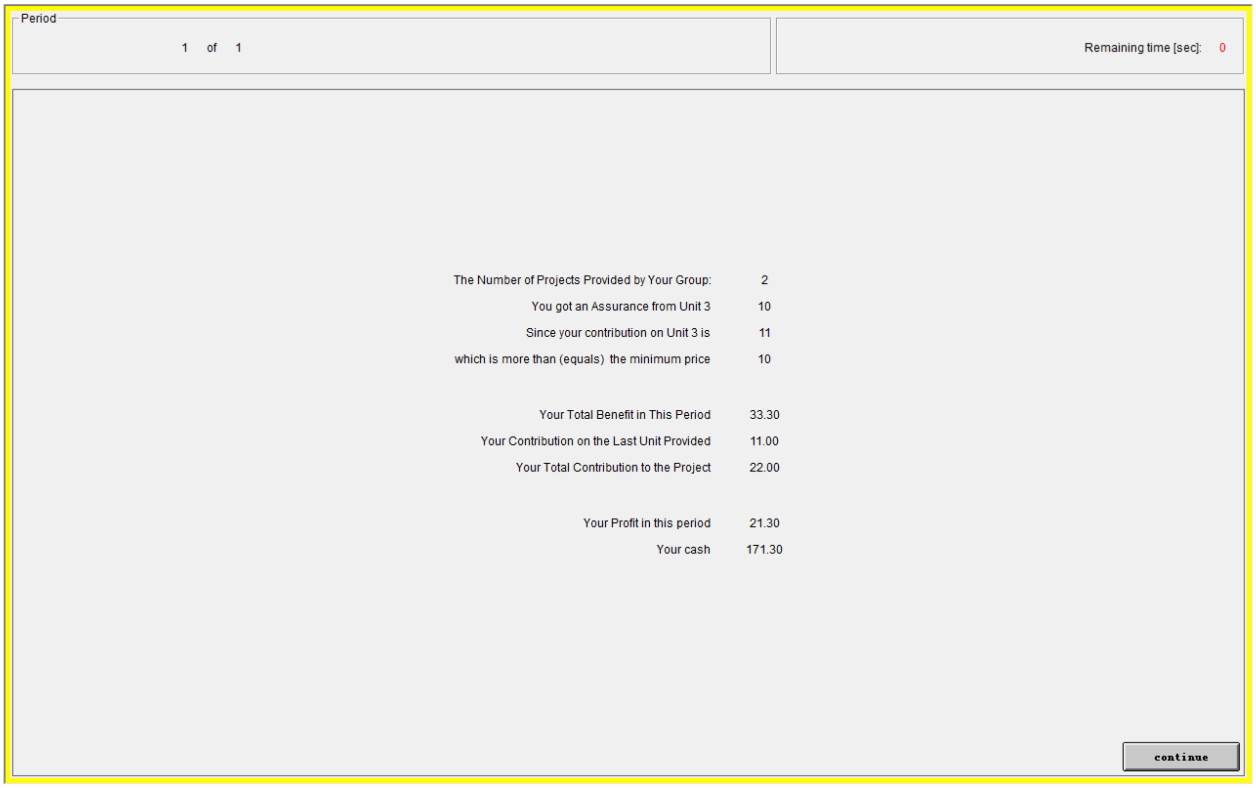

Period
1 of 1
Remaining time [sec]: 0
The Number of Projects Provided by Your Group: 2
You got an Assurance from Unit 3 10
Since your contribution on Unit 3 is 11
which is more than (equals) the minimum price 10
Your Total Benefit in This Period 33.30
Your Contribution on the Last Unit Provided 11.00
Your Total Contribution to the Project 22.00
Your Profit in this period 21.30
Your cash 171.30
continue

Figure D.1: Field Experiment Mailing Material: Introduction

Bobolink Project 2014 Donation and Pledge Agreement:

[redacted]

Protect Your Money, Help Our Environment

The Bobolink Project began as a pilot program in Jamestown, Rhode Island, in 2007. Since then, the Bobolink Project has reached throughout Rhode Island and Vermont, with focused effort in Jamestown, Aquidneck Island and northwestern Vermont. Last year we successfully supported 24 fields covering 200 acres in Vermont and 40 acres in Rhode Island. We write you today to enable our efforts to continue in Jamestown for 2014.

Please read about our **Participation Challenge Fund** below. While this is part of our research to explore and test new ways that help us better connect your environmental values with the farmers who can help, this project provides a means for actual conservation of bird habitat during the nesting season. Your participation is voluntary, and we will keep your decision confidential.

We raise money to pay farmers for altered farming practices that better provide the environmental services (like bird habitat) you value. All your contributions will be directed to support as many fields as possible in Jamestown. All other costs of the project, such as the postage, advertising, and research effort, are currently supported by grants and other funds through the University of Connecticut. Any donation you choose to make will **only** be used to help farmers provide for nesting birds in Jamestown.

As a resident of Jamestown, you know we are trying new approaches. This year, we have a **Participation Challenge Fund** from a private supporter of the University of Connecticut; these funds are available to encourage participation in the Bobolink Project in Jamestown:

- If you agree to a *minimum* donation of $40, and *if we fail* to raise enough money to provide a field for nesting Bobolinks in Jamestown, then we will *not only* return your donation *but we will also* send you $20 from our "Participation Challenge Fund" as compensation for your generous consideration.
- Of course, if you want to donate less than $40, we would be happy to have your help, but in that case if we fail to provide a field we would only return your check, along with our thanks for the effort to help.
- And, of course, if you and other donors provide enough to succeed in funding one or more fields in Jamestown, we will process your donation, compensate farmers for their efforts to support grassland nesting birds, and rebate, to you, your share of any funds left over, while also providing a receipt for your donation.
- Our deadline is April 15 for Jamestown. We will let you know the outcome by May 15, 2014.

We have farmers ready to contract for hayfields in Jamestown this summer, in an increment of 10-acres. The cost for supporting a 10-acre field is around $5000, per field, in Jamestown this year. Recent changes in energy markets have actually caused farmers to face even more costs if they join with the Bobolink Project, so your help is needed even more this year than last.

You can simply choose how much to contribute by completing the questions on the next page. Remember, as in previous years, **if we raise more** than the amount needed to support a field, we will refund that excess back to those who donated so that we don't keep any extra money. Your money either helps farmers provide for birds or it gets sent back to you.

Sincerely,

[redacted]

Figure D.2: Field Experiment Mailing Material: Assurance Experiment

Bobolink Project 2014 Donation and Pledge Agreement:

[redacted]

Protect Your Money, Help Our Environment

Please complete these questions

Making a donation of $40 or more will qualify you for an “assurance payment” of $20 from our Challenge Fund. If, despite your help, our efforts fail to fund a field in Jamestown, and if you offered at least $40, we will not only return your donation but also send you a check for $20 which you can use for anything important to you. Of course, we hope to succeed, with your help, and put your donation to good effect in Jamestown.

1. Are you willing to contribute at least $40 to the Bobolink Project?

   Yes_________ (You are eligible for a thank you gift of $20 from our Participation Challenge Fund *if we fail* to provide a Jamestown field. Please go to question 2).

   No_________ (Please go to question 3).

2. Are you willing to contribute more than $40? (If yes, please specify your amount below; if no, just return the payment card with your check, as instructed below.)

   $_________ (You are still eligible for the Participation Challenge gift. Skip question 3.)

3. Are you willing to contribute less than $40? If yes, please specify your amount below and return this form with your check as instructed below: if no, please just return the payment card.

   $_________ (Of course, we appreciate ANY level of donation you choose.)

If you are agreeing to support farms and habitat in Jamestown today, please make a check payable for the amount you named above to “University of Connecticut;” on the memo line, please write “Bobolink Project-Jamestown.” If not, we hope you’ll still return this card, and your opinions will help us better protect the things you care about.

Phone Number__________________________
Email__________________________

____
Please sign here

Check the website to learn more about the Bobolink Project: http://www.bobolinkproject.com/index.php. **You can also pledge through the website by using your ID** [redacted]

With this form, please write a check Payable to the “University of Connecticut” for your donation (on the memo line, write “Bobolink Project – Jamestown”) and mail it, ***with this form*** to:

[redacted]