Are tax-financed contributions to a public good completely crowded-out? Experimental evidence

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Abstract

We report the results of a laboratory experiment on crowd-out in a voluntary contribution mechanism public goods game. In our setting, a standard argument states that a tax should not be effective in raising contributions because agents respond by reducing voluntary contributions by the amount of the tax. Our experiment design focuses on this intuition by abstracting away from several potential confounds. We use a specification for the payoff function in which there is a dominant strategy for own-earnings maximizing agents, located interior to and in the upper half of the strategy space. The dominant strategy ensures that changes in contributions are attributable to the tax directly, rather than second-order effects due to responses to out-of-equilibrium play by other agents. The dominant strategy is made more transparent by the use of a novel graphical decision interface. We find that individuals robustly choose at or above the own-earnings dominant strategy level. Even with the controls of the design, crowd-out is incomplete, but the degree of crowd-out is higher than in previous studies. Analysis of individual-level decisions provides evidence of different player types. Behavior of subjects not choosing the dominant or Pareto-efficient contributions is well-organized by a model of warm-glow giving with a logit decision error.

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

The voluntary contributions mechanism (VCM) is a fundamental benchmark institution in the theory of public goods. A striking property of the Nash equilibria of the VCM, first identified by Warr (1982) and later refined by Bergstrom, Blume, and Varian (1986) and Andreoni (1988), is that government spending on the public good will be neutralized by reductions in private contributions. This strong crowd-out hypothesis, that government action reduces voluntary contributions dollar-for-dollar, has been challenged by studies using both field and laboratory approaches. Studies from the field suggest that crowd-out is not dollar-for-dollar in most instances. Steinberg (1991) reviews field data estimates and concludes that most studies indicate low levels of crowd-out. Manzoor and Straub (2005) estimate a wide confidence interval for crowd-out, ranging from nearly complete crowd-out to crowding-in. Hungerman (2009) argues that much of this range of crowd-out estimates is due to the diversity of community characteristics. Andreoni and Payne (2011) decompose crowd-out into “classic” or direct crowd-out (substitutability of government grants with voluntary contributions), as well as reduced fundraising efforts on the part of charities receiving grants. These results suggest that crowd-out may be sensitive to unobserved factors which vary across individuals, institutions, and settings. Experimental research on crowd-out in VCMs seeks to avoid these confounds by changing the tax that finances the public good while controlling institutional features.

This paper reports on a laboratory experiment designed to focus on the logic underpinning the proof of the theoretical crowd-out result. We build on the payoff specification developed by Keser (1996), in which a subject’s monetary payoff is quadratic in the amount of the private good consumed, and linear in the amount of the public good provided. A subject motivated solely by her own expected earnings has a strictly dominant strategy in the interior of the action space both in the baseline game and when the tax is applied. Therefore, changes in contribution levels are attributable to the direct effect of the tax, rather than the effects of responses to the (anticipated) choices of other agents. As the incentives provided by a quadratic payoff function are not easy to convey without resorting to mathematics, in our experiment, subjects make their decisions using a graphical interface that allows them to explore and project the earnings consequences of their actions. The interface is intended to make the earnings-maximizing dominant strategy salient without requiring any calculation by the subject. These design features allow us to rule out changes in the game structure as an explanation for incomplete crowd-out.

In previous laboratory experiments studying the complete crowd-out hypothesis, Andreoni (1993) and Chan et al. (2002) observe substantial but incomplete crowd-out of tax-financed contributions. In both designs, the tax is implemented by deleting from the subject’s set of feasible contributions.\footnote{A related line of research finds that individuals contribute more to a public good when other individuals contribute}
actions contribution levels below the amount of the tax. While the Nash equilibria of the games remain the same, the removal of some actions changes the strategic structure of the game. Some contribution levels which are not dominated in the game without a tax become dominated when the tax is applied. The “high tax treatment” of Chan et al. (2002) changes the solution concept from an interior, non-dominant Nash equilibrium to a corner solution in dominant strategies. Given that non-equilibrium choices are frequent in both experiments, it is not possible to identify whether incomplete crowd-out is evidence of warm-glow motivations, or to secondary strategic effects which are artifacts of the Cobb-Douglas (Andreoni) and quadratic (Chan et al.) payoff functions.

A game with a dominant strategy equilibrium, where the dominant strategy can be identified by exploring the strategy space with a graphical interface, should provide favorable conditions for observing complete crowd-out. We can reject the hypothesis of complete crowd-out, but find higher levels of crowd-out than Andreoni or Chan et al. The dominant strategy is the modal choice, and many subjects choose the dominant strategy contribution in most or all periods, which supports the hypothesis that the design made the dominant strategy nature of the game accessible. Among those subjects who do not choose the dominant strategy, almost all systematically choose contributions in excess of the dominant strategy. We therefore find evidence of different player types, in support of the assertion by Ashley, Ball, and Eckel (2010) that studying individual-level behavior is essential for understanding competing models in public good games. We analyze subject decisions by estimating a parametric model of warm-glow giving (Andreoni 1989) combined with a logit decision error (McKelvey and Palfrey 1995, Anderson, Goeree, and Holt 1998). We obtain estimates for both parameters which are consistent across treatments. This supports warm-glow as an organizing model for the behavior of the subset of the population who contribute in excess of the own-earnings-maximizing level.

This paper is organized as follows. In section 2 we introduce the formal game being played, and build up a model which incorporates both the possibility of warm-glow giving (following Andreoni 1989) and noisy decision-making (following McKelvey and Palfrey 1995). Section 3 provides details on our laboratory implementation of the game. Section 4 presents the main results both in terms of group-level and individual-level behavior. Section 5 concludes with a discussion of the placement of these results in the literature and possible future directions.

2 Analytical framework

We consider an economy consisting of one private good, one public good, and $n$ consumers. The marginal rate of transformation of the private good into the public good is constant, and normalized
to one. Consumers are homogeneous with respect to preferences and endowments. The decision problem for consumer $i$ is to divide her endowment, $\omega$, between a private good $x_i \geq 0$ and a contribution to a public good $g_i \geq 0$. The government may attempt to increase contributions to the public good by collecting a lump-sum tax $\tau \geq 0$ from each consumer, dedicating all revenues to the provision of the public good. Private good consumption is therefore the endowment less the individual’s contribution to the public good, including amounts contributed nonvoluntarily via tax. Consumers choose $g_i$ to maximize utility subject to the constraint $x_i + g_i + \tau = \omega$. The total supply of the public good is the sum of all contributions, $G \equiv \sum_{i=1}^{n} g_i + n\tau$. For notational convenience, define $G_{-i} \equiv G - g_i - n\tau$ to be the sum of all voluntary contributions by players other than $i$.

2.1 The baseline model

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

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

(1)

with $\gamma > 0$, where $0 < m < 1$ is the private return to each player for each dollar contributed to the public good. The utility function in (1) is strictly concave, and therefore the maximizer $g_i^*$ is unique.\(^2\) We assume that

$$\frac{1 - m}{2\gamma} + \tau < \omega,$$

(2)

in which case utility is maximized at a strictly interior contribution,

$$g^* = \omega - \frac{1 - m}{2\gamma} - \tau.$$  (3)

Because $g^*$ is independent of $G_{-i}$, contributing $g^*$ is a strictly dominant strategy. The strong crowd-out hypothesis that taxation reduces contributions dollar-for-dollar is evident in the expression in the right side of (3); an increase of the tax decreases contributions by the same amount, as long as the tax is small enough that (2) is maintained. Viewed from the perspective of the total amount contributed both individually and via the tax, there is no net change in the amount spent on the public good; crowd-out is complete.

We furthermore maintain a standard feature in the literature of the voluntary contribution mechanism, in which the efficient allocation transforms all of the private endowment into the public good.\(^3\) When the marginal benefit of a contribution to the contributor is $m$, the sum of marginal

\(^2\)A non-dominant Nash equilibrium may introduce a coordination problem in an experiment; see, for example, Sefton and Steinberg (1996).

\(^3\)For an exception, see Seely, Van Huyck, and Battalio (2005).
benefits to all consumers in the economy is $mn$. We assume that $mn \geq 1$, so that the Pareto efficient contribution, $g^{PE}$, is the entire endowment, i.e. $g^{PE} = \omega$. A fortiori, for contributions above $g^*$, the marginal benefit to the individual is negative, but the marginal benefit to all consumers taken together is positive.

### 2.2 The warm-glow model

The baseline model accounts only for the material consumption of public and private goods, and does not distinguish among whether contributions to the public good are made voluntarily, or involuntarily via the tax mechanism. Andreoni (1989) proposed a warm-glow model of preferences, which posits that preferences depend also on the amount of the contribution to the public good that is made voluntarily. Following Chan et al. (2002), we assume the warm-glow component enters the payoff function as an additively separable term,

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

where $\phi(\cdot)$ captures warm-glow utility. We assume $\phi$ is $C^2$, with $\phi(0) = 0$, $\phi' > 0$ and $\phi'' < 0$. The best response for a player with warm-glow preferences satisfies

$$g^{WG} = \omega - \frac{1 - \frac{m}{2\gamma} \phi'(g^{WG})}{\frac{m}{2\gamma} - 1} - \tau.$$  

(5)

Note that $g^{WG}$ is also a dominant strategy. The assumption that the warm-glow function is strictly increasing ensures that $g^{WG} > g^*$.

Because the player cares about the amount of his voluntary contribution, crowd-out is no longer dollar-for-dollar. To find the degree of crowd-out, totally differentiate (5) and rearrange to obtain

$$\frac{dg^{WG}_i}{d\tau} = \left( \frac{\phi''}{\frac{m}{2\gamma} - 1} \right)^{-1}.$$  

(6)

When $\phi'' \to 0$, $\frac{dg^{WG}_i}{d\tau} \to -1$. As $\phi''$ increases in absolute value and approaches $-\infty$, $\frac{dg^{WG}_i}{d\tau}$ increases and asymptotically approaches zero. Therefore, $\frac{dg^{WG}_i}{d\tau}$ takes on values in the open interval $(-1, 0)$. A player with warm-glow preferences who is taxed $1 to finance a public good will reduce her voluntary contribution, but by less than $1$. Because each individual reduces her contribution by an amount between zero and $\tau$, 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; 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. In the logit choice model, the probability density that player $i$ chooses action $g_i$ is

$$f(g_i) = K \exp \left\{ \frac{EU_i(g_i)}{\mu} \right\},$$

with the constant $K$ chosen to ensure the distribution integrates to one. The error parameter $\mu > 0$ captures the tendency to make errors. As $\mu$ approaches zero, the probability of choosing the payoff-maximizing contribution approaches one. As $\mu$ approaches infinity, the density function given by (7) approaches a uniform distribution. For any given (finite) value of $\mu$, increasingly costly mistakes, i.e. greater deviations from the payoff-maximizing contribution, are less likely to occur.

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 results in a truncated normal distribution over each player’s action set. We extend the analysis to the case of additive warm-glow preferences. Applying (4) to (7), and merging all terms independent of $g_i$ into a new constant of integration $K'$ yields

$$f(g_i) = K' \exp \left\{ \frac{(m + 1 - 2\gamma)g_i - \gamma g_i^2 + \phi(g_i)}{\mu} \right\}$$

(8)

Because $g_{WG}$ is a dominant strategy, the mode of $f$ occurs at $g_{WG}$. In general, the distribution of choices will not be a truncated normal.

**Proposition 1.** The distribution of contributions predicted by the logit model is a truncated normal distribution with mean $g_{WG}$ if and only if the warm-glow function is of the form $\phi(g) = c_1 g^2 + c_2 g$, with $c_1 < 0$ and $c_2 > 0$. For any other form of the warm-glow function, the distribution of contributions is not symmetric around $g_{WG}$.

**Proof.** In order for the distribution to be symmetric around $g_{WG}$, it must be that, for any $\varepsilon > 0$,

$$\frac{f(g_{WG} + \varepsilon)}{f(g_{WG} - \varepsilon)} = 1.$$ 

(9)

Applying (8) and simplifying, we obtain

$$\exp \left\{ \left[ \phi(g_{WG} + \varepsilon) - \phi(g_{WG} - \varepsilon) - 2\varepsilon \phi'(g_{WG}) \right] / \mu \right\} = 1$$

(10)

$$\phi(g_{WG} + \varepsilon) - \phi(g_{WG} - \varepsilon) - 2\varepsilon \phi'(g_{WG}) = 0$$

(11)
Differentiating twice with respect to $\varepsilon$,

$$
\phi' (g^{WG} + \varepsilon) + \phi' (g^{WG} - \varepsilon) - 2\phi (g^{WG}) = 0
$$

(12)

$$
\phi'' (g^{WG} + \varepsilon) = \phi'' (g^{WG} + \varepsilon)
$$

(13)

Because (13) holds for all $\varepsilon > 0$, it follows that $\phi''$ is constant, and therefore $\phi$ must have the form

$$
\phi(g) = c_1 g^2 + c_2 g + c_3
$$

(14)

Because $\phi$ is strictly increasing and strictly concave, it follows that $c_1 < 0$, $c_2 > 0$, and $c_3 = 0$.

When $\phi$ has the form (14), the distribution of contributions satisfies

$$
f (g_i) \propto \exp \left\{ \left[ (m + 1 - 2\gamma \omega + c_2) g_i - (\gamma - c_1) g_i^2 \right] / \mu \right\}
$$

(15)

That is, the parameters $c_1$ and $c_2$ of the warm-glow function $\phi$ essentially modify the model parameters $\gamma$ and $m$, respectively. Therefore, the argument of Anderson, Goeree, and Holt (1998) applies, and the distribution $f$ is a truncated normal.

When $\phi$ is not a quadratic function, the direction of the skew in the distribution of contributions depends on the third derivative of $\phi$, if it exists. For $\phi''' > 0$, the distribution is left-skewed, and for $\phi''' < 0$, the distribution is right-skewed.

An implication of (8) is that the logit choice distribution for player $i$ depends only on $\mu$, and is independent of the distribution of 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. This is a strong property, and is not in general true of games even with strictly dominant strategies. We will exploit this property in analyzing the individual-level contribution data.
3 Experimental design

3.1 Parameter values and tax policy

The experimental design studies the crowd-out hypothesis with four players. The endowment \( \omega \) was 100, and the return to each player for each dollar contributed to the public good was \( m = 0.4 \). The payoff function for each player was

\[
\Pi(g_i, G_{-i}) = \frac{1}{2} \left[ 50 + (100 - g_i - \tau) - 0.015 (100 - g_i - \tau)^2 + 0.4 (g_i + G_{-i} + 4\tau) \right]. \tag{16}
\]

With this specification, the dominant strategy contribution for own-earnings-maximizing subjects is \( g^* = 80 \).

We consider two treatments. In the baseline no government policy treatment, the tax \( \tau = 0 \). This is contrasted with the with government policy treatment, in which the tax is set to \( \tau = 20 \). Because the amount of the tax is less than the dominant strategy, the Nash equilibrium prediction for own-earnings-maximizing subjects is complete crowd-out.

The parameters are chosen to place the dominant strategy solution above 50 percent of the endowment to distinguish among competing potential explanations for contributions in excess of the dominant strategy. Anderson et al (1998) derive the “sandwich” property of quantal response equilibrium, which predicts average contributions between the equilibrium and one-half the endowment. Isaac and Walker (1998) find evidence for anchoring on contributing one-half the endowment in a design using a non-dominant Nash equilibrium. With the dominant strategy at 80, an increase in the total amount spent on the public good cannot be attributed to such anchoring. Further, models with noisy decisions such as the logit model predict low contributions with positive probability, and therefore the imposition of a tax will necessarily increase spending on the public good simply by censoring out contributions below the level of the tax. Because the focus of the current study is to identify the possible effects of warm-glow, placing the dominant strategy solution on the high end of the strategy space minimizes the effects of censoring.

3.2 Implementation of the decision frame

Andreoni (1995) and Houser and Kurzban (2002) explored the hypothesis that generous contribution levels observed in public goods games are not reflective of deliberate action based on a subject’s own preferences, but rather could be attributed to confusion about the experimental design

\footnote{We focus on groups of 4 for comparability with general practice in the literature. Ledyard (1995) is an excellent review. Ribar and Wilhelm (2002) analyze the importance of group size effects as it related 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.}
or the relationship between choices and earnings. In our design, subjects made their contribution choices using a novel computer interface, which eliminates the need for subjects to carry out computations to determine how their earnings depend on their choice and the choices of others, and which makes it straightforward to identify the own-earnings-maximizing choice.

To maintain comparability across the two treatments, the cardinality of the strategy space was kept the same. Subjects chose $X$ from the integers $\{0, 1, \ldots, 100\}$. $X$ is interpreted as the percentage of the endowment after the tax which the subject contributes to the public good. Therefore, the effective contribution corresponding to a choice of $X_i$ is $g_i = X_i(100 - \tau)/100$. Figure 1 displays a screenshot of the decision screen used by the subjects. The design used neutral terminology in presenting the game.\(^5\) Relative to Andreoni (1993) and Chan et al. (2002), the experiment reported here employs a different user interface and different strategy space. The implementation of the tax by maintaining the strategy space is not expected to drive our results. In our baseline no government policy treatment, we observe no contribution levels below 20. We maintain the cardinality of the strategy space so the two treatments are as similar as possible. The logic behind the warm-glow motivation for giving is that individuals are willing to sacrifice some of their own earnings to benefit other members of their group. The implementation of the tax essentially relabels the feasible after-tax voluntary contributions. The warm-glow benefit from contributing in the experiment comes not from the integer choice per se, but rather from the trade-off between own earnings and the earnings of other group members; this trade-off is communicated to participants by the user interface.

The subject’s own choice, displayed on the vertical axis, is labeled as the “choice of X.” The average of the choices of the other three players in the subject’s group is referred to as the “market statistic.” The central box of the interface communicates the relationship between choices and the subject’s earnings. Lighter shades correspond to higher earnings, and darker shades to lower earnings. By adjusting the locations of the lines indicating the subject’s own choice X and the market statistic, subjects could explore earnings from any hypothetical combination of these variables. In particular, for any given market statistic, a subject could scroll their hypothetical choice of X up and down, which would reveal that the choice maximizing their own earnings would always be the same.\(^6\)

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 earnings

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\(^5\)Instructions and handouts used in the experiment are available upon request.

\(^6\)Best responses occur when 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.
in the Nash equilibrium. Because the decision interface displays the relationship between own choice, the market statistic, and earnings, and eliminates the need for subjects to carry out earnings computations, systematic deviations from the own-earnings dominant strategy cannot be attributed to misunderstanding or confusion about how earnings are determined.

The formulation of the strategy space and the use of the graphical decision interface incorporate the effects of the tax into the subjects’ payoff calculations. As a result, there is no need to mention taxes at all in the instructions, and we did not do so. Tax salience has been shown to affect behavior in the laboratory (Eckel et al. 2005) and consumer behavior in field studies (Chetty et al. 2009). By fully integrating the tax into the payoff calculation directly, we maintain our focus on crowd-out as a strategic response rather than as a response to framing or experimenter demand effects.

3.3 Procedures

Table 1 summarizes the experimental design relative to Andreoni (1993) and Chan et al. (2002). Ninety-six undergraduates participated in the experiment, recruited in eight cohorts of twelve, in a between-subjects design. After reading the instructions, but before the session began, the subjects completed a questionnaire to determine that they understood how to use the interface to determine earnings.

Four cohorts participated in the no government policy treatment, and four cohorts participated in 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. Subjects had common and complete information about their own and the other participants’ payoff tables.

In each session, the VCM game was the first of two decision tasks. Subjects received a $4.00 show-up fee for the whole session, which lasted approximately ninety minutes. Instructions and the ten rounds of the VCM took between forty-five minutes and an hour. On average subjects earned $9.78 from the ten decisions in the no government policy treatment, and $9.89 from the ten decisions in the with government policy treatment.

4 Results

4.1 Group-level contributions

Even with an experimental design chosen a priori to favor contributions equal to the own-earnings maximizing level, we find that spending on the public good exceeds the dominant strategy prediction in both treatments, and we further find that the government tax-and-spend policy does not
completely crowd out voluntary contributions.

Table 2 summarizes mean group contributions by session. The mean group contribution in the no government policy treatment is 338, compared to the mean of 346 in the with government policy treatment. Figure 2 displays the cumulative distributions of group contributions by treatment. In both treatments, a sizeable majority of groups exceed the baseline prediction of 320. The distribution of contributions under the with government policy treatment first-order stochastically dominates that under the no government policy treatment, reflecting a systematic shift in spending on the public good in the presence of the tax. The result that most groups exceed 320 contrasts with Isaac and Walker (1998), who report undercontribution on average with a non-dominant Nash equilibrium also located at approximately 80% of the endowment. We do not observe evidence for the “sandwich” property of logit choice or anchoring on the midpoint of the strategy space.

To test the crowd-out hypothesis formally, we use the robust rank-order test. The null hypothesis is that the median of the contributions in the with government policy treatment is the same as the median in the no government policy treatment. The alternative hypothesis is that the with government median is greater than the no government median. We reject the null hypothesis at the 5% significance level ($U = 6.29$). Crowd-out is incomplete. However, the estimated mean degree of crowd-out is 90%, which is greater than 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.

Our finding of mean contributions greater than 320 is not a result of players over-contributing in the early periods before settling on the dominant strategy of the benchmark model. Figure 3 plots average group contributions as a function of period, and suggests that there is no significant trend over time. To formalize this observation, we use the non-parametric test proposed by Cuzick (1985) (see also Altman 1991) which extends the Wilcoxon rank-sum test to test for trend. The null hypothesis is that there is no trend over time. The null hypothesis cannot be rejected in either treatment ($z$-score 0.80, $p$-value 0.42 in the no government treatment; $z$-score -0.18, $p$-value 0.85 in the with government treatment).

### 4.2 Individual contributions

A closer examination of individual contribution data provides further insight to the participant response that generates incomplete crowd-out. A striking feature of the individual-level data is

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7 Throughout we report all contributions data inclusive of tax, for direct comparability of results across treatments.

8 Alternatively, the Mann-Whitney-Wilcoxon rank sum test yields a $z$-score of -2.447, which rejects the null hypothesis ($p$-value 0.0144) and suggests that group contributions in the with government treatment are significantly greater than those in the no government treatment.

9 The average amount of crowd-out is calculated by $1 - [(\text{with government mean} - \text{no government mean})/\text{taxes collected from groups}]$. 

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that the dominant strategy and full contribution, corresponding to the Pareto efficient outcome, are played with high frequency.

Figure 4 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.

Table 3 reports the number of subjects, of the 48 per treatment, who contribute the baseline model dominant strategy amount $g^* = 80$, in the first and last periods of the session. 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 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 from 25% to 23%.

The individual contribution data provides evidence of multiple player types. We 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 periods; there are 18 dominant strategy players in the no government policy treatment and 13 in the with government policy treatment. Pareto strategy players are those who choose the Pareto strategy more than 3 times out of the 10 choices; there are 5 Pareto strategy players in the no government policy treatment and 10 in the with government policy treatment. The remaining players, 25 in each treatment, 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 $\mu$ and the warm-glow parameter $k$ are estimated jointly by maximum likelihood.\textsuperscript{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 quantal response equilibrium; we need not assume that our warm-glow choosers are aware of the presence or the proportion of dominant or Pareto strategy players.

Figures 5 and 6 display the distributions of tax-inclusive contributions of subjects in this category in both treatments. For both treatments, the estimated logit model distributions are displayed in the figure as dashed curves. The estimated parameter values for the no government policy treat-

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\textsuperscript{10}We assume a common warm-glow function for all participants. Most participants in this subsample varied their choices by small amounts period by period, consistent with a logit model with period by period shocks. Mean contributions do vary across participants in the warm-glow category, but our design is not sensitive enough to attempt to identify idiosyncratic warm-glow parameters.
ment are $\mu = 1.06$, $k = 0.593$, with log-likelihood -813.1 on 239 observations. For the with
government policy treatment, the estimated parameter values are $\mu = 0.984$, $k = 0.564$, with
log-likelihood -890.0 on 247 observations. The parameter estimates for the logit model are similar
across the two treatments. The level of contributions of subjects in this category is organized by
the same warm-glow parameter across both treatments. The logit precision parameter $\mu$ is stable
across treatments, which provides an internal consistency check. Because the payoff surfaces dis-
played in the choice interface in the two treatments are identical up to scaling of the strategy space,
we should expect the precision parameter estimate to be independent of the treatment.

These results suggest that the own-payoff maximizing strategy was made clear to some propor-
tion of the participants, who found it compelling to choose in accordance with the own-earnings
maximizing dominant strategy. Others recognized that full contribution maximized total earnings
and attempted to encourage implementation of that outcome. Incorporating a warm-glow for giv-
ing plus a logit model for decision noise organizes the distribution of choices of the non-dominant,
non-Pareto types across the two treatments.

5 Conclusion

We report a laboratory experiment investigating the hypothesis that a government tax-and-spend
policy for funding public goods will be neutral, because the tax will crowd out voluntary contribu-
tions dollar-for-dollar. The design of the experiments controls for some competing explanations for
incomplete crowd-out in previous laboratory experiments. We choose the parametric form of the
VCM game to have a dominant strategy for own-earnings-maximizing subjects, with the dominant
strategy occurring at greater than 50 percent of the endowment to rule out anchoring on the center
of the strategy space as an explanation. We present the game, with and without the tax-and-spend
policy, in the same graphical decision frame with the same strategy space, maintaining a uniform
presentation in which subjects have the means to identify the existence of the dominant strategy
for maximizing own earnings.

With these design choices and controls in place, we continue to find that crowd-out is high but
not complete. At the individual level, the modal choice is the own-earnings-maximizing dominant
strategy. A majority of individual contributions are not equal to the dominant strategy. Contribu-
tions at other levels are biased above the dominant strategy; only 13% of all subject contributions
are less than the own-earnings-maximizing dominant strategy. By comparison, Andreoni (1993)
and Chan et al. (2002) each report more than 40% of all subjects contributing less than the sym-

11 The difference in parameter estimates is not significant. Imposing the restriction that $\mu$ and $k$ are the same across
treatments and estimating using both sets of data results in maximum likelihood estimates $\mu = 1.024$ and $k = 0.578$,
with log-likelihood -1703.8, compared with log-likelihood -1703.1 when the parameters are allowed to be different
across treatments.
metric Nash equilibrium contribution. The frequency of dominant-strategy choices combined with the systematic bias of choices above the dominant strategy taken together support the hypothesis that the decision frame is successful in communicating the financial incentives of the game, and that contributions in excess of the dominant strategy are deliberately chosen.12

Within the population of subjects, we identify three types of subjects: those who predominantly choose the own-earnings dominant strategy, those who predominantly choose the Pareto-efficient level of contributing the entire endowment, and those who vary their contributions round-by-round. Among this latter group, we jointly estimate a warm-glow model with logit decision error, and find warm-glow and noise parameter values which are comparable between the treatments. This finding supports the existence of a group within the population of subjects who have preferences consistent with the warm-glow model.

Our main research objective in this study was to establish a powerful environment for testing the strong crowd-out hypothesis. The trade-off in choosing the environment to focus on testing this hypothesis is that our design varies from most of the standard public goods experimental environments in both the formulation of the strategy space and the graphical implementation of the subjects’ decision environment. Therefore, our results are not able to identify directly the relative importance of these factors relative to the effects of the payoff structure. By way of comparison, in the first paper to use the dominant-strategy formulation, Keser (1996) found average contributions in excess of the dominant strategy, with the dominant strategy also being the modal choice, results qualitatively similar to the ones reported here. Roughly one-third of the contributions overall in our experiments are exactly at the dominant strategy level, which matches well to Keser’s reported 27%. The game in that paper placed the dominant strategy, a contribution of 7 tokens, below one-half the endowment of 20. Therefore, effects of anchoring on the midpoint of the strategy space could not be ruled out in Keser’s study, but our results permit conclusive rejection of anchoring as an explanation for contributions above the dominant strategy.

In our case, the use of the computer decision interface facilitated our use of a much finer strategy space consisting of 101 levels, compared to 7 in Andreoni (1993) or 20 in Chan et al (2002) or Keser (1996). The distribution in 4 demonstrates that subjects used the interface to choose contribution levels at all integers within the relevant range, rather than focusing on salient numbers like 85, 90, or 95. We attribute this to the use of a continuous slider device rather than a text input field. It is not clear what the net effect would be if decisions had been elicited using numbers rather than positions on a slider, with the rounding that would entail, except to note that it is possible many of the observed choices between 80 and 85 might be rounded to 80 in a design

12Other recent evidence of contributions greater than a dominant strategy include include Ahn, Isaac, and Salmon (2008, 2009). The dominant strategy in these papers are below the midpoint of the decision space. Our finding of generous contributions when the dominant strategy is above the midpoint of the decision space contrasts with the findings reported by Laury and Holt (2008).
where participants type in a number. Because the dominant strategy is well above the midpoint of the strategy space, and because the data show very few low contributions in either treatment, it would seem unlikely that the relabeling of the strategy space, or the slight distortion of the payoff function on the screen to accommodate this, makes a significant difference in our case. What is essential in our design is not the relabeling per se, but the fact that truncation of the strategy space does not change the strategic structure. In the Andreoni and Chan et al designs, low contribution levels are an own-earnings best response to generous contributions amounts by other players, so ruling those out changes the out-of-equilibrium incentives of players. As our rescaling of the strategy space affected parts of the game which were strategically irrelevant, both in theory and, apparently, in the data, it is unlikely this design choice drives the main results.

Our result of extensive, though incomplete crowd-out has an important implication for public goods receiving both voluntary contributions and governmental support, as do many charitable organizations. Holding constant the fundraising effort of charities, the income of contributors and the like, extensive crowd-out implies that government grants are not very effective in remediating the free rider problem.

Acknowledgements

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References


Questions of graphical design of experiments in economics, both in presenting information to participants and in eliciting their decisions, has received only haphazard attention in the literature. Our results fill in but one cell in what ideally will be in future a factorial matrix encompassing design choices both in the specification of the formal game and the way in which players are presented information and make decisions.


<table>
<thead>
<tr>
<th>Design Features</th>
<th>Andreoni (1993)</th>
<th>Chan et al. (2002)</th>
<th>This paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group size</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Between/Within</td>
<td>Between</td>
<td>Within</td>
<td>Between</td>
</tr>
<tr>
<td>Payoffs</td>
<td>Cobb-Douglas</td>
<td>Quadratic</td>
<td>Quadratic</td>
</tr>
<tr>
<td>Endowment</td>
<td>7</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Baseline equilibrium</td>
<td>3</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Baseline concept</td>
<td>Nash</td>
<td>Nash</td>
<td>Dominant</td>
</tr>
<tr>
<td>With tax equilibrium</td>
<td>1</td>
<td>2, 0</td>
<td>60</td>
</tr>
<tr>
<td>With tax concept</td>
<td>Nash</td>
<td>Nash, Dominant</td>
<td>Dominant</td>
</tr>
<tr>
<td>Rematching</td>
<td>Every 4th round</td>
<td>Every round</td>
<td>Every round</td>
</tr>
<tr>
<td>Decisions</td>
<td>Paper-and-pen</td>
<td>Text-based computer</td>
<td>Graphical computer</td>
</tr>
</tbody>
</table>

Table 1: Summary of experimental designs
<table>
<thead>
<tr>
<th>Session</th>
<th>Treatment</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>No government</td>
<td>358</td>
</tr>
<tr>
<td>2</td>
<td>No government</td>
<td>333</td>
</tr>
<tr>
<td>3</td>
<td>No government</td>
<td>318</td>
</tr>
<tr>
<td>4</td>
<td>No government</td>
<td>343</td>
</tr>
<tr>
<td>5</td>
<td>With government</td>
<td>345</td>
</tr>
<tr>
<td>6</td>
<td>With government</td>
<td>356</td>
</tr>
<tr>
<td>7</td>
<td>With government</td>
<td>335</td>
</tr>
<tr>
<td>8</td>
<td>With government</td>
<td>349</td>
</tr>
</tbody>
</table>

Table 2: Mean group contributions, including contributions via tax, by session.
Table 3: First and last period contributions by treatment. $g^* = 80$ is the own-earnings maximizing choice, and $g^{PE} = 100$ is the choice corresponding to the Pareto-efficient outcome.

<table>
<thead>
<tr>
<th>Period 1 choice</th>
<th>Treatment</th>
<th>$g^*$</th>
<th>$g^* \pm 1$</th>
<th>$g^* \pm 5$</th>
<th>$g^{PE}$</th>
<th>$g^{PE} - 1$</th>
<th>$g^{PE} - 5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>no government</td>
<td>15 (31%)</td>
<td>19 (40%)</td>
<td>26 (54%)</td>
<td>5 (10%)</td>
<td>5 (10%)</td>
<td>6 (13%)</td>
<td></td>
</tr>
<tr>
<td>with government</td>
<td>12 (25%)</td>
<td>16 (33%)</td>
<td>21 (44%)</td>
<td>12 (25%)</td>
<td>14 (29%)</td>
<td>17 (35%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period 10 choice</th>
<th>Treatment</th>
<th>$g^*$</th>
<th>$g^* \pm 1$</th>
<th>$g^* \pm 5$</th>
<th>$g^{PE}$</th>
<th>$g^{PE} - 1$</th>
<th>$g^{PE} - 5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>no government</td>
<td>18 (38%)</td>
<td>19 (40%)</td>
<td>27 (56%)</td>
<td>3 (6%)</td>
<td>3 (6%)</td>
<td>4 (8%)</td>
<td></td>
</tr>
<tr>
<td>with government</td>
<td>11 (23%)</td>
<td>12 (25%)</td>
<td>28 (58%)</td>
<td>9 (19%)</td>
<td>9 (19%)</td>
<td>12 (25%)</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1: The subject decision interface.
**Figure 2**: Distributions of group contributions, by treatment. The black line represents the no government policy treatment, and the gray line the with government policy treatment.
Figure 3: Mean group contributions by period for each treatment. The black line represents the no government policy treatment, and the gray line the with government policy treatment.
Figure 4: CDF of individual contributions, by treatment. The black line represents the no government policy treatment, and the gray line the with government policy treatment.
Figure 5: Actual and fitted logit CDFs of choices, no government policy treatment. The solid line represents the actual distribution of individual choices, and the dashed line the logit fit.
Figure 6: Actual and fitted logit CDFs of choices, with government policy treatment. The solid line represents the actual distribution of individual choices, and the dashed line the logit fit.