Contributions and Crowd-Out of Public Goods: Competing Models and Experimental Evidence

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Abstract

We report the results of a voluntary contributions mechanism (VCM) public good game designed to distinguish among four major competing models of behavior. A new user interface and implementation of a tax are introduced to focus attention on the effect that a government contribution to a public good financed by lump-sum taxes has on voluntary contributions. We observe contributions greater than the individually rational and own-money motivated amount, as well as incomplete crowd-out of the government policy. These observations are consistent with a warm-glow model with a logit decision error. Analysis of individual-level observations provides evidence of different player types.

Keywords: Public goods; crowd-out; warm-glow; logit choice.

1 Introduction

The voluntary contributions mechanism (VCM) is a benchmark institution in the theory of public goods. Within the standard environment, the Nash equilibria for the voluntary contributions mechanism possess several interesting properties. As identified in an important theoretical paper by Andreoni (1988), two of the most striking of these properties are (i) a minimal proportion of the population will provide positive contributions, and (ii) government spending on the public good will be almost completely neutralized by reductions in private contributions. The zero giver mass hypothesis has been challenged by observing actual contributions to public goods (Andreoni 1988), and by experimental evidence (such as Isaac, McCue, and Plott 1985 and Isaac and Walker 1988; see Ledyard 1995 for a survey). The strong form of the crowding-out hypothesis, which asserts government action reduces voluntary contributions dollar-for-dollar, has been challenged by studies using both field and laboratory approaches. Steinberg (1991) provides a review of field data estimates of crowd-out as well as their limitations. He concludes that most estimates indicate low levels of crowd-out. In a recent study, Manzoor and Straub (2005) estimate a wide confidence interval for crowd-out, ranging from nearly complete crowd-out to crowding-in.

Experimental research generally controls institutional features and changes the tax that finances the public good. In two laboratory studies using a public goods frame, Andreoni (1993) and Chan et al. (2002) observe substantial though incomplete crowd-out of tax financed contributions. The baseline model of Andreoni (1988) or Bergstrom et al (1986) is implemented by constructing payoff specifications in which own-earnings-maximizing participants will choose positive contribution levels in a Nash equilibrium. This interior solution permits interpretation of systematic deviations from own-earnings-maximizing behavior in terms of some type of warm-glow motivation. However, because predictions depend upon the assumption of Nash equilibrium play, deviations may also be boundedly-rational strategic responses to the choices of other participants. For example, in Andreoni's design, subjects could contribute zero to seven tokens of their endowment to the public good, with the Nash equilibrium contribution equal to three tokens. In the baseline treatment where subjects can contribute any number of tokens, contributing the full seven tokens is dominated. However, in the experimental treatment, subjects were taxed two tokens, which automatically were contributed to the public good. This manipulation does not change the Nash equilibrium level of three tokens, but it does result in contributions of five or more tokens now being dominated. It is not possible to identify whether the response observed in Andreoni's experiment is due to warm-glow or the effects of changing the strategic structure.

One response to this confound proposed in the literature is to replace the public goods game with a simple decision problem. Bolton and Katok (1998) study the dictator "game," in which one participant decides how to allocate a sum of money between herself and another subject. They observe incomplete crowd-out when subjects are taxed. While this setting eliminates the confound from strategic interaction, it moves the optimal choice for own-money maximizers to the boundary of the decision space, because the own-earnings maximizing choice involves allocating the minimum allowed to the other participant. In addition, the choice is moved from a public goods setting to a setting where framing effects are known to be important; for instance, Eckel, Grossman, and Johnston (2005) report the amount of crowd-out depends on framing effects.

Instead, our design builds on the specification proposed by Keser (1996) which keeps the choice task in the public goods setting, maintains the optimal contribution level in the interior of the strategy space, and minimizes the effects of strategic interaction. Keser's payoff specification is quadratic in the amount of the private good consumed, but linear in the amount of the public good provided. As a result, subjects motivated solely by their own expected earnings have a strictly dominant strategy.

Andreoni (1995) was the first to explore the extent to which generous contribution levels could be explained by confusion about the experimental design as opposed to intrinsic motivations. To further control for confusion or computational errors, in our design subjects make their contribution choices using a novel computer interface. The interface is designed to make transparent to the subjects that the decision which maximizes the subject's own cash earnings is always the same, given any contribution levels by other participants. We find that the dominant strategy is by far the modal choice, and that many subjects adopt the dominant strategy in most or all periods. We interpret this as evidence that the interface does make the dominant strategy transparent. Among subjects who do not choose the dominant strategy, almost all systematically choose contribution levels in excess of the dominant strategy, which is an interior equilibrium. Our observations cannot be attributed to a "drunks against the wall fall into the room" phenomena. Taken together, these observations provide evidence that contribution levels in excess of the own-earnings dominant strategy are indeed deliberate choices, and not due to confusion about the payoff structure of the game.

We observe incomplete crowd-out of the government tax and spend policy. Analysis of individual-level observations provides evidence of different player types. The observed crowd-out is driven by changes in the relative proportions of the dominant-strategy and Pareto-optimal choosers. The remaining players are organized using a model of warm-glow combined with a logit model of noisy payoff evaluation. Employing a between-subject design with two treatments that differ only by the presence or absence of a government tax and spend policy, we find a stable parameter estimate of the warm-glow function between treatments, which is further evidence of warm-glow preferences.

A standard observation in linear VCM experiments is the rejection of the strong free-rider hypothesis (Isaac, Walker, and Thomas 1984; Holt and Laury forthcoming). Our results are a clean rejection of the strong free-rider hypothesis, because of the transparency of the own-earnings-motivated dominant strategy. Andreoni (1995) and Houser and Kurzban (2002) conclude that approximately half of the cooperative participants in public good experiments are confused in the sense that they make decision errors or they do not understand the incentives in the game. We find systematic deviation above the dominant strategy that suggests these deviations are not due to player confusion. Another common observation in VCM experiments is contribution decay, a decline of contributions with repetition (Ledyard 1995). Our results display no significant change in contributions as players gain experience in the experiment.

The remainder of the paper is organized as follows. In Section 2, we examine group contributions and crowd-out for the baseline ("pure altruist"), warm-glow ("impure altruist"), logit choice, and logit choice with warm-glow models in a common environment. Section 3 describes the experimental design and the predictions of each model in the context of the experimental environment. The experimental results are reported in Section 4. Concluding remarks are provided in Section 5.

2 Analytical Framework

Consider an economy consisting of one private good, one public good, and n consumers. The marginal rate of transformation of private good into public good is constant, and normalized to one. Consumers are assumed to be homogeneous with respect to preferences and endowments. The decision problem for consumer i is to divide her endowment, ω, between a private good $x_i \geq 0$ and a contribution to a public good $g_i \geq 0$. Private good consumption is the difference between the endowment and the individual's contribution to the public good. Consumers therefore choose to maximize utility subject to the constraint $x_i + g_i = \omega$. The total supply of the public good is the sum of the contributions, $G = \sum_{i=1}^{n} g_i$.

2.1 The Baseline Model

In Keser's (1996) specification, utility is separable in private good consumption and public good consumption.

$$U_i = \omega - g_i - \gamma(\omega - g_i)^2 + m(g_i + G_{-i}), \quad (1)$$

with $\gamma > 0$, where $0 < m < 1$ is the return to each player for each dollar contributed to the public good, and G_{-i} is the sum of contributions from players other than i. The utility function in (1) is strictly concave with a unique maximum.[1]Given the comparative model focus of this paper, we want a sharp equilibrium prediction from this baseline model.

Solving for the best response function, and assuming identical preferences

$$g_i^* = g^* = \omega - \frac{1-m}{2\gamma}, \forall i. \quad (2)$$

Under the assumption that $(1-m)/2\gamma \leq \omega$, g^* lies between 0 and ω. All players have a dominant strategy to contribute g^*.

A standard feature in the literature of the voluntary contribution mechanism is that the efficient allocation transforms all of the private endowment into the public good.[2] We maintain this feature as well, both in the interest of comparability and in order to separate clearly the equilibrium prediction in the baseline model from the efficient allocation. Whereas the marginal benefit of a contribution to the contributor is m, the sum of marginal benefits to all consumers in the economy is mn. We will assume that $mn \geq 1$ so that the Pareto efficient contribution, g^{PE}, is the entire endowment, i.e. $g^{PE} = \omega$.

Because $g^\star < g^{PE}$, there is a free rider problem between what is individually rational and what is socially efficient. Each individual has an incentive to contribute $g^\star$ to the public good, although each consumer would have a higher level of utility if everyone else contributes g^{PE}.

Suppose a government attempts to increase contributions to the public good by collecting a lump-sum tax τ from each consumer and dedicating all revenues to the provision of the public good. This tax is assumed to satisfy $\tau \leq g^\star$. The total provision of the public good is $G + n\tau$. Player i's utility is then represented by

$$U_i = \omega - g_i - \tau - \gamma(\omega - g_i - \tau)^2 + m(G + n\tau) \quad (3)$$

[1] A non-dominant Nash equilibrium may introduce a coordination problem in an experiment; see, for example, Sefton and Steinberg (1996).

[2] For an exception, see Seely, Van Huyck, and Battalio (2005).

and is subject to $g_i \leq \omega - \tau$. Each player's best response is now

$$g^{T*} = \omega - \frac{1-m}{2\gamma} - \tau \tag{4}$$

or

$$g^{T*} = g^* - \tau \tag{5}$$

Each player will reduce her contribution by the amount of the tax, thereby restoring the original mix of private and public good consumption.

Crowd-out is typically analyzed as a group response to a tax and spend policy (Warr 1982; Bergstrom, Blume, and Varian 1986; Andreoni 1989). Because total individual contributions to the public good are unchanged (individual contributions plus tax revenue), the aggregate provision of the public good is also unchanged. Therefore, crowd-out is complete.

2.2 The Warm-Glow Model

The warm-glow model assumes utility is a function of private good consumption, the total supply of the public good, and the amount of the individual's voluntary contribution to the public good (Andreoni 1989). Following Chan et al. (2002), we assume the direct individual warm-glow component enters the payoff function as a separable term added to the utility of private and public good consumption. Warm-glow preferences can then be expressed as:

$$U_i^{WG} = \omega - g_i - \tau - \gamma(\omega - g_i - \tau)^2 + m\left(g_i + G_{-i} + n\tau\right) + \phi\left(g_i\right) \tag{6}$$

where $\phi(\cdot)$ measures warm-glow utility for player i. We will assume ϕ is C^2 with $\phi' > 0$ and $\phi'' < 0$. Each player balances her marginal utility of warm-glow with her marginal utility of the monetary payoff, both of which are independent of the contributions of other players. Without a tax and transfer policy, that is, $\tau = 0$, the best response for a player with warm-glow preferences is characterized by

$$g_i^{WG} = \omega - \frac{1 - m - \phi'\left(g_i^{WG}\right)}{2\gamma}. \tag{7}$$

Comparing (7) to (2), we can see that $g^{WG} > g^\star$ given $\phi' > 0$. Under this specification of warm-glow preferences, each player also has a dominant strategy, as in the baseline model, with the contribution level in the warm-glow dominant strategy being higher than the baseline.

Again, suppose the government attempts to increase contributions to the public good by collecting a lump-sum tax $\tau \leq g^\star$ from each consumer and transferring all of the revenue to the public good. The best response is then characterized by

$$g_i^{WG,T} = \omega - \frac{1 - m - \phi'\left(g_i^{WG,T}\right)}{2\gamma} - \tau \tag{8}$$

To find the degree of crowd-out, totally differentiate (8) and rearrange:

$$\frac{dg_i^{WG,T}}{d\tau} = \left(\frac{\phi''}{2\gamma} - 1\right)^{-1} \tag{9}$$

Note that $\phi'' \to 0 \Rightarrow \frac{dg_i^{WG,T}}{d\tau} \to -1$. As ϕ'' increases in absolute value (and approaches $-\infty$), $\frac{dg_i^{WG,T}}{d\tau}$ increases and asymptotically approaches zero. Therefore, the differential in (9) takes on values in the open interval $(-1, 0)$.

An individual who is taxed \$1 will reduce her voluntary contribution by less than \$1, assuming the tax revenue is contributed to the public good. Because each individual reduces her contribution by an amount between zero and τ, aggregate contributions fall by less than the tax revenue collected and spent on the public good. The government policy is successful in increasing total contributions, that is, crowd-out is incomplete.

2.3 The Logit Choice Model

McKelvey and Palfrey (1995) develop an error-based model by introducing an unobserved shock to the utility function. Utility has the same structure as the baseline model given by (1) except that a player can make a decision error due to confusion about the payoff structure or because of errors in their calculations. An alternate but behaviorally equivalent interpretation of the decision error is that the utility function has a random unobservable component (random variations in emotions or experimentation).

Anderson, Goeree, and Holt (1998) apply the logit form of the quantal response equilibrium model to public good games. They include an analysis of the Keser (1996) specification, and show that the combination of the baseline model with a logit specification for the decision error structure gives a probability distribution over player i's actions that is a truncated normal distribution. The combination of the baseline quadratic payoff function and a logit exponential model of the decision error structure is shown to yield a probability distribution over player i's actions which is a truncated normal density:

$$f_i(g_i) = K_1 \exp\left\{-\frac{\gamma}{\mu}(g_i - g^\star)^2\right\} \tag{10}$$

for $g_i \in [0, \omega]$, where $K_i(\mu, g^\star)$ ensures the density integrates to one over $[0, \omega]$.

The error term $\mu > 0$ parameterizes the tendency to make errors. As μ approaches zero, the probability of choosing the payoff maximizing contribution approaches one. As μ approaches infinity, the density function given by (10) approaches a uniform distribution, so each possible contribution can occur with probability of $\frac{1}{\omega}$, regardless of the payoff associated with each contribution. For any given (finite) value of μ, increasingly costly mistakes (i.e. greater deviations from the payoff maximizing contribution $g^{\star}$) are less likely to occur.

Characteristics of the quantal response equilibrium include the modal contribution equaling the dominant strategy contribution of $g^{\star}$, while the mean contribution is between $g^{\star}$ and half of the endowment. An implication of this model is that when the dominant strategy is greater than half of the endowment, as it is in our design, the predicted mean contribution is less than the dominant strategy. Because the mean individual contribution is less than $g^{\star}$, the aggregate provision of the public good is less than that of the baseline model.

The analysis of the tax and spend policy is an application of the properties of a truncated distribution. With the tax policy in place, no consumer can have a tax inclusive contribution (that is, voluntary contribution plus tax) in the range of $[0, \tau)$, The tax policy truncates the left tail of the distribution of contributions so that the mean contribution and thus the total supply of the public good increases as a result of the tax.

2.4 Logit Choice with Warm-Glow

Anderson, Goeree, and Holt (1998) also introduce altruism to the logit form of the quantal response equilibrium model by adding a term to the utility function that is linear in the amount voluntarily contributed. We now derive the analog to (10) allowing for an additive warm-glow component to preferences. Recall that the payoff to player i of contributing g_i with the warm-glow specification is given by[3]

$$U_i^{WG}(g_i) = \omega - g_i - \gamma(\omega - g_i)^2 + mG + \phi(g_i).$$

In the logit choice model, the probability that a contribution g_i is made is

$$f(g_i) = K_2 \exp\left\{U_i^{WG}(g_i)/\mu\right\},$$

with the constant K_2 chosen to ensure the distribution integrates to one. Paralleling the derivation in Anderson et al, we move all the terms not depending on g_i into the constant to obtain

$$f(g_i) = K_3 \exp\left\{\left[(m+1-2\gamma\omega)g_i - \gamma g_i^2 + \phi(g_i)\right]/\mu\right\}. \tag{11}$$

[3]For notational simplicity we develop the analysis for the case where there is no tax.

An implication of (11) is that the logit choice distribution for player i depends only on μ, and is independent of the choices made by other players. Therefore, the predictions of the logit choice model do not depend on an assumption that other players are themselves logit choosers. As such, we choose to refer to this as the logit choice model, rather than a quantal response equilibrium, since the predicted logit distribution of choices does not depend on an assumption that each player is correctly anticipating others will themselves be quantal responders. We will take advantage of this strong property in analyzing the individual-level contribution data.

As in the analysis in Anderson et al, (11) predicts the dominant strategy g^{WG} is the modal choice in the logit distribution. When $\phi(\cdot)$ is not linear, as we assume, the predicted distribution is no longer a truncated normal. Consider contribution levels $g^{WG}+\varepsilon$ and $g^{WG}-\varepsilon$ for some small $\varepsilon>0$. Using (11) and the first-order condition for the dominant strategy g^{WG} from (7) we obtain

$$\frac{f\left(g^{WG}+\varepsilon\right)}{f\left(g^{WG}-\varepsilon\right)}=\exp\left\{\left[2\gamma g^{WG}-\phi'\left(g^{WG}\right)(2\varepsilon)-4\gamma\varepsilon g^{WG}+\phi\left(g^{WG}+\varepsilon\right)-\phi\left(g^{WG}-\varepsilon\right)/\mu\right]\right\}.$$

This can be simplified to

$$\frac{f\left(g^{WG}+\varepsilon\right)}{f\left(g^{WG}-\varepsilon\right)}=\exp\left\{\left[\phi\left(g^{WG}+\varepsilon\right)-\phi\left(g^{WG}-\varepsilon\right)-2\varepsilon\phi'\left(g^{WG}\right)\right]/\mu\right\}. \tag{12}$$

The term in square brackets in (12) is zero if and only if ϕ is linear. Also, assuming $\phi(\cdot)$ is concave is not enough to sign the direction of the skew.

3 Experimental Design

We tailor several design choices specifically to focus the analysis on warm-glow and crowd-out. A new graphical user interface is developed to make the social dilemma evident and to reduce confusion. We also introduce a new implementation of the tax and spend policy which preserves the decision space in each treatment. The baseline model dominant strategy is greater than half of the endowment. This design choice not only allows us to distinguish between competing theoretical models, it also mitigates the censoring of data due to the tax and spend policy.

3.1 Graphical User Interface

A new graphical user interface (GUI) was developed to communicate clearly to participants what choice maximizes their own earnings. The GUI is designed so that participants also know that the own-money maximizing choice is independent of the choices of other participants. The design employed neutral language. The instructions and interface referred to the subject's own choice as the "choice of X," and the average of the choices of the other three group members as the "market statistic." See Figure 1 for a screenshot of the decision screen presented to the subjects. Subjects could use the decision screen to determine hypothetical earnings by selecting any integer combination of their choice of X and market statistic. The GUI consists of two gray bars and a gray box. The gray box summarizes the earnings surface the subject faces, with lighter shades corresponding to higher earnings. By clicking in the horizontal gray bar above the gray box, a player can select a hypothetical value of the market statistic. If a player does so, she can then click the mouse to restore the cursor and click in the vertical gray bar to select her choice of X. By moving the mouse up or down, a player can determine her earnings for different values of her choice of X and the hypothetical market statistic previously selected. A player can determine her earnings for that choice of X and a different market statistic by clicking once again in the horizontal gray bar. Moving the mouse left or right displays potential earnings associated with her choice of X and various hypothetical values of the market statistic.

A second method to determine potential earnings is to click in the gray box. Clicking in the gray box allows a player to select a choice of X and a hypothetical market statistic simultaneously. A player can choose a value of X without first selecting a hypothetical market statistic. If a player does not choose a hypothetical market statistic, question marks appear to the right of the value of X chosen to remind the player that earnings depend on the market statistic chosen by the three other group members.

When a player is ready to finalize her choice of X, she does so by clicking the confirmation button at the bottom of the screen. After all participants enter their choice of X, an outcome screen is displayed for fifteen seconds (Figure 2). The outcome screen summarizes the choices made each period. Each player sees her choice and period earnings highlighted in green. The market statistic is highlighted in red.

This and other information is recorded on a display to the right of the GUI. This display contains the period number, the history of the player's past choices of X, the history of past market statistics, the player's earning in each period, and a running balance of accumulated earnings.

This interface was chosen to make the dominant strategy, which maximizes own earnings, as clear as possible to the participants, while at the sametime allowing a fine grid over the action space. Both the shading in the GUI and the ability to scroll within the GUI are intended to allow participants to identify easily the dominant strategy.[4]This design makes it straightforward to choose the own-earnings-maximizing best response, and to observe, either immediately or after a few rounds of experience, that the choice which maximizes earnings is independent of the market

[4]Observe that best responses occur where the level sets of the payoff function are vertical. Therefore, one can see the dominant strategy in the screenshot by observing that all the level sets are vertical at the same value of the subject's choice.

statistic.

Participants could also determine that contributions in excess of the own-earnings dominant strategy benefit others. For any contribution level, earnings increase with the market statistic. For any market statistic, an individual's earnings decrease for choices greater than the dominant strategy. Additionally, earnings associated with the Pareto efficient outcome are greater than that of the Nash equilibrium, while the best response to the Pareto efficient contribution by others is of course the dominant strategy. Because of these properties, it is more compelling to argue that systematic deviations from the own-earnings dominant strategy are deliberate, and not due to misunderstanding or confusion about how earnings are calculated.

3.2 Selection of Parameter Values

The explicit form of equation (1) used to generate payoffs is

$$\Pi = \frac{1}{2}\left[50 + (100 - g_i - \tau) - 0.015\,(100 - g_i - \tau)^2 + 0.4\,(g_i + G_{-i} + 4\tau)\right]. \tag{13}$$

The decision space is the 101 integers $\{0, 1, \ldots, 100\}$. The tax τ is either 0 or 20. We refer to the treatment with $\tau = 0$ as the *no government policy* treatment, and $\tau = 20$ as the *with government policy* treatment.

In contrast to previous public good crowd-out experiments, the decision spaces in both treatments are the same. Requiring a minimum contribution of 20 tokens in the *with government policy* treatment would reduce the decision space to the 81 integers from 0 to 80. Andreoni (1993) discusses the presentation bias that can occur if the decision space in the two treatments differ. The Andreoni (1993) experiment employs three experimental designs to implement the tax and spend policy. The first design truncates the decision space but choices are relabeled, so the minimum contribution is zero rather than τ. The two treatments then differ both in the geometry of the payoff matrix and in the information presented to participants. The second implementation (the *min* condition) restores the geometry of the payoff matrix by maintaining the location of the baseline model equilibrium contribution in the range of zero to full contributions (ω), although this range is not the feasible decision space. Cells in the payoff matrix that correspond to choices ranging from zero to τ are left blank and are unattainable. Reducing the number of feasible choices in a treatment potentially affects behavior as the amount of cognitive effort to locate the equilibrium may then differ in the two treatments. The third implementation (the *augmented-tax* condition) is similar to the first, except dominated rows and columns are added to the payoff matrix to maintain the same decision space as the treatment without the tax and spend policy. Chan et al. (2002) implement the tax by requiring a minimum contribution, similar to the Andreoni (1993) *min* condition.

This experiment utilizes a new experimental design that neither reduces the decision space, nor requires the addition of dominated rows and columns to the payoff matrix. Choices are defined to be the percent of the after-tax endowment available to the player. In the *no government policy* treatment, a choice of 90 for example, is a choice of 90% of the 100 token endowment, which is 90 tokens. In the *with government policy* treatment, a participant's choice of 90 represents 90% of her 80 after-tax token endowment, which is 72 tokens. The tax-inclusive contribution is then $72+20=92$. This transformation of the decision space leaves the player with the same number of potential actions in both treatments, the 101 integers from 0 to 100. To transform choices in percents in the *with government policy* treatment to the choice of X comparable to the *no government policy* treatment, multiply the choice in percents by 0.8. Note that the budget constraint is not violated in the *with government policy* treatment, as the maximum contribution remains 100 tokens: 100% of the 80 token after-tax endowment plus the 20-token tax.

For a given value of ω, the parameters m and γ determine the baseline model dominant strategy (2). An important design feature of this experiment is that the baseline model dominant strategy is greater than 50% of the endowment with and without the government policy. In public good experiments with a linear payoff function, the marginal per capita return (MPCR) takes a variety of values, but is typically 0.5.[5] With a payoff function that is quadratic in consumption of the private good, the MPCR is the ratio of benefits to costs from contributing an incremental amount to the public account. The value of m therefore, should not be interpreted as the MPCR.

The values of m and γ were chosen so the baseline model dominant strategy is equal to 80. Placing the dominant strategy above half the endowment ensures that deviations from the dominant strategy for a participant with warm-glow preferences can be distinguished from deviations due to anchoring on the center of the decision space. Additionally, a baseline dominant strategy of 80 mitigates censoring of the data. Using a quadratic payoff function, imposing a tax of 20 will censor fewer observations if the dominant strategy is 80 compared to a situation in which the dominant strategy is less than 50.[6]

3.3 Procedures

Ninety-six undergraduates from Texas A&M University participated in the experiment, recruited in eight cohorts of twelve. A between-subject experimental design is employed. Subjects were recruited from undergraduate classes at Texas A&M University. After reading the instructions, but before the session began, the subjects filled out a questionnaire to determine that they understood how to read the earnings tables. Each session lasted approximately ninety minutes. Repeated play of the own-earnings maxmizing dominant strategy by all players for the duration of the experiment

[5] Examples include Andreoni (1995) and Houser and Kurzban (2002).

[6] We observe no choices of zero in either treatment in our data, so censoring of low contribution levels is not a concern in our analysis going forward.

Model	Group Contribution	Crowd-Out
Baseline	320	Complete
Warm-Glow	> 320	Incomplete
Logit Choice	< 320	Incomplete
Logit Choice with Warm-Glow	Indeterminate	Incomplete

Table 1: Group Contributions and Crowd-Out Predictions for Each Model

would have resulted in each subject earning $19.20.

Cohorts 1-4 played the *no government policy* treatment, and cohorts 5-8 played the *with government policy* treatment. The participants were informed they would be randomly re-matched with a group of three other players each period, and that they would play the game for ten periods. As in many VCM public good experiments, participants were assigned to groups of four.[7]Subjects had common and complete information about their own and the other participants' payoff tables.[8]

The contribution of each player to the public good was labeled "Choice of X", which ranged from zero to one hundred. The average choice of the other three group members was labeled "Market Statistic". Each subject chooses one action in each period.

3.4 Predictions

We combine our specific payoff function (13) with our theoretical model analyses from Section 2 to generate our experimental model predictions with respect to group contribution levels and crowd-out. These predictions are summarized in Table 1.

4 Results

4.1 Group Contributions Patterns

Three important features of the data emerge. First, the group contributions in both treatments are consistently above the baseline model predicted value of 320. Second, *with government* session contributions tend to be above the group outcomes in the *no government* sessions. Third, there is little evidence of significant contributions decay across periods.

The government tax policy is not completely crowded-out. Total contributions are significantly higher in the *with government* treatment. Figure 3 graphs the mean group contribution by round

[7]Ledyard (1995) is an excellent review of the literature. Ribar and Wilhelm (2002) analyze the importance of group size effects as it relates to public good crowd-out. Groups of size four have been common since Cox, Smith, and Walker (1988) demonstrate behavior in first-price auctions is similar among groups of four, five, or six.

[8]All handouts and instructions are available upon request.

Session	Treatment	Mean
1	No government	358
2	No government	333
3	No government	318
4	No government	343
5	With government	345
6	With government	356
7	With government	335
8	With government	349

Table 2: Group Mean Contributions

and by treatment. The mean group contribution in the *no government policy* treatment is 338 while the mean is 346 in the *with government policy* treatment. Both means are above the benchmark prediction of 320. Contributions are 5.6% higher in the *no government policy* treatment and 8.1% higher in the *with government policy* treatment than predicted by the baseline model.

Figure 4 displays histograms of the pooled group contributions by treatment. The tax policy reduces the frequency of group contributions in the range of 320 to 329, and increases the frequency of group contributions greater than 380, Furthermore, the distribution of contributions under the *with government policy* treatment first-order stochastically dominates that under the *no government policy* treatment.

4.2 Hypothesis Tests

We have two main hypotheses about group-level predictions to test. One test relates to the level of contributions in each treatment. The second test is for crowd-out and relates to changes in the level of contributions between the *no government* and *with government* environments. We treat the session as the unit of independent observation, and so the data for these tests are the eight session means, where each session mean is based upon the 30 observed group contributions decisions generated per session. The eight session means are reported in Table 2.

The null hypothesis in the *no government* treatment is group contributions total 320, the prediction from the baseline model. A two-tailed t-test of this hypothesis yields $t = 8.5$; we can reject the null hypothesis at the 1% significance level. The corresponding null hypothesis in the *with government* treatment is tax inclusive group contributions of 320 is also rejected at the 1% significance level ($t = 14.3$). The mean contribution in both treatments is significantly greater than the baseline model dominant strategy of 320.

The complete crowd-out hypothesis test is based upon a comparison of the *no government*

	no government	with government
z-score	0.80	-0.18
Prob $> |z|$	0.42	0.85

Table 3: Cuzick's nonparametric test for trend

to the *with government* session observations. The null hypothesis is that the data from the two treatments are drawn from the same parent population. Alternatively stated, the null hypothesis is that the median of the *with government* population is the same as the median of the *no government* population. The alternative hypothesis is that the *with government* median is greater than the *no government* median. We utilize a Robust Rank Order test to test for the presence of crowd-out. The test statistic U takes on a value of 6.29 and the null hypothesis is rejected at the 5% significance level (one-tailed test).[9] Crowd-out is incomplete.

The estimated mean degree of crowd-out is 90%. This is greater than what is reported in other experimental findings. Andreoni (1993) estimates crowding out to be 71%, while Chan et al. (2002) report a range of 64% to 75%, increasing with the size of the tax policy.

A common observation in public good experiments is decay, which is a decline in contributions over time toward the predicted stage game equilibrium. It is possible that our finding of mean contributions greater than 320 is a result of players over-contributing in the early periods before settling on the dominant strategy of the benchmark model. Although the display of the data in Figure 3 suggests that this is not a feature of behavior in our experiment we also provide a formal test of the decay hypothesis.

Cuzick (1985) and Altman (1991) provide a non-parametric test for contribution decay. The null hypothesis is that group contributions are serially independent. The statistical test is an extension of the Wilcoxon rank-sum test. The results, as reported in Table 3, suggest that contributions decrease slightly in the *with government policy* and increase slightly in the *no government policy* treatment. However, neither treatment displays a trend of decreasing contributions over time that is statistically significant at the 5% significance level.

4.3 Individual Contributions Data

The group contributions data are consistent with both the warm-glow model and the model of logit choice with warm-glow, but are inconsistent with the logit choice model without warm-glow. An examination of individual contribution data distinguishes between these two models and provides

[9] We also performed a non-parametric Wilcoxon rank sum test (also known as the Mann-Whitney test). This test yields a z-score of -2.5, which rejects the null hypothesis and suggests that group contributions in the *with government* treatment are significantly greater than those from the *no government* treatment.

	Period									
Treatment	1	2	3	4	5	6	7	8	9	10
no government	31%	29%	31%	29%	44%	29%	29%	38%	29%	38%
with government	25%	31%	23%	27%	27%	25%	25%	17%	35%	23%

Table 4: Percentage of subjects contributing the dominant strategy ($n = 48$ subjects)

further insight to the participant response that generates incomplete crowd-out. The tax policy alters the proportion of participants contributing the baseline model dominant strategy versus other contributions. It is this change in the number of players contributing the dominant strategy that leads to the observed incomplete crowd-out.

A striking feature of the individual-level data is that the dominant strategy and the strategy corresponding to the Pareto efficient outcome are played with high frequency. Table 4 reports the percentage of the 48 subjects (per treatment) in each period who contribute the baseline model dominant strategy quantity of 80. The percentage of subjects contributing the dominant strategy does not systematically increase with repetition of the game. In the *no government policy* treatment, the percentage of subjects contributing $g^{\star}$ in the first period is 31%, and increases to 38% in the tenth period. In the *with government policy* treatment, the number contributing the baseline model dominant strategy decreases slightly (by two percentage points) when comparing the first and final periods.

The top panel in Table 5 displays the number of individuals making the following contributions in the first period by treatment: the dominant strategy, the dominant strategy ± 1, the dominant strategy ± 5, the Pareto efficient contribution, the Pareto efficient contribution minus 1, and the Pareto efficient contribution minus 5. The bottom panel shows the same range of contributions, but for the final period. In the first period, players in the *with government policy* treatment are less likely to contribute the dominant strategy and are much more likely to contribute the Pareto efficient quantity. The pattern is similar in the tenth and final period. In the tenth period, players are somewhat less likely to contribute amounts near the baseline model dominant strategy in the *with government policy* treatment, but they are much more likely to make the Pareto efficient contribution.

Figure 5 shows the cumulative empirical distribution function of all choices by treatment. In the *no government policy* treatment, 157 of the 480 choices (32.7%) were of the dominant strategy, and 60 of the 480 choices (12.5%) were of the Pareto efficient strategy. In the *with government policy* treatment, 124 of the 480 choices (25.8%) were of the dominant strategy, and 96 of the 480 choices (20.0%) were of the Pareto efficient strategy.

Analysis of the individual contribution data provides evidence of multiple player types. We

Period 1 Choice

Treatment	$g^\star$	$g^\star \pm 1$	$g^\star \pm 5$	g^{PE}	$g^{PE}-1$	$g^{PE}-5$
no govenment	15	19	26	5	5	6
	(31%)	(40%)	(54%)	(10%)	(10%)	(13%)
with government	12	16	21	12	14	17
	(25%)	(33%)	(44%)	(25%)	(29%)	(35%)

Period 10 Choice

Treatment	$g^\star$	$g^\star \pm 1$	$g^\star \pm 5$	g^{PE}	$g^{PE}-1$	$g^{PE}-5$
no govenment	18	19	27	3	3	4
	(38%)	(40%)	(56%)	(6%)	(6%)	(8%)
with government	11	12	28	9	9	12
	(23%)	(25%)	(58%)	(19%)	(19%)	(25%)

Table 5: First and last period contributions by treatment

categorize players into one of three types. *Dominant strategy players* are those who choose the dominant strategy more than 3 times out of the 10 choices. *Pareto strategy players* are those who choose the Pareto strategy more than 3 times out of the 10 choices. The remaining players generally vary their choices period by period. For these players, we estimate the parameters of the logit model with warm-glow. We assume a functional form of $\phi(g_i) = g_i^k$ for the warm-glow function, with $0 < k < 1$. Values of the logit parameter μ and the warm-glow parameter k are estimated jointly by maximum likelihood.[10] Recall that with this specification, the logit distribution for choices is independent of the strategies played by other players; therefore, the presence of the dominant strategy and Pareto strategy types does not affect the estimation. This makes this estimation process more robust in the sense that we do not need to rely on mutual-consistency assumptions such as the one underlying the QRE; we need not assume that our warm-glow choosers are aware of the presence or the proportion of dominant or Pareto strategy players.

Figure 6 displays the distribution of choices in the *no government policy* treatment for players not in the dominant strategy nor Pareto strategy categories, and the logit model estimated by maximum likelihood. The estimated parameter values are $\mu = 1.08$, $k = 0.60$, with log-likehiood -813.1 on 239 observations. Figure 7 displays the distribution of choices in the *with government policy* treatment for players not in the dominant strategy nor Pareto strategy categories, and the logit model estimated by maximum likelihood. The estimated parameter values are $\mu = 0.974$,

[10] We assume a common warm-glow function for all participants used in the estimation. Of the participants in this subsample, most varied their choice by small amounts period by period, consistent with a logit model with period by period shocks. Mean contributions of each participants do vary, but with almost all the mass of contributions between 80 and 90, our design is not sensitive enough to attempt to identify idiosyncratic warm-glow parameters.

$k = 0.56$, with log-likelihood -890.0 on 247 observations. Note that the parameter estimates for the logit model are similar across the two treatments. Participants in this category do not appear to play focal strategies, such as multiples of 5 or 10, disproportionately often, except for the dominant strategy and Pareto strategy which are focal for other reasons.

These results suggest that the own-payoff maximizing strategy was made clear to some proportion of the participants, who found it compelling to choose in accordance with the own-earnings-maximizing dominant strategy. Most of the difference in the group-level contributions between the two treatments seems to be driven by changes in the proportions of the dominant-strategy and Pareto-optimal choosers. Incorporating a warm-glow for giving plus a logit model for decision noise organizes the distribution of choices of the non-dominant, non-Pareto types across the two treatments.

5 Conclusions

This paper examines contributions to and crowd-out of a public good within a clean, controlled economic environment. Our design was chosen to rule out several explanations of incomplete crowd-out not directly related to preferences. We use a payoff specification with a dominant strategy for subjects whose goal is to maximize their own earnings, and a computer interface which transparently communicates the dominant strategy. Random anonymous rematching across the ten decision periods rules out repeated-game strategies and reciprocity. We use a fine-grained decision space, and avoid framing and presentation effects due to changing the size or indexing of the decision space. In the no government treatment, the number of observed contributions less than the symmetric Nash equilibrium contribution is 40% of the total in both Andreoni (1993) and Chan et al. (2002). We find only 13% of the observations are less than the Nash equilibrium contribution in this experiment. We interpret this as evidence of both the efficacy of the graphical user interface and that deviations from the dominant strategy are predominantly deliberate choices.

We find that group-level contributions when there is no government tax exceed the predictions of the baseline model. When a government tax towards the provision of the good is imposed, crowd-out is incomplete; total contributions inclusive of the tax are higher in the with government treatment than in the no government treatment. After each decision making round, participants are shown their choice and the market statistic (the average choice of others). Given that participants can easily determine the best response to any market statistic, the observation that mean contributions are greater than the Nash prediction suggests that some participants realize their choices benefit others. These results are consistent with a model of warm glow giving.

The individual-level data suggest there are three participant types: dominant-strategy choosers, Pareto-optimal choosers, and those who vary their choice round by round. We organize the choices of this third group using a logit model of noisy payoff evaluation combined with an additive warm glow utility term. We find that estimates of the logit and warm-glow parameters are comparable between the two treatments. Therefore, most of the difference in group-level contributions between the two treatments is driven by changes in the relative proportions of the dominant-strategy and Pareto-optimal choosers.

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References

[1] Altman D.G. 1991. *Practical Statistics for Medical Research*. London: Chapman & Hall.

[2] Anderson, Simon P., Jacob K. Goeree, and Charles A. Holt. 1998. “A Theoretical Analysis of Altruism and Decision Error in Public Goods Games.” *Journal of Public Economics*, 70: 297-323.

[3] Andreoni, James. 1988. “Privately Provided Public Goods in a Large Economy: The Limits of Altruism.” *Journal of Public Economics,* 35: 57-73.

[4] Andreoni, James. 1989. “Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence.” *Journal of Political Economy*, 97(6): 1447-1458.

[5] Andreoni, James. 1993. “An Experimental Test of the Public-Goods Crowding-Out Hypothesis.” *American Economic Review*, 83: 1317-1327.

[6] Andreoni, James. 1995. “Cooperation in Public-Goods Experiments: Kindness or Confusion?” *American Economic Review*, 85(4): 891-904.

[7] Bergstrom, T. C., L.E. Blume and H.R. Varian. 1986. “On the Private Provision of Public Goods.” *American Economic Review*, 29: 25-49.

[8] Bolton, Gary E., and Elena Katok. 1998. “An Experimental Test of the Crowding Out Hypothesis: The Nature of Beneficent Behavior.” *Journal of Economic Behavior and Organization*, 37(3): 315-331.

[9] Chan, Kenneth S., Rob Godby, Stuart Mestelman, and R. Andrew Muller. 2002. "Crowding-Out Voluntary Contributions to Public Goods." *Journal of Economic Behavior and Organization,* 48: 305-317.

[10] Cox, James C., Vernon L. Smith, and James M. Walker. 1988. "Theory and Individual Behavior of First-Price Auctions." *Journal of Risk and Uncertainty.* 1988, 1, pp. 61-99.

[11] Cuzick J. 1985. "A Wilcoxon-Type Test for Trend." *Statistics in Medicine,* 4: 87-90.

[12] Eckel, Catherine C., Philip J. Grossman, and Rachel M. Johnston. 2005. "An Experimental Test of the Crowding Out Hypothesis." *Journal of Public Economics,* 89(8): 1543-1560.

[13] Holt, Charles A., and Susan K. Laury. Forthcoming. "Theoretical Explanations of Treatment Effects in Voluntary Contributions Experiments." *Handbook of Experimental Economics Results*, Charles Plott and Vernon Smith, eds.

[14] Houser, Daniel, and Robert Kurzban. 2002. "Revisiting Kindness and Confusion in Public Good Experiments." *American Economic Review*, 92(4): 1062-1069.

[15] Isaac, R. Mark, James M. Walker, and Susan H. Thomas. 1984. "Divergent Evidence on Free Riding: An Experimental Examination of Possible Explanations." *Public Choice*, 43: 113-149.

[16] Isaac, R. Mark, Kenneth F. McCue, and Charles R. Plott. 1985. "Public Goods Provision in an Experimental Environment." *Journal of Public Economics*, 26(1): 51-74.

[17] Isaac, R. Mark, and James M. Walker. 1988. "Group Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism." *Quarterly Journal of Economics,* 103(1): 179-200.

[18] Keser, Claudia. 1996. "Voluntary Contributions to a Public Good When Partial Contribution Is a Dominant Strategy." *Economics Letters,* 50: 359-366.

[19] Ledyard, John. 1995. "Public Goods: A Survey of Experimental Research." *The Handbook of Experimental Economics*, John Kagel and Alvin Roth, eds. Princeton University Press.

[20] Luccasen, R. Andrew. 2003. "Contributions and Crowd-Out of Public Goods: Competing Theories and Experimental Evidence." Dissertation, Texas A&M University, College Station, TX.

[21] Manzoor, Sonia H., and John D. Straub. 2005. "The Robustness of Kingman's Crowd-Out Estimate: Evidence from New Data on Contributions to Public Radio." *Public Choice*, 123: 463-476.

[22] McKelvey, Richard D., and Thomas R. Palfrey. 1995. "Quantal Response Equilibria in Normal Form Games." *Games and Economic Behavior*, 10: 6-38.

[23] Ribar, David C., and Mark O. Wilhelm. 2002. "Altruistic and Joy-of-Giving Motivations in Charitable Behavior." *Journal of Political Economy*, 110: 425-457.

[24] Seely, Beth, John Van Huyck, and Raymond Battalio. 2005. "Credible Assignments Can Improve Efficiency in Laboratory Public Goods Games." *Journal of Public Economics*, 89: 1437-1357.

[25] Sefton, Martin, and Richard Steinberg. 1996. "Reward Structures in Public Good Experiments." *Journal of Public Economics*, 61: 263-287.

[26] Steinberg, Richard. 1991. "Does Government Spending Crowd Out Donations? Interpreting the Evidence." *Annals of Public and Cooperative Economics*, 62: 591-617.

[27] Warr, Peter G. 1982. "Pareto Optimal Redistribution and Private Charity." *Journal of Public Economics*, 19: 131-138.

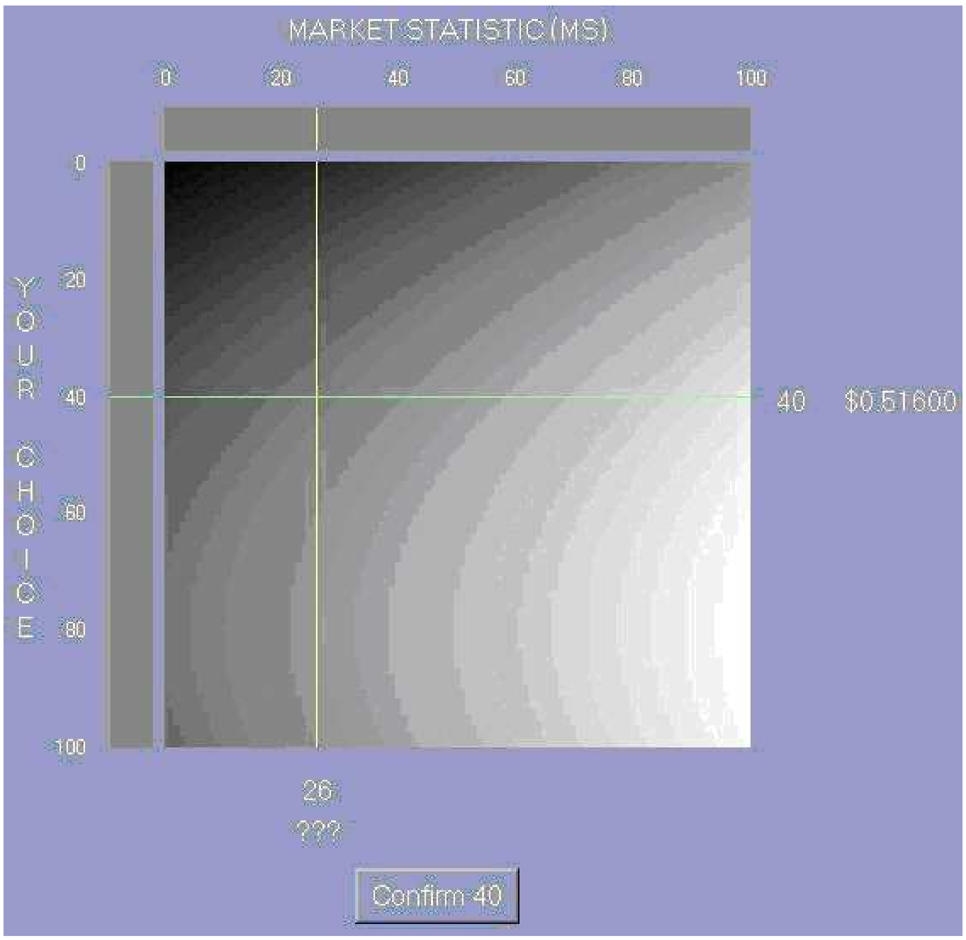

Figure 1: The graphical user interface.

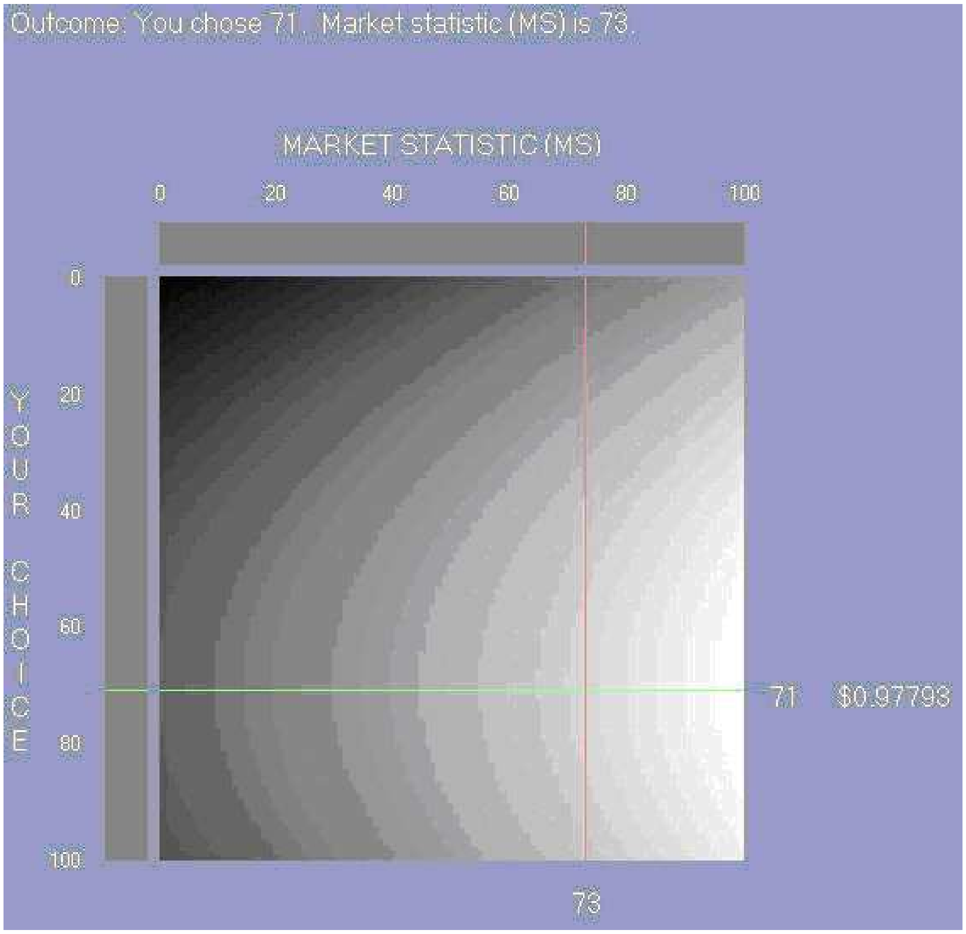

Figure 2: An example of the outcome screen.

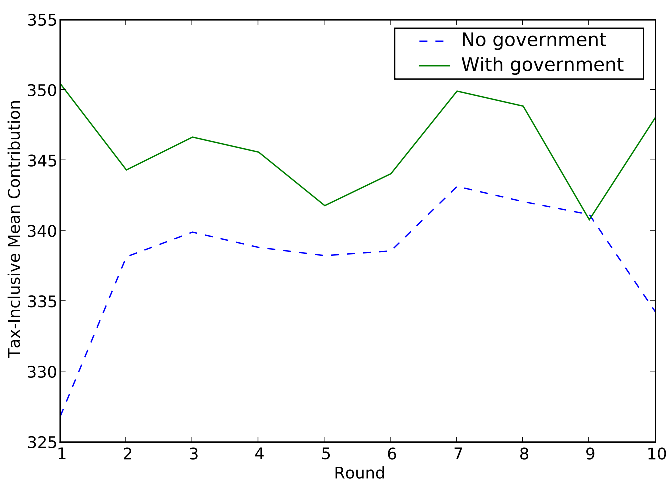

Figure 3: Mean Group Contributions, by Round and Treatment.

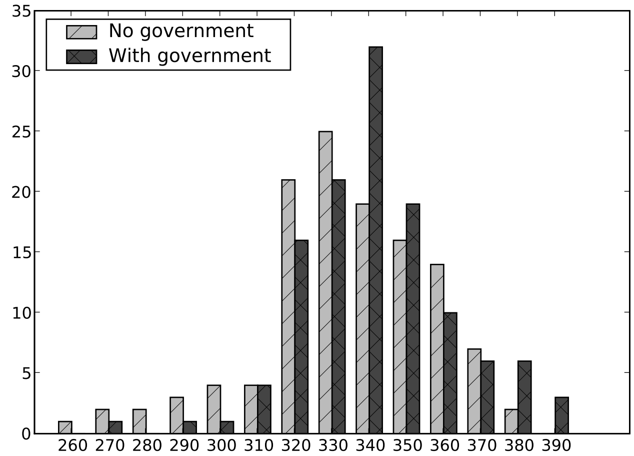

Figure 4: Frequencies of Group Contributions, by Treatment.

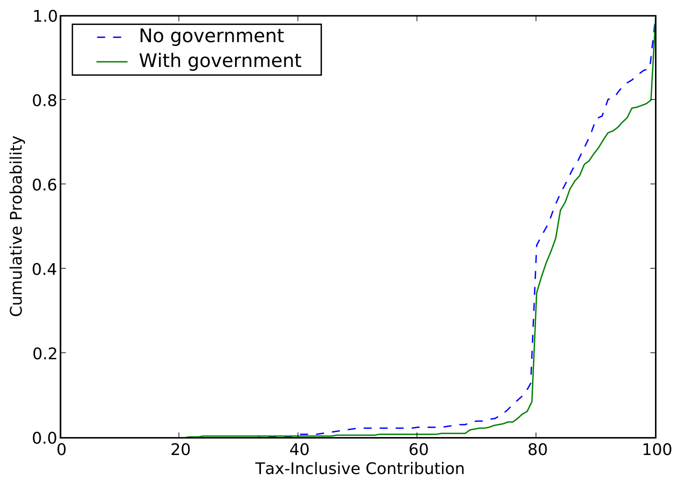

Figure 5: CDF of individual choices, by treatment

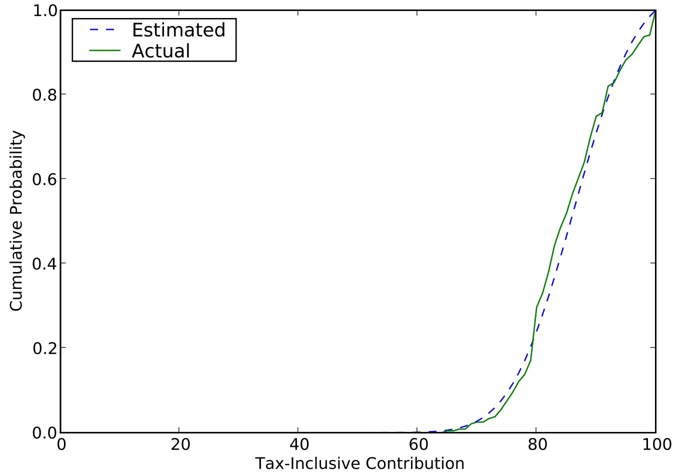

Figure 6: Actual and estimated logit CDFs of choices, no government policy

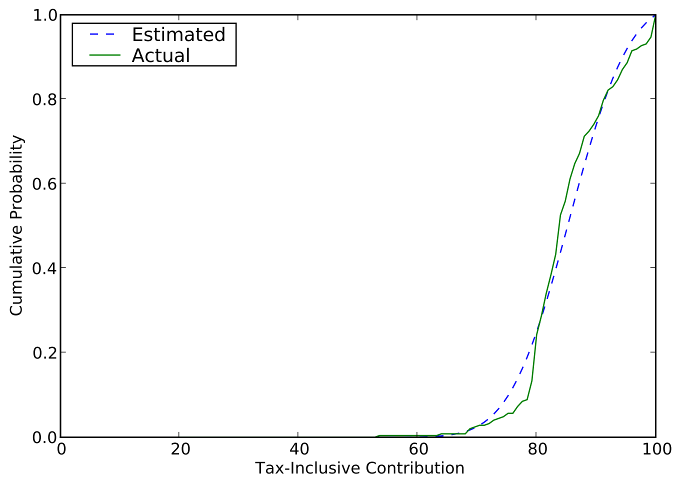

Figure 7: Actual and estimated logit CDFs of choices, with government policy