CROWDING OUT VOLUNTARY CONTRIBUTIONS TO PUBLIC GOODS*

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Abstract

We test the null hypothesis that involuntary transfers for the provision of a public good will completely crowd out voluntary transfers against the warm-glow hypothesis that crowding-out will be incomplete because individuals care about giving. Our design differs from the related design used by Andreoni in considering two levels of the involuntary transfer and a wider range of contribution possibilities, and in mixing groups every period instead of every four periods. We analyse the data with careful attention to boundary effects. We retain the null hypothesis of complete crowding-out in two of three pairwise comparisions, but reject it in favour of incomplete crowding-out in the comparison most closely akin to Andreoni's design. Thus we confirm the existence of incomplete crowding-out in some environments, but suggest that the warm-glow hypothesis is inadequate in explaining it.

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Crowding Out Voluntary Contributions to Public Goods

1. INTRODUCTION

Warr (1982, 1983), Roberts (1984, 1987), Bernheim (1986) and Bergstrom, Blume, and Varian (1986) suggest that voluntary contributions by individuals to public goods may be completely crowded out by government contributions to the same public goods. These results suggest a futility to government spending policy. Empirical research investigating the issue of the neutrality of government spending on public goods by Abrams and Schmitz (1978, 1984), Clotfelter (1985), and Kingma (1989) suggests that crowding out is incomplete, and likely to be small (less than thirty percent of private contributions may be crowded out by government spending).

Andreoni (1993) has attempted to ascertain whether the incomplete crowding out found in the empirical studies can be attributed to institutional features not captured by the theoretical models or to individual preferences different from those incorporated into the theoretical models. This is done in a laboratory environment. He finds incomplete crowding out when an involuntary transfer resembling a tax is levied on individuals and the resulting revenue is transferred to the provision of the public good. Andreoni (1993: 1317) suggests that his results may be "taken as evidence for alternative models that assume people experience some private benefit from contributing to public goods." This would support Andreoni's (1990) warm-glow giving as an explanation for incomplete crowding out.

There is an alternative explanation to warm-glow giving as an explanation for incomplete crowding out observed in laboratory experiments. Boundary effects induced by the tax on the choices that individuals have regarding contributions of resources for the provision of public goods may be reflected in increased public good provision under the tax regimes. Andreoni’s (1993) results, however, suggest this is not a credible alternative in his environment.

This paper extends Andreoni's analysis by providing subjects larger endowments of resouces to allocate and by permitting the subjects to experience three different tax treatments. We test the null hypothesis of complete crowding-out against an alternative model of individual behaviour which assumes people experience a private benefit from contributing to public goods but that this benefit increases at a decreasing rate as voluntary contributions rise is tested. This model can be consistent with Andreoni's crowding-out results in a laboratory setting and it provides a testable prediction which can extend the laboratory evidence on incomplete crowding out of government contributions to public goods. We analyse the data with close attention to boundary effects. We retain the null hypothesis of complete crowding-out in two of three pairwise comparisons but reject it in favour of incomplete crowding-out in the comparison most closely akin to Andreoni’s design. Thus we confirm the existence of incomplete crowding-out in some environments but suggest that the warm-glow hypothesis is inadequate in explaining it.

The alternative behavioral models are presented in section 2. Section 3 contains the experimental design. Predictions, results, and a concluding discussion are presented in sections 4, 5, and 6, respectively.

2. THE BEHAVIOURAL MODELS

2.1. The Conventional Model

The conventional model of the allocation of resources by individuals among public and private goods is described by Bergstrom *et al.* Following Bergstrom *et al.* the individual chooses private consumption, x_i, and contributions to the public good, g_i, to solve the problem

$$\max_{x_i,\, g_i} \quad u_i(x_i, G) \tag{1}$$

subject to the budget constraint $x_i + g_i = w_i$, the public goods identity $G = G_{-i} + g_i$, and the non-negativity constraint $g_i \geq 0$. G_{-i} denotes the allocations of all individuals except i, and w_i is the individual's income.

If the payoff to individual i is given by

$$u_i = x_i + G + x_i G \tag{2}$$

where G denotes aggregate contributions to the public good, the best response function for individual i is

$$g_i = \max(\frac{w_i - G_{-i}}{2},\ 0) \tag{3}$$

If the returns to individuals are fully captured by the payoff function **(2)**, Bergstrom *et al.* prove there is a unique Nash equilibrium.[1] This model has been tested in a laboratory environment

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[1] This equilibrium has the following properties: richer individuals contribute more to the provision of the public good than do poorer individuals; if the distribution of income is sufficiently unequal, very poor individuals contribute nothing; redistribution of income among individuals who contribute a positive amount both before and after the redistribution has no effect on the aggregate quantity of the public good; redistribution of income from non-contributing individuals to contributing individuals increases the aggregate quantity of the public good. See Theorems 3 and 5 in Bergstrom, Blume, and Varian (1986: 34, 38).

by Chan, Mestelman, Moir, and Muller (1996) and is supported by the data when incomes are equally distributed among participants in three-person groups.

2.2. The Alternative Model

Following Andreoni (1990), if individuals experience a private benefit from contributing to the public good, **(1)** should be modified to

$$\max_{x_i,\ g_i} \quad u_i(x_i,\ G,\ g_i) \tag{4}$$

and the individual's problem is unchanged. If the payoff to individual i in **(4)** is expressed as

$$u_i = x_i + G + x_i G + f(g_i) \tag{5}$$

where $\frac{df(g_i)}{dg_i} > 0$ and $\frac{d^2 f(g_i)}{dg_i^2} < 0$, the best response function for individual i is

$$g_i = \max\left(\frac{w_i - G_{-i}}{2} + \frac{1}{2}\frac{df(g_i)}{dg_i},\ 0\right) \tag{6}$$

Comparing **(3)** and **(6)** shows that *ceteris paribus* caring about giving leads to increased contributions. This is the prediction of the theory of warm-glow giving presented by Andreoni (1990) using a specific explicit utility function.

2.3. The Behavioural Models and Taxation for Public Goods Provision

If individuals are taxed and the tax receipts are contributed to the provision of the public good, the functions **(2)** and **(5)** become

$$u_i = x_i + (G + T) + x_i(G + T) \tag{7}$$

$$u_i = x_i + (G + T) + x_i(G + T) + f(g_i) \tag{8}$$

where T is the sum of the lump-sum taxes collected from all the individuals. The best response functions **(3)** and **(6)** become

$$g_i = \max\left(\frac{w_i - G_{-i} - T_{-i}}{2} - t_i,\ 0\right) \tag{9}$$

$$g_i = \max\left(\frac{w_i - G_{-i} - T_{-i}}{2} - t_i + \frac{1}{2}\frac{df(g_i)}{dg_i},\ 0\right) \tag{10}$$

where t_i is the tax paid by individual i and $T_{-i} = T - t_i$. The equilibria of these models augmented by the tax and spending provisions are described by Bergstrom *et al.* and Andreoni (1990). Assuming n individuals have the same payoff functions and same endowments, when an equilibrium is realized total contributions to the public good, $C = G + T$, equal $\frac{n}{n+1}[w_i + \frac{df(g_i)}{dg_i}]$. Total contributions in equilibrium are lower under the conventional model than under the alternative model which includes a warm-glow from giving. As well, contributions rise as the tax is increased ($\frac{dC}{dT} = \frac{1}{n+1}\frac{d^2f(g_i)}{d(g_i)^2}[-1 + \frac{1}{n+1}\frac{d^2f(g_i)}{d(g_i)^2}]^{-1} > 0$), implying that g_i falls as the tax is increased, but it falls by less than the tax increase.[2] Therefore crowding out increases as tax collections increase.

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[2] If individuals have the same payoff functions and endowments and if in equilibrium $G > 0$, then from $G = ng_i$ and equation **(10)**, $G = [W - (n-1)G - (n-1)T] - T + (n/2)[df(G/n)/d(G/n)]$ where $W = nw_i$. Differentiating $C = G + T$ with respect to T yields $dC/dT = [dG/dT] + 1$ and differentiating G with respect to T yields $dG/dT = [-1 + [(d^2f(g_i)/dg_i^2)/(n+1)]]^{-1}$. Finally, $dC/dT = [1/(n+1)][d^2f(g_i)/dg_i^2]/[-1 + [1/(n+1)][d^2f(g_i)/dg_i^2]]$, which is positive.

3. EXPERIMENTAL DESIGN

An environment was created in a laboratory in which individuals were given endowments of tokens, were told they were members of small groups, and were asked to allocate their token incomes between a private good and a public good. Their payoffs depended upon their decisions and the decisions of the others in their group, and were given by equation **(7)**. Sometime the incomes of these individuals were taxed, sometime they were not. The tax varied between fifteen percent and twenty-five percent of their endowments. The tax was implemented in a decision round (period) by requiring that subjects make a particular minimum contribution to the public good in that period.

Five sessions were conducted during which sixty subjects (twelve each session) participated in groups of three for a series of fifteen periods.[3] In each period subjects were asked to allocate endowments of twenty tokens across two markets. Each subject was given a payoff table which reflected payoffs from equation **(2)** for each possible allocation to the public good (identified to the subject as a Market 2 allocation) and each possible allocation to the public good by the other members of the subject's group. This table formed a matrix with forty-one rows and twenty-one columns. Each subject knew the other subjects' endowments and payoff functions. All this information was common knowledge. Token payoffs were converted into Canadian dollars at the exchange rate 200 tokens to one Canadian dollar.

After each period, the members of the groups were scrambled. At the start of each period the

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[3] The sessions were conducted between July and September 1993. Nearly all of the subjects were from McMaster University. There were several subjects who were students at the University of Western Ontario and King's College. Several of the McMaster students were graduate students -- five in Economics and one in English. These students were scattered throughout the five sessions (there was no session which was dominated by graduate students in Economics). The payoffs ranged from $16.00 to $25.00 with a mean of $20.62 and a standard deviation of $1.51.

members of each group were informed of the minimum required contribution for that period.[4] This minimum contribution of zero, three or five tokens was common for all members of any given group in any one period but was varied from period to period, so that individuals were neither participating with the same partners nor facing the same minimum contribution period after period. This was done to eliminate reputation effects, to eliminate incentives to send signals to partners, to offset subject effects, and to create an environment in which each decision round could be treated as a one-shot contribution game. The number of observations of individual contributions in each period by minimum required contribution is shown in Table 1. The treatments are identified as A, B, and C, corresponding to no tax, a tax of 3 tokens, and a tax of 5 tokens.

The subjects were inexperienced in this environment. No subject participated in more than one session. Instructions were read to the subjects, who each followed along on their own copies of the instructions.[5] A short quiz was administered to assure the investigators that the subjects understood the nature of their tasks and how to read a payoff table. In each period, subjects entered their contributions on a computer terminal. At the end of the period, each terminal displayed each subject's own contribution, contributions made by each of the members of the subject's group, the subject's payoff for the period, and the subject's cumulative payoff. In addition, the screen displayed the minimum required contribution at the start of each period. The computer would not accept

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[4] The groups were not constructed randomly. A conscious effort was made to minimize the number of times individuals participated in groups with each other. As well, the allocation of minimum requirements to groups was done in such a way as to be certain that they were spread as evenly as possible across the last twelve periods and that they were allocated as evenly as possible across the subjects. This was done to minimize the likelihood that some minimum requirements appeared more frequently in early periods rather than later periods or the likelihood that some subjects were presented with a particular minimum requirement more than four or five times.

[5] Copies of the instructions are available from the authors.

contributions which violated the minimum contribution constraint; the subject was informed of this violation by the absence of a contribution on the terminal's screen. The period ended when all subjects had submitted allowable contributions.

4. PREDICTIONS

4.1. Crowding Out Predictions: General

If income is taken from individuals via a lump-sum tax and this income is contributed to the provision of the public good, both the conventional and alternative models predict that private contributions will be crowded out. For the payoffs given by **(7)**, Bergstrom *et al.* show that crowding out will be complete for individuals who are contributors before the imposition of the tax if the tax does not exceed their before-tax contributions. Private contributions will be crowded out one dollar for one dollar, and the tax/spending policy will be neutral with respect to public good provision. Andreoni (1990) shows that for individuals who care about contributing, and who receive payoffs given by **(8)**, crowding out will be incomplete. Private contributions to the public good will be crowded out by less than one dollar for each tax dollar collected and contributed by the taxing authority to the public good. Public good provision will increase.

In the laboratory environment, each subject is provided with a payoff table reflecting the payoffs given by **(7)**. The imposition of a lump-sum tax which is used to provide a public good is accomplished by requiring that subjects make a minimum contribution. Changing the minimum required contribution does not affect the Nash equilibrium contribution per subject per period if **(7)** is the payoff function actually followed by the subject. Changing the minimum contribution does affect the Nash equilibrium contribution per subject per period if the payoff function is **(8)**. If a subject receives a payoff in addition to the induced payoff given by the payoff table, and if this additional payoff is related to the subject's voluntary contribution (total contribution less the minimum required contribution) as characterized by $f(g_i)$, a subject's total contribution will rise as the minimum required contribution rises.

For the environment described in the previous section (three-subject groups, income of twenty tokens each period, and payoffs given by **(7)**), the Nash equilibrium total contribution for each subject is five tokens. The Nash equilibrium voluntary contributions fall from five to two to zero tokens as the minimum required contribution (the tax) rises from zero to three to five tokens.[6]

Because participants must make integer contributions the payoff tables reflecting the best response function **(3)** contain multiple individual Nash equilibrium allocations when the minimum required contributions are zero and three tokens.[7] If it is equally likely that each of the Nash equilibria occur, the expected total contribution of each subject is five tokens. This also is the individual Nash equilibrium contribution for the continuous payoff function.

If subjects augment their induced payoffs so that **(8)** is the appropriate representation of their payoff function, individual Nash equilibrium total contributions will rise as the minimum required contribution rises. Individual Nash equilibrium voluntary contributions will exceed five, two, and

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[6] The Nash equilibrium voluntary contributions of five and two tokens, when the minimum required contributions are zero and three tokens, respectively, do not represent dominant strategy equilibria. The Nash equilibrium voluntary contribution of zero tokens when the minimum required contribution is five does represent a dominant strategy equilibrium.

[7] For minimum required contributions of zero or three tokens, (5,5,5), (4,5,6), (4,6,5), (5,4,6), (5,6,4), (6,4,5), and (6,5,4) are the possible contributions by participants (1,2,3) which are Nash equilibria. When the minimum required contribution is five tokens, (5,5,5) is the only Nash equilibrium allocation.

zero when the minimum required contributions are zero, three, and five, respectively. The equilibrium predictions from payoff functions **(7)** and **(8)** are presented in Table 2. The conventional model predicts that with no tax the individual contribution will be 5 tokens and that with the introduction of any tax crowding out will be complete. The alternative model predicts that

P_1: *When there is no tax imposed, individual contributions will exceed 5.*

P_2: *When a tax of 3 is imposed, total individual contributions will exceed the individual contributions made when there is no tax imposed.*

P_3: *When a tax of 5 is imposed, total individual contributions will exceed the individual contributions made when there is no tax imposed.*

P_4: *When a tax of 5 is imposed, total individual contributions will exceed the total individual contributions made when there is a tax of 3 imposed.*

4.2. Boundary Effects

For any number of reasons, subjects in public goods environments may wish to make contributions at, above, or below the induced Nash equilibrium contribution. Even if the Nash equilibrium contribution characterizes the central tendency of individual contributions in laboratory public goods environments, the contributions themselves will be distributed around the Nash equilibrium value. If, however, contributions are bounded at or below the Nash equilibrium prediction some of the low contributions will be *censored*. By setting a minimum required contribution, some contributions which would otherwise be below the boundary will be forced to the boundary. This will raise the mean value of the observed contributions over what the mean value would have been if the boundary was not imposed.[8] This implies that under either form of the underlying behavioural function

Implication 1: *The mean of the observed contributions will increase as the minimum required contribution is increased from 0 to 3 to 5.*

On the null hypothesis that subjects do not care about giving (that payoff function **(7)** reflects the preferences of subjects in this experiment), the distribution of observed contributions under each treatment should differ only by the effect of the changing boundary. If g_{jt} is the observed total contribution for subject j in time period t (j = 2,...,60; t = 4,...,14), g^{n} is the total contribution in Nash equilibrium when subjects do not care about giving, and g_{jt}^{mr} is the minimum required contribution for subject j in time period t,

$$\text{prob } (g_{jt} \le k) = \Phi[\frac{k-g^{n}}{\sigma}] \quad \forall k \ge g_{jt}^{mr} \tag{11}$$

so that the cumulative distribution of contributions is equal to the cumulative normal distribution $\Phi[\cdot]$, and is independent of treatment for all contributions greater than or equal to the maximum of the minimum required contributions in the treatments being compared. This leads to the following predictions on the alternative hypothesis that the subjects care about giving:

$P_{5:}$ *If the observations from Treatments A and B that are less than 5 are recoded to equal 5, the new distributions, A_5, B_5, and the distribution of the observations for Treatment C will be different.*

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[8] A formal development of this prediction is provided in Chan, Godby, Mestelman, and Muller (1994).

P_6: *If the observations from Treatment A that are less than 3 are recoded to equal 3, the new distribution,* A_3*, will be different from the distribution of the observations for Treatment B.*

P_7: *If the observations from Treatment B that are less than 5 are recoded to equal 5, the new distribution,* B_5 *, will be different from the distribution of the observations for Treatment C.*

P_8: *If the observations from Treatment A that are less than 5 are recoded to equal 5, the new distribution,* A_5 *, will be different from the distribution of the observations for Treatment C.*

5. RESULTS

Table 1 shows the number of observations in each period by minimum required contribution. In total there are 720 observations. For each minimum required contribution there are 240 observations spread across 12 periods or decision rounds. The mean contributions (and corresponding standard deviations) and median contributions across all participants and the mean median contributions (and corresponding standard deviations) across sessions are presented for each treatment in Table 3.

It is clear that mean observed contributions increase in accordance with Implication 1. Because the observations are censored, standard t-tests are not valid. Employed descriptively, however, t-tests indicate that the mean contribution for treatment A is not significantly different from the Nash equilibrium contribution of 5 tokens ($p = 0.596$) and that the mean contributions for treatments B and C are significantly greater than 5 tokens ($p = 0.000$ for both cases). In addition, the mean contribution for treatment B is significantly greater than the mean contribution for treatment A and the mean contribution for treatment C is significantly greater than the mean contribution for treatment B (p = 0.000 for both cases).[9] Thus we have

Result 1: *We retain the null hypothesis that mean contributions in Treatment A are 5 tokens.*

Result 2: *The mean of observed contributions increases as the tax (and boundary) rises from 0 to 3 to 5 tokens.*

Because the mean contributions for each treatment are sensitive to boundary effects, it is inappropriate to use mean data to identify the existence of incomplete crowding out without first accounting for these effects. The median of the distribution of individual total contributions is a measure of central tendency which should not be sensitive to boundary effects introduced by tax treatments as long as the taxes are less than the median contribution in the no-tax treatment. For each of Treatments A, B, and C the median of the distribution of contributions is 5. This suggests that whatever impact the tax treatments have on the distribution of contributions, it is not sufficient to change the median. This is a weak test of the null hypothesis that crowding out is complete. A second test uses the median values of the distributions for each treatment generated in the five sessions in this experiment. The mean across the five sessions of the median values for each treatment are presented in Table 3. Neither the means of Treatments A and B, B and C, nor A and C are significantly different from each other (exact randomization tests, p = 0.183, p = 0.500, and p = 0.143 respectively).

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[8] Tobit regressions which account for the censored observations confirm these results. A detailed analysis of the Tobit regression results are included in Chan, Godby, Mestelman, and Muller (1994).

These results suggest that the data from this experiment may support complete crowding out and the conventional public good model. It is important, however, to try to account for boundary effects and to use all of the contribution data. In particular, it is important to use the same methodology introduced in Andreoni (1993) to evaluate the extent of crowding out in this experiment.

The distribution of contributions, by minimum required contribution, across all of the possible contributions, is presented in Table 4. For Treatment A, contributions range from 0 to 15 tokens. The range extends to the full endowment of 20 when a minimum contribution is required. Under all three treatments, contributions greater than or equal to 10 tokens (half of each subjects endowment) account for approximately ten percent of all contributions.

A test of the null hypothesis that crowding out is complete can be conducted by comparing the distributions of Treatments A, B, and C for which the observations are recoded so that all contributions less than or equal to 5 tokens are coded as 5 tokens (columns A_5, B_5 and C in Table 4). A test of the null hypothesis that three distributions are the same against the alternative that they differ cannot be rejected ($\chi^2 = 29.493$, $p = 0.202$). This is a rejection of Prediction 5. However, a visual comparison of columns A_3 and B or A_5 and B_5 in Table 4 suggest that there may be a difference between Treatments A and B taken by themselves.

The distribution for Treatment B is significantly different from the distribution for Treatment A regardless of whether columns A_3 and B or A_5 and B_5 in Table 4 are compared ($\chi^2 = 31.392$, $p = 0.003$ and $\chi^2 = 21.762$, $p = 0.026$ respectively). This is consistent with the result reported by Andreoni (1993) and suggests that there appears to be incomplete crowding out of voluntary contributions to public good provision when the tax of 3 is imposed. These results support

Predictions 2 and 6.

However, extending this test to comparisons of Treatments B and C and Treatments A and C does not support incomplete crowding out. The distribution for Treatment C is neither significantly different from the distribution for Treatment A after recoding to group all contributions less than or equal to 5 ($\chi^2 = 18.163$, $p = 0.111$), nor different from the distribution for Treatment B ($\chi^2 = 5.923$, $p = 0.878$). This provides support for the rejection of Predictions 3, 4, 7 and 8.

Result 3: *Although the data support incomplete crowding out when when a tax less than the no-tax individual voluntary contribution is imposed, complete crowding out cannot be rejected if the tax is equal to the average individual voluntary contribution or if a larger tax replaces a smaller tax.*[10]

6. DISCUSSION AND CONCLUSIONS

6.1. Boundary Effects

When individuals' decisions to contribute to the provision of public goods are constrained or bounded, the mean of the resulting contributions may not correctly reflect the true central tendency of contributions made by individuals. Because of this, it is inappropriate to use parameter estimates which have not accounted for boundary effects.

Accounting for boundary effects by using median rather than mean contributions suggests that, when no minimum contribution is required, the central tendency of the contribution of subjects to the provision of a public good is not different from that predicted by the conventional public goods

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[10] These results also can be obtained using Tobit regression analysis to account for the boundary effects created by the censoring associated with the imposition of the tax. A detailed analysis of the Tobit regression results are included in Chan, Godby, Mestelman and Muller (1994).

model. Furthermore, the tax treatments do not appear to move the median contribution from the Nash equilibrium contribution of the conventional model.

Nevertheless, the significant difference in the censored distributions of contributions under Treatments A and B suggest that boundary effects are incapable of fully explaining the observed rise in mean contributions in this case. The range over which this unknown effect operates is limited, however, because imposing a 5 token minimum contribution has no statistically significant effect on the individual total contributions compared to the other two treatments. Although boundary effects are important, they cannot account for all of the instances of overcontributions.

6.2. Crowding Out and Warm-Glow Giving

Andreoni (1993) has conducted the only laboratory evaluation of the public goods crowding-out hypothesis. As noted, he found incomplete crowding-out and attributed it to warm-glow giving. The environments in which Andreoni's subjects participated were similar to the environments described here. There were several notable differences. First, Andreoni's subjects were reallocated to different groups after every four periods. In the sessions described here, subjects were reallocated after every period. Second, Andreoni's subjects experienced only one environment, either no minimum required contribution or a minimum required contribution which was less than the Nash equilibrium contribution for the conventional model. In the sessions described here, subjects experienced three different environments with minimum required contributions of zero, fifteen, and twenty-five percent of their per-period incomes. Third, Andreoni's subjects had to allocate endowments of seven tokens to two markets. In the sessions described here, subjects had to allocate endowments of twenty tokens.

Our results confirm Andreoni's incomplete crowding-out results in the case most similar to his, but do not support the warm-glow interpretation. The Andreoni design is comparable to the contrast between Treatments A and B. For both data sets the minimum required contribution increases from nothing to something less than the Nash equilibrium contribution of the conventional model. Result 2 shows that in the no-tax treatment the prediction of the conventional model, that subjects will contribute five tokens to the provision of the public good, cannot be rejected in favor of the alternative that their individual contributions will exceed five tokens. This is consistent with the result reported by Andreoni (1993) for the comparable treatment.[11] Result 3 shows that the distributions of contributions for Treatments A and B are different and that in this case crowding out is incomplete. This also is comparable to the result reported by Andreoni, and provides support for the alternative model which incorporates warm-glow giving.[12]

Nevertheless, when the analysis is extended by increasing the minimum required contribution, the warm-glow alternative model fails. Section 2 established that on the alternative hypothesis, contributions should be monotonic decreasing in the level of taxes. Since imposition of a minimum required contribution of 3 tokens under Treatment B leads to a significant shift in the distribution of

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[11] In both the Andreoni (1993) sessions and the sessions reported here the point estimates of the mean contribution, unadjusted for censoring, subject effects, and period effects, are less than the Nash equilibrium prediction for the conventional model under Treatment A. These values are not statistically different from the Nash equilibrium prediction when the alternative is that they exceed the Nash equilibrium prediction, which is the prediction from the alternative model incorporating warm-glow giving.

[12] The extent to which crowding out exists between Treatments A and B is comparable to that reported by Andreoni (1993). The imposition of a minimum required contribution that is less than the Nash equilibrium contribution predicted by the conventional model leads to crowding out of voluntary contributions of more than sixty-five percent of the minimum contribution. This is slightly lower than the crowding out reported by Andreoni (1993), but much greater than the effects reported in the work cited in Section 1.

contributions, the imposition of a minimum required contribution of 5 tokens should lead to a larger shift. Yet Result 3 indicates that that we cannot reject the null hypothesis that the distributions under Treatments A and C are identical, thus providing no support for the warm-glow interpretation.

6.3. Conclusions and Conjectures

This experiment establishes at least one circumstance in which voluntary contributions to a public good are not completely crowded out in laboratory markets. The incomplete crowding out, however, is not as great as suggested by the empirical studies of this phenomenon in the naturally occurring environment. Furthermore, the laboratory evidence suggests a simple extension of the public good model to incorporate warm-glow giving cannot adequately account for the crowding out behaviour observed in the laboratory.

Our specification of warm-glow giving, with $\frac{df(g_i)}{dg_i} > 0$ and $\frac{d^2f(g_i)}{dg_i^2} < 0$ does not adequately describe the laboratory results. A warm-glow model for which $\frac{df(g_i)}{dg_i}$ is small and positive when g_i is small, but falls to zero and becomes negative as g_i continues to rise, will yield predictions consistent with the laboratory results reported here and by Andreoni (1993) provided $\frac{df(g_i)}{dg_i}$ is very close to zero when g_i equals the Nash equilibrium prediction of the conventional model. We conjecture such a model would apply in future experiments. Because the Nash equilibrium prediction of the conventional model differs in the present design and the Andreoni design (5 of 20 tokens in the former, 3 of 7 in the latter), the above conjecture suggests that the subjects' attitudes towards giving depend not only on how much is given voluntarily, but on the Nash equilibrium which would emerge if the public good were funded entirely by voluntary contributions. This suggests a complex relationship between voluntary giving, income, and preferences which might profitably be investigated in future research.

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TABLE 1

NUMBER OF OBSERVATIONS

Treatment	**Minimum Required Contribution**	**Period** **4, 7, 10, 13**	 **5, 8, 11, 14**	 **6, 9, 12, 15**
A	0	21	18	21
B	3	21	21	18
C	5	18	21	21

Note: During periods 1, 2, and 3 subjects were introduced to each of the three minimum contribution constraints for the first time. These periods were treated as preliminary trials and the data from these periods are not included in the analysis in this paper.

TABLE 2

EQUILIBRIUM PREDICTIONS

		Conventional Model		Alternative Model	
Treatment	**Minimum Required Contribution**	**Total Contribution**	**Voluntary Contribution**	**Total Contribution**	**Voluntary Contribution**
A	0	5	5	$g_0 > 5$	$g_0 > 5$
B	3	5	2	$g_3 + 3 > g_0$	$g_3 > 2$
C	5	5	0	$g_5 + 5 > g_3 +3$	$g_5 > 0$

Note: g_0, g_3, and g_5 are the voluntary contributions made in Treatments A, B, and C.

TABLE 3

CONTRIBUTIONS
(standard deviations in parentheses)

Treatment	**Minimum Required Contribution**	**Mean Contribution**			**Median g_{it} by Treatment**	**Mean of Median g_{it} by Session**
		g_{it} Raw Data	**$g_{it} \leq 3$ Recoded as 3**	**$g_{it} \leq 5$ Recoded as 5**		
A	0	4.896 (3.049)	5.396 (2.427)	6.138 (1.830)	5	5 (0.707)
B	3	5.925 (2.725)	5.925 (2.725)	6.467 (2.278)	5	5.6 (0.548)
C	5	6.504 (2.341)	6.504 (2.341)	6.504 (2.341)	5	5.7 (0.837)

Note: g_{it} is the contribution by subject i in period t. The means of g_{it} are based on 240 observations for each treatment. The means of the medians are based on 5 observations for each treatment.

TABLE 4

DISTRIBUTION OF CONTRIBUTIONS

	Treatment					
Contribution	**A**	**A_3**	**A_5**	**B**	**B_5**	**C**
0	26					
1	12					
2	18					
3	22	78		47		
4	22	22		36		
5	47	47	147	43	126	126
6	27	27	27	22	22	26
7	19	19	19	43	43	34
8	14	14	14	17	17	19
9	10	10	10	8	8	9
10	18	18	18	14	14	15
11	3	3	3	1	1	2
12	0	0	0	4	4	4
13	1	1	1	2	2	0
14	0	0	0	0	0	2
15	1	1	1	0	0	0
16	0	0	0	1	1	1
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	2	2	2

Note: A_3 and A_5 are the distributions of treatment A contributions with contributions of 0, 1, 2 and 3 pooled and of 0, 1, 2, 3, 4 and 5 pooled respectively. B_5 is the distribution of treatment B contributions with contributions of 3, 4 and 5 pooled.