Supporting Private Provision of Ecosystem Services through Contracts: Evidence from Lab and Field Experiments

Abstract The free riding incentive that exists in public good provision has been a major obstacle to establishing markets or payment incentives for 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, while the producer surplus suffers from a slight decrease. 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 proximate motivation is to support bird habitat provided by farmland, but our approach contributes to the private provision of ecosystem services and other types of public goods in general.

Keyword: Assurance Payments, Public Good Provision, Multi-units Provision, Experimental Economics, Individualized Pricing, Ecosystem Service

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, the benefits that nature provides to human well-being (Millennium Ecosystem Assessment 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 point or non-point sources and public goods such as wildlife habitat enhanced (or degraded) but some agricultural practices. Social institutions and governments have addressed these externalities through command and control regulation, philanthropic (conservation) efforts, government payment for ecosystem services (PES) (such as through the USDA Conservation Reserve Program), and, increasingly, through market-based approaches such as regulatory-driven cap-and-trade systems (Swallow et al. 2008; Shortle 2013; Schomers and Matzdorf 2013; Ferraro 2008, 2011). Such 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 some (unregulated) individuals may voluntarily enter such markets; for example, web sites exist where individuals may buy carbon offsets in relation to personal travel.[1]

Our research contribution addresses the demand side and contributes to understanding alternative mechanisms to engage individuals who value ecosystem services to enter markets or market-like exchanges. Johnston and Russell (2011) explicitly link the definition of ecosystem services to the concept of human well-being by establishing the criteria that a change in ecosystem outputs or conditions is only an ecosystem service if at least one rationale individual is willing to pay for more of that ecosystem-dependent change in the absence of any other type of change. While the willingness to pay (WTP) for nature's benefits constitutes a foundation for regulatory, PES, and philanthropic approaches, we contribute to a 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 (e.g., Banerjee et al. 2013; Swallow et al. 2008; Swallow 2013; Swallow et al. 2018; Uchida et al. 2018). In particular, we focus attention 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.

[1] The ecosystemmarketplace.com provides an overview of alternatives, and a Google inquiry uncovers numerous alternatives (i.e., https://www.terrapass.com).

Our motivating example for both laboratory experiments and a pilot field experiment, reported here, is the provision of safe habitat for grassland nesting birds, particularly the bobolink. In the northeast, bobolinks largely depend on working hayfields for habitat, but as reviewed by Swallow et al. (2018), the nesting season directly conflicts with the desirable harvest schedule for agricultural producers to capture the peak nutritional value of hay as feed for livestock. While not endangered nationally, bobolink populations have experienced steep declines and are attractive to even casual bird watchers due to their visibility over grasslands and their song that even a novice can easily identify simply by listening for a sound similar to the robotic character R2-D2 from Star Wars movies. In focus groups and in feedback from donors to The Bobolink Project (Swallow et al. 2018), many individuals identify these birds with rural or childhood and family experiences. These factors stimulate a willingness to pay for many individuals. Unfortunately, conservation of nesting habitat requires that farms forego harvests of a minimum of 10-acre hayfields (ideally with a low edge-area ratio, such as a circle or square rather than a long, thin rectangle), so that a provision point of funding is necessary to compensate farmers for a discrete increment in foregone harvesting of hay.

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 general support for the organizations 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 part or in full. In contrast, we intend a more market-like approach which connects donations (contributions or purchases) directly to a specific good or service being delivered. Accordingly, funds raised to support a 10-acre field of bobolink 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. Swallow et al. (2018) provides an extensive review of the relationship between such an approach and the literature on charitable giving, including related experimental economics, while also considering insights from environmental valuation literature. In particular, our approach strives to maintain a direct connection between contribution and the good being delivered, just as markets for private goods connect 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 (e.g., Rondeau et al. 1999; Rondeau et al. 2005; Poe et al. 2002; Rose et al. 2002). Many of these studies have involved 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 there can yield a multiplicity of equilibria. In this context, the individual needs to decide whether to participate and then, conditional on participation, decide how much to contribute. While the MBG reduces the incentive to free ride, it does not necessarily lead to participation or donation consistent with individual's marginal WTP. For provision of a single unit, researchers have considered various forms of a rebate of any funds raised in excess of the provision point (e.g., 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 (producer) surplus generated by the generosity of donations made in excess of 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 additional, rather strong refinements (Bagnoli and Lipman 1989; Bagnoli and McKee 1991; Bagnoli et al. 1992), particularly in a multiple-units public good setting. Of course, if the challenges were simple, the public goods problem would have already been settled through use of, for example, incentive compatible mechanisms; unfortunately, such mechanisms either do not actually fund public goods (they are not budget balancing) or they are complex and difficult for novices to grasp (Clarke 1971; Groves and Ledyard 1977; Ledyard 1975; 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 (e.g., Falkinger et al. 2000; Masclet et al. 2003). Here,

[2] Here, free-riding occurs when an individual expresses a positive Hicksian willingness to pay (WTP) for a good but nonetheless 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.

we examine an alternative approach that rewards individuals who commit to contribute toward provision of the public good.

We begin from Tabarrok's (1998) 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 (or actually donates) $40 or more toward 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 $20 in addition to refunding the $40 donation. Tabarrok (1998) shows that the assurance contact can successfully eliminate the non-provision equilibria 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 public good provision by offering compensation (an assurance payment) to would-be contributors if, in the end, the group fails to provide the public good. 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 tested experimentally for public good provision, which motivates this paper.[3]

In our laboratory experiment, we expand the assurance contract to address the multiple-units 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. Indeed, in a separate project, we are already collaborating with a coalition of state-level bird-conservation societies in New England whereby these organizations are aggregating donations to provide grassland bird nesting habitat across several northeastern states. In our theoretical analysis, we show that the assurance contract can reduce the number of non-provision equilibria, possibly eliminating them, but sometimes while also reducing the space for provision equilibria. 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. In the laboratory

[3] 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.

experiments with multiple units, we show that a positive assurance payment always out-performs the case without an assurance payment, using criteria such as the rate of provision, revelation of the group's value (aggregate WTP), and realized social surplus. However, it remains possible that the provider (producer) incurs a deficit if the assurance contract inadvertently leads to frequent non-provision.

We follow up 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 field experiment, is too small to draw definitive conclusions, there are indications that the direction of effect for the assurance payment is encouraging. We find that the influences of assurance payment are predicted by our theory. Although a relatively high assurance payment may decrease contributions from low value individuals, this effect can be offset by increased contributions from high value contributors, while the net effect is determined by the interactions between the value range and the assurance payment level in equilibrium. As a result, better information on individual value range may be needed to design an "optimal" assurance payment level. This observation suggests that future research is needed to enable market-makers to optimize the assurance contract as a tool for success.

Before the remainder of the paper presents the theoretical discussion, the laboratory results, and the field experiment in successive sections, one note is 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 with regard to charitable giving, requiring a balance between stimulating participation and donation while offsetting effects of crowding-out donations partially or wholly for some individuals (e.g., List and Lucking-Reiley 2002; List 2011). We suggest that one can view the assurance payment fund as an alternative form of 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. While we do not address those details here, we suggest these perspectives indicate the potential to implement the assurance contract is real.

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 cost *C* through voluntary contributions. Each individual is indexed by $i \in \{1,\ldots,N\} \equiv I$ and each unit of the public goods is indexed by $j \in \{1,\ldots,J\} \equiv J$. Individuals are asked to bid or contribute toward each unit of the public goods. Let v_i^j and b_i^j be individual *i*'s value and bid toward Unit *j*, respectively. The total bids on Unit *j* are $B_j = \sum_{i\in I} b_i^j$, where $j \in J$. Individual *i*'s value on Unit *j* v_i^j is independently and randomly drawn from $[\underline{v}_j, \overline{v}_j]$ for $i \in I$, *j*=1 and *J*, and v_i^j for *j*=2, …, *J* – 1 is determined by $v_i^j = v_i^1 - (j-1)(v_i^1 - v_i^J)/(J-1)$, assuming $\underline{v}_1 \geq \overline{v}_J$.

2.1 Multi-Unit Public Goods Provision without Assurance Payment

The baseline mechanism is called the uniform price (UP) mechanism in a multiple units setting where an individual pays for the same price for all units provided.[4] In the UP mechanism, we compare the total bids from all individuals on each unit with the unit cost of the public good, starting from Unit 1. If individuals' total bids on the first unit are greater than or equal to the cost of Unit 1, we continue to the second unit, and so on. We will stop when the total bids for a unit are less than the unit cost. For example, if the total bids on the first, second and third units are all greater than the unit cost, but the total bids 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

[4]The price mechanism is discussed as one of individualized pricing approaches to support multiple units of a public good in Swallow et al. (2013).

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

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

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 bid on the last unit that the group can collectively provide. Therefore, the pricing rule in UP for individual *i* is given by

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

The payoff function π_i for individual *i* in UP is[5]

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

2.2 Assurance Payment Schemes

Assurance payment is a predetermined compensation to whoever bids at or above a pre-specified minimum offer when the provision fails. For example, if the assurance payment is $10 on the first unit when one bids at or above the $10, and if the total group bids are below the cost of the first unit (nothing will be provided in this case), whoever bids $10 or above on the first unit will receive an assurance payment of $10 in addition to a full refund of their original bids (money back guarantee), while those bid less than $10 will only receive their refunds but no assurance payment.

Assurance payment schemes vary in terms of the minimum offer and the compensation on different units. The original assurance contract in Tabarrok (1998) includes a dichotomous contribution choice and specifies the number of individuals to accept the contract in order to provide the good. In this paper, we allow for a continuous contribution in a threshold public

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

good setting with the minimum offer equals the compensation.[6] Specifically, let AP_j denote the assurance payment (which equals the minimum offer) for Unit *j*, then the payoff function for individual *i* is

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

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

3 Theoretical Benchmarks: Nash Equilibria with Assurance Payment

A theoretical characterization of the equilibrium set of a multi-unit UP with *AP* in an information environment close to the real world is beyond the scope of this paper. Our lab and field 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, we characterize the Nash equilibrium of UP with assurance payment for a single unit case under complete information and provide numerical examples in the online appendix.[7] 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 UP without assurance payments (*a.k.a.* provision point mechanism, i.e., $AP = 0$) are characterized by Bagnoli and Lipman (1989) as follows:

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

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[6]This assumption will be relaxed in our field experiment where the minimum price and assurance payment can differ.

[7]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.

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

Proposition 1 states that any contribution strategy profile where the group contributions exactly add up to the provision cost, and no one contributes above their values, is a Nash equilibrium. **Proposition 2** states that if group contributions are less than the cost, no one can fill in the gap alone without contributing above her value. Note that both equilibrium sets in UP include multiple equilibria (or a continuum of equilibria) and the non-provision equilibrium set is never empty under UP. Next we show that UP with *AP* reduces the multiplicity of the equilibrium sets above, especially the non-provision equilibria, and can eliminate the non-provision equilibria in a quite general parameter setup. The provision and non-provision Nash equilibrium sets under UP with *AP* are characterized as follows. [8]

Proposition 3 (provision equilibrium with *AP*): Any strategy profile $\{b_i\}_{i \in I j}$ *s.t.* $\sum_{i \in I} b_i = C$ is a pure-strategy Nash equilibrium for one-unit UP with $AP \in [C/N, C]$ if $b_k \leq \max\{v_k - AP, AP\}$ for $v_k \geq AP$ and $b_k \leq v_k$ for $v_k < AP$, for any $k \in I$.

Proof. See online appendix.

Proposition 4 (non-provision equilibrium with *AP*): Any strategy profile $\{b_i\}_{i \in I j}$ *s.t.* $\sum_{i \in I} b_i < C$ is a pure-strategy Nash equilibrium for one-unit UP with $AP \in [C/N, C]$ if

(i) $AP > v_k - b_k - (C - \sum_{i \in I} b_i)$ for all $k \in I^{+} = \{i \in I j\, b_i \geq AP\}$; and

(ii) $AP > C - \sum_{i \neq k} b_i > v_k$ for all $k \in I^{-} = \{i \in I j\, b_i < AP\}$.

Proof. See online appendix

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

Under UP with *AP*, the contribution for individuals with values greater than or equal to *AP* cannot exceed the maximum of *AP* and the difference between their values and *AP*, hence reduces the multiplicity of the provision equilibria. Note that in the equilibrium with a given *AP*, the upper bound of the group contribution is $\sum_{i\in\{k:v_k\geq 2AP\}}(v_i - AP) + \sum_{i\in\{k:AP\leq v_k<2AP\}} AP$ $+\sum_{i\in\{k:v_k<AP\}} v_i$, and the provision equilibrium set becomes empty when the upper bound is less than *C*. However, as long as $\sum_i v_i \geq C$, we can always choose an *AP* large enough so that the upper bound of the group contribution is greater than or equal to *C* and the provision equilibrium is non-empty.[9] More importantly, UP with *AP* significantly reduces the non-provision equilibria. The following corollary based on **Proposition 2** and **4** shows the bounds of the group contributions in non-provision equilibria.

Corollary 1. In a non-provision equilibrium strategy profile with complete information, we have $\sum_{i\in I} b_i \in \left[0,\ C - \left(\sum_{i\in I} v_i - C\right)\big/\left(N-1\right)\right]$ under one-unit UP, and

$$\sum_{i\in I} b_i \in \left[C - AP + \frac{\sum_{i\in I^-} b_i}{N^-},\ \min\{C - \frac{\sum_{i\in I^-}(v_i - b_i)}{N^-}, C + AP - \frac{\sum_{i\in I^+}(v_i - b_i)}{N^+}\}\right]$$ under one-unit UP

with $AP \in [C/N, C]$, where $N^- = |I^-| = |\{i \in I \mid b_i < AP\}|$, $N^+ = |I^+| = |\{i \in I \mid b_i \geq AP\}|$.

Proof. See online appendix.

Comparing with the bounds of the group contributions in equilibrium under UP, UP with *AP* eliminates a substantial subset of contribution profiles supporting a non-provision equilibrium. Note that $C - AP \leq C - AP + \sum_{i\in I^-} b_i \big/ N^-$, and hence UP with *AP* increases the lower bound of the group contributions from 0 under UP to at least $C - AP$, meaning that even in a non-provision equilibrium, the difference between the group contributions and the cost is no more than *AP*. For example, when *AP* is equal to *C*/*N*, the group contributions should be at least *C* – *C*/*N*, while in UP, a zero-group contribution is always an equilibrium outcome.

[9] Note that when *AP* = *C*, the upper bound of the group contribution under UP with *AP* is always greater than or equal to *C*, as long as the group values are at or above *C*.

The key insight here is that assurance payment provides a strong incentive to contribute even in the case of non-provision. In the next corollary, we identify a condition where the non-provision equilibrium set becomes empty and provision is the only equilibrium outcome with assurance payment.

Corollary 2. For any value distribution Q with a group of N individuals and a provision cost C, if there exists a v^* such that $C/v^* \leq n\,(v^*) = |\, i \in I\, j : v_i \geqslant v^*$ for all $v_i \in \mathrm{Q}\,|$, then provision is the only equilibrium outcome for one-unit UP with $AP = v^*$.

Proof. See online appendix.

To see this, note that **Proposition 4** (ii) implies that if $b_k < AP$, then $v_k < AP$, and hence if $v_k \geq AP$, we have $b_k \geq AP$ for any $k \in I$, which means that in a non-provision equilibrium, whoever has a value of at least AP will not contribute less than AP. If the number of individuals with values at or above AP is greater than C/AP, then all these individuals will contribute at least AP in a non-provision equilibrium, which is not possible as their total contributions would be at least C. Thus, the non-provision equilibrium does not exist.

The theoretical analyses above show that *assurance payments reduce the multiplicity of equilibria by increasing the lower bound of group contributions in non-provision equilibria and lowering the upper bound of individual contribution in provision equilibria* and imply that the equilibrium set may vary with the value distribution and AP. Compared to UP, where as long as the total group value $\sum_{i\in I} v_i$ is greater than equal to the provision cost C, provision and non-provision equilibria will coexist, for UP with $AP \in [C/N, C]$, *both sets of provision and non-provision equilibria become smaller and either of them may become empty*. Therefore, *an optimal assurance contract would balance these two effects to minimize the non-provision equilibrium set and to keep the provision equilibrium set as large as possible to increase the success rate*. In the next section, we test a series of assurance payment schemes in the lab to investigate the conditions for a potentially optimal assurance contract.

4 Lab Experiments

4.1 Experimental Design and Implementation

In the lab experiment, a maximum of 6 (=J) units of a discrete public good are available. Individuals' induced values for the public good follow a linear, decreasing marginal benefit curve. The induced values for Units 1 and 6 are randomly drawn from the uniform distributions over [15, 25] and [5, 15], respectively. The induced values for Units 2 to 5 are interpolated linearly based on values on Units 1 and 6. The average individual cost for each unit is 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 the following six treatments: A0) No assurance baseline; A1) the same assurance payment 10 for the first three units; A2) the same assurance payment 14 for the first three units; A3) decreasing assurance payments 18, 14, and 10 for the first three units, respectively; A4) the same assurance payment 10 for the first unit that cannot be provided; A5) the same assurance payment 14 for the first unit that cannot be provided. Treatments A1, A2, and A3 are partial assurance, while A4 and A5 are conditional assurance since all six units are potentially covered by the assurance payment. We use 10, 14, and 18 to represent low, medium, and high assurance levels, respectively. Note that 10 is the minimum assurance payment allowed.

We conducted two phases of lab experiments on networked computer terminals, with the phase 1 including the full assurance treatments and the phase 2 including the partial assurance treatments (Table 1). Each session has 10 to 14 subjects in total, split into two groups of 5 to 7. At the start of each treatment, the experimenter read the instructions aloud as subjects read along. In the end of the instruction and before 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 and were assigned induced values for each unit as described above. Then they submitted bids 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 added across all periods. Subjects were recruited through a university-wide email server (mainly for undergraduates). 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 (Fischbacher, 2007) was used for the program.

4.2 Experimental Conjectures

Our experiment was designed to mimic the real world scenarios (private value information and multiple units) which are much more complicated than the one-unit case with complete information in Section 2. However, the results in Section 2 are helpful to conjecture the outcomes in the experimental design. If we assume group contributions are guided by equilibrium outcomes, then the provision rate represents the percent of realized provision equilibria out of the total of realized equilibria (including both provision and non-provision equilibria). The relative size of provision equilibria compared to that of non-provision equilibria determines the provision rate if each equilibrium is equally possible. Our discussion in Section 3 suggests that the equilibrium set and hence the provision rate depends on the relationship between the value distribution, *AP*, and *C*.

Given our experimental design, the value distribution is determined by the value range in a uniform distribution on a fixed length of value interval, and its relationship with *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 provision rate is then determined by the value-cost ratio and *AP*. For a given value-cost ratio, if an *AP* significantly reduces the size of the non-provision equilibrium set by increasing the lower bound of equilibrium group contributions from 0 to $C – AP$, and only slightly reduces the size of provision equilibria by capping the individual contributions at $\max\{v_k - AP, AP\}$, then this *AP* increases the provision rate. Thus, we have the following conjectures.

1) For a value distribution with many high values (i.e., a high value-cost ratio), if there exist AP's such that provision is the only equilibrium outcome, these AP's will increase the provision rate; if both provision and non-provision equilibria coexist, a high *AP* will not significantly reduce the provision equilibrium set and will increase the provision rate; a

low *AP* may reduce both of provision and non-provision equilibria significantly, the effect on provision rate will be ambiguous, but may reduce the variance of contributions.

2) A medium value-cost ratio result in outcomes similar to a high ratio where the provision and non-provision equilibria coexist, but the provision rate will be lower.
3) With a low value-cost ratio, an *AP* may not increase the provision rate since there are fewer values higher than *AP*, however, group contributions will be higher compared to assurance payment due to the increased lower bound in a non-provision equilibrium. The provision rate will be the lowest.
4) When both provision and non-provision equilibria coexist under two *AP*'s, the higher *AP* may induce a higher provision rate due to a higher maximum contributions.

4.4 Results from Lab Experiments

Provision (Success) Rate for Each Unit

Fig. 1 shows the ex post provision rate for each unit by assurance scheme.[10] We find that provision rate decreases over units from above 80% (Unit 1) to 0 (Unit 6) as the value-cost ratio decreases. We also have the following observations.

Observation 1 Assurance payments improve provision rate on Units 1 to 5.
The no-assurance scheme A0 has the lowest provision rates at all units except Unit 4, from 0.80, 0.53, 0.13, to 0.01 for Units 1 to 4, and 0 for the last two units. An assurance payment of 14 generates the highest provision rate at all units. Specifically, A2 with *AP* = 14 on Units 1 to 3 has the highest provision rates 0.95, 0.77, and 0.45 for the first three units. A5 with *AP* = 14 on all units has the highest provision rates 0.13 and 0.05 for Units 4 and 5, respectively.

The comparisons are generally consistent with our conjectures. On Units 1 and 2 where the value-cost ratio is relatively high (2 and 1.8), the medium and high assurance payments improve provision rate significantly. A2 with *AP* = 14 on both units and A3 with *AP* = 18 on Unit 1 and 14 on Unit 2 have significantly higher provision rates than A0: on Unit 1, 0.95 and 0.90 *vs*. 0.80,

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

with p = 0.0088 and 0.0969; on Unit 2, 0.77 and 0.75 *vs*. 0.53 with p = 0.0028 and 0.0057. On Unit 3 with a medium value-cost ratio of 1.6, provision rate under A1 to A5 are all significantly higher than A0: 0.58, 0.77, 0.75, 0.58 and 0.58 *vs.* 0.53, all with $p<0.01$. Conditional assurance scheme generates higher provision rates on units beyond partially assured: On Unit 4, provision rates under A4 and A5 are significantly higher than A0, both 0.125 *vs*. 0.01 with p = 0.0024; on Unit 5, provision rate under A5 is significantly higher than A0, 0.05 *vs*. 0 with p = 0.0265.[11]

There are two sets of unexpected outcomes. One is that A1 and A4 are not statistically different A0 on Units 1 and 2 where provision is the only equilibrium outcome with AP = 10. This outcome indicates a drawback of a low AP on a unit with a high value-cost ratio. On Units 1 and 2, the value-cost ratios are large, all subjects with induced values at or above 15 or 13 can coordinate toward a contribution of the average individual cost share (10) even without an assurance payment. Furthermore, when the contributions without an assurance are already relatively high, the upper bound of contributions greater than AP, $\max\{v_i - AP, AP\}$, which equals 10 for all v_i's below 20, limits the ability of high-value subjects to offset the influence of low contributions (contributions below 10). When AP = 14 and 18, the upper bound is at least 14 or 18. Therefore A2 and A3 can improve provision rates on Units 1 and 2 while A1 and A4 cannot. When the value-cost ratio is at the medium level of 1.6 (Unit 3), the minimum assurance payment 10 does matter and A1 and A4 both with AP = 10 generate significantly higher provision rates.

The other one is that A5 is not statistically different from A0 on Units 1 and 2, does not perform as well as A2 on the first three units, and is similar to the assurance schemes with AP = 10 on all first five units in terms of provision. This outcome reveals a drawback of the provision rule under UP over multiple units: Unit 2 cannot be provided if Unit 1 is not provided even when the group contributions on Unit 2 exceeds the cost. If units could be provided independently, A5 may generate provision rates higher than A4 on Units 3 to 5, and A5 is indifferent from A2 at Unit 3.[12] Fig. 2 in the group contribution subsection shows that there are no significant

11 All the test statistics reported in this paragraph are based on the test of proportions.

[12] Assuming units can be provided independently, provision rates under A5 on Units 3 to 5 are 0.525, 0.275 and 0.10, which are greater than those under AP4, 0.350, 0.175, 0.025, are similar to A2 on Unit 3 (0.525 vs. 0.533).

differences in the group value revelation (defined later) between A2 and A5, both of which generate higher value revelations than A1 and A4. Thus we have the following observation.

Observation 2 A medium or high assurance payment generally improves the provision rate compared to a low assurance payment. The influence of an assurance payment on the provision rate is the highest at a medium level of value-cost ratio.

Further, the conjecture that when both provision and non-provision equilibria coexist under two *AP*'s, the higher *AP* may induce a higher provision rate, is generally supported by the results. A2 has significantly higher provision rates than A1 on Units 2 and 3 (p = 0.0320 and 0.0897), and A3 with *AP* = 14 on Unit 2 is significantly higher than A1 on Unit 2 (p = 0.0528); A2 has higher provision rates than A1 on Unit 1 and A3 with *AP* = 10 on Unit 3, although not statistically significant (p = 0.1137 and 0.1905).

Group Value Revelation for Each Unit

To understand the patterns of provision rates across assurance payment schemes, we investigate the group value revelation rate for each unit. Fig. 2 shows the group value revelation (group contributions divided by realized group induced values) for each unit. Group value revelations are generally consistent with the observations of provision rates across assurance schemes over units. Under A0 with *AP* = 0 for all units, 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. A higher assurance payment generally induces a higher group value revelation. A1 on Units 1 to 3, A3 on Unit 3, and A4 on Units 1 to 6 all have *AP* = 10 and all have a similar group revelation around 0.60; A2 on Units 1 to 3, A3 on Unit 2, and A5 on Units 1 to 6 all have *AP* = 14 and all have a similar group revelation around 0.62; A3 on Unit 1 has the highest *AP* = 18 and also has the highest group value revelation of 0.72. This pattern of group value revelation is consistent with the pattern of provision rate over units.

We run a 2-factor (group- and period-specific) random effects regression of group value revelation on assurance payment and schemes dummies for each unit based on data from the last

10 periods (Table 3).[13] A0 is the baseline scheme, 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. [14]

Observation 4 Assurance payments significantly increase group value revelations on all units.

On Units 1 to 3, all assurance payment schemes lead to higher group value revelations with a significance level of at least 0.1, except for A1 at Unit 1. At Units 4 to 5, A4 and A5 are statistically significant with $p<0.01$ and increase the value revelations rate by about 12% to 19% compared to A0.

Observation 5 On each unit, group value revelations are similar across assurance schemes with the same assurance payment level.

Table 3 shows that all the interaction terms between assurance payment levels and assurance schemes are not significant. Only a few exceptions exist on Units 4 to 6 when there is no assurance payment. On Units 4 to 6, although A1 to A3 all have zero assurance payments, they generally induce lower group revelation than A0, and the differences are significant for A1 on Units 4 to 6 and A2 on Unit 6, which suggest that the assurance payments on the first three units discourage the value revelation on the last three units that are not assured.

Observation 6 On Units 1 to 3 with medium and large value-cost ratios, a higher assurance payment results in a higher group value revelation; on Units 4 to 6 with low value-cost ratios, the minimum assurance payment induces a higher group value revelation.

[13] We exclude the observations from the first five periods to isolate potential mechanism-learning in the early periods.

[14] In the online appendix, we also report results based on individual contributions. Regressions results show that assurance payment encourage individual value revelation, consistent with group contribution results.

On Unit 1, the highest assurance payment of 18 generates a significantly higher group value revelation than 14 and 10 all with $p < 0.01$; on Units 2 and 3, the medium assurance payment of 14 generates higher group value revelations than the minimum assurance payment of 10 with p = 0.054 and 0.164. On Units 4 to 6, however, the assurance payment 10 induces higher group value revelations than 14 with p = 0.241, 0.008, and 0.089 respectively for Units 4 to 6.

Note that the ranking between A4 and A5 on the group value revelation switches for Units 1 to 3 and Units 4 to 6: on Units 1 to 3, A5 is higher, while A4 is higher on Units 4 to 6. The switch is consistent with our theoretical predictions. On Units 1 to 3, the value-cost ratios are relatively high, the effect of AP on the upper bound of individual contributions in provision equilibrium is significant. With $AP = 10$, the upper bound equals 10 for all v_i's below 20, lower than that of AP = 14, which is 14 for all v_i's below 28 (i.e., the whole value range is covered), thus A5 with AP = 14 generally induces a higher group contribution and group value revelation than A4 with AP = 10. For Units 4 to 6, however, the value-cost ratio is low, there are not many high values and the lower bound of group contributions in a non-provision equilibrium $C – AP$ starts to matter more, and thus a smaller AP may induce higher group value revelations than a larger one.

This observation is also consistent with the pattern of provision rate. Note that, although A4 with $AP = 10$ induces relatively high group value revelations, it may not induce a higher provision rate due to a smaller variance of group contributions around a contribution level below C, which is conjectured by the increased upper bound and the capped maximum contributions resulted from the minimum assurance payment. Comparing the variance of group contributions between $AP = 10$ and 14 on all six units, we find the variance under $AP = 10$ is significantly less than that under $AP = 14$ on all but the first unit.[15] In the online appendix, Fig. A1 presents the distribution of group-size normalized group contribution (group contributions divided by group size) by the assurance payment level on each unit. It is shown that the cumulative distribution curve with $AP = 10$ is narrower (more concentrating) around a contribution level less than the provision level than that with $AP = 14$, which lies below that with $AP = 14$ at the provision level on all units, indicating a larger provision rate under $AP = 14$. Thus, $AP = 14$ generally induces

[15] 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.

higher provision rates on all units and higher group value revelations on units with a medium or high value-cost ratio compared to *AP* = 10. [16]

Individual Contributions by Assurance Payments

Fig. 3 shows the cumulative distribution of individual contribution by assurance payments on Units 1 to 3.[17] Since the patterns of individual contributions are similar between Units 1 to 3 and Units 4 to 6, we focus on Units 1 to 3. To keep the same value distribution across assurance payments, the cumulative percent curve for *AP* = 10 include A1 and A4 on all three units, similarly, the curve for *AP* = 14 includes A2 and A5 on all three units. We exclude A3 to focus on the treatments where the assurance payments are constant across units.

Observation 7 Assurance payments reduce the percentage of contributions below the average individual cost share and make *AP* as a focal point of individual contributions, which help coordinate contributions toward provision.

First note that both *AP* = 10 and *AP* = 14 reduce the percentage of individual contributions below 10, the average individual cost share. On Units 1 to 3, when *AP* = 0, 37.7% of individual contributions are less than 10, the percentage reduces to 20.9% and 31.3% with *AP* = 10 and 14, respectively. Second, even when *AP* = 0, subjects voluntarily use 10 as a focal contribution level, a total of 23.0%. However, with *AP* = 10, the percent of contributing 10 increases dramatically to 44.7%. With *AP* = 14, the focal contribution level is 14 (37.6% of the contributions). Third, an assurance payment of 10 also reduces the percent of contributing above 10 from 39.3% (when *AP* = 0) to 34.3%, and individual contributions are much more concentrated on 10 from both below and above 10, i.e., a smaller variance. However, there are still contributions less than 10. To increase the provision rate, a larger percentage of contributions above 10 is needed. Although an *AP* = 14 does not reduce the percentage of contributions less 10 as much as an *AP* = 10 does, it induces a much larger percent of contributions above 10 and the upper bound of equilibrium contributions for high value subjects

[16] We also conduct similar regressions based on individual contributions. Results are presented in the online appendix, Table A1, and are consistent with group level contribution outcomes.
[17] A similar figure on Units 4 to 6 is included in the online appendix.

is also higher than that under AP = 10, thus the AP = 14 (and 18) result in higher provision rates and value revelations than when AP = 10.

Observation 8 An assurance payment of 18 induces significantly higher contributions at high values than other assurance payments; assurance payments of 10 and 14 induce higher contributions from low to medium values than a zero-assurance payment.

Fig. 4 presents the mean individual contributions by induced value (rounded to integer for an easy comparison) with all six units pooled and shows that individuals with higher values generally contribute more. The presence of an assurance payment increases individual contribution for almost all values. When AP = 18, an assurance payment induces significantly higher contributions over all observed induced values.[18] When AP = 10 or 14, we find such increase is more obvious over low and medium induced values (5 to 18).

Social Efficiency and Surplus Allocation

Our results show that assurance payment can significantly increase provision rates and group value revelations. Also, it seems that a sufficiently high assurance payment may improve both provision rate and value revelation significantly. However, if a provision fails, the producer may incur a budget deficit by paying assurance payment. Although the payment is simply a *surplus transfer* from the producer to consumers from a societal perspective, this transfer could be costly to the producer and inconvenient in reality. In this section, we are interested in comparing the realized social surplus across treatments, as well as the allocation of social surplus between consumers and the producer.

Table 4 presents the realized social surplus and its allocation between consumers and the producer. The potential maximum social surplus equals the sum of the realized induced values of all units minus the total provision cost; the realized social surplus equals the sum of values on each unit provided minus the total cost for providing these units; the consumers' surplus equals the sum of values on each unit provided minus their contributions, and *plus* an assurance payment if any; the producer's surplus equals consumers' contributions *minus* the provision cost

[18] Since an assurance payment of 18 is only used on Unit 1, we only observe values from 15 to 25.

and the assurance payment if any, or equivalently the realized social surplus minus consumers' surplus. Since the realized maximum social surplus varies across treatments and the group size varies across sessions, we scaled the individual-averaged realized maximum surplus to 100, and proportionally adjusted the surpluses in the other categories.

Observation 9 All assurance schemes improve the realized consumer surplus significantly. All assurance schemes result in a significantly lower realized producer surplus compared to A0; all but A2 have a negative producer surplus. All assurance schemes improve realized social surplus.

First, A1 to A5 all have higher realized consumer surpluses than A0, which are all significant with $p<0.001$ by rank sum test. A4, the conditional scheme with an assurance payment of 10, results in the highest consumer surplus 70 compared to 39 of A0, which is consistent with that A4 has a higher provision rate on Unit 4. Second, A0 has the highest realized producer surplus 5, which is significantly higher than those from A1 to A5 all with $p<0.001$. It is worth noting that in A2, the producer still maintains a positive surplus, indicating that A2 is the least costly assurance scheme on average. Lastly, A1 to A5 all have higher realized social surpluses than A0, in which A2, A3, and A4 are significantly higher with $p<0.0001$, $p=0.0069$ and 0.092, respectively. Although A2 does not have a realized consumer surplus as high as A3 or A4, A2 involves a relatively smaller assurance payment and hence a much higher producer surplus than A3 and A4. Therefore, A2 stands out as the “best” assurance payment scheme in our tested schemes, which induces the highest social surplus level. This result implies a budget-balancing assurance scheme is possible based our experimental data. A medium (or sufficiently high) assurance payment may dramatically increase the social efficiency of public goods provision with a medium or high value-cost ratio.

5. A Pilot Field Experiment

In this section, we report results from a pilot field experiment using the assurance contract. Our motivation is to construct a pilot, field test based on the theoretical and lab experiment results. However, we encountered several major challenges when we attempted to design the field experiment, including 1) finding a real public project where people are willing to contribute, 2) estimating the potential number of donors and contributions, relative to the project cost, and 3) estimate 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 idea. This section intends to serve as a proof of concept for future studies. Our 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 (Swallow et al, 2018).

The field experiment was conducted 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. Figure A3 and A4 in the online 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 costs around $5000 for one year and generated an average donation of about $40, based on our previous experience with the Bobolink project (Swallow et al., 2018); 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 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 minus 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 5).

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 A1, 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 A2, 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 to be returned to residents (because of the 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/he would receive $60, the original donation, plus $40, the assurance payment. Table 5 summarizes the five treatments in terms of the applicability of assurance contract, minimum price levels and assurance payment levels.

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).[19] 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

$$\widetilde{d_i} = Z_i'\alpha + \epsilon_i,$$

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

$$\widetilde{y_i} = X_i'\beta + \sigma_i,$$

[19] 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. Double hurdle model is better justified in our scenario to detect the influence of assurance contracts (von Haefen et al., 2005).

where the observed donation amount $y_i' = \max(\widetilde{y_i}, 0)$ 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,

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

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:

$$LogL = \sum_{i \in \{D_0 | d_i = 0\}} \ln\left(1 - F(Z_i'\alpha) F\left(\frac{X_i'\beta}{\rho}\right)\right) + \sum_{i \in \{D_1 | d_i = 1\}} \ln\left(F\left(\frac{Z_i'\alpha}{\rho}\right) f\left(\frac{y_i - X_i'\beta}{\rho}\right)\right)$$

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 5). 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 6 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 below focuses on the estimated coefficients in Model 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 the participation while a higher assurance payment has a larger effect on the 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 in contribution 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, we find that a high assurance payment (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 a small sample size and needs further investigations.

Although we only observe a limited number of positive contributions, the 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, particularly with reference to ecosystem services. While the coordination problem, and incentives for free-riding or cheap-riding, for provision of public goods remains a thorny barrier to broader, market-like methods for ecosystem services, we encourage others to suggest creative alternatives. In this spirit, this paper builds on the assurance contract introduced by Tabarrok (1998) and the paper develops an assurance payment to improve the provision of public goods, particularly with multiple units. Under this approach, a market-maker rewards a would-be donor for committing to a minimum contribution; if 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 economics 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 public good provision. Theoretically, we first characterize the Nash equilibibira of one-unit uniform price (UP) approach with assurance payment and compare them with those without assurance payment. Then we design 6 treatments of assurance payment schemes and run lab experiments to test the effects of assurance payment on the provision rate, the group value revelation, and the social efficiency. Our laboratory experiments show the assurance payment works in the expected directions, improving the prospect for public good provision.

We show that assurance payment significantly eliminates non-provision equilibria by *increasing the lower bound of group contributions*, and reduces the multiplicity of provision equilibria by *lowering the upper bound of individual* contributions. This theoretical advantage is supported by our lab experiment results: a 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, it is possible for the producer to 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 6 units available and the last unit with a zero net social gain from provision, 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 reversed effects of a low assurance on group revelations with different value-cost ratios imply that we may choose different assurance levels based on different goals.

The various interactions between assurance payments and value-cost ratios indicate some future research directions. Recall that in out 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, in relation to 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.

The assurance payment is different from other provision mechanisms in several significant ways, particularly regarding how the realized social surplus is allocated between the consumer and the producer. Here, we compare to provision point mechanisms where donors contribute to a particular public good (rather than to the general mission of, for example, a conservation organization), and receive a money-back guarantee in the case of non-provision of a unit of the public good; these mechanisms may offer to donors a rebate of a share of any excess contributions donated above a provision point. Compared to the provision point mechanism with no rebate, the allocation, under the assurance contract approach, of realized social surplus is the same *if* the public good is provided, while there is a positive benefit transferred from producer to consumer using an assurance payment scheme *if* the public good is not provided. Compared to the provision point mechanism with rebate, the producer, who uses assurance contracts, can acquire more surplus *if* the public good is provided, while facing a potential deficit *if* the public good is not provided. Compared to the pivotal mechanism (Clarke 1971) where the producer always has a zero or negative surplus, our experimental results show that it is possible for the producer to at least break even and even profit from supplying the public good, while at the same time, the society is better off with an increased overall social surplus under the assurance payment.

Lastly, our results have important policy implications. First, the provision-point based mechanism with assurance payment 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 (producers) may be identified through various reverse auction mechanisms where, for agro-ecosystem 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 has the capacity to 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, as has been seen in earlier efforts applied to bobolink habitat conservation (Swallow et al. 2018). 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 to grasp the concept, as has been seen in research involving novel incentive-compatible mechanisms (e.g., Kawagoe and Mori 2001). By this speculation, we again suggest that the assurance contract approach has practical potential.

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Table 1 Treatment Arrangement of Experimental Sessions

Phase	Treatments	No. of Groups	No. of Sessions	Number of Subjects
1	A0	6	3	34
(partial assurance)	A1	6	3	36
	A2	6	3	36
	A3	6	3	38
2	A0	4	2	26
(conditional assurance)	A4	4	2	26
	A5	4	2	26

Notes: We test 1) No assurance baseline (AP0); 1) a constant assurance payment 10 for the first three units (AP10); 2) a constant assurance payment 14 for the first three units (AP14); 3) a decreasing assurance payments 18, 14, and 10 for the first three units, respectively (APD); 4) a constant assurance payment 10 for the first unit that cannot be provided (AP10C); 5) a constant assurance payment 14 for the first unit that cannot be provided (AP14C).

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

Unit	1	2	3	4	5	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: v_H, v_{Mean} and v_L represent the upper bound, mean, and lower bound of the value range, respectively.

Table 3 Two-factor random effects models of group value revelation for each unit

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

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

Table 4 Realized Average Social Surplus and Its Allocation*

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

Notes: The numbers are essentially in percentage, which is based on a maximum social surplus assumed to be 100. The Realized Social Surplus equals the sum of Realized Consumer Surplus and Realized Producer Surplus. The Realized Producer Surplus can be negative when we assume the assurance payment is a surplus transfer from producer to consumer.

Table 5: Summary Statistics By Treatment

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.)	(117.85)	(0.50)	(0.39)	(13.48)	(13.13)	(0.29)	(0.41)	(0.3)	(16.18)	(0.22)	
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)	(0.50)	(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)	(0.50)	(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)	(0.50)	(0.37)	(13.22)	(13.05)	(0.34)	(0.41)	(0.31)	(14.20)	(0.22)	
MP=60, AP=40	N=295										
Mean	141.99	0.52	0.16	59.88	18.39	0.13	0.20	0.09	1.02	0.02	*p=0.5741*
(s.d.)	(108.62)	(0.50)	(0.37)	(12.86)	(12.84)	(0.34)	(0.40)	(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.

Table 6: Estimation Results: Double-Hurdel Model

Variables	Model 1		Model 2	
	Probit	Tobit	Probit	Tobit
Equation:	(Participation)	(Contribution)	(Participation)	(Contribution)
MP60	-0.283	37.06	-0.251	29.10
	(0.233)	(24.85)	(0.220)	(24.29)
AP20	0.310	21.49	0.195	13.15
	(0.243)	(28.30)	(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	-7.110		
	(0.158)	(13.64)		
Donation_before	1.040***	5.196	0.771***	4.672
	(0.232)	(26.86)	(0.196)	(27.02)
Donation_before*AP20	-0.573	-53.20		-64.13*
	(0.485)	(42.61)		(35.93)
Donation_before*AP40	-0.728	117.4**		111.1***
	(1.020)	(49.87)		(35.47)
Donation_before*MP60*AP40	-0.312	-58.52		-122.5**
	(1.171)	(72.34)		(49.96)
Age	-0.00335	0.141		
	(0.00748)	(0.699)		
LengthofResidence	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	

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1;

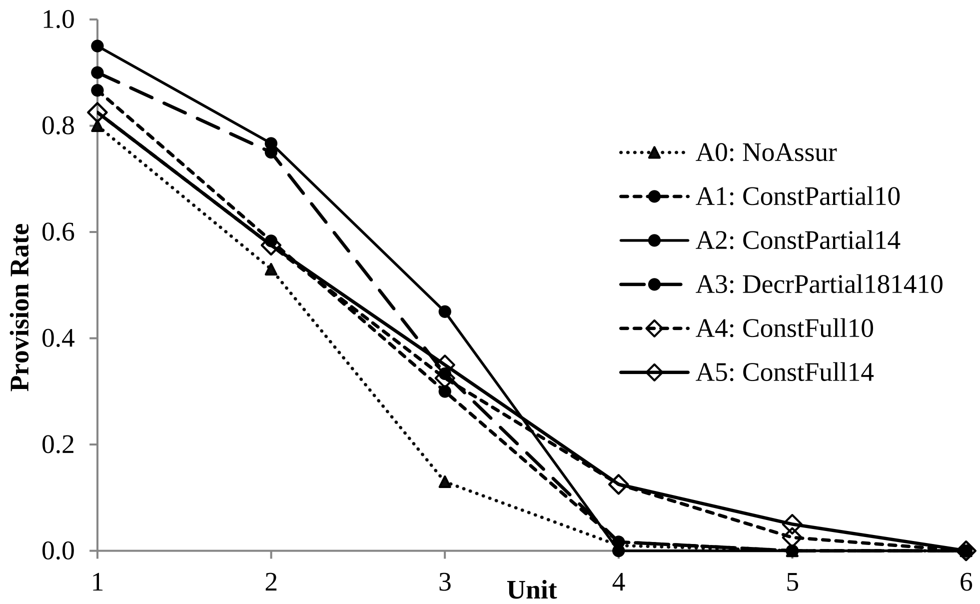

Fig. 1. Provision rate for each unit by assurance scheme

Notes: The above figure shows the provision rate difference among the six assurance payment schemes, including the baseline A0 where assurance payment is not applicable at all units.

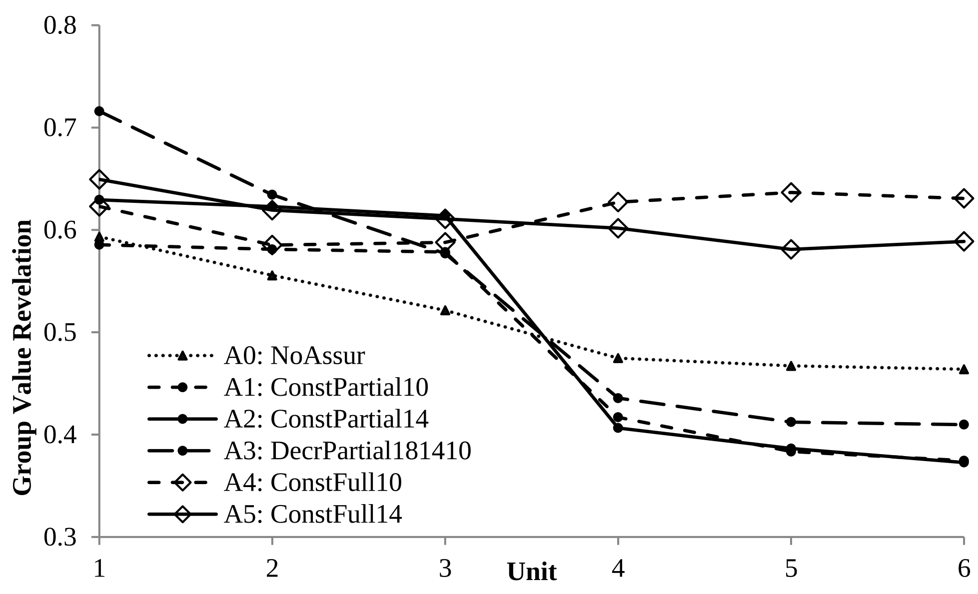

Fig. 2. Group revelation for each unit by assurance scheme

Notes: The above figure shows the group value revelation (bids divided by induced value) in the six assurance payment schemes, including the baseline A0 where assurance payment is not applicable at all units.

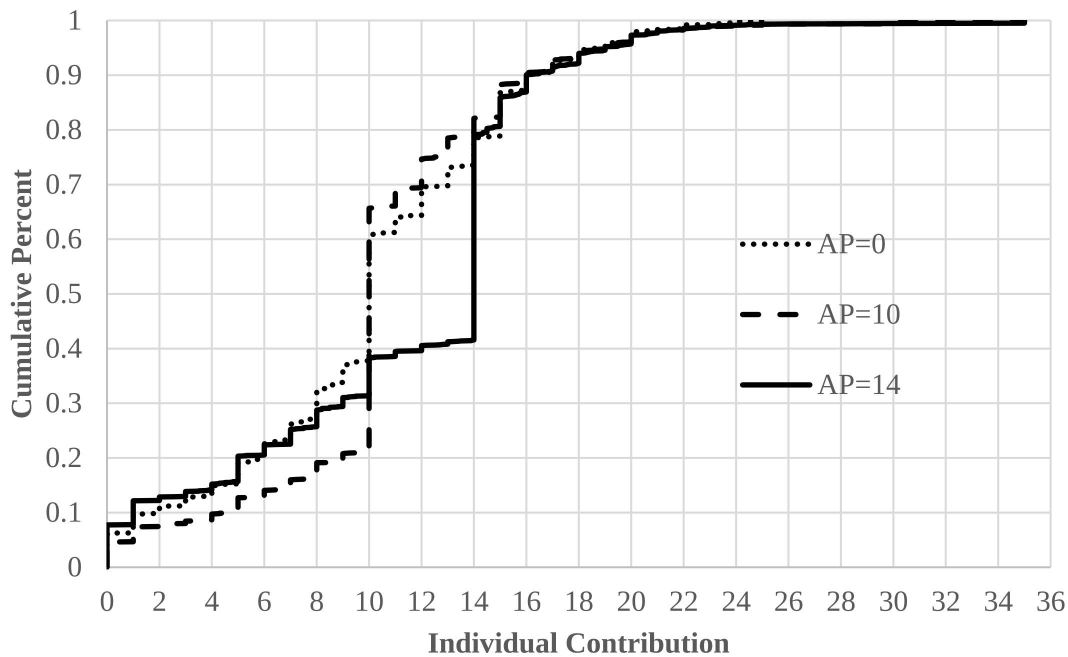

Fig. 3 Cumulative distriubtion of individal contribution by assurance payments on Units 1 to 3

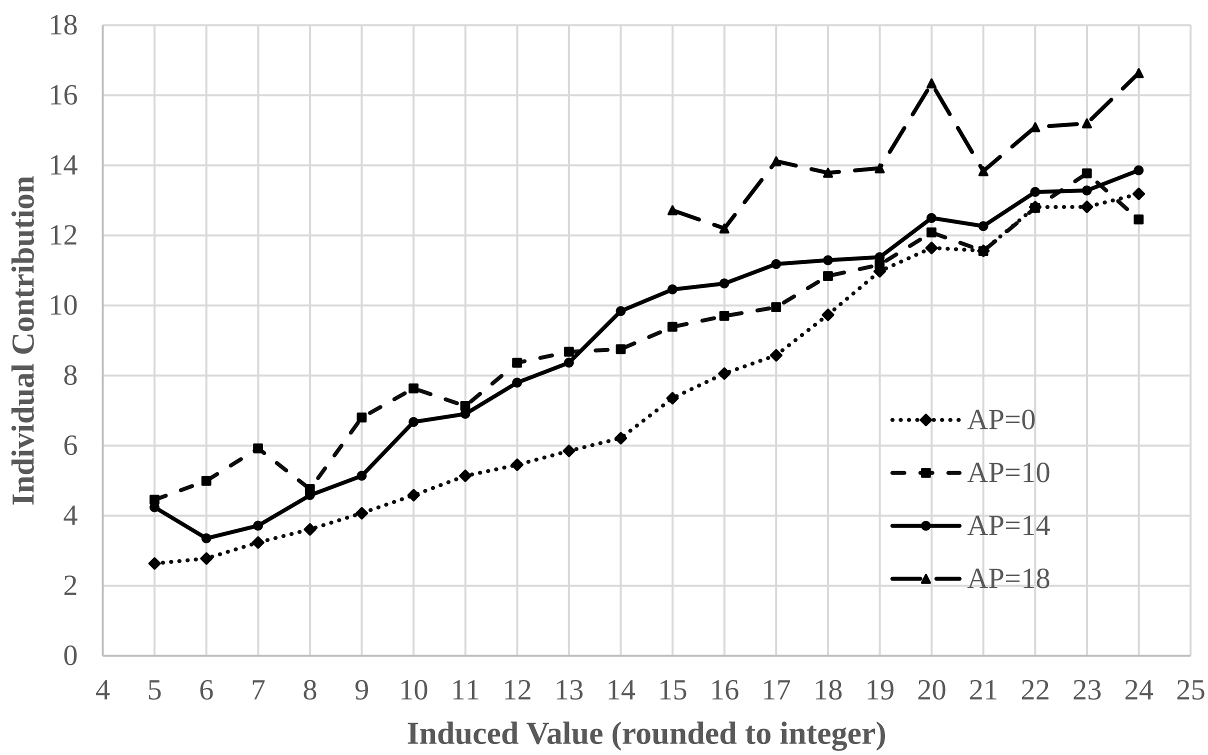

Fig. 4 Mean individual contributions by induced value

Supplementary Materials/Online Appendix

(Additional Tables, Figures, and Proofs)

Table A.1. Two-factor Random Effects Models of Individual Contribution for Each Unit

Individual Contribution	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
AP10 (A4)	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*A1	-2.639	-3.539	0.0302			
	(2.527)	(2.349)	(2.182)			
AP14 (A5)	5.228**	4.995**	-1.868	-0.348	-1.214	1.079
	(2.181)	(2.078)	(1.986)	(1.730)	(1.202)	(0.813)
AP14*A2	-2.080	-1.851	7.828***			
	(2.470)	(2.339)	(2.213)			
AP18 (A3)	4.759**					
	(2.027)					
AP14*A3		0.915				
		(2.317)				
AP10*A3			4.283*			
			(2.198)			
A1				-2.034	-1.534	-1.460*
				(1.548)	(1.090)	(0.748)
A2				0.766	0.194	-0.0136
				(1.536)	(1.055)	(0.710)
A3				0.266	1.237	0.377
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 (A4)	-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*A1	0.123	0.211	-0.00279			
	(0.125)	(0.129)	(0.135)			
Value*AP14 (A5)	-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*A2	0.0865	0.126	-0.466***			
	(0.122)	(0.129)	(0.137)			
Value*AP18 (A3)	-0.0896					
	(0.1000)					
Value*AP14*A3		-0.0191				
		(0.128)				
Value*AP10*A3			-0.254*			
			(0.137)			
Value*A1				0.118	0.0696	0.0680
				(0.108)	(0.0878)	(0.0699)
Value*A2				-0.0625	-0.0343	-0.0369
				(0.109)	(0.0861)	(0.0675)
Value*A3				-0.0125	-0.110	-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)	(0.0510)	(0.0555)	(0.0516)	(0.0473)
Constant (A0)	-1.073	-0.508	1.363	2.358	2.298	2.132
	(4.458)	(3.885)	(3.386)	(3.609)	(3.304)	(3.000)
Log-likelihood	228.1	255.0	268.2	216.7	224.1	194.3
Chi-square	84.98	57.90	101.8	76.46	95.48	88.19
Number of Observations	180	180	180	180	180	180
Number of Periods	10	10	10	10	10	10

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

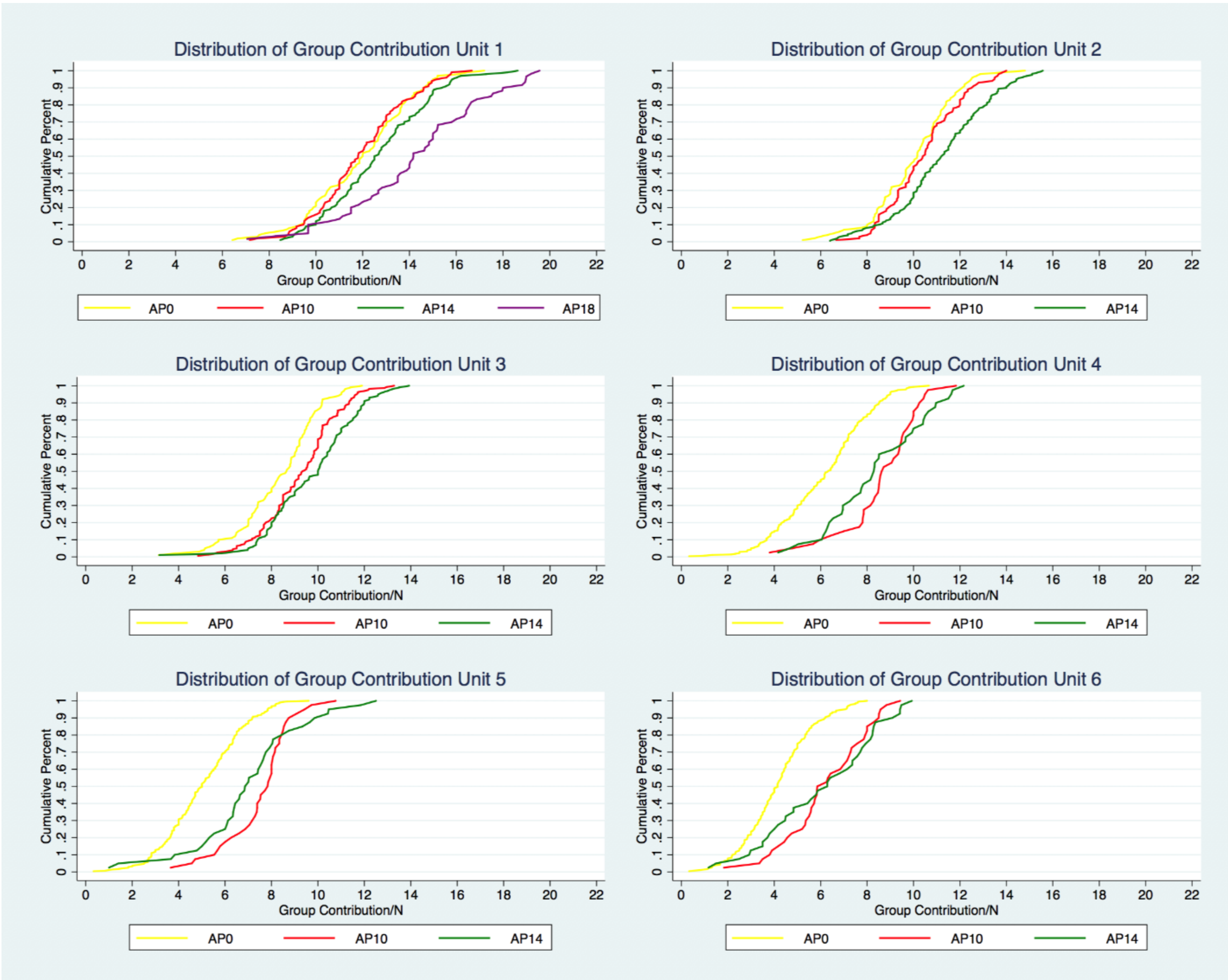

Fig. A1 Distribution of group-size normalized group contribution by assurance payment

Note: Since the provision cost is $10N$, the cumulative percent of group-size normalized group contribution above 10 represents the provision rate when each unit is provided independently.

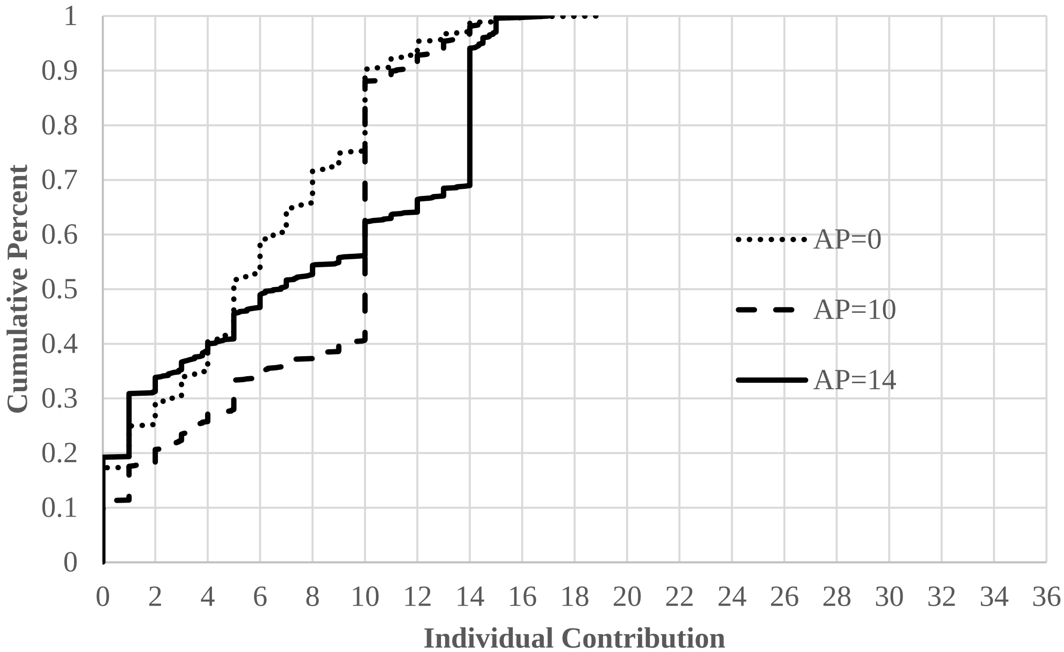

Fig. A2 Cumulative distriubtion of individal contribution by assurance payments on Units 4 to 6

<u>Bobolink Project 2014 Donation and Pledge Agreement:</u>

[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 **<u>Participation Challenge Fund</u>** 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 **<u>only</u>** 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 **<u>Participation Challenge Fund</u>** 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 *<u>minimum</u>* donation of $40, and *<u>if we fail</u>* to raise enough money to provide a field for nesting Bobolinks in Jamestown, then we will *<u>not only</u>* return your donation *<u>but we will also</u>* 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, **<u>if we raise more</u>** 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]

Fig. A3 Mailling Materials for the Field Experiment, Page 1

Bobolink Project 2014 Donation and Pledge Agreement:

Protect Your Money, Help Our Environment

[redacted]

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]

Fig. A4 Mailling Materials for the Field Experiment-2, Page 2

Supplementary Materials: Proofs.

Proposition 3 (provision equilibrium with *AP*): Any strategy profile $\{b_i\}_{i \in I j}$ *s.t.* $\sum_{i \in I} b_i = C$ is a pure-strategy Nash equilibrium for one-unit UP with $AP \in [C/N, C]$ if $b_k \le \max\{v_k - AP, AP\}$ for $v_k \ge AP$ and $b_k \le v_k$ for $v_k < AP$, for any $k \in I$.

Proof.

First, $b_k \le \max\{v_k - AP, AP\}$ eliminates the incentive to deviate for individuals with $v_k \ge AP$: 1) individual *k* bidding below or at AP will not reduce the bid since $v_k \ge AP \ge b_k \Rightarrow v_k - b_k \ge 0$; and 2) individuals bidding below or at $v_k - AP$ will not deviate since $v_k - b_k \ge \max(AP, 0)$.

Second, for individuals with $v_k < AP$, $b_k \le v_k$ guarantee a non-negative payoff, any deviations would result in a negative or zero payoff. □

Proposition 4 (non-provision equilibrium-AP): Any strategy profile $\{b_i\}_{i \in I j}$ *s.t.* $\sum_{i \in I} b_i < C$ is a pure-strategy Nash equilibrium for one-unit UP with *AP* such that $C \ge AP \ge C/N$ if

(i) $AP > v_k - b_k - (C - \sum_{i \in I} b_i)$ for all $k \in I^{+} = \{i \in I j b_i \ge AP\}$; and

(ii) $AP > C - \sum_{i \ne k} b_i > v_k$ for all $k \in I^{-} = \{i \in I j b_i < AP\}$.

Proof.

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

Corollary 1. In a non-provision equilibrium strategy profile with complete information, we have $\sum_{i \in I} b_i \in \left[0,\ C - \left(\sum_{i \in I} v_i - C\right) \big/ \left(N-1\right)\right]$ under one-unit UP, and

$$\sum_{i \in I} b_i \in \left[C - AP + \frac{\sum_{i \in I^{-}} b_i}{N^{-}},\ \min\{C - \frac{\sum_{i \in I^{-}} \left(v_i - b_i\right)}{N^{-}}, C + AP - \frac{\sum_{i \in I^{+}} \left(v_i - b_i\right)}{N^{+}}\} \right]$$ under one

UP with AP such that $C \geq AP \geq C/N$, where $N^{-} = \left|I^{-}\right| = \left|\{i \in I j\, b_i < AP\}\right|$ and

$N^{+} = \left|I^{+}\right| = \left|\{i \in I j\, b_i \geq AP\}\right|$.

Proof.

For one-unit UP, a summation of $\sum_{i \neq k} b_i + v_k \leq C$ on both sides over $k \in I j$ will give

$\sum_{k \in I j} \left(\sum_{i \neq k} b_i + v_k\right) \leq NC$, i.e., $\sum_{k \in I j} \left(\sum_{i \in I} b_i + v_k - b_k\right) \leq NC$.

Then we have

$$\begin{aligned}
&\sum_{k \in I j} \left(\sum_{i \in I} b_i + v_k - b_k\right) = N \sum_{i \in I} b_i + \sum_{k \in I j} \left(v_k - b_k\right) = N \sum_{i \in I} b_i - \sum_{k \in I j} b_k + \sum_{k \in I j} v_k \\
&= \left(N-1\right) \sum_{i \in I} b_i + \sum_{k \in I j} v_k \leq NC = \left(N-1\right) C + C \\
&\Rightarrow \sum_{i \in I} b_i \leq C - \left(\sum_{i \in I} v_i - C\right) \big/ \left(N-1\right)
\end{aligned}$$

For one-unit UP with *AP*.

Given $\sum_{i \neq k} b_i + v_k \leq C + AP$ for all $k \in I^{+} = \{i \in I j\, b_i \geq AP\}$, we have

$$\sum_{k \in I^{+} j} \left(\sum_{i \neq k} b_i + v_k\right) = \sum_{k \in I^{+} j} \left(\sum_{i \in I} b_i + v_k - b_k\right) = N^{+} \sum_{i \in I} b_i + \sum_{k \in I^{+} j} \left(v_k - b_k\right) \leq N^{+} \left(C + AP\right)$$

Thus, $\sum_{i \in I} b_i \leq C + AP - \sum_{k \in I^{+} j} \left(v_k - b_k\right) \big/ N^{+}$

Similarly, $v_k \leq C - \sum_{i \neq k} b_i \leq AP$ for all $k \in I^{-} = \{i \in I j\, b_i < AP\}$ implies

$$\begin{aligned}
&C - AP \leq \sum_{i \neq k} b_i \leq C - v_k \Rightarrow C - AP + b_k \leq \sum_{i \in I} b_i \leq C - \left(v_k - b_k\right) \\
&\Rightarrow N^{-}\left(C - AP\right) + \sum_{k \in I^{-} j} b_k \leq N^{-} \sum_{i \in I} b_i \leq \sum_{k \in I^{-} j} \left(C - \left(v_k - b_k\right)\right) \\
&\Rightarrow N^{-}\left(C - AP\right) + \sum_{k \in I^{-} j} b_k \leq N^{-} \sum_{i \in I} b_i \leq N^{-} C - \sum_{k \in I^{-} j} \left(v_k - b_k\right) \\
&\Rightarrow \sum_{i \in I} b_i \in \left[C - AP + \frac{\sum_{i \in I^{-}} b_i}{N^{-}},\ C - \frac{\sum_{i \in I^{-}} \left(v_i - b_i\right)}{N^{-}} \right]
\end{aligned}$$

Combining the implications by **Proposition 4** (i) and (ii), we have

$$\sum_{i\in I} b_i \in \left[C - AP + \frac{\sum_{i\in I^-} b_i}{N^-},\ \min\{C - \frac{\sum_{i\in I^-}(v_i - b_i)}{N^-}, C + AP - \frac{\sum_{i\in I^+}(v_i - b_i)}{N^+}\} \right] \quad \square$$

Corollary 2. For any value distribution Q of a group of N individuals and a provision cost level of C, if there exists a v^* such that $C/v^* \le n(v^*) = |i \in I j : v_i \geqslant v^*$ for all $v_i \in Q|$, then provision is the only equilibrium outcome for one-unit UP with $AP = v^*$.

Proof.

By **Proposition 4** (ii), the existence of a non-provision equilibrium requires $AP > C - \sum_{i\neq k} b_i > v_k$ for all $k \in I^- = \{i \in I j\, b_i < AP\}$, which implies that if $v_k \ge AP$, then $b_k \ge AP$ for any $k \in I$. Since $AP = v^*$, and the number of individuals with values greater than or equal to v^* is great than C/v^*, the contributions from the set of individuals with values greater than or equal to v^* would be at least C, contradicting with the non-provision condition. Thus the non-provision equilibrium set is empty with $AP = v^*$. Further, since $\sum_{i\in\{k:AP\le v_k\}} AP \ge C$, we have $\sum_{i\in\{k:v_k\ge 2AP\}}(v_i - AP) + \sum_{i\in\{k:AP\le v_k<2AP\}} AP + \sum_{i\in\{k:v_k<AP\}} v_i \ge C$, then by **Proposition 3**, the provision equilibrium set is not empty with $AP = v^*$. Thus, provision is the only equilibrium outcome. □

Supplementary Materials: Numerical Examples

We use a series of numerical examples to present the intuition and the equilibrium predictions of UP with various *AP*'s. We assume a group size $N = 5$ and the unit provision cost $C = 50$.

Example 1. The reduced multiplicity of both provision and non-provision equilibria due to the existence of assurance payments. Let $\{v_1, v_2, v_3, v_4, v_5\} = \{9, 13, 17, 21, 25\}$ with a total value of 85. When $AP = 0$, any strategy profile such that $\sum_{i=1}^{5} b_i = 50$ with $b_i \le v_i$ for $i = 1, \ldots, 5$, e.g., $b = \{6, 9, 11, 12, 12\}$ or $b = \{6, 9, 10, 11, 14\}$, is a provision equilibrium since any deviation will *not* result in a strictly increase in payoff. And $b = \{0, 5, 7, 11, 16\}$ where $\sum_{i=1}^{5} b_i = 39$ is a non-provision equilibrium where everyone earns 0 since no one could increase their own contribution to provide the good without earning a negative payoff. The strategy profile of everyone contributing 0 is also a non-provision equilibrium.

When $AP = 10$ ($= C/N$), both sets of provision and non-provision equilibria are not empty but are smaller than those under UP. In provision equilibria, **Propositions 3** requires $b_k \le \max\{v_k - AP, AP\}$ for $v_k \ge AP$ and $b_k \le v_k$ for $v_k < AP$, for any $k \in I$, therefore $b = \{b_1, b_2, b_3, b_4, b_5\}$ is upper bounded by $\{v_1, AP, AP, v_4 - AP, v_5 - AP\}=\{9, 10, 10, 11, 15\}$ with a total of 55, which will result in a smaller equilibrium set than UP with b bounded by {9, 13, 17, 21, 25}; in non-provision equilibria, **Proposition 4** and **Corollary 1** show that UP with *AP* put even more restrictions on equilibrium contributions and hence has a much smaller set of non-provision equilibria than UP.

Specifically, note first that the equilibrium $b = \{6, 9, 11, 12, 12\}$ under $AP = 0$ is not a provision equilibrium under $AP = 10$ while $b = \{6, 9, 10, 11, 14\}$ is still a Nash equilibrium. For the former, individual 3 can decrease b_3 from 11 to 10 ($=AP$) to increase π_3 from 6 to 10, given that the assurance payment from the non-provision is greater than the payoff from providing the good, that is, $b_3 = 11$ violates the upper bound of $b_3 \le \max\{17 - 10,\ 10\} = 10$. A similar argument works for individual 4 due to $b_4 = 12$ violating the upper bound of $\max\{21 - 10,\ 10\} = 11$. For the latter, $b = \{6, 9, 10, 11, 14\}$ is still a Nash equilibrium under $AP = 10$ since $b_1 \le v_1 = 9$, b_2 and b_3

both $\leq AP = 10$, $b_4 \leq v_4 - AP = 11$, and $b_5 \leq v_5 - AP = 15$. This comparison shows how UP with *AP* reduces the multiplicity of the provision equilibria.

Secondly, UP with *AP* also reduces the multiplicity of the non-provision equilibria substantially. Note that the non-provision equilibrium under UP $b = \{0, 5, 7, 11, 16\}$ is not an equilibrium under $AP = 10$ by **Proposition 4** (ii): b_2 and b_3 both $\leq AP = 10$ while v_2 and v_3 both > 10, which means individuals 2 and 3 can increase their contributions to *AP* (=10) to earn the assurance payment instead of 0. Actually, based on **Corollary 1**, the group contributions in a non-provision equilibrium under UP are bounded between [0, 41.25], while under UP with $AP = 10$ the largest allowable range of the group contributions is [40, 50) with $b_1 = v_1$ and the smallest is [40, 41] with $b_1 = 0$. Hence, any non-provision equilibrium strategy profile under UP with group contributions less than 40 is eliminated from the equilibrium set under UP with $AP = 10$.

Further, UP with *AP* pushes the non-provision equilibrium group contributions up toward the cost, which makes non-provision equilibria less robust to trembling hand perfection than those under UP in the sense of Bagnoli and Lipman (1989) and thus could facility more provision equilibria. For example, $b = \{5, 10, 10, 10, 11\}$ with $\sum_{i=1}^{5} b_i = 46$ is a non-provision equilibrium under UP with $AP = 10$ but is not an equilibrium under UP. A small trembling of b_5 from 11 to 13 would induce individual 1 to increase b_1 from 5 to 7 to provide the good, which would not be possible under UP due to the smaller upper bound of 41.25.

Example 2. The effects of *AP* on the existence of provision and non-provision equilibria.
Case 2.1. $\{v_1, v_2, v_3, v_4, v_5\} = \{9, 13, 17, 21, 25\}$ with a total value of 85. In the previous example, we have shown that both provision and non-provision equilibria exist when $AP = 10$. When $AP = 12.5$, however, the set of non-provision equilibria becomes empty and only provision equilibria exist, since individuals 2 to 4 would all contribute at least 12.5 to support a non-provision equilibria, which results in a group contribution of at least 50 contradicting the non-provision condition. Similarly for $AP = 16.7$. The insight here is that the competition to earn an assurance payment in case of non-provision eliminates the possibility of non-provision when the number of individuals with values higher than *AP* is at or above *C*/*AP*.

Case 2.2. $\{v_1, v_2, v_3, v_4, v_5\} = \{7, 13, 17, 18, 22\}$ with a total value of 77. First note that, when $AP = 10$, only non-provision equilibria exist since $b = \{b_1, b_2, b_3, b_4, b_5\}$ is upper bounded by $\{v_1, AP, AP, AP, v_5 - AP\} = \{7, 10, 10, 10, 12\}$ with a total of $49 < 50$. However, when AP = 12.5 or 16.7, provision and only provision equilibria exist.

Case 2.3. $\{v_1, v_2, v_3, v_4, v_5\} = \{6, 10, 14, 18, 22\}$ with a total value of 70. Similar to *Case 2.2*, when $AP = 10$, only non-provision equilibria exist. When AP = 12.5 or 16.7, both provision and non-provision equilibria exist. The insight from *Case 2.2* and *2.3* is that when AP is low, the set of provision equilibria could be empty, and but when AP is high enough, provision equilibria always exist while non-provision equilibria may or may not exist.

Case 2.4. $\{v_1, v_2, v_3, v_4, v_5\} = \{16, 18, 20, 22, 24\}$ with a total value of 100. In this case, only provision equilibria exist under all assurance payments between 10 and 20. When AP is above 20, both provision and non-provision equilibria exist.