Altruism and Noisy Behavior in One-Shot Public Goods Experiments

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September 1999

Abstract. An increase in the common marginal value of a public good has two effects: it increases the benefit of a contribution to others, and it reduces the net cost of making a contribution. These two effects can be decomposed by letting a contribution have an "internal" return for oneself that differs from the "external" return to someone else. We use this framework in a series of one-shot public goods games in which subjects make choices in ten treatments with no feedback. Contributions are generally increasing in the external return and group size, which suggests that altruism in this context is not simply of the "warm glow" variety, i.e. giving only for the sake of giving. Contributions are also increasing in the internal return, indicating that decisions are sensitive to the costs of helping others. We specify a logit equilibrium model in which individuals are motivated by own and others' earnings, and in which choice is stochastic. Maximum likelihood estimates of altruism and logit error parameters are significant and of reasonable magnitudes, and the resulting two-parameter model tracks the pattern of contributions across the ten treatments remarkably well.

[*] This work was funded in part by the National Science Foundation (SBR-9753125 and SBR-9818683). The research assistance provided by Cara Carter and Todd Farnworth is gratefully acknowledged.

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I. INTRODUCTION

As Ledyard (1995) concludes, there is still no consensus on what is driving the diverse behavior patterns in public goods experiments. Some plausible factors include altruistic preferences for others' earnings, reciprocal responses to others' contributions, and some degree of confusion and error. The wealth of laboratory data has stimulated a number of theoretical papers that consider preference-based, error-based, and learning-based explanations.[1] Most subsequent laboratory experiments have used clever designs to eliminate or control for particular factors in order to isolate the effects of others.

Because many issues remain unresolved, it is useful to consider an alternative approach that is more closely tied to economic theory and standard econometrics. In particular, several economists have specified more general models of behavior motivated by altruism and/or relative earnings.[2] The experiments reported here use both experimental design/control and theory-based econometric techniques to investigate contribution behavior in a series of one-shot public goods games. We are able to obtain precise distinctions by independently varying the net cost of making a contribution and the external benefit to others in the group. We then specify and estimate an equilibrium model that incorporates preferences that depend on others' earnings and noisy decision making.

Before describing our design, it is useful to review the structure of a standard linear public goods game, in which subjects begin with an endowment of "tokens" that can either be kept or contributed. Each token not contributed yields a constant monetary return for the subject, and each token that is contributed also yields a constant return, both for that person and for all others in the group. The sum of all group members' returns from the contribution typically exceeds the individual's return from keeping the token, so group earnings are maximized by full contribution. The net monetary loss from making a contribution is the difference between the value of a token

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[1] See Holt and Laury (1997) for a recent survey of theoretical explanations of behavior in public goods games.

[2] See, for example, Andreoni and Miller (1998), Palfrey and Prisbrey (1997), Bolton and Ockenfels (1999), and Fehr and Schmidt (1999).

that is kept and what the subject earns from a token contributed to the public good. A positive net loss ensures that the Nash equilibrium is to contribute nothing, at least in a one-shot game with no altruistic feelings about others' payoffs. In the absence of altruism, an individual may make some contributions if the net loss from contributing is relatively small and there is some "noise" in the decision-making process. By noise, we mean things like recording errors, experimentation, confusion, random variations in emotions, etc. Whether the noise is largely due to mistakes or to rational responses to unobserved preference shocks, the effects of such noise should be greater when the net cost of contribution is small.

When there is altruism, the net loss from making a contribution should be compared with the benefit that is enjoyed by others in the group. The presence of at least some altruism is suggested by the most consistent treatment effect in linear public goods games: an increase in the common marginal value of the public good will raise contributions. This treatment change confounds two separate factors, however. It increases the marginal value of the public good and lowers the net cost of contributing and raises the benefit to others at the same time.

Following Carter, Drainville, and Poulin (1992), we allow a costly contribution to have two distinct effects, an "internal return" to oneself and a possibly different "external return" to others in the group. In one treatment, for example, a token that is worth 5 cents if kept, returns 4 cents to that person if contributed, but provides an external return of only 2 cents for each other person in the group. Thus the net cost to oneself is 1 cent, and the act of contributing increases each other person's earnings by 2 cents. A modification of the internal return changes the net cost of contributing, without altering the benefits to others. Conversely, a change in the external return alters others' benefits without affecting the cost of contribution.

Carter, Drainville, and Poulin (1992) conclude that behavior is affected by both internal and external returns.[3] Although these results are intuitive, we believe that their conclusions can be strengthened with an analysis based on formal economic models and the estimation of the parameters of those models. In order to obtain enough independent observations on individual

[3] Carter *et al*. (1992) report only one (twenty-person) session per treatment. With random matching in groups of size four, there is some question about whether the individual contributions can be treated as independent observations, given the common exposure to others' decisions that is inevitable in this setup. In this situation, it difficult to infer significance from standard statistical tests, at least without modeling the effects of "history" on individual decisions.

decisions, we let subjects make a series ten decisions in one-shot games with independent variations of internal and external returns and group size. An additional benefit of this design is that it allows us to evaluate individual differences. We estimate individual-specific altruism parameters and we obtain similar results from a related model in which altruism parameters are drawn from population distributions.

This experimental design is described in the next section and the data are summarized in the third section. In section IV, we present a model of altruism with decision error, and report maximum likelihood estimates of altruism and error parameters. The final section concludes. The instructions are contained in Appendix A and Appendix B contains individual contribution decisions.

II. EXPERIMENTAL DESIGN AND PROCEDURES

The experiment was designed to provide a reasonable number of independent individual decisions under a range of payoff conditions. The treatments were selected to facilitate the isolation of separate factors that may cause behavior to diverge from the dominant strategy Nash prediction of zero contributions in all treatments. Subjects were asked to allocate 25 tokens between public and private consumption in each of ten treatments, with the relevant treatment chosen *ex post* by the throw of a ten-sided die. Thus the ten decisions were made with no feedback about others' decisions, and the context is best viewed as a one-shot game.[4]

In each treatment, a token kept earned a constant return of 5 cents, and a token contributed to the public good earned a return both to the individual contributing the token and to each other person in the group. Table 1 shows the internal and external returns for each of the ten treatments (the data shown in the lower part of Table 1 will be discussed in section III below). Group size was either two or four. Internal returns, which measure how much a person gets back from contributing a token, were either two or four cents. The external returns represent how much everyone *else* gets from a token contributed, and ranged from two to twelve cents. The

[4] Others have used similar techniques to obtain individual decisions in a variety of treatments in public goods and bargaining games. For instance, Andreoni and Miller (1998) obtained decisions in two-person dictator games. Brandts and Schram (1995) varied the value of a token kept (holding constant the value of a token contributed) in a repeated variation of this technique.

Table 1. Summary of Treatments

	Treatment									
	1	2	3	4	5	6	7	8	9	10
group size	4	2	4	4	2	4	2	2	4	2
internal return	4	4	4	2	4	4	2	4	2	4
external return	2	4	6	2	6	4	6	2	6	12
mean contribution	10.7	12.4	14.3	4.9	11.7	10.6	7.7	6.7	10.5	14.5
median contribution	10	14	17	5	14	11	7	5	10	16.5

order in which the decisions were listed on the decision sheets follows Table 1, and was such that at least two treatment variables changed between adjacent decisions. All ten decisions were distributed in the same handout, so the order of treatments in Table 1 is not necessarily the order in which the subjects made their choices.

Notice that the value of a token kept (5 cents) is greater than the individual's internal return from a token contributed in all treatments. Thus, the single-round dominant strategy for a selfish participant is to contribute no tokens. However, it is also the case that the total return to participants from a token contributed is greater than the value of a token kept. Thus, full contribution by all would maximize group earnings. Even though the setup decomposes internal and external returns, the basic social dilemma structure of the standard public goods game is preserved.[5]

The participants were recruited from undergraduate economics classes at the Universities of South Carolina and Virginia, and none had participated in a previous public goods experiment. The 32 subjects each made ten decisions with no feedback, so there are 32 individual sets of ten decisions. Groups of eight subjects were in the same room, but were visually isolated from other participants by the use of "blinders." The instructions in Appendix A were distributed and read aloud by the experiment monitor. After participants made contribution decisions for all ten scenarios, the record sheets were collected and the relevant treatment was selected by the throw

[5] For example, the change from treatment 4 to treatment 6 corresponds to an increase in the marginal per capita return (MPCR) from .4 to .8 in a standard four-person public goods game.

of a ten-sided die. Matchings (in groups of size two or four) were done with draws of marked ping-pong balls, and the contribution decisions were used to calculate earnings, which were recorded and subsequently returned to participants. Subjects were told in advance that the experiment would be followed by a different decision making experiment, which helped augment their earnings. Participants were paid their earnings from the treatment selected, along with a $6 participation payment and earnings for the subsequent experiment. Earnings ranged from about $14 to $26 in sessions that lasted no more than 90 minutes, including subject payment.

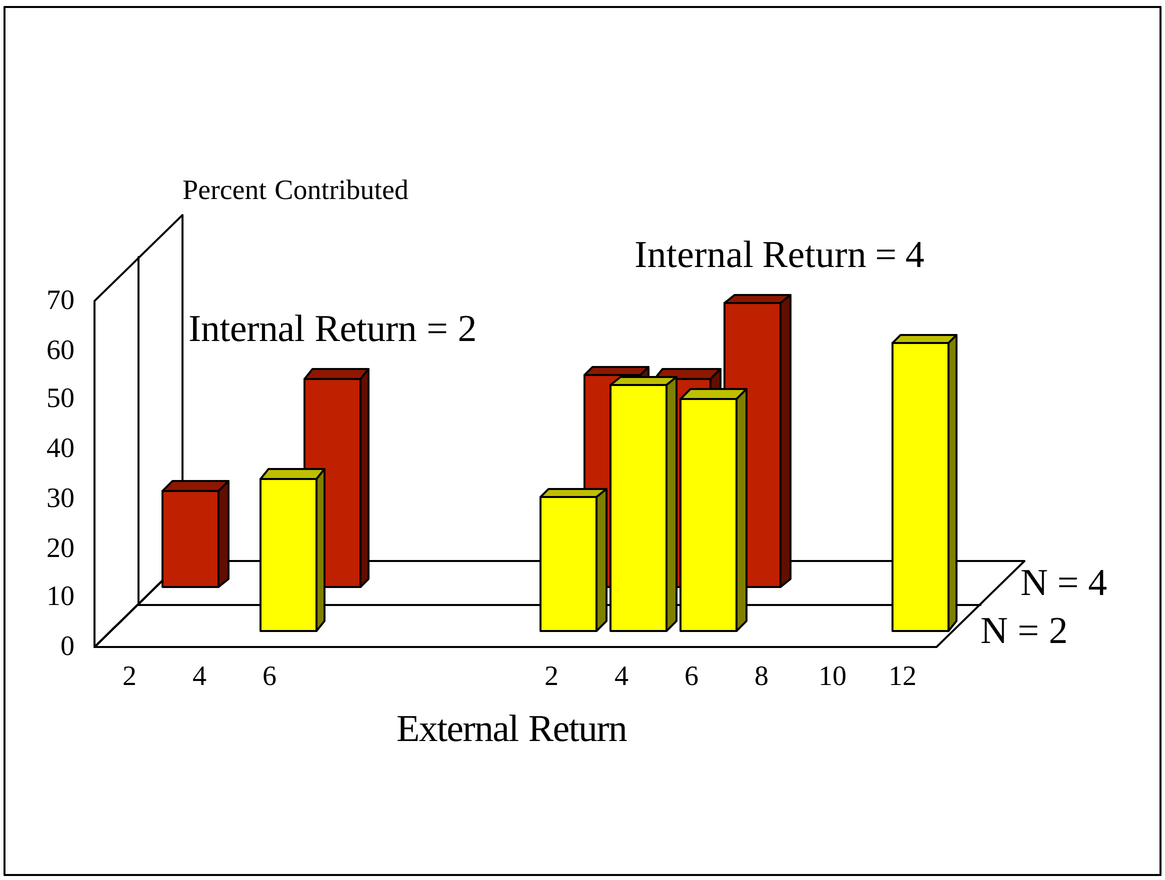
III. DATA PATTERNS

In this section, we examine the primary treatment effects using non-parametric tests. Econometric estimates of a structural model are presented in the next section. The final two rows of Table 1 present summary statistics for the data in terms of number of tokens contributed out of 25. It is immediately apparent that the highest contributions are for treatments 3 and 10 with high external returns, and the lowest contributions are for treatment 4 with low internal and external returns. Figure 1 shows average contributions ordered by treatment. Treatments with an internal return of 2 cents are shown on the left of this graph, while treatments with an internal return of 4 cents are shown on the right. For each internal return, bars from left to right reflect contributions in treatments ordered from low to high external return. The bars in the front row correspond to treatments with a group size of two, and bars in the back row are treatments with a group size of four.

The cost of making a contribution has the strongest effect on contribution decisions. When the internal return increases from 2 to 4 cents (reflecting a decrease in the net cost of contributing from 3 cents to 1 cent), contributions increase, both for groups size of two and four. To see this in the figure, compare the three bars on the left side with the corresponding three bars on the right side (skip the bars with external returns of 4 on the right). This treatment effect is significant in nonparametric tests at the one-percent level.[6]

[6] Because all participants made decisions in each of the 10 treatment conditions, matched pair test statistics may be computed to establish treatment differences. We use a non-parametric Wilcoxon signed-rank test. There are a number of cases in which subjects make identical decisions in both treatments. Following Siegel (1956), these tied observations are discarded. For the tests reported, there were 20 to 28 matched pairs (out of a total of 32 possible pairs). Unless otherwise indicated, one-tailed significance tests with significance levels of 1 percent are used.

Figure 1. Average Contributions by Treatment
(percentage of endowment contributed)



An increase in contributions is also associated with an increase in the external return to the public good, as suggested by the tendency for bar heights to increase from left to right in each part of Figure 1. With a group of size two and an internal return of 4 cents, a Friedman test rejects the null hypothesis that contributions in the four treatments are the same (e.g. Siegel, 1956). Conducting pairwise comparisons, contributions increase significantly when the external return increases from 2 to 4 cents, and also from 6 cents to 12 cents. However, there is no significant difference in contributions when the external return increases from 4 to 6 cents. Similar results hold for groups of size 4. With an internal return of 4 cents, a Friedman test again rejects the null hypothesis of no treatment effect. In pairwise comparisons, contributions do not change significantly when the external return increases from 2 to 4 cents, but they do increase when the external return increases from 4 to 6 cents.[7] For groups of size 4 and an internal return of 2 cents, contributions increase significantly when the external return increases from 2 cents to 6 cents.[8]

Finally, contributions generally increase with group size, as reflected by the taller bars in the back row of Figure 2. Contributions decrease slightly when the internal and external returns are 4 cents; otherwise, the effect of group size is positive and significant.[9]

The above results provide some evidence of altruism in subjects' contribution decisions. This altruism is not simply of the warm-glow variety (defined as increased utility from the act of giving, rather than from what the others receive) because it is responsive to the external return and group size. But neither are subjects acting as pure altruists, i.e. they do not behave in a way that maximizes others' earnings. Other-regarding behavior is less common in our data when the

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[7] Contributions actually decrease slightly when the external return increases from 2 to 4 cents. This happens also for groups of size 2 when the external return increases from 4 to 6 cents. Notice that the median contribution does not decrease with an increase in the external return for any group size.

[8] Similarly, Goetze and Galderisi (1989) set up a one-shot public goods experiment in which a contribution to the public good has a return that is not divided equally between the contributor and the other members of the group. Observed contributions were sensitive to both the external benefits, which is consistent with altruism, and to the private net loss associated with making a contribution. However, only the effects of an increase in the external return, holding constant the internal return, and a simultaneous increase in internal and external return were significant.

[9] Since there is no reason to believe that contributions will be higher with larger group sizes, a two-tailed test was used for these comparisons.

private cost of a contribution increases (holding constant the benefit of a contribution to others). This suggests that decision errors, which are sensitive to their economic costs, provide an additional explanation for the observed contributions. The following section presents a formal model of contribution behavior that incorporates both altruism and decision error.

IV. A PARAMETRIC THEORY OF ALTRUISM WITH DECISION ERROR

When it is a dominant strategy for selfish players not to contribute in a one-shot public goods game, any contribution is a type of error. These errors cause data to be dispersed away from the full free-riding outcome, and the degree of dispersion indicates the importance of errors. Following McKelvey and Palfrey (1995), we use a probabilistic choice function to model noisy decision-making, supplemented with a Nash-like equilibrium condition on the consistency of actions and beliefs. A convenient specification for empirical work is the logit probabilistic choice function, and the equilibrium that results is called a *logit equilibrium*.[10] Decisions are stochastic in a logit equilibrium: all options have a non-zero chance of being selected, with choice probabilities positively related to expected payoffs. In other words, non-optimal choices, or mistakes can occur, but the probability of a mistake is inversely related to its cost. In the context of the present paper, a logit equilibrium analysis therefore predicts that contributions are lower when they are more costly, i.e. when the internal return is small. This prediction is borne out by the data. Figure 1 shows that for a fixed group size and external return, contributions are significantly higher with a high internal return. Errors alone, however, cannot explain the other treatment effects: the impact of group size and the external return on contribution levels suggest the importance of "other-regarding" preferences.

When individuals care about raising others' payoffs, perhaps because of altruism or because of a sense of obligation, we can model preferences as including own and others' earnings. The simplest model of altruism is a linear one, in which a person's utility is modeled as their own monetary payoff plus the others' monetary payoffs, weighted by an altruism parameter α (e.g.

[10] See Anderson, Goeree, and Holt (1998) for a theoretical analysis of logit equilibria in public goods games. Offerman, Schram, and Sonnemans (1998) use this type of equilibrium in the analysis of decisions in step-level public goods games with a binary choice of whether or not to contribute. Palfrey and Prisbrey (1997) use a similar error specification.

Ledyard, 1995; Anderson, Goeree, and Holt, 1998). One advantage of the logit equilibrium approach is that noisy decision-making and altruism can be combined into a single model, in which contributions are sensitive to changes in both the internal and external returns. The relative importance of altruism and error parameters can then be estimated using standard maximum-likelihood techniques. We allow for individual differences by estimating a model in which individual-specific altruism parameters are drawn from common distributions.

Simple introspection suggests that altruistic motives, if they are important, may not be linear. For example, a person who is willing to give up 10 cents to produce a dollar for somebody else, may not be willing to give up a hundred dollars, knowing that a thousand dollars will then be given to another randomly selected individual. Or would the person give up a hundred dollars to give one dollar to each of a thousand people? We will also consider a non-linear specification, and variations in group size and external returns will help identify non-linearities. A natural way to introduce non-linear altruism is to describe an individual's utility as a non-linear function of own and others' earnings. Specifically, we will use a Cobb-Douglas specification to model altruism, again incorporating some decision error via a logit formulation.[11]

First, let us introduce some notation. The public goods games discussed in this paper have a linear payoff structure. Individual token endowments are denoted by ω and each token not contributed to the public good is worth v cents. An individual i who contributes x_i tokens to the public good earns $\nu(\omega\text{-}x_i)$ cents for the tokens kept. In addition, each token contributed yields m_I cents for the contributor and m_E cents for the other group members. Using the terminology presented above, the internal return is m_I and the external return is m_E. The expected payoff to player i, denoted by $\pi_i^e(x_i)$, is: $\pi_i^e(x_i) = v(\omega\text{-}x_i) + m_I\, x_i + m_E(n\text{-}1)x_j^e$, where x_j^e is the expected contribution of the (n-1) other people in the group. Note that the constant marginal values produce linear payoff functions that are maximized at full free riding when $v > m_I$, as is the case in all of our treatments.

The linear altruism model is obtained by replacing the expected payoff $\pi_i^e(x_i)$ by a

[11] Andreoni and Miller (1997) report some asymmetric pie-sharing experiments in which a person can give up money that is then multiplied by a constant and given to a randomly selected other participant. They consider Cobb-Douglas and other specifications to explain the observed tendency for individuals to give up money when the conversion rate into others' earnings is high.

weighted sum: $U_i = \pi_i^e + \alpha\pi_j^e$, where the altruism parameter, α, is typically assumed to be between 0 and 1. In a linear altruism model, an individual is willing to give up \$$\alpha$ in order to increase the other's earnings by \$1. With linear altruism and linear payoffs, the resulting utility is linear in x_i, so full contribution is optimal if α is large enough to make the coefficient of x_i positive. Full free-riding is optimal if the coefficient of x_i is negative. Of course, the level of α, v, m_E, and m_I determine the magnitude of the payoff error from not choosing an optimal decision of full contribution or full free-riding.

Decision errors are introduced via a standard logit probabilistic choice rule, which implies that the choice probabilities are proportional to an exponential function of the expected payoffs

$$P(x_i) = \frac{\exp(U_i(x_i)/\mu)}{\sum_{x=0}^{25} \exp(U_i(x)/\mu)}, \tag{1}$$

where the denominator ensures that the probabilities add up to 1. The error parameter, μ, determines the sensitivity of a player's decisions with respect to payoffs. When μ is very large, payoff differences get washed out, and behavior is close to being random. For a small value of μ, however, the decision with the highest payoff is very likely to be selected, i.e. behavior is close to being rational.

The particular parameterization in (1), with U_i determined by the linear altruism model, can be used to estimate the effects of error and altruism. The probability that individual *i* contributes x_i tokens is given by (1) and assuming that decisions are independent, the likelihood function is simply given by a product of these decision probabilities.[12] Hence, $\ln(L) = \Sigma_i \ln(P(x_i))$ and estimates of μ and α can be obtained by maximizing the log-likelihood function with respect to these parameters. The top row of Table 2 gives the results for this linear model. It is clear that the Nash prediction of no error (i.e. $\mu = 0$) can be rejected at very low significance levels. The interpretation of the linear altruism parameter, $\alpha = 0.1$, is that a person values a

[12] There is, of course, the possibility that the 10 choices made by one individual are drawn from a different distribution than the choices made by someone else, which we accommodate below by allowing for heterogeneity among individuals.

dollar to oneself the same as ten cents for the other.[13] Palfrey and Prisbrey (1997) estimate a significant "warm-glow" altruism effect in their data, but find no evidence for (linear) altruism.[14] Since a change in the external return, m_E, has no effect on contributions in a model with only warm-glow altruism, our data do not seem to support such a model. The rough correlation between group size and contributions is another indication for the presence of altruism rather than pure warm glow. A more convincing test for altruism versus warm glow is obtained by combining them into a single model, in which player *i*'s utility function is given by: $U_i = \pi_i^e + \alpha \pi_j^e + g\, x_i$, where the warm glow parameter g is the utility obtained from contributing one token (independent of how much it benefits others). Estimation of this combined model yields error and linear altruism parameters that are not significantly different from the ones in the first row of Table 2 and an insignificant warm-glow parameter.[15]

Since some people seem to be more altruistic than others, across all treatments, we considered a model that allows for individual differences. Specifically, we estimated a linear altruism model with individual-specific altruism coefficients, α_i, and a single error parameter, μ. Almost all of the estimated altruism parameters were significantly different from zero at the 5 percent level. The estimates ranged between -.5 and .5, with a mean of $\bar{\alpha} = 0.11$, as shown in the second row of Table 2 for the heterogeneous model. Of course, a model with 31 more parameters results in a better fit of the *individual* data as indicated by the higher value of the log-likelihood function. Surprisingly, however, it does not provide as good a fit of the average contributions by treatment. One way to measure how well the model tracks the averages is to use the mean-squared difference, i.e. the sum of squared differences between the actual and predicted number of tokens contributed, divided by the number of treatments. The mean-squared

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[13] A significant altruism effect is in line with the findings of Anderson, Goeree, and Holt (1998) who estimated an altruism parameter of $\alpha = 0.07$, using data from public goods experiments conducted by Isaac and Walker (1988) and Isaac, Walker, and Williams (1994).

[14] Their model involves a binary decision, contribute or not, and randomly varying private values for keeping a token. The warm glow model specifies that the act of contributing provides utility independent of how much it actually benefits others, as discussed below.

[15] The estimates were: $\alpha = .14$ (.04), $g = -.1$ (.1), and $\mu = 22$ (5), where the numbers in parentheses are the standard deviations of the estimates.

Table 2. Maximum-Likelihood Estimates (Standard Errors in Parentheses)

	Altruism parameter	Error parameter	Log(L)	MSD
homogeneous linear model	α = .10 (.01)	μ = 19 (3)	-1011.3	2.98
heterogeneous linear model	$\bar{\alpha}$ = .11 (.23)[a]	μ = 17 (3)	-847.1	3.58
linear model distribution of α's	α_0 = .10 (.02) σ_α = .14 (.04)	μ = 17 (3)	-1006.9	2.69
non-linear Cobb-Douglas model	β = .13 (.03)	μ = .12 (.02)[b]	-1010.6	2.37

[a] This is the average of all the individual altruism parameter estimates. Ranked from low to high, the individual altruism parameters were estimated to be: -.5, -.34, -.25, -.24, -.22, -.21, .0, .0, .0, .05, .08, .1, .12, .14, .14, .14, .14, .15, .16, .16, .18, .2, .23, .25, .26, .32, .33, .36, .39, .41, .43, .45, where the altruism parameters of the three perfect Nash players are assigned to be zero.

[b] The μ estimate for the Cobb Douglas is of a different order of magnitude because the payoffs have been transformed using the natural logarithm.

differences are shown in the far-right column of Table 2.

An alternative way to incorporate some heterogeneity is to model the individual-specific altruism coefficients as draws from some population distribution and use the data to estimate the parameters underlying the distribution. For instance, suppose the altruism parameters are drawn from a normal distribution with mean α_0 and variance σ^2_α. Estimation of this model yields a similar value of the error parameter, μ = 17 (3), and the mean of the normal population distribution of altruism parameters, α_0 = .10 (.02), is quite close to the estimate for the homogenous linear model. This model provides a better fit of the data averages than a simple one-parameter linear altruism model, as indicated in the "MSD column" of Table 2.

While linear models may be appropriate for some parameter values, they may not apply when "large" amounts of money are being transferred as is the case for large groups and high external returns. One way to model non-linear tradeoffs between own and other's expected earnings is to specify a non-linear utility function of expected earnings.[16] Using the familiar Cobb-Douglas specification, player *i*'s utility function becomes: $U_i(x_i) = (1-\beta)\ln(\pi_i^e) + \beta\ln(\pi_j^e)$, with $0 \leq \beta \leq 1$. The maximum likelihood estimates for the utility and error parameters are presented in the bottom row of Table 2.[17, 18] The non-linear model predicts the treatment effects best, as indicated by the lowest value of the mean squared deviation in the far right column of Table 2.

Figure 2 shows the average contribution (thick line) for all 10 treatments listed in the same order as in Table 1, together with the predictions of the linear altruism model (thin line) and the non-linear model (dashed line). Both models track the data averages remarkably well: except for the decision labeled as number eight (the $N = 2$, $m_I = 4$, and $m_E = 2$ treatment), all predicted averages are close to the actual ones. While the non-linear model does not result in a significantly higher likelihood, it outperforms the linear model in terms of reproducing the treatment effects.

V. CONCLUSIONS

The most salient result of public goods experiments is that contributions are correlated with the common marginal value of the public good, even though it is a dominant strategy to free ride. An increase in the marginal value of the public good confounds two important payoff

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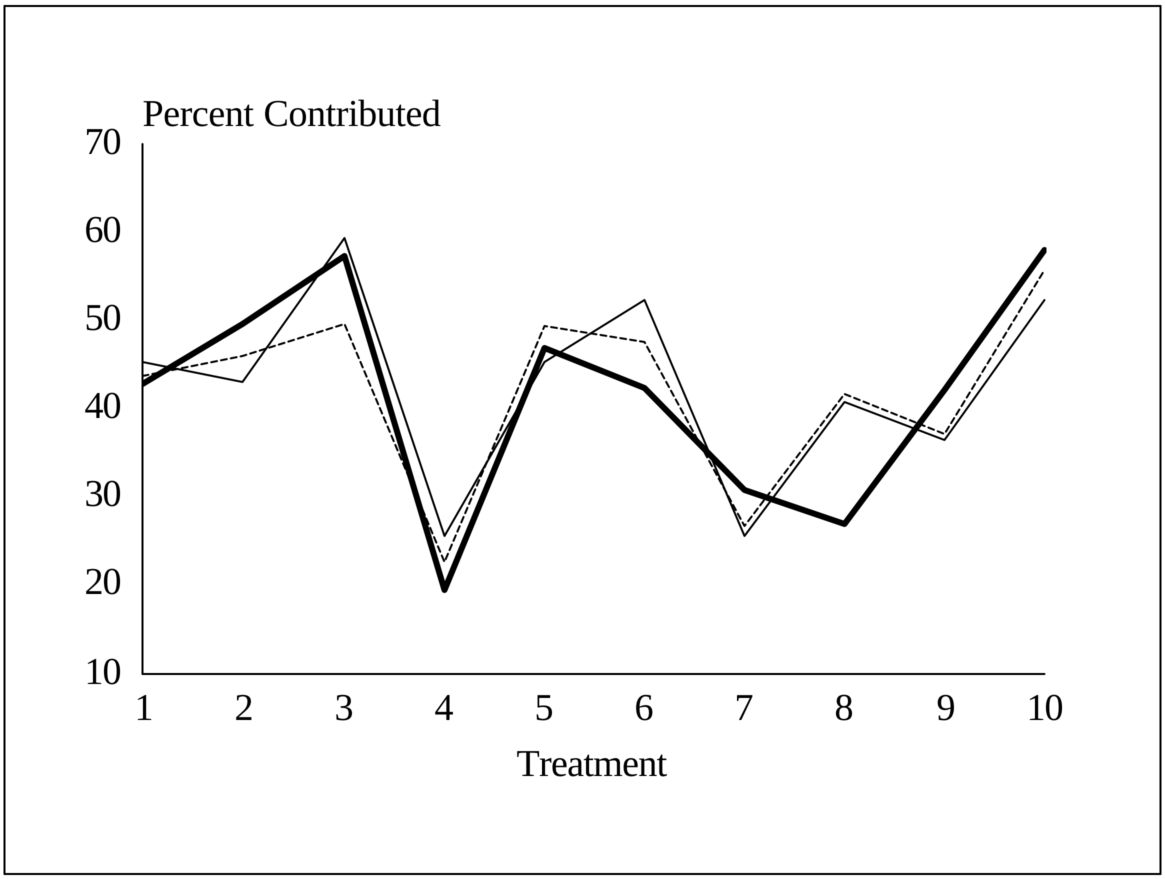
[16] Putting expected earnings in arguments of such a function simply means that the rate at which you are willing to trade off your own expected earnings in order to increase another's expected earnings is non-linear. The function implies that only expected earnings matter, i.e. there is no risk aversion. There is no inconsistency in having non-linear altruism and risk neutrality.

[17] The logit equilibrium condition is more complicated for the non-linear altruism model. Note that the logit choice probabilities in (1) remain unchanged when a constant is added to expected payoffs. Hence, others' expected contributions have no effect on decisions in the linear altruism model. For the non-linear model, however, the expected contribution of the (n-1) other people, x_j^e, does affect the choice probabilities. Since the logit probabilities, in turn, determine x_j^e, the equilibrium level of contributions has to be calculated as a fixed point. In this way, the log-likelihood function is evaluated at each combination of parameter values (μ, β). An iterative search is then used to determine the values of μ and β that maximize the log-likelihood.

[18] A Cobb-Douglas parameter of .13 means that, in the absence of any error, a person would divide one dollar by taking 87 cents and giving 13 cents to somebody else, which is roughly consistent with the implication of the linear model that a person is willing to give up 10 cents to provide an additional dollar to another. In the non-linear altruism model, however, the level of own and others' payoffs will affect how much a person is willing to give up. For instance, when others are already better off, a person may decide to give less than 13 cents from an extra dollar provided.

Figure 2. Average Number of Tokens Contributed By Treatment Number

Key: data averages (thick line), linear altruism model (thin line), and Cobb-Douglas model (dashed line)



effects: it reduces the error that a selfish person makes by contributing, and it increases the incentive for an altruist to contribute. As Ledyard (1995, p.170) notes in the conclusion of his survey of public goods experiments, "there are at least two explanations for the data: (a) subjects trade off altruistic and cooperative responses against personal payoffs, or (b) subjects make mistakes, do not care, are bored, and choose their allocations randomly." Palfrey and Prisbrey (1997) and Andreoni (1995) approached this issue with clever changes in the structure of the public goods game, and they find some evidence for both altruism and noisy behavior. In this paper we preserve the basic structure of the standard linear public goods game and decompose changes in the marginal value of the public good into independent changes in the internal return to oneself and the external return to others. By maintaining a constant internal return, the cost of contributing is held constant, while changes in the external return alter the value of a contribution to others.

We implement this structure in a one-shot public goods game: each subject makes a contribution decision in ten treatments with no feedback about others' decisions. Internal return, external return, and group size are independently varied across these treatments, which allows for precise estimates of a model that includes both altruism and decision error. Moreover, by examining individual contribution decisions over a range of external returns and group sizes, we are able to evaluate nonlinear altruism effects and to accommodate individual heterogeneity.

Our results are intuitive. The strongest treatment effect is that an increase in internal return is associated with an increase in individual contributions. In other words, by reducing the cost to oneself of making a contribution, people contribute significantly more to the public good. Decision errors, which are sensitive to their economic costs, provide a possible explanation of this finding. Contributions are also positively correlated with an increase in external return. Holding constant the cost of contributing, subjects contribute more when others receive a larger benefit, which suggests that in addition to decision errors, "other-regarding" preferences play a role. The positive treatment effects for group size and external return indicate that altruism is not simply of the "warm glow" type.

We find that a simple model of altruism and logit decision error organizes the observed data patterns surprisingly well. (When we include warm glow altruism in our model, the warm glow coefficient is not significant.) Introducing heterogeneity between individuals results in essentially the same error parameter and a distribution of individual altruism parameters that is centered around the single estimate of the homogeneous model. Despite the large increase in the number of parameters, the model does not provide a better fit of the treatment averages. Finally, intuition and some nonlinearities in external effects suggest a nonlinear altruism specification, and the estimated Cobb-Douglas model provides a better fit of the treatment averages and reproduces the treatment effects for a wide range of external returns.

The results we report here are not inconsistent with the presence of other explanations for contributions to a public good, e.g. social distance, reciprocity, signaling, and strategic motives for giving in all but the final period in repeated public goods games. We have attempted to design an experiment that mitigates and controls these other factors, which allows us to focus on the economic incentives in a one-shot context. Our design with independent changes in internal and external returns provides strong evidence for the presence of altruism and noisy decision making, based on parametric and non-parametric tests. The estimated altruism model dressed up with logit error provides a simple and parsimonious specification that can serve as a building block to analyze and predict behavior in a broad class of economic environments.

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Appendix A: Instructions

This is an experiment about decision making. You will be paid for participating, and the amount of money you earn depends on the decisions that you and the other participants make. At the end of today's session you will be paid privately and in cash for your decisions. Several research foundations have provided the funds for this experiment.

You will never be asked to reveal your identity to anyone during the course of the experiment. Your name will never be associated with any of your decisions. In order to keep your decisions private, please do not reveal your choices to any other participant.

At this time, you will be given $6 for coming on time. All the money that you earn after this will be yours to keep, and your earnings will be paid to you in cash at the end of today's experiment.

THIS EXPERIMENT

In this experiment you will be asked to make a series of choices about how to allocate a set of tokens. You and the other subjects will be randomly assigned to groups, and you *will not* be told each others' identities.

In every choice you will be told how many people are in your group. In each choice you will have 25 tokens to allocate. You must choose how many of these tokens you wish to keep and how many tokens you wish to invest. The amount of money that you earn depends on how many tokens you keep, how many tokens you invest, and how many tokens the others in your group invest.

EXAMPLES OF CHOICES YOU WILL MAKE IN THIS EXPERIMENT

Each choice that you make is similar to the following:

Example 1: You are in a group of size 2 (you plus one other). Both of you have 25 tokens to allocate. You will earn 5 cents for each token you keep. For each token you invest, you will earn 4

cents and the other person will earn 3 cents (a total of 7 cents for both of you together).

For each token the other person keeps, this person will earn 5 cents. For each token the other person invests, this person will earn 4 cents and you will earn 3 cents (a total of 7 cents for the group).

To summarize, you will earn:

5 cents times the number of tokens you keep
+ 4 cents times the number of tokens you invest
+ 3 cents times the number of tokens the other person in your group invests.

Keep __________ tokens   Invest __________ tokens (These choices must sum to 25 tokens)

You can choose any number of tokens to keep and any number to invest, but *the number of tokens you keep plus the number of tokens you invest must sum to the total number of tokens you have been given to allocate*.

Please feel free to use your own calculator, or one provided by the experimenter, to verify earnings and to ensure that all tokens have been allocated.

To be sure you understand how your earnings would be calculated in this example, please fill out the following. Choose numbers for tokens that you keep, the tokens that you invest, and the tokens that the other person invests. This is only to illustrate how your earnings are calculated. In the actual experiment, everyone will make their own choice and we will calculate all earnings for you.

If I Keep _______ tokens and invest _______ tokens; and the other person in my group invests _ ______ tokens, I will earn:
_______ cents for the tokens that I keep (5 cents each)
_______ cents for the tokens that I invest (4 cents each)
_______ cents for the tokens the other person invests (3 cents each)
For a total of: _______ cents.

Please fill this out, and we will come to each of you individually to answer any questions that you have and to check your answers.

When you are done, you may proceed to the second example:

Example 2: You are in a group of size 4 (you plus 3 others). Each of you has 25 tokens to allocate. You will earn 5 cents for each token you keep. For each token you invest, you will earn 2 cents and each of the other three people in your group will earn 3 cents (a total of 11 cents for all four of you together).

For each token another person in your group keeps, this person will earn 5 cents. For each token this person invests, this person will earn 2 cents, and each of the other people in your group will earn 3 cents (a total of 11 cents for the group).

To summarize, you will earn:
5 cents times the number of tokens you keep
+ 2 cents times the number of tokens you invest
+ 3 cents times the number of tokens the other people in your group invest.

Keep __________ tokens Invest __________ tokens (These choices must sum to 25 tokens)

Again, to be sure you understand how your earnings would be calculated in this example, please fill out the following:

If I Keep _______ tokens and invest _______ tokens; and the other three people in my group invest a total of _______ tokens, I will earn:
_______ cents for the tokens that I keep (5 cents each)
_______ cents for the tokens that I invest (2 cents each)
_______ cents for the tokens the other three people invest (3 cents each)
For a total of: _______ cents.

EARNING MONEY IN THIS EXPERIMENT

You will be asked to make 10 allocation decisions like the examples we have just discussed. We will calculate your earnings as follows:

After all your decision sheets have been collected, we will verify that everyone has completed all decisions and that all 25 tokens have been allocated for each choice. Then we will roll a 10-sided die. The number that appears on the die will determine which *one* of your decisions we will carry out. For example, if we roll a 1 you will be paid for your first decision. If we roll a 0 you will be paid for your 10th decision (the die contains the numbers 0 through 9). You will be paid only for the decisions that you and the others in your group make for this one decision. For example, if a 1 is rolled you will be paid based on the decisions you and the others in your group made in decision 1. You will not be paid for any other decisions.

After determining which decision is chosen, we will randomly assign you to groups of the size specified in this decision. We will do this by drawing numbered ping-pong balls. For example, if a decision is chosen in which you are in a group of size four, we will draw four ping-pong balls. The subjects whose ID numbers correspond to these four draws will be in one group. We would then draw another four balls to determine which subjects are in the second group. This would be repeated until all subjects are assigned to a group.

You will then earn money based on the number of tokens you kept in this decision, the number of tokens you invested in this decision, and the number of tokens invested by the other(s) in your group (the total number invested by each other person in your group) in this decision.

After all choices are made, we will conduct another decision-making experiment. We will compute your earnings for this part during the second experiment. At the end of the second experiment, we will return an earnings report to you so that you may see how much money you earned in this portion of the experiment. You will only be told the total number of tokens invested by the other(s) in your group. You will not be told who you are matched with.

During the experiment, you are not permitted to speak or communicate with the other participants. If you have a question while the experiment is going on, please raise your hand and one of us will come to your desk to answer it. At this time, do you have any questions about the instructions or procedures? If you have a question, please raise your hand and one of us will come to your seat to answer it.

On the following pages are the 10 choices we would like you to make. Please fill out the form, taking the time you need to be accurate. When everyone is done we will collect the forms.

DECISION SHEET

Please fill in all of the blanks for each choice below. Make sure that the number of tokens listed under *Keep* plus the number listed under *Invest* equals 25 tokens.

Choice 1. You are in a group of size 4 (you plus three others). Each of you have 25 tokens to allocate. You will earn 5 cents for each token you keep. For each token you invest, you will earn 4 cents and each of the other three people in your group will earn 2 cents (a total of 10 cents for all four of you together).

For each token another person in your group keeps, this person will earn 5 cents. For each token this person invests, this person will earn 4 cents, and each of the other people in your group will earn 2 cents (a total of 10 cents for the group).

To summarize, you will earn:

5 cents times the number of tokens you keep
+ 4 cents times the number of tokens you invest
+ 2 cents times the number of tokens the other people in your group invest.

Keep __________ tokens Invest __________ tokens. (These choices must sum to 25 tokens)

(The other nine choices were presnted in a similar manner.)

Appendix B: Individual Data

Individual Token Contribution Decisions: University of Virginia Subjects

	Treatment									
group size	N=2	N=2	N=2	N=2	N=2	N=4	N=4	N=4	N=4	N=4
internal return	$0.02	$0.04	$0.04	$0.04	$0.04	$0.02	$0.02	$0.04	$0.04	$0.04
external return	$0.06	$0.02	$0.04	$0.06	$0.12	$0.02	$0.06	$0.02	$0.04	$0.06
subject 1	10	5	15	15	15	10	25	20	20	25
subject 2	1	7	7	1	0	2	2	6	0	3
subject 2	15	17	20	20	25	0	10	15	5	25
subject 4	0	3	10	15	23	0	5	15	20	25
subject 5	15	0	20	12	23	3	20	17	9	20
subject 6	0	3	5	5	5	0	0	3	3	5
subject 7	0	25	25	25	25	5	20	25	15	25
subject 8	5	5	15	15	15	5	5	10	10	15
subject 9	0	0	0	0	0	0	0	0	0	0
subject 10	0	0	0	0	0	0	0	0	0	0
subject 11	7	0	10	5	18	2	15	7	12	20
subject 12	7	12	17	20	24	1	14	20	15	21
subject 13	20	14	20	20	20	14	18	20	20	22
subject 14	0	0	0	0	0	0	0	0	0	0
subject 15	7	15	15	18	19	1	7	17	13	20
subject 16	10	5	15	18	20	8	12	12	15	18

Individual Token Contribution Decisions: University of South Carolina

	Treatment									
group size	N=2	N=2	N=2	N=2	N=2	N=4	N=4	N=4	N=4	N=4
internal return	$0.02	$0.04	$0.04	$0.04	$0.04	$0.02	$0.02	$0.04	$0.04	$0.04
external return	$0.06	$0.02	$0.04	$0.06	$0.12	$0.02	$0.06	$0.02	$0.04	$0.06
subject 17	14	10	12	12	15	11	14	10	13	14
subject 18	2	5	6	4	2	7	1	3	5	5
subject 19	4	1	5	2	1	3	10	1	5	1
subject 20	19	7	5	8	20	6	16	9	6	15
subject 21	15	14	20	15	10	7	6	8	3	21
subject 22	3	9	25	6	4	7	8	10	25	5
subject 23	15	10	15	15	15	15	20	20	20	20
subject 24	20	1	10	20	23	5	24	12	10	25
subject 25	10	11	20	13	22	8	12	8	12	10
subject 26	11	5	17	25	23	12	18	20	21	20
subject 27	4	0	15	15	25	5	25	10	18	20
subject 28	0	10	10	0	5	0	0	10	5	5
subject 29	2	1	4	5	7	1	3	2	3	5
subject 30	11	11	9	8	14	7	12	12	10	16
subject 31	10	1	13	23	25	2	5	5	13	20
subject 32	9	8	16	15	20	9	10	15	12	12