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Uniform Price Mechanisms for Threshold Public Goods Provision: An Experimental Investigation

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Research Highlights:

We introduce two novel "uniform price" mechanisms for provision point public goods
We compare them to proportional rebate (PR) and provision point (PPM) mechanisms
Mechanisms are evaluated with heterogeneous values and a range of provision points
Our novel mechanisms generate higher contributions than PR and PPM.
Differences in contribution behavior are explained by the marginal penalty structure.

Abstract

This paper introduces two new mechanisms for provision point public goods, motivated by the design of uniform price auctions: the uniform price auction mechanism (UPA) collects an endogenously determined uniform price from everyone offering at least that price, while the uniform price cap mechanism (UPC) collects the uniform price from everyone offering at least that price, plus the full offer of everyone offering less. UPA and UPC are compared with the provision point mechanism (PPM) and the proportional rebate mechanism (PR). We use undominated perfect equilibrium and the marginal penalty associated with overcontribution to provide benchmark predictions for an experimental comparison with heterogeneous induced values, and with different provision point treatments. We find UPA generates by far the highest group and individual contributions at all provision points and values, but has the lowest provision rate; UPC elicits higher aggregate contributions than PPM and PR, and has the highest provision rate, driven by higher contributions from high-value individuals, especially at moderate provision points. This is consistent with subjects offering more in mechanisms with lower expected marginal penalty, but the effect is most significant when marginal contributions are more likely to affect provision.

Keywords: Uniform price auction, Uniform price cap, Proportional rebate, No rebate

- We introduce two novel "uniform price" mechanisms for provision point public goods
- We compare them to proportional rebate (PR) and provision point (PPM) mechansims
- Mechanisms are evaluated with heterogeneous values and a range of provision points
- Our novel mechanisms generate higher contributions than PR and PPM.
- Differences in contribution behavior are explained by the marginal penalty structure.

1. Introduction

A provision point public good is one that can be provided only when a threshold level of funding contributions is met. Canonical examples include bridges, parks and schools that require a particular amount of funding to be built, and realistic examples include public radio broadcasting, hospital and university buildings, and environmental conservation projects to which people actually make contributions. The public goods literature typically envisions determining outcomes through the provision point mechanism (PPM), in which people voluntarily and simultaneously contribute toward funding the good; if the total contribution reaches or exceeds the cost (provision point or threshold), the good is provided; otherwise contributions are refunded (money back guarantee). Because it is simpler than other public goods mechanisms with an interior Nash equilibrium that supports provision—in contrast to the unique zero-contribution prediction of the voluntary contribution mechanism—PPM has been systematically studied, both theoretically[1] and experimentally.[2]

The presence of a provision point has induced an additional literature on how to rebate contributions in excess of the provision cost, and how the rebate rules affect incentives for making contributions. Marks and Croson (1998) compare no-rebate, proportional rebate (PR), and utilization rebate, and find a utilization rebate leads to higher contributions, but no significant difference between no-rebate and PR under complete information; while Gailmard and Palfrey (2005) find PR (called PCS in their paper) induces significantly higher contributions than no-rebate when value is private information. However, only a few of the possible factors affecting contributions have been explored. Rondeau et al. (1999) assessed the group size effect and information (about group size and provision point) effects in PR; Rondeau et al. (2005) compared PR with the voluntary contribution mechanism; and Spencer et al. (2009) compared PR and five other rebate rules in one-shot games. Therefore, in introducing two novel mechansims, this paper extends our understanding of how rebate rules affect the contribution levels as private value and relative provision point change.

[1] Bagnoli and Lipman (1989) study PPM under complete information; Nitzan and Romano (1990), McBride (2006), and Barbieri and Malueg (2010a) discuss threshold uncertainty; Alboth et al. (2001), Menezes et al. (2001), Laussel and Palfrey (2003), and Barbieri and Malueg (2008, 2010b) discuss PPM with private value information.

[2] See Chen (2008) for a recent review of related experimental studies; for earlier reviews see Davis and Holt (1993) and Ledyard (1995).

Our novel mechanisms are motivated by payment rules in multi-unit uniform price auctions. In our uniform price auction mechanism (UPA), everyone who pays, pays the same price: if there exists a price such that the number of contributions at or above that price multiplied by the price equals the provision point, then the good is provided, with only those offering at or above the uniform price paying the uniform price; the lowest such price will be chosen if more than one uniform price is possible. Our second mechanism addresses the inefficiency inherent in UPA, that contributions can exceed the provision cost, but still no uniform price meeting the provision rule exists. In the uniform price cap mechanism (UPC), no one pays more than the uniform price: if the provision point is exceeded, the lowest price cap will be calculated so whomever contributes above the cap only pays the cap, and those contributing less than the cap pay their full offer, such that the final collected payments equal the provision point.

The intuitive motivation for these mechanisms is fairness, in the sense that high contributors are not penalized by being required to make higher payments, and contributors with low values not penalized by offering a greater portion of their value, unless their money is absolutely needed for provision. Thus, when public good benefits are heterogeneous, the high value people sensitive to distributional considerations might contribute more in UPA and UPC than in PPM and PR, since their additional contributions might not be needed; they improve the likelihood of provision if they are.

Even in the absence of strong other-regarding preferences, the rebate rules in UPA and UPC have different marginal penalty structures from PPM and PR, and hence could induce different contribution levels. Marginal penalty, as used by Marks and Croson (1998), describes the cost of contributing an additional dollar conditioned on provision, which differentiates among rebate rules since it essentially captures how extra money is returned. For example, PPM has a marginal penalty of -1 since there is no rebate, and the marginal penalty in PR is, in general, between -1 and 0. Intuitively, in an environment with value or strategic uncertainty, the lower the marginal penalty of contribution, the higher the potential contribution and the higher the likelihood of provision. However, when comparing PPM and PR, Marks and Croson (1998) and Gailmard and Palfrey (2005) find mixed results, indicating that the effects of marginal penalty need further investigation. The ranges of contributions with zero marginal penalty in UPA and

UPC extend the range of observable marginal penalties beyond those achievable with PPM and PR, and can provide more insights about the conditions under which agents can be induced to make higher offers in support of public goods.

Uniform price auctions have been widely studied in application to the private supply for public resources (e.g., Cason and Gangadharan, 2004, 2005; Jack et al., 2009; Evans et al., 2009), but not in provision applications of private demand. Gailmard and Palfrey (2005) apply uniform price auctions to excludable public goods, or club goods, leading to a fundamentally different implementation of the auction. Like this paper, they use heterogeneous values with incomplete information, which also extends the standard public good environments. Marks and Croson (1998) use homogeneous induced values under complete information, and Rondeau et al. (1999) and Spencer et al. (2009) use heterogeneous values but only in one-shot games.

The rest of the paper is organized as follows. Section 2 defines precisely the four mechanisms to be compared. Section 3 characterizes the mechanisms' undominated perfect Nash equilibria, and their respsective marginal penalty structures. Section 4 describes the experimental design and procedures. Sections 5 and 6 discuss the observed aggregate and individual contributions. Section 7 synthesizes these results.

2. The Mechanisms

Consider a group of size N, in which each subject is endowed with the same initial monetary fund I. Each subject simultaneously chooses to contribute a c_i to the provision of a threshold public good with the cost of PP (provision point), and how much $I - c_i$ to keep for themselves. If the public good is provided, each subject receives a private value of v_i, which is the individual-specific benefit from the public good. If the public good is not provided, all contributions are refunded (money-back guarantee).

2.1 Provision Point Mechanism (PPM)

The payoff function for subject i under PPM is

$$(1) \qquad \pi_i = \begin{cases} I - c_i + v_i & if \ \sum_{j=1}^{N} c_j \geq PP \\ I & otherwise \end{cases}$$

Under PPM, if the provision point is met or exceeded, each subject receives the initial endowment minus their contribution, plus their private value, v_i, for the public good; otherwise, they only get the initial endowment.

If the provision point is exceeded, mechanisms can return the excess contribution; it is "burned" in PPM. The three mechanisms PR, UPA, and UPC return excess contributions in different ways.

2.2 Proportional Rebate (PR)

Individual *i*'s payoff under PR is

$$(2) \qquad \pi_i = \begin{cases} I - c_i + v_i + \dfrac{c_i}{\sum_{j=1}^{N} c_j}\left(\sum_{j=1}^{N} c_j - PP\right) & if \ \sum_{j=1}^{N} c_j \geq PP \\ I & otherwise \end{cases}$$

Under PR, if $\sum_j c_j \geq PP$, the excess contribution ($\sum_j c_j - PP$) will be rebated. The rebate to each subject is proportional to the ratio of their individual contribution to the total contribution.

2.3 Uniform Price Auction (UPA)

Under UPA, a uniform price (*UP*) will be calculated. *UP* is the lowest price such that the number of contributions higher than that price times the price is equal to the provision point. The payoff under UPA is

$$(3) \qquad \pi_i = \begin{cases} I + v_i & if \ \sum_{j=1}^{N} c_j \geq PP, \ UP \ exists, \ and \ c_i < UP \\ I - UP + v_i & if \ \sum_{j=1}^{N} c_j \geq PP, \ UP \ exists, \ and \ c_i \geq UP \\ I & otherwise \end{cases}$$

where $UP = \min\{p > 0 : np = PP, n = |\{i : c_i \geq p\}|\}$. If a subject contributes less than *UP*, the subject pays nothing and all the contribution will be rebated. If a subject contributes *UP* or more, the subject will pay only the price *UP* and the excess contribution will be rebated.

It should be noted that to provide the good, UPA requires not only that the total contribution meet or exceed *PP*, but also that the number of relatively high individual contributions be sufficient. More precisely, *PP* and the group size together determine a set of at most *N* possible prices, where *PP* is shared by $n \leq N$ individuals offering at least *PP/n*. If the individual contributions exceed *PP*, but cannot satisfy *np=PP*, the good cannot be provided even when contributions offered meet or exceed *PP*.

2.4 Uniform Price Cap (UPC)

UPC is a modified version of UPA that ensures the good can be provided whenever total contributions exceed *PP*. The payoff under UPC is

$$\pi_i = \begin{cases} I - c_i + v_i & \text{if } \sum_{j=1}^{N} c_j \geq PP \text{ and } c_i < UC \\ I - UC + v_i & \text{if } \sum_{j=1}^{N} c_j \geq PP \text{ and } c_i \geq UC \\ I & \text{otherwise} \end{cases} \tag{4}$$

where $UC = \min\{p > 0 : \sum_{j \in \{j : c_j < p\}}^{N} c_j + np = PP, n = |\{i : c_i \geq p\}|\}$. Under UPC, if there are excess contributions, a uniform price cap (*UC*) will be calculated. If a subject contributes less than *UC*, the subject will pay their offer amount (under UPA they would pay nothing). If a subject contributes *UC* or more, the subject will pay only the price cap and the excess contribution will be rebated just like under UPA. *UC* is calculated as the lowest price that could collect only the exact amount needed. Since the contributions lower than the price will not be rebated, the uniform cap *UC* always exists as long as *PP* is met or exceeded.

3. Theoretical Benchmarks: Nash Equilibrium and Marginal Penalty

To predict how the four mechanisms will lead to different individual and aggregate contributions, we use undominated perfect equilibrium (UPE) and the marginal penalty associated with contribution beyond the provision point as theoretical benchmarks. UPE makes a precise prediction about aggregate contributions, but includes a broad continuum of equilibria leading to that aggregate. We use marginal penalty to understand patterns of disequilibrium, which may be interpreted as a (non-refinement) selection process among UPE.

3.1 Undominated Perfect Equilibrium

Bagnoli and Lipman (1989) show that the undominated perfect equilibria (UPE)[3] of PPM with complete information lead to Pareto efficient Nash equilibrium outcomes, wherein the provision point is exactly met and no one contributes more than their value, v_i. They also argue that, when rebate rules are incorporated into PPM, as long as the rebate scheme has the property that increasing one's contribution by \$1 never increases one's rebate by more than \$1, the resulting game has the same equilibrium outcomes using the concept of UPE. Since both PR and UPC satisfy the rebate scheme property, and have the same condition for provision as PPM, they will have the same Pareto efficient UPE equilibrium outcomes as PPM.

UPA has a different set of UPE from the other three mechanisms. Bagnoli and Lipman (1989) also require that the only condition of provision be that *PP* is met or exceeded, while UPA imposes constraints on the configurations of contributions that aggregate to meet the provision condition. In fact, a UPE of UPA is any strategy profile such that one and only one uniform price of PP/n can be set, and no agent i chooses c_i greater than or equal to the lowest $PP/k \geq v_i$, for k in $\{1,..,N\}$. Since the UPE of UPA are based on the possible uniform prices instead of group contributions, UPA has two main properties different from the other mechanisms. First, in the UPE of UPA, aggregate contributions above *PP* are supported as equilibria. The only condition under which a uniform price *UP* exists when the provision point is exactly met is that $n=PP/UP$ is an integer number of subjects each contributing *UP* and the other $N-(PP/UP)$ subjects choose $c_i=0$. There are at most N cases of UPE satisfying this condition; other UPEs of UPA involve aggregate contributions strictly higher than *PP*. Second, the UPE of UPA does not exclude

[3] UPE means first eliminating dominated strategies and then refining Nash equilibria by the concept of trembling hand perfection (See Bagnoli and Lipman (1989) for more detail).

(typically dominated) c_is that are greater than v_i, as long as corresponding payments will not exceed v_i under any tremble. It is easy to see that a contribution c_i from subject *i* higher than her induced value v_i is undominated as long as c_i is less than the lowest possible price higher than v_i. These two properties imply that the UPE of UPA includes aggregate and individual contributions that are not supported in the UPE of the other three mechanisms, which, respectively, include only the provision point and individual contributions not greater than v_i.

While the UPE refinement makes distinct predictions for UPA and the other mechanisms, it is inadequate in two ways. First, equilibrium predictions are not strongly predictive in existing PPM and PR experiments: Bagnoli and McKee (1991) report that the provision point is exactly met in only 54% of their PPM rounds with five homogeneous subjects; Marks and Croson (1998) report 34% in PPM and 7% in PR. Second, there is still a wide continuum of individual UPE strategies in each mechanism, and three mechanisms have the same equilibrium strategy set. Within this continuum, equilibria have widely varying distributional outcomes, and thus UPE does not provide insight into how the other regarding preferences that motivated the development of our novel mechanisms will manifest. Therefore, we use the marginal penalty associated with additional contributions once provision occurs as a second theoretical benchmark.

3.2 Marginal Penalty of Over Contribution

The marginal penalty of over contribution captures the private payoff loss associated with an additional unit of contribution, conditioned on provision. Marks and Croson (1998) associate the marginal penalty with the level of group contributions, arguing that aggregate contributions will be higher when the penalty is lower. When total private value exceeds provision cost, provision is efficient, but the continuum of equilibria makes selection among equally refined equilibria difficult; hence, excess contribution is likely in the absence of external coordination devices. The higher the loss associated with over contribution, the more conservative people may become about contributing more to increase the chance of provision in the face of strategic uncertainty about others' contributions, and the lower the contribution level would be.

Figure 1 shows individual payoffs and the structures of marginal penalty for agent *i* under different mechanisms, conditioned on provision. For PPM (Panel A), since excess contributions

will not be rebated and bring no additional benefits to subjects, every experimental dollar contributed to the public good beyond *PP* will be wasted and thus the marginal penalty of over contribution is -1. For PR (Panel B), the marginal penalty is $\frac{\partial \pi_i}{\partial c_i} = -PP\frac{C_{-i}}{C^2}$ (Marks and Croson, 1998), where $C = \sum_j c_j$ and $C_{-i} = \sum_{j \neq i} c_j$. This is bounded between -1 and 0, and typically greater than -1. Marks and Croson argue the lower marginal penalty will lead to higher contributions under PR than PPM.

UPC has a different marginal penalty structure from PR and PPM, although the set of UPE is the same. It can be discussed in two cases. First, if the c_i being incremented is at or above $UC(c_i|c_{-i})$, then any incremental contribution will not change the uniform price and will be fully rebated, creating a marginal penalty of 0. Second, if $c_i < UC(c_i|c_{-i})$, the marginal penalty is illustrated in Figure 1 (Panel C). Here, there exists a cutting point, c_i^*, at which the marginal penalty changes from -1 to 0. In Figure 1, the intercept of the grey solid line with the *y*-axis represents the realized uniform price when c_i=0. When approaching c_i^* from below, $UC(c_i|c_{-i})$ decreases and the increased contribution is fully collected, leading to a marginal penalty of -1; when approaching c_i^* from above, $UC(c_i|c_{-i})$ stays constant at c_i^* and the marginal penalty is 0; at $c_i = c_i^*$, marginal penalty is not defined. Based on these expected marginal penalities (with expectations taken over beliefs about c_{-i} implied by various UPE) between -1 and 0, we would expect higher aggregate contributions in UPC than in PPM, while UPC and PR might be comparable.

The marginal penalty structure of UPA is similar to that of UPC, but with a critical difference. If $c_i < UP(c_i|c_{-i})$ (Figure 1, Panel D) where $UP(c_i|c_{-i})$ involves payments of *PP/m* by *m* other agents, there exists a cutting point, c_i^{**}, at which *i*'s contribution is sufficient that it can be included in payments of the next lowest uniform price, and the final payment by *i* jumps from 0 to the new price, $UP(c_i^{**}|c_{-i}) = \frac{PP}{m+1}$. At all other points, the marginal penalty is 0, even when the contribution is lower than c_i^{**}. Thus, the marginal penalty of UPA is zero almost always, except at the cutting point with a lump sum penalty. Given the broad range of values with no marginal penalty, we conjecture higher contributions in UPA than the other mechanisms.

Note that the marginal penalty structures of UPC and UPA not only suggest differences in aggregate contributions among mechanisms, but if agents with higher v_is tend to make higher contributions, they are also suggestive of how incentives may differ across the range of values. Since the marginal penalties vary with contribution level, agents offering a constant share of their v_is will be treated differently in UPC and UPA: higher contributions may be seen from high value people in UPC and UPA than in PPM and PR, because the marginal penalty for higher contributions is lower. Following the same logic, we would also expect a higher contribution level from low value people in UPA than in the other mechanisms, while the contribution level from low value people in UPC could be higher or lower than that from PPM or PR.

4 Experimental Design and Procedures

To test the predictions of UPE and the effects of marginal penalty among the four mechanisms, we designed a controlled laboratory experiment in which agents with heterogeneous values make contributions toward an induced value public good. In addition to varying the mechanism, treatments also varied *PP* to alter where in the range of values the provision outcome was likely to be binding.

Table 1 shows the treatments presented in each session, with a treatment designated by the mechanism abbreviation and *PP*. The first treatment is always PPM (10 rounds), which is used to get subjects familiar with the baseline game. The following treatments (15 rounds each) apply the other mechanisms and provision points in a partial Latin Square to control for order effects.

In each session, sixteen to twenty subjects were seated in private computer carrels in the laboratory. At the start of each treatment, the experimenter read the instructions (see the Appendices) aloud as subjects read along. Subjects were then given an initial budget of 14 experimental dollars to begin the treatment. Prior to each round, subjects were randomly assigned to equally-sized groups (off-by-one if the number of subjects in a session was odd),[4] and assigned a v_i. The private v_is were drawn from an (unknown) distribution on the common-knowledge range of 4 to 12, in dollar increments: four, five and six had probability of 3/15 each;

[4] The instructions indicated group size would be 5 to 12.

seven to twelve had probability of 1/15 each.[5] Subjects then simultaneously choose a contribution, $c_i \in [0,14]$ towards of the project. At the end of each round, subjects were informed whether the project is provided, and their earnings, payment and rebates. At the end of a session, earnings were totaled across all rounds.

The unknown *PP* for a group of *N* subjects was set at $\alpha \bullet (6.8N)$, where 6.8 is the average v_i and α a treatment parameter. In Sessions 1 to 6, α was set at 0.6 of expected induced value for PPM, PR, and UPC; UPA was reduced to α of 0.3 after pilots with nearly zero provision rate. In Sessions 7 to 12, we used α of 0.3, 0.6, and 0.9, as shown in Table 1. We denote the provision point treatments as PP0.3, PP0.6, and PP0.9, respectively. For UPA, α of 0.36 was chosen based on simulations that suggested a similar provision rate as the other mechanisms at α of 0.6.

Subjects were recruited from introductory economics classes and from an email list of students interested in participating in experiments. A total of 226 subjects participated in the twelve complete sessions, leading to an average group size of 9 (two groups in each round), and an average payment of $32 for roughly 90 minutes. The software z-Tree (Fischbacher, 2007) is used for the program.

5 Group Contribution Results

Figure 2 gives an overview of group contribution data in each round by provision point and mechanism. Aggregate contributions are rescaled by session-round-specific aggregate induced values in order to make them comparable across groups with different group sizes. Grey lines represent group contributions from each session, and dark lines represent averages at each *PP*.

Figure 2 shows that, in each treatment, average aggregate contributions stabilize after roughly five rounds. Across mechanisms, higher provision points lead to higher contributions: subjects are tracking down the provision point and contributing in its neighborhood, even though group members are reshuffled in each round. Comparing across mechanisms, UPA has considerably

[5] This structure is chosen to mirror an underlying value distribution of interest to the funder, i.e., many people value the good a little, some value moderately and a few value it a lot.

higher contributions at each provision point level, and UPC looks to be slightly higher than PR and PPM at PP0.3 and PP0.6.

The results below characterize statistically these observations, focusing on data from after the first five periods of each treatment.

Result 1*: Group contributions are not equal to the UPE predicted level of the provision point in PPM, PR, and UPC. However, consistent with UPE, contributions are above the provision point in UPA; and contributions in all mechanisms are higher when provision points are higher.*

Figure 3 shows average group contributions at each *PP* for each mechanism, excluding the first 5 rounds of each treatment[6]. The provision point axis represents α. The group contribution is the average fraction of total induced value contributed.

First, group contributions in PPM, PR, and UPC are inconsistent with the specific UPE prediction that, under complete information, contributions will exactly equal *PP*. Only for PR with PP0.6 does a two-tailed *t*-test fail to reject the hypothesis that contributions are equal to the provision point (p=0.903). At PP0.3, contribution rates are 40.9% (PPM; p<0.001), 40.2% (PR; p<0.001), and 45.1% (UPC; p<0.001); at PP0.6, 58.1% (PPM; p=0.020) and 63.0% (UPC; p<0.001); at PP0.9, 78.1% (PR; p<0.001) and 75.2% (UPC; p<0.001); all are significantly different than the provision point. This contrasts with Marks and Croson (1998), who found average group contributions under PPM and PR are not statistically distinguishable from *PP*, and could be attributable to the heterogeneous values or unknown provision point in our experiment.

UPA contributions are consistent with the UPE prediction that they may exceed the provision point. At PP0.3, the contribution rate is 64.8% (p<0.001), 77.7% at PP0.36 (p<0.001), and 87.9% at PP0.6 (p<0.001). Because *PP* is only the lower bound of the UPA equilibrium set, these results are not by themselves inconsistent with UPE strategies.

[6] Conclusions are robust to excluding different numbers of initial rounds.

While the precise prediction of UPE does not hold, the comparative static prediction that contribution rates increase with provision points does, though they are biased toward one half. In PPM, PR, and UPC, group contributions increase from approximately 40% to 60% and 75% when *PP* increases from 0.3 to 0.6 and 0.9; in UPA, they increase from 65% to 78% to 88% as the *PP* increases from 0.3 to 0.36 to 0.6. By *t*-test, group contributions are signifincantly different (at the 0.01 level or better) from each other for any pair of provision point levels within each mechanism.

One important difference between UPA and the other mechanisms that could be driving differences in contributions is in the provision rule that may require contributions above *PP*, and may thus lower the provision rate. Result 2 compares provision rates across mechanisms.

Result 2: *UPA has a significantly lower provision rate than the other mechanisms; UPC has a significantly higher provision rate than PR and PPM at moderate provision points, but the differences disappear at low or high provision points; PR and PPM have similar provision rates.*

Figure 4 shows how average provision rates vary with *PP* among mechanisms. Given our induced value distribution and chosen rates, provision was the efficient outcome for 100% of groups at PP0.3, PP0.36 in all mechanisms; for 100% of groups at PP0.6 in all mechanisms but UPA, which was 55.0%; and for 77.5% of PR groups and 85.0% of UPC groups at PP0.9.

Provision rates strongly decrease at higher provision points, a result consistent with Isaac et al. (1989) and Suleiman and Rapoport (1992). The level and rate of decrease are significantly different among mechanisms. Due to its constraints on the distribution of the contributions, UPA has a dramatically lower provision rate at every *PP* than the other mechanisms. For PPM, PR and UPC, however, we cannot reject the hypothesis of similar provision rates at PP0.3, where provision is easy, and at PP0.9, where provision is very difficult. It is at PP0.6, where marginal changes in contributions affect outcomes, that differences emerge among mechanisms: UPC has a 60.7% provision rate, followed by PR at 48.3% (z-test p=0.045 different from UPC) and PPM at 42.9% (p=0.377 below PR but p=0.003 below UPC). These differences parallel differences in contribution rates, and thus may be key drivers of contribution dynamics, as subjects try to

contribute just enough to obtain regular provision as a group, but also minimize their individual costs (cf. Issac et al.'s (1989) notion of cheap riding).

In order to understand the observed differences in contributions and provision rates beyond what UPE predicts, we focus on the effect of marginal penalty to analyze individual and group data. The first result finds a broad effect of marginal penalty, controlling for provision point and provision rate.

Result 3: *Mechanisms' group contributions are ordered by marginal penalty: PPM and PR generate similar group contributions; UPC generates higher levels of group contributions than PPM and PR; UPA contributions are much higher than those of PPM, PR, and UPC.*

We run a series of group-treatment random effects models to investigate how aggregate contributions differ among mechanisms. The dependent variable is the proportion of total induced value contributed. We include indicator variables for mechanisms, provision point levels (α values), and the provision rate observed in the previous five rounds. In Table 2, Model 1 provides a baseline that includes only mechanism dummies, using PPM as the base. Model 2 controls for provision point level, which Result 1 suggests has a significantly positive effect on group contribution. Comparing Models 1 and 2, provision point increases between-treatment R^2 from 0.309 to 0.925, meaning that provision point explains a large portion of group contribution variation across treatments; a likelihood ratio test advises including provision point ($p<0.001$). Model 3 additionally controls for the previous five rounds' provision rate. It is significantly negative ($p=0.002$), which is further evidence of "cheap riding" where individuals reveal less of their value when provision has been occurring. Though this effect is relatively small--a roughly five percent decrease in contribution rate at typical provision rates, compared to a nearly fifty percent increase in response to a higher provision point—a likelihood ratio test advises using Model 3 for interpretation. [7]

[7] To validate the results from Model 3, we run models from 4 to 7. Model 4 includes an interaction between provision point and provision rate. The interaction term has a positive effect but is not significant, and the relationships among mechanisms are consistent with Model 3. From Model 5 to Model 7, we incorporate interactions between mechanism, provision point and provision rate, none of which make a significant improvement on Model 3, while introducing serious multicollinearity. Including round number, session fixed effects, or AR(1) error processes does not result in significant improvements over Model 3.

Model 3 reflects an ordering of contribution rates generated by each mechanism that is broadly consistent with higher contributions occurring where the expected marginal penalty is lower, especially for the marginal penalty structures of our new mechanisms. UPA—with an almost-everywhere zero marginal penalty that expands the single-element equilibrium outcome set (the provision point) to a continuum range of contributions where *PP* is only the lower bound—is significantly higher than PPM (likelihood ratio $p<0.001$), PR ($p<0.001$) and UPC ($p<0.001$). Similarly, the lower expected marginal penalty from UPC leads to significantly higher aggregate contributions than PPM ($p=0.006$) and PR ($p=0.084$). Increasing contributions for a higher probability of provision will not result in losing money in a broad contribution range in these mechanisms. However, controlling for other covariates, we cannot reject the hypothesis that PR and PPM generate the same aggregate contributions, consistent with Marks and Croson (1998).

To further test the marginal penalty story, we examine individual level contributions at different induced values, where marginal penalty makes different predictions across mechanisms.

6 Individual Contribution Results

Figure 5 shows average individual contributions at each induced value across provision points and mechanisms. Average observed uniform prices from UPA and UPC are also shown to calibrate how being close to the kink in the marginal penalty function in those mechanisms affects contributions. Looking across values, the amount contributed is increasing in induced value in all mechanisms and at all provision points. As with aggregate contributions, UPA stands out as generating much higher contributions, and UPC has generally slightly higher contributions at all value levels.

To investigate statistically how individual contribution varies with induced value, provision point, and mechanism, we run a series of subject-treatment random effects tobit models of dollar amount contributed, incorporating all data except the first five rounds and including UPA at PP0.36 (not shown in Figure 5). Table 3 shows the results, using PPM as an excluded base mechanism. In the experiments, subjects are asked to make an offer from 0 up to 14 experimental dollars.

In Table 3, Model 1 is a baseline model which estimates mechanism-specific intercepts with mechanism dummies; intercept variation with a *PP* term; variation in slope captured by induced value; and provision point based variation in slope with an interaction of *PP* and value. Various interaction terms among mechanisms, provision point, and induced value are added in Models 2 to 5, of which Model 3 is the most reliable. Models 2, 4, and 5 either involve many insignificant interaction terms or suffer from serious multicolinearity. Model 6 has significantly lower log-likelihood, but loses the significance of *PP* due to colinearity. Thus, we interpret Model 3, as it has similar signs and significance, and is straightforward to explain. Three results are supported by the regressions.

Result 4: *In all mechanisms, contributions increases with higher induced values*.

Value alone is large and statistically significantly positive ($p<0.001$), and there are no offsetting negative coefficients on the individual mechanisms. This result provides strong statistical evidence of a positive relationship between individual contribution and induced value, which has not been widely documented across provision point mechanisms, though Rondeau et al. (2005) and Spencer et al (2009) find similar effects in one-shot PR games. For PPM, the result is consistent with related theoretical predictions (Alboth et al., 2001; Laussel and Palfrey, 2003; Barbieri and Malueg, 2008).

Result 5: *As provision point increases, the intercept and the slope of the contribution functions also increase.*

The significantly positive ($p<0.001$) coefficient on *PP* reflects that contributions increase when the provision point does, and the significantly positive interaction with value ($p<0.001$) indicates people with higher values contribute proportionately more as *PP* increases. The effect here is rather large, as an increase from α=0.3 to α=0.6 in PPM increases the contribution by 1.459 (=2.775*(0.6-0.3) + 0.209*(0.6-0.3)*10) dollars at a value of 10. Combining the positive effects on both the intercept and the slope, this result is consistent with the result that aggregate contribution increases with *PP*.

Result 6: *UPA generates higher contributions across values, and proportionately larger contributions at higher values; UPC has a significantly higher slope than PPM and PR.*

Based on Model 3, the intercept and the slope of UPA's contribution function are significantly higher than those for PPM (intercept p=0.001; slope p<0.001) and PR (intercept p<0.001; slope p<0.001). UPA has a significantly higher intercept (p<0.001) and a higher (not significantly, p = 0.220) slope than UPC. Combined, these results indicate that UPA generates higher contributions throughout the value range. This effect is relatively large, at a value of 10 with α=0.3, the predicted UPA contribution is \$2.375 (=0.859+0.148*10) higher than PPM, \$2.194 (=0.895+0.294+(0.148-0.0475)*10) higher than PR and \$1.762 (=0.895+0.587+(0.148-0.12)*10) higher than UPC.

UPC has a slightly lower intercept than PPM (p = 0.018) and is not distinct from PR (p = 0.249). Its contribution function has a significantly higher slope throughout the range of induced values, which implies UPC elicits higher contributions from higher valued people than do PPM and PR.

PR and PPM look similar. Although PR has a borderline significantly (p=0.051) higher slope than PPM, it has a small, negative intercept (-0.294) that suggests that the intersection of PPM and PR's contribution functions is around a low-end induced value of 6 (0.294/0.0475≈6.2), and that PR generates an economically meaningful increase in contributions only among those with the highest induced values.

Organizing these contribution function results according to the marginal penalty benchmark requires further decomposing the data, because the expected marginal penalty varies throughout the value range. Further, the different values at which the contribution functions in Figure 5 intersect the average uniform prices for UPA and UPC suggest that the marginal penalty at a given value may vary with mechanism. To capture this, we compare mechanisms within each of three ranges of induced value. In the low range, even contributions of a high proportion of induced value have small effect on the provision likelihood; this is also the range where UPA and UPC are distinct. In the high range, contributions of a relatively small portion of value

considerably affect the likelihood of provision; this is the range where PPM and PR are most different from the uniform price mechanisms. In the medium range, contributions typically fall near the observed uniform prices in UPA and UPC. We use differences in contribution behavior within these value ranges to explore how differences among mechanisms are related to their marginal penalty structures.

We use two conventions to define value levels. First, we divide the value range evenly into three levels: 4-5-6 as a low level, 7-8-9 as medium, and 10-11-12 as high. This partition is neutral to any marginal penalty structure and especially suitable for PPM and PR, since their marginal penalties are continuous in contribution. Second, we group values based upon the expected marginal penalties of people with those values, which is appropriate for the discrete marginal penalty structure of UPA and UPC. As shown in Figure 1, the marginal penalty in UPC and UPA changes significantly around the uniform price, which naturally differentiates induced values based on the relationship between value and contribution. We identify who expects to make contributions in each range of marginal penalty by calculating the mean price[8] for UPC and UPA, and consider contributions within one standard deviation of the mean as "close" to the uniform price. Then, for each mechanism, we look at the induced values for which the average contributions are clearly below the uniform price, clearly above it, or likely to be near the observed uniform price. The resulting induced value levels for UPA and UPC at each provision point are shown in Table 4.

To pool contributions at different values within each value level, we use the ratio of contribution to value to measure value revelation. Then we pairwise compare value revelations of different mechanisms within each value level. Table 5 shows the value revelation comparisons based on evenly divided and UPC-price-based value levels. For example, at the low value level of PP0.3, the average value revelations in UPA and PR are respectively 0.690 and 0.436, which are different at the 0.01 significance level by a Wilcoxon rank sum test; the next row compares UPC to the other mechanisms.

[8] Ideally, the uniform prices for UPA and UPC can be calculated ex ante based on contribution functions in equilibrium, and the value levels for each mechanism can be determined accordingly. However, the contribution functions have not been solved yet, so we use this feasible empirical benchmark.

Comparing mechanisms within each level provides three key results consistent with agents' responding to differences in marginal penalty in making their contribution choices.

Result 7: *Consistent with the marginal penalty effect, value revelation is significantly higher in UPA than the other mechanisms, throughout the value range.*

Regardless of the how value levels are determined,[9] UPA generates significantly (at 0.01 level) higher contributions from the other three mechanisms across all three value levels, which is consistent with Result 6 and the pattern shown in Figure 5. The marginal penalty argument explains well here: by having zero marginal penalty across most of the value range, UPA generates significantly higher contributions over the value range. Importantly, this is true even in the range of observed uniform prices (near), as this is where there is a risk of a discrete jump in penalty from an incrementally higher contribution.

Together, Results 6 and 7 add that UPA generates significantly higher contributions not only in aggregate, but also at each induced value level. The performance of UPC relative to the other mechanisms varies by value level and depends on the provision point, and is reported in two results.

Result 8: *UPC generates comparable value revelation with PR and PPM at all value levels when the provision point is low; UPC and PR are comparable at all value levels at higher provision points.*

Table 5 indicates UPC is not significantly different from PPM and PR when at PP0.3, and additionally PR at PP0.9, at any value level. Since, at high induced values, the marginal penalty of UPC is zero compared to positive and close to one for PPM and PR, this is evidence against the marginal penalty model. However, combined with the next result, it shows that there is an important additional condition for the marginal penalty effect to be observed: salience.

[9] Table 5 only shows the evenly divided value levels for UPA; value levels based on the UPA uniform price lead to the same significance levels.

Result 9: *At moderate provision points, UPC generates significantly higher value revelation than PPM at near- and above-price values; UPC generates significantly higher value revelation than PR at above-price value levels.*

Understanding how UPC is different than PR and PPM requires focusing on value levels defined based on proximity to observed UPC uniform prices, in the lower section of Table 5. The marginal penalty is the same (-1) for UPC and PPM at below-price values and, as expected, value revelation from UPC and PPM is not significantly different at PP0.6 (0.637 vs. 0.632, p=0.140). At above-price values, marginal penalties are different between UPC (0) and PPM (-1), and the PP0.6 value revelations of UPC and PPM are accordingly significantly (at 0.01 level) different.

UPC generates significantly higher contributions than PR in PP0.6 treatment at above-price values (p=0.030), but not at near- (p=0.184) and below- (p=0.383) price value levels. At high levels, marginal penalties are different between UPC (0) and PR (smaller than, but generally close to, -1 in PP0.6), so the significant difference is consistent with agents responding to marginal penalty. At the below-price level, UPC's marginal penalty is -1, and PR's remains close to -1, so comparable contributions are consistent with the marginal penalty effect; the insignificant difference in the neighborhood of the UPC uniform price is similarly explained.

Interpreting Results 8 and 9 jointly, contributions vary across mechanisms consistent with marginal penalty, but only when there is sufficient incentive for agents to consider their contributions carefully. At PP0.9, provision is difficult in all mechanisms, and thus one person's incremental contribution is very unlikely to affect the probability of provision and thus payoffs; at PP0.3, provision is easy, occurring in nearly all PR, PPM and UPC rounds, typically with aggregate contributions far above *PP*, and thus one person's incremental contribution is unlikely to affect payoffs by an economically meaningful amount. In both these cases, small changes in contribution do not generate large enough changes in payoffs to lead subjects to a strategic response that would allow us to detect differences in the incentives provided by the different

mechanisms.[10] However, when incremental contribution changes are empirically sufficiently likely to affect provision, mostly at PP0.6, subjects are considering their contribution decisions more carefully. In these pivotal value ranges, differences among mechanisms are observed, and the observed differences reflect subjects' responding to differences in marginal penalty.

7 Conclusions

This paper introduces two new mechanisms for threshold public goods, based on uniform price auctions: the uniform price auction mechanism (UPA) and the uniform price cap mechanism (UPC). It seeks to establish whether they generate higher levels of contributions than the widely studied provision point mechanism without a rebate (PPM), and with a contribution-proportional rebate (PR). We first characterize these four mechanisms using the concepts of undominated perfect equilibrium (UPE) and the marginal payment penalty associated with over-contribution. Then we run experiments characterized by heterogeneous values, repetition, and varying provision points to compare the mechanisms' performance in terms of group contribution, provision rate, and individual contribution across the range of induced values.

We have two observations about group contributions from the experiments: 1) after an adjustment period, aggregate contributions are mainly determined by--but generally not equal to—the provision point; 2) different mechanisms lead to significantly different levels of group contributions. The first observation is associated with the provision point representing the aggregate equilibrium outcome of UPE. Whether it is known or not, the existence of a provision point induces the group contribution to converge toward the minimum level of contribution that allows subjects to secure the added benefit of the public good. However, strategic uncertainty and heterogeneous values make it difficult to coordinate on a single distribution of the costs so that the group contribution is exactly equal to provision point.

The most prominent feature of the second observation is that UPA group contributions are significantly—statistically and economically—much higher than group contributions of the other

[10] This is a property of the mechanisms at particular parameter values, rather than a flaw in salience of the experiment. Similar effects are seen in other institutions, such as measuring the values of extramarginal buyers in second price auctions.

three mechanisms at each *PP* level. UPC has generally higher, and never lower, aggregate contributions than PPM and PR. PPM and PR generate similar aggregate contributions, extending the result reported by Marks and Croson (1998) across provision points and to heterogeneous values.

The tendency for aggregate contributions to approach the provision point with repetition offers an important contrast to Rondeau et al.'s (1999) and Spencer et al.'s (2009) one shot games. Both of these papers report that people in large groups (around 50 subjects) contribute nearly all of their induced value under PR: the average aggregate contribution with group size 50 is 107.1% of the total induced value in Rondeau et al. (1999); the average group contribution with group size 45 is 98.7% of the total value in Spencer et al. (2009). The provision points used in their studies are respectively 38% and 35% of the total value, which are close to our PP0.3. Even considering the possible group size effect, our results suggest that subjects approach provision point mechanisms differently when repetition provides an opportunity to resolve the equilibrium selection problem.

As provision point increases, all four mechanisms experience a decrease in provision rate--even when provision remains efficient--consistent with the results from Isaac et al. (1989) and Suleiman and Rapoport (1992). UPA has a much lower provision rate than the others at each provision point, due to its additional requirements on the distribution of individual contributions. At moderate provision points, UPC has a significantly higher provision rate than PPM and PR, but the differences disappear at low or high provision points, where provision is either very hard or very easy in all mechanisms. Higher observed provision rates do negatively affect aggregate contributions as subjects try to reduce their share of the cost within each mechanism, but the effect is economically small.

At the individual level, contributions increase with induced value for all of the four mechanisms. UPA is significantly higher than others at each value level. UPC is generally higher than PPM and PR, but only significantly so at higher value levels, or the values resulting in contributions near or higher than the price at moderate provision points. This implies that the marginal penalty effect is significant only when the marginal changes of contributions matter in provision.

The difference between UPA and the other three mechanisms is fundamental in the sense that, in equilibrium, UPA generally generates higher group contributions than the others, and hence significantly higher group and individual contributions at all provision points and value levels are observed in UPA. Group contributions in UPC exceed PPM and PR by less than those for UPA because the UPE concept for UPA supports as equilibria strategies leading to aggregate contributions above *PP*; the provision point is only a lower bound for UPA, while it is the entire set for the other mechanisms. Among the mechanisms with a common set of UPE, UPC attracts higher contributions because middle and higher value people can tender larger contributions, knowing marginal increases will be rebated in full unless they are critical to provision. That variation is so well explained by differences in equilibrium and marginal penalty incentive properties suggests that the different notions of distributional fairness that motivated the uniform price mechanisms are not primary determinants of success.

The novel UPA and UPC mechanisms do improve upon existing budget-balancing mechanisms in value revelation and provision of a threshold public good. If valuation is the goal, UPA is the best choice among the four mechanisms, as it elicits agents' values most accurately. If actually providing the public good is the major concern, UPC represents a meaningful improvement over the well studied PPM and PR. This is especially true if the group being targeted for provision has a relatively large proportion of high value people, in which case the zero or low marginal penalty in the uniform price mechanisms allows them to make larger contributions, more fully revealing their values and increasing prospects for provision.

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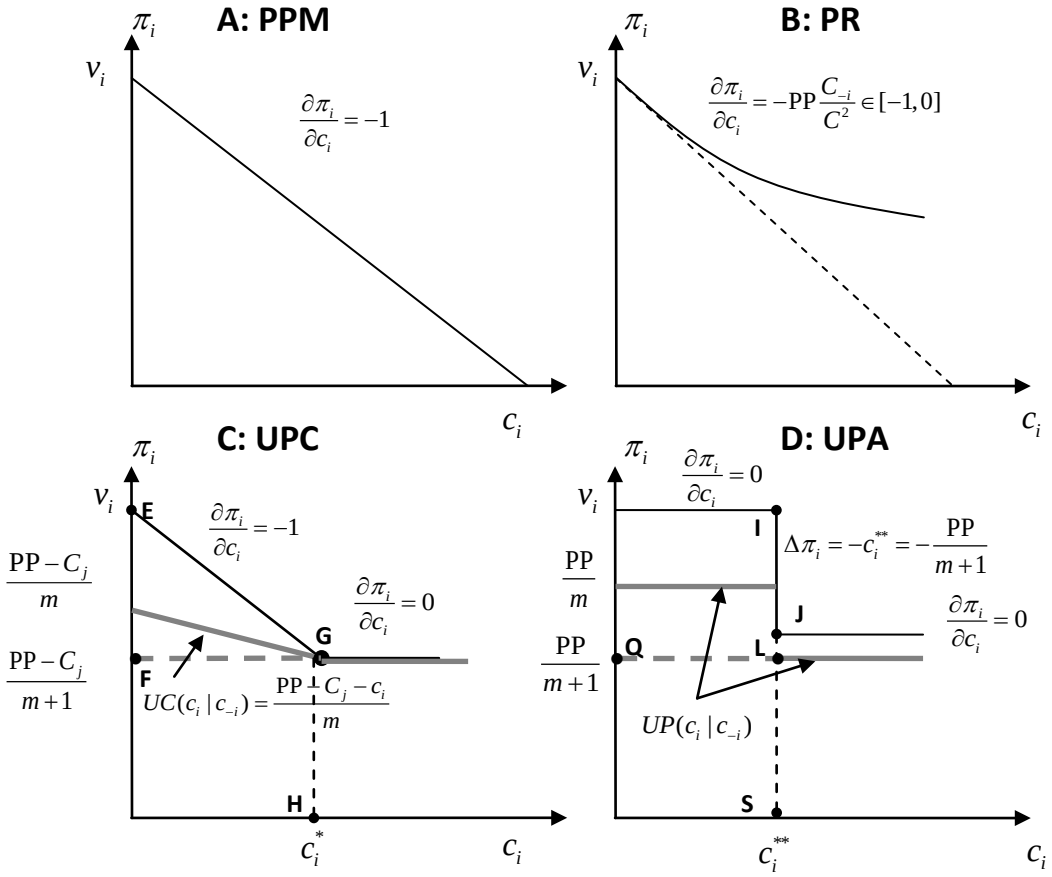

Figure 1 Individual Payoff and the Structures of Marginal Penalty, Conditioned on Provision

Note:

π_i is subject *i*'s payoff; v_i is *i*'s induced value; c_i is *i*'s contribution; *PP* is provision point; N is the group size; $C_j = \sum_{j \in \{j: c_j < UC,\, j \neq i\}} c_j$;

m indicates the number of subjects contributing not less than the uniform price in UPC or UPA excluding subject i; $UC(c_i|c_{-i})$ and $UP(c_i|c_{-i})$ are respectively uniform cap and uniform price as a function of c_i given the others' contributions. c_i^* and c_i^{**} are the cutting points respectively for UPC and UPA; EF=FG=GH if assuming no price below $\frac{\mathrm{PP}-C_j}{m+1}$ is possible in UPC; IJ=QL=LS; the initial endowment is set to be zero for convenience.

Table 1 Treatment Arrangement of Experimental Sessions

Treatment Order	1st (10 rounds)	2nd (15 rounds)	3rd (15 rounds)	4th (15 rounds)
Session 1	PPM (0.6)	PR (0.6)	UPC (0.6)	
Session 2	PPM (0.6)	PR (0.6)	UPA (0.3)	
Session 3	PPM (0.6)	UPC (0.6)	PR (0.6)	
Session 4	PPM (0.6)	UPC (0.6)	UPA (0.3)	
Session 5	PPM (0.6)	UPA (0.3)	PR (0.6)	
Session 6	PPM (0.6)	UPA (0.3)	UPC (0.6)	
Session 7	PPM (0.3)	PR (0.3)	UPC (0.3)	
Session 8	PPM (0.3)	UPC (0.3)	PR (0.3)	PR (0.6)
Session 9	PPM (0.6)	UPC (0.6)	UPA (0.6)	UPA (0.3)
Session 10	PPM (0.6)	UPA (0.6)	UPC (0.6)	UPC (0.3)
Session 11	PPM (0.6)	UPA (0.36)	UPC (0.9)	PR (0.9)
Session 12	PPM (0.6)	PR (0.9)	UPA (0.36)	UPC (0.9)
Session A1	*PPM (0.6)*	*UPC (0.6)*		
Session A2	*PPM (0.6)*	*UPA (0.3)*		
Session A3	*PPM (0.6)*	*UPA (0.6)*		
Session A4	*PPM (0.3)*	*PR (0.6)*		

Note: the number in the parentheses is the provision point in terms of the percentage of expected total induced value. Sessions A1-4 had software problems, but we use data collected prior to the program crash.

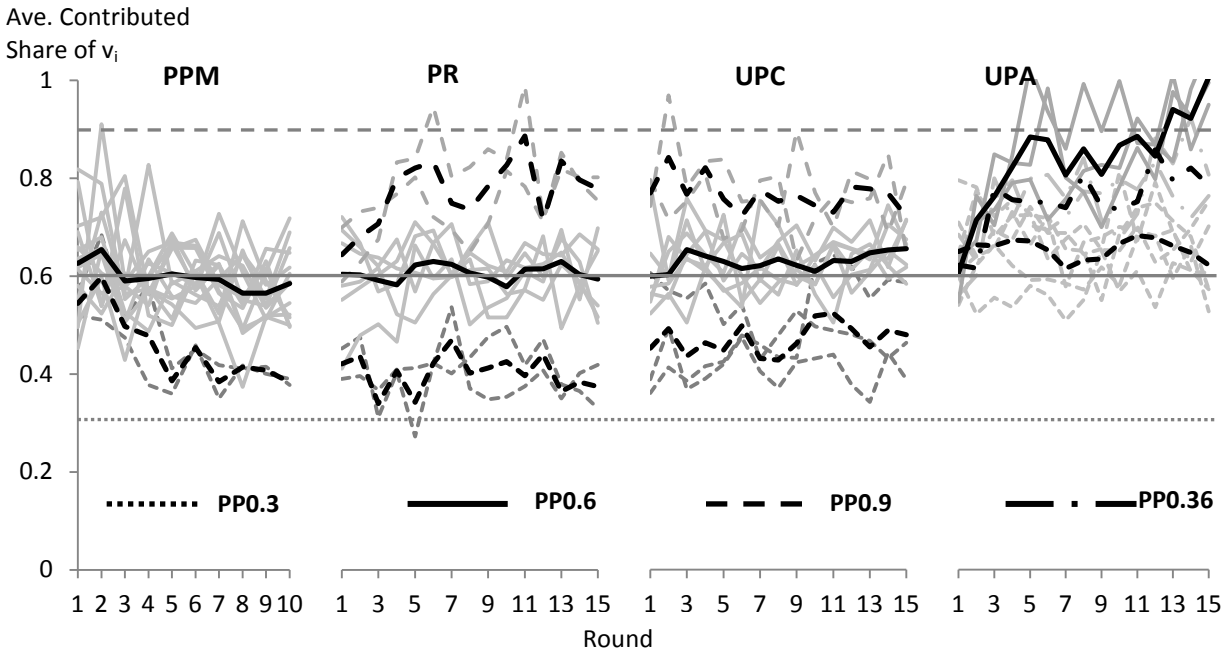

Figure 2 Group Contribution Rates in Each Round, by Provision Point and Mechanism

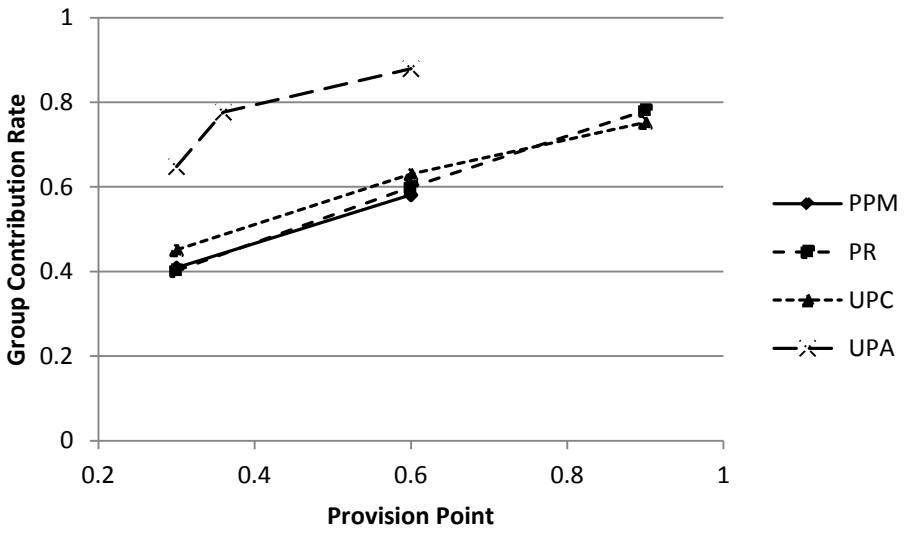

Figure 3 Average Group Contribution Rate at Each Provision Point

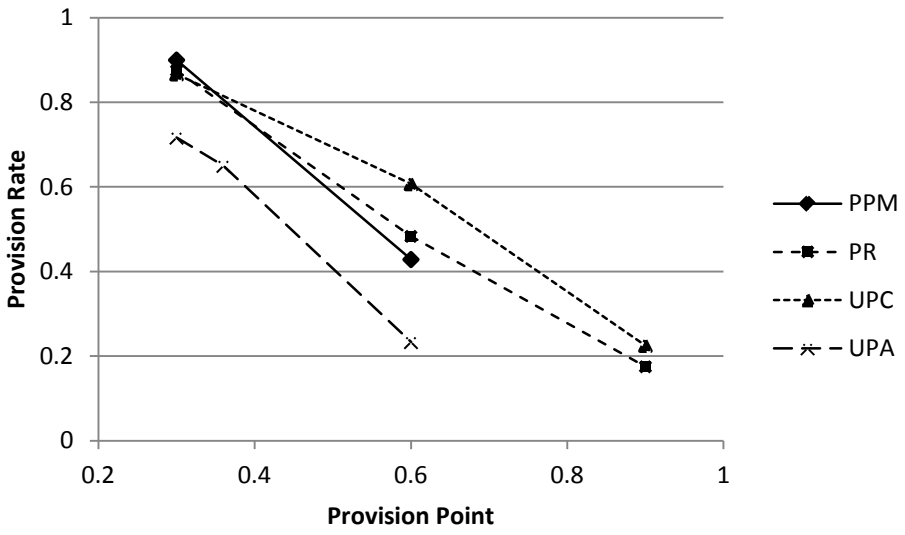

Figure 4 Average Provision Rate at Each Provision Point

Table 2 Random Effects Models of Group Contribution Rate

Group Contribution Rate	(1)	(2)	(3)
PR	0.0365	0.0141	0.0138
	(0.0398)	(0.0154)	(0.0165)
UPC	0.0464	0.0389***	0.0435***
	(0.0377)	(0.0147)	(0.0158)
UPA	0.175***	0.276***	0.258***
	(0.0387)	(0.0161)	(0.0182)
PP		0.596***	0.485***
		(0.0346)	(0.0517)
Provision Rate			-0.0890***
Based on previous 5 rounds†			(0.0288)
Constant	0.560***	0.224***	0.337***
	(0.0249)	(0.0220)	(0.0434)
log-likelihood	512.9	560.5	565.3
Chi-Square	17.97***	113.1***	122.7***
R^2_within treatment	0.000	0.00349	0.0483
R^2_between treatment	0.309	0.925	0.908
R^2_overall	0.249	0.745	0.739
Obs: 410 No. of Group: 49	Tbar = 7.538		
g_max = 10 g_ave = 8.367	g_min = 5		

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

†: Number of times provided by the two groups in each session in the previous five rounds, divided by 10

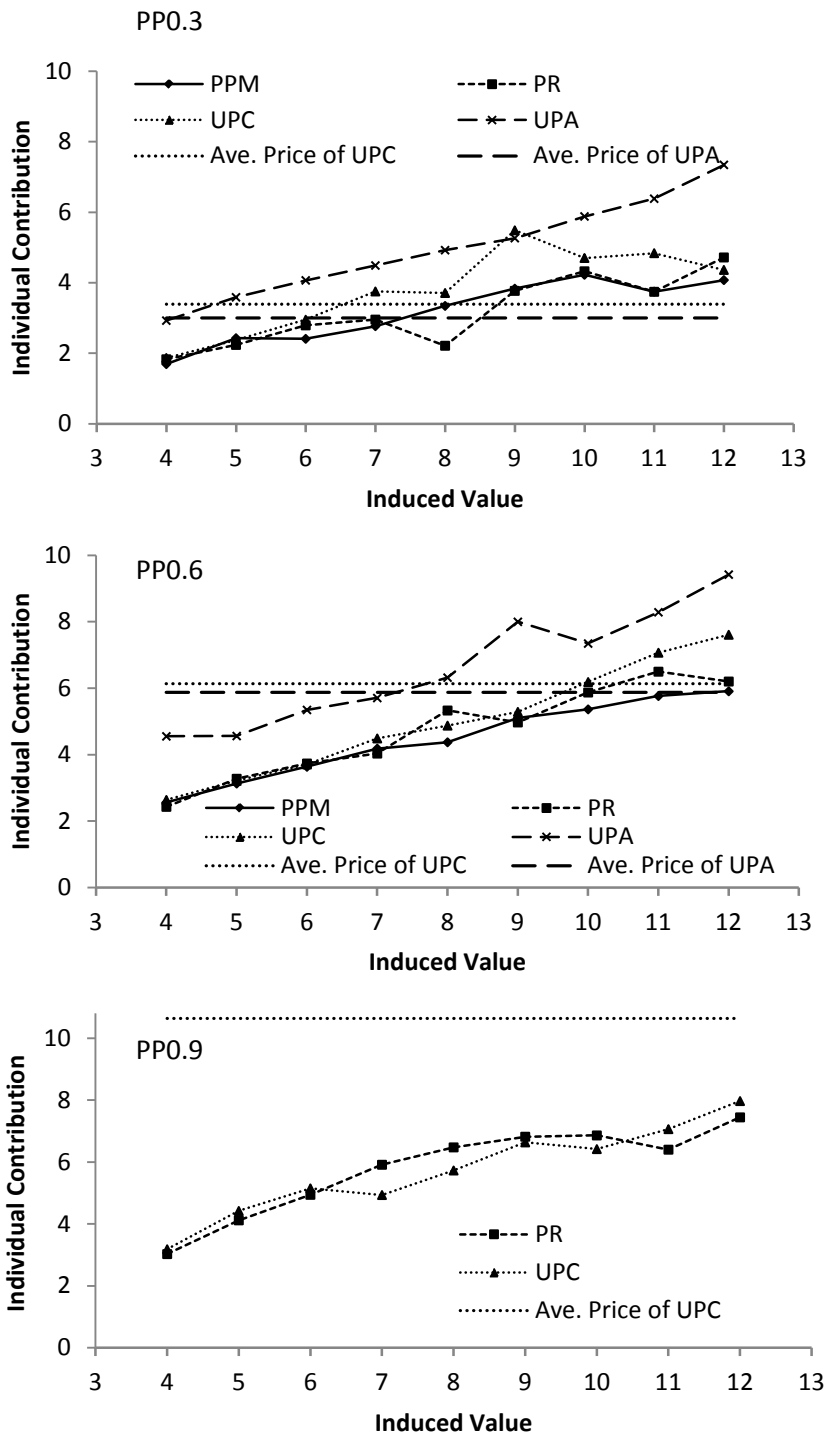

Figure 5 Mean of Individual Contribution at Provision Point Level with α set to 0.3, 06 and 0.9

Table 3 Random Effects Tobit Models of Individual Contribution

Contribution	(1)	(2)	(3)	(4)	(5)	(6)
PR	0.0320	-0.187	-0.294	-0.293	0.311	-0.285
	(0.196)	(0.859)	(0.257)	(0.257)	(1.215)	(0.258)
UPC	0.237	0.577	-0.587**	-0.587**	-0.0793	-0.480*
	(0.188)	(0.828)	(0.249)	(0.249)	(1.183)	(0.250)
UPA	1.908***	1.499*	0.895***	0.904***	0.925	0.621**
	(0.209)	(0.848)	(0.272)	(0.273)	(1.198)	(0.278)
PP	3.436***	3.384***	2.775***	2.813***	3.485*	0.861
	(0.549)	(1.265)	(0.571)	(0.575)	(1.828)	(0.657)
PR*PP		0.371			-1.049	
		(1.464)			(2.078)	
UPC*PP		-0.589			-0.894	
		(1.429)			(2.042)	
UPA*PP		1.034			0.253	
		(1.700)			(2.320)	
Value	0.450***	0.450***	0.313***	0.348***	0.378***	0.186***
	(0.0246)	(0.0246)	(0.0336)	(0.0801)	(0.111)	(0.0553)
Value*PP	0.115***	0.115***	0.209***	0.147	0.0942	0.329***
	(0.0439)	(0.0439)	(0.0495)	(0.138)	(0.194)	(0.0656)
PR*Value			0.0475*	-0.0328	-0.0740	0.0466*
			(0.0243)	(0.0877)	(0.123)	(0.0241)
UPC*Value			0.120***	0.128	0.0917	0.112***
			(0.0237)	(0.0857)	(0.121)	(0.0236)
UPA*Value			0.148***	0.0937	0.0809	0.164***
			(0.0255)	(0.0878)	(0.122)	(0.0262)
PR*Value*PP				0.138	0.210	
				(0.148)	(0.211)	
UPC*Value*PP				-0.0136	0.0505	
				(0.145)	(0.209)	
UPA*Value*PP				0.112	0.120	
				(0.165)	(0.228)	
Provision Rate†						-1.604***
						(0.264)
Provision Rate *Value						0.104***
						(0.0354)
Constant	-1.672***	-1.643**	-0.725**	-0.749**	-1.128	1.255**
	(0.332)	(0.720)	(0.367)	(0.370)	(1.047)	(0.494)
log-likelihood	-15575	-15574	-15552	-15551	-15550	-15516
Chi-Square	4229***	4231***	4302***	4306***	4307***	4229***
R^2_within	0.387	0.387	0.390	0.391	0.391	0.399
R^2_between	0.129	0.131	0.129	0.131	0.132	0.107
R^2_overall	0.254	0.255	0.256	0.257	0.258	0.249
Observations=7705	Number of group=922		g_max=10		g_avg=8.357	g_min=5

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

†: Provision rate from previous 4 rounds. Sum up times of provision of the groups the individual is in from previous 4 rounds and divide it by 4. Other round numbers are also tested, while four results in the largest log-likelihood.

Table 4 Value Levels Determined by Uniform Prices for UPC and UPA

Provision Point (α)	UPC				UPA			
	Critical Value*	Below Price	Near Price	Above Price	Critical Value	Below Price	Near Price	Above Price
PP0.3	6	4	5 - 8	9 - 12	4	n/a	4 - 5	6 - 12
PP0.6	10	4 - 7	8 - 11	12	6	n/a	4 - 8	9 - 12
PP0.9	>12	4 - 12						

*: lowest induced value for which the average individual contribution is greater than the average observed uniform price.

Table 5 Value Revelation Comparison by Value Levels†

Evenly Divided Value Ranges		Low (4,5,6)				Medium (7,8,9)				High (10,11,12)			
		Mean	UPC	PR	PPM	Mean	UPC	PR	PPM	Mean	UPC	PR	PPM
PP0.3	UPA	0.690	0.483***	0.436***	0.399***	0.632	0.483***	0.385***	0.384***	0.594	0.426***	0.381***	0.371***
	UPC	0.483		0.436	0.399	0.483		0.385	0.384	0.426		0.381	0.371
PP0.6	UPA	1.009	0.643***	0.632***	0.634***	0.814	0.642***	0.581***	0.570***	0.747	0.619***	0.551***	0.519***
	UPC	0.643		0.632	0.634	0.642		0.581*	0.570***	0.619		0.551*	0.519***
PP0.9	UPC	0.860		0.844		0.723		0.797		0.679		0.674	
UPC Price Based Value Ranges		Below				Near				Above			
		Mean	UPA	PR	PPM	Mean	UPA	PR	PPM	Mean	UPA	PR	PPM
PP0.3	UPC	0.467	0.732***	0.458	0.423	0.491	0.671***	0.431	0.412	0.502	0.609***	0.368	0.418
PP0.6	UPC	0.637	0.991***	0.624	0.632	0.621	0.799***	0.581	0.535***	0.634	0.785***	0.517**	0.492***
PP0.9	UPC	0.778		0.799									

†: By rank sum test. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendices

Appendix 1 Experimental Instructions for PPM

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

Experiment Overview

Each decision that you make is considered one *period* of the experiment. In each of these periods, you will be randomly assigned to a group that will range in size from 5 to 12 participants. You will be asked to decide how much money you will offer towards the cost of a project. This cost is predetermined but unknown to you. All members of your group receive a benefit when the project is implemented, which occurs only when the total offers of all members in your group meet or exceed the cost of the project.

How You Earn Money

At the beginning of each period, you will be told the individual value (benefit) you will receive if the project is implemented. This value will be between 4 and 12 experimental dollars. You will then be asked to make an offer from zero up to 14 experimental dollars.

You will be working with experimental dollars. One experimental dollar is equal to thirty cents. Your initial fund will be 14 experimental dollars, which represents your fee for showing up today. Your earnings for each period will be added to this amount.

The Process

You will be asked to decide how much money you will offer towards the cost of a project.

- If your group's total offers are **sufficient** for the project to be implemented, you will receive your individual value for the project, minus a contribution in the amount of your offer.

- If the group's total offers are **not sufficient** to implement the project, your offer will not be collected and you will receive no additional earnings.

Examples

There are two possible outcomes in each period:

(Outcome 1) The group offers **do** allow the project to be implemented.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$11	*Others in your group may have values higher or lower than yours*
Your Offer	$1	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$110	*Project cost exceeded*
Your Earnings for This Period	$10	*$11 Value* *-$1 Contribution* *=$10 Earnings*

The total offers of your group are sufficient for the project to be implemented. In this case, the project cost is exceeded. Your earnings ($10) are your individual value ($11) minus your contribution ($1).

(Outcome 2) The group offers **do not** allow the project to be implemented.

In this example, your offer will not be collected and you will not receive any additional earnings.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$12	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$85	*Does not meet project cost*
Your Earnings for This Period	$0	*No additional value received*

The project cost is not met, so the project is not implemented. You do not receive your individual value for this period. Your $12 offer is not collected.

Please do not speak to other participants during the experiment. Follow the instructions to the best of your ability. If you have questions, raise your hand and the administrator will assist you.

Instructions At-A-Glance

- In each period you will be randomly assigned to a group of 5 to 12 participants.
- You will be asked to decide how much money you will offer towards the cost of a project.
- Based on the offers of everyone in your group, the administrator will determine whether the project can be implemented.
- If the total offers meet or exceed the project cost, the project is implemented and your earnings will be your individual value minus your contribution.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.
- If you offer more, in exchange for incurring some of the costs, you increase the chance that the project is implemented.

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

Appendix 2 Experimental Instructions for PR

Experiment Overview

The overall process for this treatment is the same as for the previous treatment in terms of group size (5-12), range of values (4-12), conversion rate (30 cents per experimental dollar), and the steps you will take. The difference in this treatment is the method by which your net contribution or possible rebate is calculated.

The Process

Again, you will be asked to decide how much money you will offer towards the cost of a project.

- If your group's total offers **equal** the cost of the project, the project will be implemented. Your earnings will be your individual value for the project minus your contribution.
- If your group's total offers **exceed** the cost of the project, the project will be implemented and excess funds will be rebated. Your earnings will be your individual value for the project minus your offer, plus your rebate. Your rebate will be in proportion to the excess funds offered by your group. So, if X% of your group's total offers is not needed, your rebate will be X% of your offer.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.

Examples

There are three possible outcomes in each period:

(Outcome 1) The group offers are **exactly equal** to the project cost and the project is implemented.

In this example, all of your offer is needed, so your earnings are your individual value for the project, minus your contribution in the amount of your offer.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$2	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$100	*Exactly meets project cost*
Your Earnings for This Period	$10	*$12 Value* *-$2 Contribution (as Offered)* *=$10 Earnings*

The project cost is exactly met, so the project is implemented. Your earnings ($10) are your individual value ($12) minus your contribution ($2).

(Outcome 2) The group offers **exceed** the project cost and the project is implemented.

In this example, total offers exceed the amount needed, so a portion of each offer will be rebated. Your earnings are your individual value for the project, minus your offer, plus your *rebate*. This rebate is based upon the proportion of total offers represented by excess funds offered by your group.

Project Cost (*unknown to you*)	$150	
Your Individual Value	$10	*Others in your group may have values higher or lower than yours*
Your Offer	$10	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$200	*Exceeds project cost*
Total Excess Contributions	$50	*$200 offered - $150 needed*
Your Rebate from Excess Contributions	$2.50	*We need 75% of the money offered, so you get 25% of your money back*
Your Earnings for This Period	$2.50	*$10 Value* *- $10 Offer* *+ $2.50 rebate* *=$2.50 earnings*

The project cost is exceeded, so the project is implemented. Because we only need 75% of the money offered, you get a 25% of your money back. Your earnings ($2.50) are your individual value ($10) minus your offer ($10), plus your rebate ($2.50).

(Outcome 3) The group offers **do not** allow the project to be implemented.

In this example, your offer will not be collected and you will not receive any additional earnings.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$10	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$85	*Does not meet project cost*
Your Earnings for This Period	$0	*No additional value received*

The project cost is not met, so the project is not implemented. You do not receive your individual value for this period. Your $10 offer is not collected.

Please do not speak to other participants during the experiment. Follow these instructions to the best of your ability. If you have questions, raise your hand and the administrator will assist you.

Instructions At-A-Glance

- In each period you will be randomly assigned to a group of 5 to 12 participants.
- You will be asked to decide how much money you will offer towards the cost of a project.
- Based on the offers of everyone in your group, the administrator will determine whether the project can be implemented.
- If the total offers of your group **equal** the cost of the project, the project is implemented. Your earnings will be your individual value minus your contribution.
- If the total offers of your group **exceed** the cost of the project, the project is implemented and excess contributions are rebated so that only the exact amount needed for the project is actually collected. Your earnings will be your individual value minus your offer, plus a rebate based upon the proportion of total offers represented by excess funds offered by your group.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.
- If you offer more, in exchange for incurring some of the costs, you increase the chance that the project is implemented.

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

Appendix 3 Experimental Instructions for UPC

Experiment Overview

The overall process for this treatment is the same as for the previous treatment in terms of group size (5-12), range of values (4-12), conversion rate (30 cents per experimental dollar), and the steps you will take. The difference in this treatment is the method by which your net contribution or possible rebate is calculated.

The Process

Again, you will be asked to decide how much money you will offer towards the cost of a project.

- If your group's total offers are sufficient to implement the project, a *Contribution Cap* will be calculated for your group.
    - If your offer is above the *Contribution Cap*, you pay only the contribution cap and we will rebate any amount you offered above the contribution cap.
    - If your offer is lower than the *Contribution Cap*, you pay your offer amount.
- Your earnings will be your individual value for the project minus your contribution in both cases.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.

The *Contribution Cap* will be the lowest amount that allows us to collect only the exact amount needed to implement the project.

Examples

There are three possible outcomes in each period:

(Outcome 1) The group offers **do** allow the project to be implemented and the *Contribution Cap* is *equal to or lower* than your offer.

In this example, your offer is higher than the *Contribution Cap*, so you pay only the *Contribution Cap*. Your earnings are your individual value for the project, minus your offer, plus a rebate of your offer above the contribution cap.

Project Cost (*unknown to you*)	$110	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$11	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$150	*Project cost exceeded*
Calculated Contribution Cap	$7.50	
Your Rebate for this Period	$3.50	*$11 Offer - $7.50 Contribution Cap*
Your Earnings for this Period	$4.50	*$12 Value* *-$11 Offer* *+ $3.50 Rebate*

		= $4.50 Earnings

The Contribution Cap is lower than your offer. Even though you offered $11, you pay only the Contribution Cap of $7.50. Your earnings ($4.50) are your individual value ($12) minus your offer ($11), plus the rebate of your offer above the Contribution Cap ($3.50).

(Outcome 2) The group offers **do** allow the project to be implemented and the *Contribution Cap* is *higher than* your offer.

In this example, your offer is lower than the *Contribution Cap*, so your contribution is the full amount of your offer. Your earnings are your individual value for the project, minus your contribution.

Project Cost (*unknown to you*)	$80	
Your Individual Value	$11	*Others in your group may have values higher or lower than yours*
Your Offer	$1	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$100	*Project cost exceeded*
Calculated Contribution Cap	$9	*Higher than your offer*
Your Earnings for This Period	$10	*$11 Value* *- $1 Contribution (as Offered)* *=$10 Earnings*

Your offer of $1 is lower than the Contribution Cap of $9, so you pay your offer amount. Your earnings ($10) are your individual value ($11) minus your contribution at your original offer amount ($1).

(Outcome 3) The group offers **do not** allow the project to be implemented.

In this example, your offer will not be collected and you will not receive any additional earnings.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$12	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$85	*Does not meet project cost*
Your Earnings for This Period	$0	*No additional value received*

The project cost is not met, so the project is not implemented. You do not receive your individual value for this period. Your $12 offer is not collected.

Please do not speak to other participants during the experiment. Follow the instructions to the best of your ability. If you have questions, raise your hand and the administrator will assist you.

Instructions At-A-Glance

- In each period you will be randomly assigned to a group of 5 to 12 participants.
- You will be asked to decide how much money you will offer towards the cost of a project.
- Based on the offers of everyone in your group, the administrator will determine whether the project can be implemented.
- If total offers are such that a contribution cap can be calculated, the project is implemented and any excess funds are rebated. The *Contribution Cap* will be calculated as the lowest amount that allows us to collect only the exact amount needed to implement the project.
    - If the project is implemented and your offer is above the *Contribution Cap*, you pay only the contribution cap. Your earnings will be your individual value minus your contribution.
    - If the project is implemented and your offer is lower than the *Contribution Cap*, you pay only your offer. Your earnings will be your individual value minus your contribution.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.
- If you offer more, in exchange for incurring some of the costs, you increase the chance that the project is implemented.

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

Appendix 4 Experimental Instructions for UPA

Experiment Overview

The overall process for this treatment is the same as for the previous treatment in terms of group size (5-12), range of values (4-12), conversion rate (30 cents per experimental dollar), and the steps you will take. The difference in this treatment is the method by which your net contribution or possible rebate is calculated.

The Process

Again, you will be asked to decide how much money you will offer towards the cost of a project.

- If your group's total offers are sufficient to implement the project, a *Uniform Contribution* will be calculated for your group.
- If your offer is above the *Uniform Contribution*, you pay only the uniform contribution and we will rebate any amount you offered above the uniform contribution. Your earnings will be your individual value for the project minus your contribution.
- If your offer is lower than the *Uniform Contribution*, you pay nothing. Your earnings will be your individual value for the project.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings. .

The *Uniform Contribution* will be the lowest amount that allows us to collect only the exact amount needed to implement the project.

Examples

There are three possible outcomes in each period:

(Outcome 1) The group offers **do** allow the project to be implemented and the *Uniform Contribution* is *equal to or lower* than your offer.

In this example, your offer is higher than the *Uniform Contribution*, so you pay only the *Uniform Contribution*. Your earnings are your individual value for the project, minus your offer, plus a rebate of your offer above the uniform contribution.

Project Cost (*unknown to you*)	$110	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$11	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$150	*Project cost exceeded*
Calculated Uniform Contribution	$7.50	
Your Rebate for this Period	$3.50	*$11 Offer - $7.50 Contribution*
Your Earnings for This Period	$4.50	*$12 Value* *-$11 Offer* *+ $3.50 Rebate*

		= $4.50 Earnings

The Uniform Contribution is lower than your offer. Even though you offered $11, you pay only the Uniform Contribution of $7.50. Your earnings ($4.50) are your individual value ($12) minus your offer ($11), plus the rebate of your offer above the Uniform Contribution (3.50).

(Outcome 2) The group offers **do** allow the project to be implemented and the *Uniform Contribution* is *higher than* your offer.

In this example, your offer is lower than the *Uniform Contribution*, so you do not contribute. Your earnings are your individual value for the project.

Project Cost (*unknown to you*)	$80	
Your Individual Value	$11	*Others in your group may have values higher or lower than yours*
Your Offer	$1	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$100	*Project cost exceeded*
Calculated Uniform Contribution	$9	
Your Earnings for This Period	$11	*$11 Value* *- $0 Contribution* *=$11 Earnings*

Your offer of $1 is lower than the Uniform Contribution of $9, so you pay nothing. Your earnings ($11) are your individual value ($11).

(Outcome 3) The group offers **do not** allow the project to be implemented.

In this example, your offer will not be collected and you will not receive any additional earnings.

Project Cost (*unknown to you*)	$100	
Your Individual Value	$12	*Others in your group may have values higher or lower than yours*
Your Offer	$12	*Others in your group may offer more or less than you do*
Total Offers of Your Group	$85	*Uniform contribution cannot be calculated*
Your Earnings for This Period	$0	*No additional value received*

The project cost is not met, so the project is not implemented. You do not receive your individual value for this period. Your $12 offer is not collected.

Please do not speak to other participants during the experiment. Follow the instructions to the best of your ability. If you have questions, raise your hand and the administrator will assist you.

Instructions At-A-Glance

- In each period you will be randomly assigned to a group of 5 to 12 participants.
- You will be asked to decide how much money you will offer towards the cost of a project.
- Based on the offers of everyone in your group, the administrator will determine whether the project can be implemented.
- If total offers are such that a uniform contribution can be calculated, the project is implemented and any excess funds are rebated. The *Uniform Contribution* will be calculated as the lowest amount that allows us to collect only the exact amount needed to implement the project.
    - If the project is implemented and your offer is above the *Uniform Contribution*, you pay only the uniform contribution. Your earnings will be your individual value minus your contribution.
    - If the project is implemented and your offer is lower than the *Uniform Contribution,* you pay nothing. Your earnings will be your individual value.
- If the group's total offers are not sufficient to implement the project, your offer will not be collected and you will receive no additional earnings.
- If you offer more, in exchange for incurring some of the costs, you increase the chance that the project is implemented.

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