On Modeling Voluntary Contributions to Public Goods

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Abstract

This paper addresses four "stylized facts" that summarize data from experimental studies of voluntary contributions to provision of public goods. Theoretical propositions and testable hypotheses for voluntary contributions are derived from two models of social preferences, the inequity aversion model and the egocentric other-regarding preferences model. We find that the egocentric other-regarding preferences model with classical regularity properties can better account for the stylized facts than the inequity aversion model with non-classical properties.

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1 INTRODUCTION

Americans gave more than $240 billion to charities in 2003 (*Giving USA 2004*). Much of this charity is distributed as private goods to recipients who are anonymous to the contributors, and hence it is only the total amounts of categories of contributions that can generate utility to the contributors. But the same total amount can be contributed if you give more and I give less. In that way, charitable contributions are public goods.

Fundamental questions in public economics center on understanding the conditions under which public goods can be supplied through voluntary contributions – if perhaps not optimally then at least at significantly positive levels. Development of this understanding requires both empirical and theoretical research.

Experiments with human subjects in simple laboratory environments provide one type of data that can guide theoretical modeling. A large literature reports the ways in which voluntary contributions to public goods vary with the treatment parameters that define the simplified experimental public economy. Some stylized facts about the properties of voluntary provision of public goods have emerged from these experiments. Theoretical modeling seeks to explain these stylized facts (and other relevant data).

It has long been accepted that traditional microeconomic and game theoretic models of self-regarding (or "economic man") preferences cannot rationalize data from public goods experiments (Ledyard 1995). We ask whether two recent models of social preferences can rationalize the data. We examine a model of inequity aversion (Fehr and Schmidt 1999) and a model of egocentric other-regarding preferences (Cox and Sadiraj 2003).

Both of these models incorporate other-regarding preferences: if you and I participate in a voluntary contributions game then my utility varies with your material payoff as well as my own and your utility also varies with both my payoff and yours. In this way, both models generalize traditional economic man preferences to incorporate what were traditionally called "consumption externalities." But the two models of social preferences we consider have different relationships to two properties of classical preference theory (Hicks 1939, Samuelson 1947), strict convexity and strict positive monotonicity. Strict convexity is the traditional assumption that indifference curves (or surfaces, for more than two variables) are strictly convex to the origin. Strict positive monotonicity is the traditional assumption that more is preferred to less. If social preferences are strictly monotonic then others' payoffs as well as one's own payoff are always goods. The egocentric other-regarding preferences model incorporates both strict convexity and strict positive monotonicity. In contrast, the inequity aversion model has preferences that are not positively monotonic and not *strictly* convex (because the indifference "curves" are piecewise linear). The inequity aversion model's inconsistency with positive monotonicity is fundamental: your material payoff is a good to me when it is less than my payoff but a bad when it is larger than my payoff.

We use the egocentric other-regarding preferences model and inequity aversion model to address the question of rationalizing data with the patterns in four stylized facts from linear public good experiments. We find that the egocentric other-regarding preferences model with classical regularity properties can better account for the stylized facts than the inequity aversion model with non-classical properties.

2 STYLIZED FACTS

Some of the data patterns that characterize voluntary contributions in experiments with linear public good games are described in the following stylized facts.

1. **Contributions:** Average contributions to a public good are a significant fraction of total endowment. About half of all individual contribution decisions involve dividing the individual's

endowment between contributions to the public good and private consumption (Holt and Laury in press). Positive contributions are markedly heterogenous across individuals even in the last round of multi-round experiments (Isaac, Walker, and Thomas 1984; Andreoni 1988, 1995a; Isaac, Walker, and Williams 1994; Laury and Petrie 2005)

2. **Marginal per capita return (MPCR):** This is an individual's rate of change in self-regarding utility from making a marginal transfer of the endowed resource from his private consumption to production of the public good.[1] Higher MPCRs have been found to elicit larger contributions (Marwell and Ames 1979; Isaac, Walker and Thomas 1984; Kim and Walker 1984; Isaac and Walker 1988; Saijo and Nakamura 1992).

3. **Group size**: For low to moderate group sizes and low values of MPCR, larger group sizes are associated with larger contributions (Isaac and Walker 1988; Isaac, Walker and Williams 1990).

4. **Endowment effects in homogeneous environments:** Environment homogeneity means that all subjects are given the same endowment and that the marginal monetary payoffs are the same for everybody. With environment homogeneity, larger endowments have been found to elicit larger contributions in both one-shot treatments (Cherry, Kroll, and Shogren 2005) and in the last round of multi-round treatments (Andreoni 1988, 1995a).

3 PREVIOUS CONLUSIONS ABOUT THEORY

Ledyard (1995) concludes that (a) "hard-nosed" game theory cannot explain the data[2] and (b) altruism cannot explain the data. In contrast, altruistic models of public good games are reported to be empirically supported by Andreoni (1995a), Anderson, Goeree and Holt (1998), and Goeree, Holt and Laury (2002).

Studies that employ altruistic models to try to explain behavior in public good games are abundant in the literature. Andreoni (1989) introduces the "warm-glow" model of altruism.[3] But Goeree, Holt and Laury (2002) find only limited empirical support for the warm-glow model. Levine (1998) develops a linear model of altruism that is consistent with some of the stylized facts in Ledyard's (1995) survey. But Palfrey and Prisbrey (1997) report that linear altruism cannot rationalize their data. Levine acknowledges the difficulty his linear model has in capturing individual contributions that are neither 0 nor the potential maximum and concludes that Andreoni and Miller's (2002) nonlinear model of altruism may better explain such contributions. However, Andreoni and Miller's discussion of public good games doesn't go further than being suggestive.

Palfrey and Prisbrey (1997) implement an experimental design with constant marginal value of the public good and randomly-varying, individual-specific values of the private good intended to identify subjects' response functions. They reject altruism that is (assumed to be) linear and homogeneous across subjects in favor of a warm glow explanation that is allowed to vary across subjects.

Goeree, Holt, and Laury (2002) address the altruism vs. noise question with an experimental design that separately varies the "internal" return (of a subject's own monetary payoff) and the "external" return (of other subjects' payoffs) from a change in contributions to the public good. They report that contributions increase with internal return, external return, and group size. Their data support the conclusion that individual choices are motivated by altruistic other-regarding preferences that respond to the external return and group size rather than warm-glow altruism. They find differences in individual altruism coefficients, that is *heterogeneous* other-regarding preferences. They also report that a linear model of altruistic other-regarding preferences does not rationalize the data as well as a Cobb-Douglas (nonlinear) other-regarding preferences model. One of the two models discussed in the following section, the egocentric other-regarding preferences model, is a constant elasticity of substitution (CES) preference model that contains Cobb-Douglas preferences as a special case.

4 MODELS OF SOCIAL PREFERENCES

In this paper, we consider two models of other-regarding preferences, the egocentric altruism model (Cox and Sadiraj 2003) which includes preferences that are altruistic, albeit egocentric, and the inequity aversion model (Fehr and Schmidt 1999) which includes preferences that are inequality averse. Both models include preferences that are heterogeneous across subjects. The egocentric other-regarding preferences model maintains the classical preference properties of strict convexity and strict positive monotonicity ("more is always preferred to less") while the inequity aversion model maintains neither of these properties. The inequity aversion model has piecewise linear indifference surfaces that are inconsistent with *strict* convexity. This model's inconsistency with positive monotonicity is fundamental: another person's money payoff is a good if it is less than one's own but a bad if it is greater than one's own.

We derive theoretical predictions of these two models for linear public good games and analyze their ability to replicate the stylized facts. The stylized facts are based on contributions in the last round of multi-round experiments. This should provide data that are free from strategic motivations.

In a voluntary contributions, linear public good game, $n \geq 2$ players simultaneously choose the amounts they will contribute to a public good. Typically, each subject is given an endowment w and asked to choose an amount $g_i \in [0, w]$ to invest in the public good. Investments in the public good yield the constant rate of return $a \in [1/n, 1)$, whereas the rate of return on investments in the private good equals 1. Thus the monetary payoff y_i to subject i from participating in one period of a voluntary contributions public good experiment is

$$y_i = w - g_i + a\sum_{j=1}^{n} g_j. \tag{1}$$

4.1 The inequity aversion model

The Fehr and Schmidt (1999) model is based on the assumption that agent i has preferences over her own payoff y_i and $n-1$ others' payoffs y_j, $j \neq i$, in which another's payoff is a good when it is less than one's own payoff and a bad when it is larger than one's own payoff. For the special case $n = 2$, the utility function for agent 1 can be written as

$$\begin{aligned} u_1(y_1, y_2) &= (1+\alpha_1)y_1 - \alpha_1 y_2, \text{ if } y_1 < y_2 \\ &= (1-\beta_1)y_1 + \beta_1 y_2, \text{ if } y_1 \geq y_2 \end{aligned} \tag{2}$$

where $\beta_1 \leq \alpha_1$ and $0 \leq \beta_1 \leq 1$. Figure 1 shows typical indifference "curves" for utility function (2). The defining property of inequality (or "inequity") aversion is shown by the positive slopes of the indifference curves above the forty-five degree line.

In general, inequity averse preferences can be represented by the family of utility functions:

$$u_i(y) = y_i - \alpha_i \frac{1}{n-1}\sum_{j\neq i}\max(y_j - y_i, 0) - \beta_i \frac{1}{n-1}\sum_{j\neq i}\max(y_i - y_j, 0)$$

where $\beta_i \leq \alpha_i$ and $0 \leq \beta_i < 1$. This model has the following implications for the final period of a voluntary contributions public good game. Let $G \equiv g_1 + g_2 + \ldots + g_n$ denote the total contribution to the public good. Then the utility $u_i(y(g_i, g_{-i}))(\equiv \Gamma_i(g))$ that agent i derives from a contribution profile $g = (g_i, g_{-i})$ is

$$\Gamma_i(g) = w - g_i + aG - \alpha_i \frac{1}{n-1} \sum_{j: g_i > g_j} (g_i - g_j) - \beta_i \frac{1}{n-1} \sum_{j: g_i < g_j} (g_j - g_i) \, . \tag{3}$$

The following proposition is proved in appendix A.1.

Proposition 1 *If $n \leq 3$ or $n > 3$ and $\beta_i \leq \frac{n-1}{n-3}(1-a)$ for all i, then:*

1. *there are no asymmetric equilibria;*
2. *the vector of zero contributions, $(0, ..., 0)$ is a Nash equilibrium, and*
   (a) *if $\beta_i < 1 - a$ for some $i \in \{1, ..., n\}$ then there no other equilibria,*
   (b) *if $\beta_i \geq 1 - a$ for all $i \in \{1, ..., n\}$, then any vector of contributions $(z, ..., z)$, $z \in [0, w]$ is a Nash equilibrium.*

The intuition for this proposition goes as follows. For any given asymmetric vector of contributions, an individual with maximum contribution $\overline{g}$ is better off by deviating down, i.e. by contributing δ less that the maximum, $\overline{g} - \delta$, yet not less than the second highest contribution. By doing so he increases his own private payoff by $(1-a)\delta$ and reduces the difference between his payoff (when $\overline{g}$ is contributed) and the payoffs of the other k_i^- individuals with lower contributions by $\frac{\alpha_i}{n-1}\delta k_i^-$, although he increases the difference between his payoff (when $\overline{g}$ is contributed) and the payoffs of the other k_i^+ individuals with contributions of $\overline{g}$ by $\frac{\beta_i}{n-1}\delta k_i^+$. Since the total gain, $(1-a)\delta + \frac{\alpha_i}{n-1}\delta k_i^-$ is not smaller than $\left((1-a) + \frac{\beta_i}{n-1}\right)\delta$ whereas the loss $\frac{\beta_i}{n-1}\delta k_i^+$ is not bigger than[4] $\frac{\beta_i}{n-1}(n-3)\delta$, then by the assumption that $\beta_i \leq \frac{n-1}{n-3}(1-a)$, individual i is better off. Since the assumption holds for all individuals, there is no individual who wants to be among the highest contributors and therefore there are no asymmetric equilibria.

Figure 1 illustrates why there can be no asymmetric equilibria for the two-agent special case. Let individual 1 invest more than individual 2 and the final payoff be $A = (y_1^*, y_2^*)$,where $y_2^* > y_1^*$.

As it can be seen from Figure 1, a smaller contribution of individual 1 that results in money allocations from the triangle with corners $A = (y_1^*, y_2^*)$, $L = (y_1^*, y_1^*)$ and $H = (y_2^*, y_2^*)$, put him on a higher indifference curve. Thus we are left with only symmetric equilibria. For any vector of symmetric contributions L, deviating up and offering more is never desirable according to this model since that would decrease the individual's own payoff and increase the unfavorable differences in payoffs with all other individuals. Figure 1 illustrates this case for a two-player game. A larger contribution by player 1 decreases his own payoff and increases the other's payoff, resulting in a final money allocation on the left and above point $L = (y_2^*, y_2^*)$, which is on a lower indifference curve. In particular, this implies that the vector of zero contributions is a Nash equilibrium since the only possible deviations are contributing more. For any other symmetric vector of positive contributions, it pays to deviate down for an individual if and only if the gain in individual payoff, $(1-a)\delta$ is bigger than the loss from increased differences in payoffs by $\frac{\beta_i}{n-1}\delta(n-1)$, i.e. if and only if $\beta_i < (1-a)$. Again referring to Figure 1, if the smaller contribution $g^* - \delta$ results in a final allocation $(w - g^* + \delta + 2ag^* - a\delta, w - g^* + \delta + 2ag^* - a\delta)$ above the line through L (which is true if $\beta_m < (1-a)$) then individual 1 would prefer it to g^* since that puts her on a higher indifference curve. Hence, if there is at least one such individual then she wants to deviate down and, furthermore, since no one wants to be the highest contributor the only Nash equilibrium is the vector of zero contributions.

The model's implications for behavioral patterns represented in the stylized facts are as follows.

Contributions implication. The experimental treatments reported in Table 1 have parameters that satisfy $1 \leq \frac{n-1}{n-3}(1-a)$. The inequity aversion model specifies that $\beta_i \leq 1$, for all i. Therefore the assumption in Proposition 1, $\beta_i \leq \frac{n-1}{n-3}(1-a)$, for all i, is satisfied for the experimental treatments reported in Table 1. Furthermore, $1 - a \geq 0.5$ in all reported experiments. Hence if we reasonably assume that there is at least one individual with $\beta_i < 0.5$ then the inequity aversion model predicts contributions of 0 as a unique Nash equilibrium.[5] The data tell a different story.

In the Table 1 treatments with $n = 4$ from Isaac, Walker, and Thomas 1984, Isaac, Walker, and Williams 1994, and Laury and Petrie 2005, together with the $n = 5$ treatments from Andreoni 1988, 1995a, seventy-two of 164 (or forty-four percent) of the subjects make positive contributions to the public good in the last round. Figure 2 shows the distribution of positive contributions in these experiments. On average, the last round contributions by positive contributors is forty-three percent of their endowments.[6] Furthermore, positive contributors are notably heterogenous; the range of positive contributions is from two percent to 100 percent of endowments.

Figures reported in the right-most column of Table 1 show percentages of subjects who make positive contributions in the last round in several experiments. Positive contributions in the last round, by eleven percent to fifty-seven percent of the subjects, cannot be explained by the inequity aversion model. We conclude that the inequity aversion model cannot account for stylized fact 1 about contributions.

MPCR implication. Proposition 1 implies that, for any given n, the value of MPCR (which is a) should have no effect on contributions as long as there is at least one individual with $\beta_i < 1 - a$ and $a \in (\frac{1}{n}, \frac{2}{n-1}]$.[7] Yet the empirical evidence is different. As an example, take studies with $n = 4$ reported in Table 1. Three studies with $a = 0.5$ report percentages of positive contributors varying from twenty-seven percent to fourty-four percent whereas two studies with $a = 0.3$ report percentages varying from twenty-five percent to thirty-one percent. Note that in case of $n = 4$, the range of a for which no effect is predicted is $a \in (0.25, 0.67]$, and since the above a values of 0.3 and 0.5 are within that range, the inequity aversion model cannot account for the change in contributions with MPCR when $n = 4$. A similar result holds for $n = 5$ data. We conclude that the inequity aversion model cannot account for stylized fact 2 about MPCR.

Group Size implication. Now with respect to the group size, Proposition 1 says that for any given a there should be no effect if $n \leq 1 + 2/a$, provided there is at least one individual with $\beta_i < 1 - a$.[8] Consider the studies with $a = 0.5$ and $n = 4$ or $n = 5$ reported in Table 1. The percentage of positive contributors varies from forty-four percent to fifty-seven percent for studies with $n = 5$ whereas for the studies with $n = 4$ it varies from twenty-seven percent to forty-four percent. Since both $n = 4$ and $n = 5$ are not larger than $1 + 2/0.5 (= 5)$, the inequity aversion model cannot explain the observed shift in the distribution of percentage of positive contributors, hence cannot account for stylized fact 3 about group size.

Endowment implication. The "if condition" in Proposition 1 is satisfied in the Andreoni 1988, 1995a experiments and therefore this proposition applies to data from the experiments. We use round ten data from the "strangers" treatment in Andreoni 1988 and the "regular" treatment in Andreoni 1995a. The only difference between these treatments is that the strangers treatment uses the homogeneous endowment of fifty while the regular treatment uses the homogeneous endowment of sixty. Empirical cumulative distributions for data from the two treatments are shown in Figure 4. The inequity aversion model predicts that all contributions equal zero, independently of the endowment, hence that there will be no endowment effect on the level of contributions. The average of the positive contributions is twenty when the endowment is fifty and twenty-nine when the endowment is sixty. These means are significantly different, with one-sided p-value of 0.06. The Epps-Singleton test on the empirical cumulative distributions detects a significant difference with p-value of 0.06. We conclude that the inequity aversion model cannot account for stylized fact 4 about endowments.

4.2 The egocentric other-regarding preferences model

The egocentric other-regarding preferences model (Cox and Sadiraj 2003) is similar to the Andreoni and Miller (2002) model in that it represents altruistic preferences in which one's own as well as others' payoffs are goods (for which more is preferred to less). In addition, this model can incorporate reciprocity naturally by allowing the altruism coefficient to depend on another person's prior behavior (or revealed intentions), as in the two-player version of the model in Cox, Friedman and Gjerstad (in press).

The egocentric other-regarding preferences model is based on the assumption that agent i has preferences over her own payoff y_i and $n-1$ others' payoffs y_j, $j \neq i$, that can be represented by constant elasticity of substitution (CES) utility functions. For the special case $n = 2$, other-regarding preference parameter θ_1, and elasticity coefficient α_1 strictly between 0 and 1, the utility function for agent 1 can be written as

$$u_1(y_1, y_2) = y_1^{\alpha_1} + \theta_1 y_2^{\alpha_1} \tag{4}$$

Figure 3 shows typical indifference curves for utility function (4). The indifference curves are strictly convex to the origin and (everywhere) have negative slopes. The egocentricity property means that for any positive values of y_1 and y_2, such that $y_1 = y_2$, and any positive value of ϵ, individual 1 prefers the outcome in which he gets $y_1 + \epsilon$ and individual 2 gets $y_2 - \epsilon$ to the outcome in which he gets $y_1 - \epsilon$ and the other gets $y_2 + \epsilon$. Egocentricity implies that $\theta < 1$, hence that the slopes of indifference curves are less than -1 where they cross the 45-degree line.

In general, egocentric other-regarding preferences can be represented by the family of utility functions:

$$u_i(y) = \frac{1}{\alpha_i}\left(y_i^{\alpha_i} + \theta_i \sum_{j \neq i} y_j^{\alpha_i}\right), \text{ if } \alpha_i \neq 0 \tag{5}$$
$$= y_i \prod_{j \neq i} y_j^{\theta_i}, \text{ if } \alpha_i = 0.$$

In the special case in which $\alpha = 0$, the CES preferences are Cobb-Douglas, as shown on the second line of statement (5).[9] Given that $\theta_i > 0$, utility function $u_i(y)$ has the classical regularity properties of strict convexity and strict positive monotonicity for all (positive, zero, *and* negative) values of the convexity parameter α_i such that $\alpha_i < 1$. In summary, egocentrity, strict positive monotonicity, and strict convexity imply the parameter restrictions $\alpha_i < 1$ and $0 < \theta_i < 1$, for all i.

The egocentric other-regarding preferences model has the following implications for the final period of a voluntary contributions public good game. (A proof is in appendix A.2.)

Proposition 2 *The egocentric other-regarding preferences model predicts outcomes for a linear public good experiment that depend on the rate of return a, the size of the group n and the individual preference parameters θ_r and α_r, as follows.*

1. *If $\theta_r \leq \frac{1/a-1}{n-1}$ for all individuals r then there are no asymmetric equilibria. In addition if the assumption is satisfied with strict inequality for at least one individual then the unique Nash equilibrium is for all contributions to equal 0.*

2. *If $\theta_r \geq \frac{1/a-1}{n-1}$ for all individuals r then there are no asymmetric equilibria. Furthermore if the condition is satisfied with strict inequality for at least one individual then the unique Nash equilibrium is for all contributions to equal w.*

3. *If neither the condition in part 1 nor the condition in part 2 is true then there are no symmetric equilibria. In any asymmetric equilibrium, individuals with $\theta_i > \frac{1/a-1}{n-1}$ make positive*

contributions whereas the ones with $\left(\frac{1}{a}+1\right)^{1-\alpha_j}\theta_j < \frac{1/a-1}{n-1}$ *contribute* 0.

Proposition 2 has the following implications for the data patterns described in the stylized facts.

Contributions implication. In all of the studies reported in Table 1, $\frac{1/a-1}{n-1}$ takes values from 0.25 to 0.78. Since $\theta_i \in (0,1)$, conditions in parts 1 and 2 of Proposition 2 are not likely to be met. Indeed, none of the experiments reported in Table 1 include observations where all subjects contributed either 0 or w. This reveals that part 3 of the proposition is relevant. According to part 3, an individual's optimal contribution will be positive or zero, depending on the ratio $(1/a-1)/(n-1)$ as well as the individual's other-regarding preference parameters θ_i and α_i. The group of experiments reported in Table 1 shows substantial numbers of individuals making both positive and zero contributions, which is consistent with part 3 of the proposition. We conclude that the egocentric other-regarding preferences model can account for stylized fact 1 about contributions.

MPCR implication. Everything else equal, if a increases then $\frac{1/a-1}{n-1}$ decreases, and therefore the fraction of individuals with $\theta_i > \frac{1/a-1}{n-1}$ increases. Part 3 of Proposition 2 implies that there will be more individuals with positive contributions as a increases. Furthermore, for any given $\alpha_j < 1$, if a increases then $\frac{1/a-1}{n-1}\left(\frac{1}{a}+1\right)^{\alpha_j-1}$ decreases. Part 3 of the proposition then implies that there will be fewer individuals with $(1/a+1)^{1-\alpha_j}\theta_j < (1/a-1)/(n-1)$ who are predicted to contribute nothing to the public good. Hence both effects imply that the number of free riders is expected to decrease. This is consistent with the observed effect of increasing a on the share of positive contributions reported in Table 1. The percentage of positive contributions for groups of size five increases from eleven percent in the study with $a = 0.33$ (row 10 in Table 1) to the average of fifty-two percent in studies with $a = 0.5$ (rows 1-3 in Table 1). Looking at the studies with group size four, we find a similar effect of increasing a on the percentage of positive contributors, the average increases from twenty-eight to thirty-five. We conclude that the egocentric other-regarding preferences model can account for stylized fact 2 about MPCR.

Group Size implication. Everything else equal, if n increases then $(1/a-1)/(n-1)$ decreases, and therefore the fraction of individuals with $\theta_i > (1/a-1)/(n-1)$ may increase. If that happens then part 3 of Proposition 2 implies that there will be more individuals with positive contributions. The same part of the proposition implies that there will be fewer individuals with $(1/a+1)^{1-\alpha_j}\,\theta_j < (1/a-1)/(n-1)$ who are predicted to contribute nothing to the public good. Thus the expected total effect of a larger n is a higher percentage of positive contributions. In the studies with $a = 0.5$ reported in Table 1, the percentage of positive contributions varies from forty-four percent to fifty-seven percent for studies with $n = 5$ whereas for the ones with $n = 4$ it varies from twenty-seven percent to forty-four percent. This is consistent with the egocentric other-regarding preferences model's predictions. We conclude that the egocentric other-regarding preferences model can account for stylized fact 3 about group size.

Endowment implication. Utility functions in statement (5) for the egocentric other-regarding preferences model are homogenous in payoffs. Payoff functions in equation (1) for linear public good games are linear. With endowments that are the same for all subjects, the composition of a utility function and payoff functions is homogenous in the common endowment w. As shown in appendix A.3, this homogeneity property implies that the equilibrium contribution proportions $g_i(w)/w$ at endowment w are the same as the equilibrium contribution proportions $g_i(\omega)/\omega$ at endowment ω for all positive w and ω.This in turn immediately implies that $g_i(\omega) > g_i(w)$ for all $\omega > w$. We use round ten data from the strangers treatment in Andreoni 1988 and the regular treatment in Andreoni 1995a, shown in Figure 4 to test two hypotheses. The Epps-Singleton test of the hypothesis that the proportional amounts sent at endowment levels of fifty and sixty are equal ($g_i(50)/50 = g_i(60)/60$) is not rejected at conventional significance levels (p-value = 0.15). We conclude that the egocentric other-regarding preferences model can account for stylized fact 4 about endowments.

5 CONCLUDING REMARKS

Traditional microeconomic and game-theoretic models of self-regarding (or "economic man") preferences imply zero contributions by all subjects in the last round of finitely-repeated voluntary contributions games. This is not observed, hence new theory is needed. We discuss the implications of two recent models of social preferences for voluntary contributions to a public good. The egocentric other-regarding preferences model incorporates the classical preference properties of strict convexity and strict positive monotonicity. The inequity aversion model has neither of these regularity properties. The egocentric other-regarding preferences model is more successful in rationalizing data from public goods experiments than is the inequity aversion model.

The inequity aversion model (Fehr and Schmidt 1999) predicts contributions of 0 as a unique Nash equilibrium for voluntary contributions in ordinary, one-stage public good experiments. In a large number of many-period experiments that we survey (see Table 1), final period contributions are positive for about thirty-eight percent of the subjects. Furthermore, the inequity aversion model has the same implications for these public good experiments as does the traditional self-regarding (or "economic man") model. We conclude that neither the economic man model nor the inequity aversion model can explain behavior in ordinary public goods experiments that is characterized by a high proportion of hetergenously-positive individual contributions.[10] Furthermore, the inequity aversion model cannot account for the other three stylized facts for data from linear public good experiments.

The egocentric other-regarding preferences model has both symmetric and asymmetric Nash equilibria. The asymmetric equilibria are consistent with typical data from linear public good experiments in which many subjects contribute zero and many make positive contributions that are less than their endowments. This model can account for the four stylized facts from linear public good experiments.

A APPENDIX

A.1 Proof of Proposition 1

Proof. Part 1. Consider any vector g with non-identical contributions. Let agent i be one of the individuals with the largest contribution in g. That is, there are no contributions larger than g_i. Since the contributions are not identical, there exists at least one individual j with a smaller contribution than g_i. These statements imply that agent i's utility is

$$\Gamma_i(g_i, g_{-i}) = w - g_i + aG - \alpha_i \frac{1}{n-1} \sum_{j \neq i} (g_i - g_j).$$

Suppose that agent i deviates and offers slightly less than g_i , say he offers $g_i - \delta$ where δ is such that $g_i - \delta$ is strictly greater than the second highest contribution in g.[11] In this case, let k_i^-(≥ 1) be the number of smaller contributors, and k_i^+ the number of individuals in the group whose contribution is g_i. Note that $k_i^- \geq 1$ and therefore $(*)$ $0 \leq k_i^+ \leq n-2$. The utility of agent i in this case is

$$\Gamma_i(g_i - \delta, g_{-i}) = w - (g_i - \delta) + a(G - \delta) - \alpha_i \frac{1}{n-1} \sum_{j: g_i - \delta > g_j} (g_i - \delta - g_j) - \beta_i \frac{k_i^+}{n-1} \delta$$

Straightforwardly, the difference in utilities is

$$\Gamma_i(g_i - \delta, g_{-i}) - \Gamma_i(g_i, g_{-i}) = \delta(1 - a + \alpha_i \frac{k_i^-}{n-1} - \beta_i \frac{k_i^+}{n-1})$$

which is positive if $(1-a)(n-1) > \beta_i k_i^+ - \alpha_i k_i^-$. Inequalities $(*)$ and $\beta_i \leq \alpha_i$ imply $\beta_i k_i^+ - \alpha_i k_i^- \leq \beta_i(n-2) - \alpha_i < \beta_i(n-3)$. Hence a sufficient condition for agent i to be better off in case of contributing $g_i - \delta$ is $\beta_i < (1-a)(n-1)/(n-3)$ which is true by assumption.

It can be straightforwardly shown that similar result holds for $n \leq 3$

Part 2. To start with, note that the vector of zero contributions, $(0, ..., 0)$ is a Nash Equilibrium. Indeed, in this case the utility of any agent is simply ω and any unilateral deviation from it, necessarily involving a strictly positive contribution, say $g_i = \varepsilon > 0$ results in $\Gamma_i(g_i, 0) = w - \varepsilon + a\varepsilon - \alpha_i\varepsilon$ which is smaller than w. Now let g be a vector of identical positive contributions, $g_j = z > 0$ for all $j = 1...n$. The utility of some agent i is $\Gamma_i(z, z) = w + (na - 1)z$ whereas in case of investing less than z, say $z - \varepsilon$, $\varepsilon \in (0, z]$, agent i's utility becomes $\Gamma_i(z - \varepsilon, z) = w - z + \varepsilon + a(nz - \varepsilon) - \beta_i\varepsilon = U_i(z, z) + \varepsilon(1 - a - \beta_i)$. This implies that if there is an agent with $\beta_i < 1 - a$ then he is better off by contributing less than z and therefore $g = (z, z, ..., z)$ is not a Nash equilibrium, so part *2.a* is shown. On the other hand if $\beta_i \geq 1 - a$, for all i then the last equality implies that nobody is better off by deviating down. Similarly, as for the vector of zero contributions, $(0, ..., 0)$ it can be shown that deviating up cannot increase utility. This concludes the proof for part *2.b*. ■

A.2 Proof of Proposition 2

Let each agent be endowed with amount w of the private good that can be consumed or contributed as input in amount g_j, $j = 1, 2, ..., n$, to production of the public good. Let $G \equiv g_1 + g_2 + \ldots + g_n$ denote the total contribution to the public good. Then the utility, $\Upsilon_i(g)$ of contribution profile $g = (g_i, g_{-i})$ to agent i is

$$\begin{aligned}
\Upsilon_i(g) &= \frac{1}{\alpha_i}\left((w - g_i + aG)^{\alpha_i} + \theta_i \sum_{j \neq i} (w - g_j + aG)^{\alpha_i}\right), \text{ if } \alpha_i \neq 0 \qquad (6) \\
&= (w - g_i + aG) \prod_{j \neq i} (w - g_j + aG)^{\theta_i}, \text{ if } \alpha_i = 0
\end{aligned}$$

Utility function (6) is used to prove the following proposition.

Proof. Let $g = (g_1, \ldots, g_n)$ be a vector of contributions to the public good. Consider some agent r. Differentiating the utility function (6) of agent r if $\alpha \neq 0$, with respect to her own contribution g_r, one finds that the partial derivative is $(a-1)y_r^{\alpha_r - 1} + a\theta_r \sum_{j \neq r} y_j^{\alpha_r - 1}$ where $y_k = (w - g_k + aG)^{\alpha_k - 1}, k \in \{j, r\}$. The sign of the partial derivative then is determined by

$$F(g_r, g_{-r}) \equiv -1 + \frac{a}{1-a}\theta_r \sum_{j \neq r} (\frac{y_r}{y_j})^{1-\alpha} \tag{7}$$

If $\alpha = 0$ for agent r, the sign of the agent's marginal utility is given by substituting $\alpha = 0$ in (7).

Part 1: $\theta_r \leq \frac{1/a-1}{n-1}$, for all $r = 1, ..., n$. *We show first that there are no asymmetric equilibria, and then we show that if the inequality is strict for at least one agent then* $g = (0, 0, \ldots, 0)$ *is the unique Nash equilibrium.*

Let a vector of contributions g be given. Suppose that g is an asymmetric vector. Let some player i be one of the highest contributors. Hence $\frac{y_i}{y_j} \leq 1, \forall j \neq i$ and $\frac{y_i}{y_j} < 1$, for at least one $j \neq i$ which is true by asymmetry of g. This and the assumption that $\theta_i \leq \frac{1/a-1}{n-1}$ imply that the sign of (7) at (g_i, g_{-i}) is negative since $F(g_i, g_{-i}) < (n-1)\theta_i a/(1-a) - 1 \leq 0$. Therefore g cannot be an equilibrium.

Suppose that g is symmetric. Then for any given r one has $\frac{y_r}{y_j} = 1, \forall j \neq r$. Let i be an agent for whom $\theta_i < \frac{1/a-1}{n-1}$. Then for that agent i one has $F(g_i, g_{-i}) = (n-1)\theta_i a/(1-a) - 1 < 0$, and therefore g cannot be in equilibrium unless $g = (0, 0, \ldots, 0)$.

Part 2: $\theta_r \geq \frac{1/a-1}{n-1}$, for all $r = 1, ..., n$. *We show first that there are no asymmetric equilibria, and then we show that if the inequality is strict for at least one agent then* $g = (w, w, \ldots, w)$ *is the unique Nash equilibrium.*

Let a vector of contributions g be given. Suppose that g is an asymmetric vector. Let some player i be one of the lowest contributors. Hence $\frac{y_i}{y_j} \geq 1$, $\forall j \neq i$ and $\frac{y_i}{y_j} > 1$, for at least one $j \neq i$ which is true by asymmetry of g. This and the assumption that $\theta_i \geq \frac{1/a-1}{n-1}$ imply that the sign of (7) at (g_i, g_{-i}) is positive since $F(g_i, g_{-i}) > (n-1)\theta_i a/(1-a) - 1 \geq 0$. Hence g cannot be an equilibrium.

Suppose that g is symmetric. Then for any given r one has $\frac{y_r}{y_j} = 1$, $\forall j \neq r$. Let i be an agent for whom $\theta_i > \frac{1/a-1}{n-1}$. Then for that agent i one has $F(g_i, g_{-i}) = (n-1)\theta_i a/(1-a) - 1 > 0$, and therefore g cannot be an equilibrium unless $g = (w, w, \ldots, w)$.

Part 3. By assumption the subsets of players $I = \{i \mid \theta_i > \frac{1/a-1}{n-1}\}$ and $J = \{j | \ \theta_j < \frac{1/a-1}{n-1}\}$ are not empty. Then there are no symmetric equilibria. Indeed, for any symmetric vector of contributions individuals from I are better off by deviating up, as part 2, shows whereas individuals from J are better off by deviating down, as part 1 shows. That individuals with $\theta_i > \frac{1/a-1}{n-1}$ make positive contributions follows from part 2 where it is shown that such individuals cannot be among minimal contributors. Since the minimum contribution is nonnegative, the contribution of such individuals must be positive. Furthermore, in any asymmetric equilibrium g, individuals with parameters such that $\left(\frac{1}{a} + 1\right)^{1-\alpha_j} \theta_j < \frac{1/a-1}{n-1}$ will make zero contributions since for any positive contribution g_j one has $F(g_j, g_{-j}) < 0$, which follows from

$$\begin{aligned}
F(g_j, g_{-j}) &= \frac{a}{1-a}\theta_j \sum_{r \neq j} (\frac{y_j}{y_r})^{1-\alpha_j} - 1 \\
&= \frac{a}{1-a}\theta_j \sum_{r \neq j} (\frac{w - g_j + aG}{w - g_r + aG})^{1-\alpha_j} - 1 \\
&\leq \frac{a}{1-a}\theta_j \sum_{r \neq j} (1 + \frac{1}{a})^{1-\alpha_j} - 1 \\
&= \frac{a}{1-a}\theta_j (n-1)(1 + \frac{1}{a})^{1-\alpha_j} - 1.
\end{aligned}$$

■

A.3 Proof of the Endowment Effect

Proof. Let the initial endowment w be the same for all agents. We show that the amount of the initial endowment:

1. has no effect on individual contributions as a percentage of the endowment;

2. has a positive effect on the absolute contributions of individuals.

First note that

$$\Upsilon_i(w, g) = w^{\rho_i} \Upsilon_i(1, \gamma) \tag{8}$$

where $\gamma = g/w$ and $\rho_i = \alpha_i$ if $\alpha_i \neq 0$ and $\rho_i = 1 + (n-1)\theta_i$ if $\alpha_i = 0$.

Indeed, denoting $G = \sum_{r=1..n} g_r$ one has

- if $\alpha_i \neq 0$ then

$$\Upsilon_i(w, g) = \frac{w^{\alpha_i}}{\alpha_i} \left(\left(1 - \frac{g_i}{w} + a\frac{G}{w}\right)^{\alpha_i} + \theta_i \sum_{j \neq i} \left(1 - \frac{g_j}{w} + a\frac{G}{w}\right)^{\alpha_i} \right) = w^{\alpha_i} \Upsilon_i(1, \gamma)$$

- if $\alpha_i = 0$ then

$$\Upsilon_i(w, g) = w^{1+(n-1)\theta_i} \left(1 - \frac{g_i}{w} + a\frac{G}{w}\right) \prod_{j \neq i} \left(1 - \frac{g_j}{w} + a\frac{G}{w}\right)^{\theta_i} = w^{1+(n-1)\theta_i} \Upsilon_i(1, \gamma)$$

Next, statement (8) implies that, for a given positive w, γ_i^* maximizes $\Upsilon_i(1, \gamma)$ if and only if $w \times \gamma_i^*$ maximizes $\Upsilon_i(w, g)$, for $i = 1, ..n$. Hence, γ^* is an equilibrium vector of individual contributions when the initial endowment is 1 if and only if, for any given w, the vector of individual contributions $g^*(w) = w \times \gamma^*$ is an equilibrium when the initial endowment is w. Thus, for any given equilibrium contributions $g^*(\omega)$ at endowment ω there exist equilibrium contributions $g^*(v)$ at endowment v

such that

$$\frac{g^*(\omega)}{\omega} = \frac{g^*(v)}{v}.$$

The last statement implies that the amount of the endowment: (1) has no effect on contributions as a percentage of the endowment; and (2) has a positive effect on the absolute contributions. ■

Notes

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[1]$MPCR$ (Isaac, Walker, and Thomas 1984) is defined as the product of the marginal rate of substitution and the marginal rate of transformation. Agent i has endowment w^i and contributes g^i to the public good. With production function φ and utility function is u^i, the marginal return can be derived from $u^i(w^i - g^i, \varphi(\sum g^j))$. This implies $MPCR = \left(u_2^i/u_1^i\right)\varphi_z$ (Ledyard (1995, 44).

[2]The "hard-nosed" game theory predictions that Ledyard discusses are ones derived from purely-selfish preferences.

[3]"Warm-glow" altruism means that people give just for the event of giving.

[4]For a discrete set of contributions, the upper bound is $\beta_i(\frac{n-2}{n-1})\delta$. (See footnote 11 in appendix A.1 for details.)

[5]According to the distribution reported by Fehr and Schmidt, 60% of the population has $\beta < 0.5$. Therefore in all groups of size 4 and larger, $\beta < 0.5$ is expected to be true for at least two individuals.

[6]The Kolmogorov-Smirnov test of the hypothesis that all contributions are zero implies rejection of the hypothesis with p-value of 0.000.

[7]If $a \in (\frac{1}{n}, \frac{2}{n-1}]$ then $\frac{n-1}{n-3}(1-a) \geq 1$ and therefore the if condition in Proposition 1 is satisfied since $\beta_i \leq 1$ for all i. If the feasible set of contributions is discrete (as it is in an experiment) then for the empirical distribution of $\beta_i (\leq 0.6$ for all $i)$ as reported by Fehr and Schmidt (1999), the range of a for which no effect is expected is $(\frac{1}{n}, \frac{2n+1}{5(n-1)}]$ since that implies $\frac{n-1}{n-2}(1-a) \geq 0.6$.

[8]If $n \leq 1 + \frac{2}{a}$ then $\frac{n-1}{n-3}(1-a) \geq 1$ and therefore the if condition in Proposition 1 is satisfied since $\beta_i \leq 1$ for all i. If the feasible set of contributions is discrete (as it is in an experiment) then for the empirical distribution of $\beta_i (\leq 0.6$ for all $i)$ as reported by Fehr and Schmidt (1999), no effect is expected for $n \leq 2 + \frac{1-a}{a-0.4}$ if $a > 0.4$ since that implies $\frac{n-1}{n-2}(1-a) \geq 0.6$. If $a \leq 0.4$ then there is no effect expected for any $n \geq 2$ since the left-hand-side of the last inequality is always true.

[9]$u_i(y)$ for $\alpha_i \neq 0$ converges pointwise as $\alpha_i \to 0$ to the Cobb-Douglas utility function $y_i \prod_{j \neq i} y_j^{\theta_i}$. The proof is similar to that for $n = 2$ in Cox, Friedman, and Gjerstad (in press).

[10]Fehr and Schmidt (1999) report that they can rationalize data from the public good experiment by Fehr and Gächter (2000) that includes a second stage with an opportunity for punishing free riders that is costly but reduces inequality. But data from a later experiment do not support inequality aversion as an explanation of punishing behavior in two-stage extended public good experiments. In the Bosman, et al. (2004) experiment, each monetary

unit cost imposed on the punishee costs the punisher one unit. Nevertheless punishment of under-contributors is observed. Such punishing behavior can be explained by negative reciprocity but it cannot be explained by inequality aversion.

[11] In case of a discrete choice set, and the only feasible contribution smaller than g_i and larger than the second highest is the second highest, nothing changes in the proof as long as there are at least three different levels of contributions in g. If not then the condition becomes $\beta_i < (1-a)(n-1)/(n-2)$. Referring to the parameter distribution reported by Fehr and Schmidt, $\beta_i \leq 0.6$ for all i. It can be easily checked that $(1-a)\frac{n-1}{n-2} > 0.66$ for all experiments reported in Table 1.

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Study	Group Size (n)	Marginal Return (a)	Positive contributors[a] (percent)
Andreoni 1988	5	0.5	44
Andreoni 1995a	5	0.5	55
Andreoni 1995b	5	0.5	57
Croson 1996	4	0.5	35
Croson forthcoming	4	0.5	27
Isaac, Walker and Thomas 1984	4	0.3	25
Isaac, Walker and Williams 1994	4	0.3	31
Keser and van Winden 2000	4	0.5	44
Laury and Petrie 2005	4	0.4	38
Ockenfels and Weiman 1999	5	0.33	11

Table 1.Percentage of positive contributors in the last round

a. Reported figures are constructed from data on free riders in the first and second rows of Table 2 in Andreoni (1988), the first row (regular condition) of Table 2 in Andreoni (1995a), the third row (positive framing) of Table 2 in Andreoni (1995b), Appendix 1 (experiments 1 and 2) in Isaac, Walker and Thomas (1984), the "Data Archives" of Isaac, Walker and Williams (1994), N=4 on Mark Isaac's homepage, the first and second rows of Table 2 ("end-game" column) in Keser and van Winden (2000), author communications for Croson (1996, forthcoming), author communications for Laury and Petrie (2005), and from Table II in Fehr and Schmidt (1999).

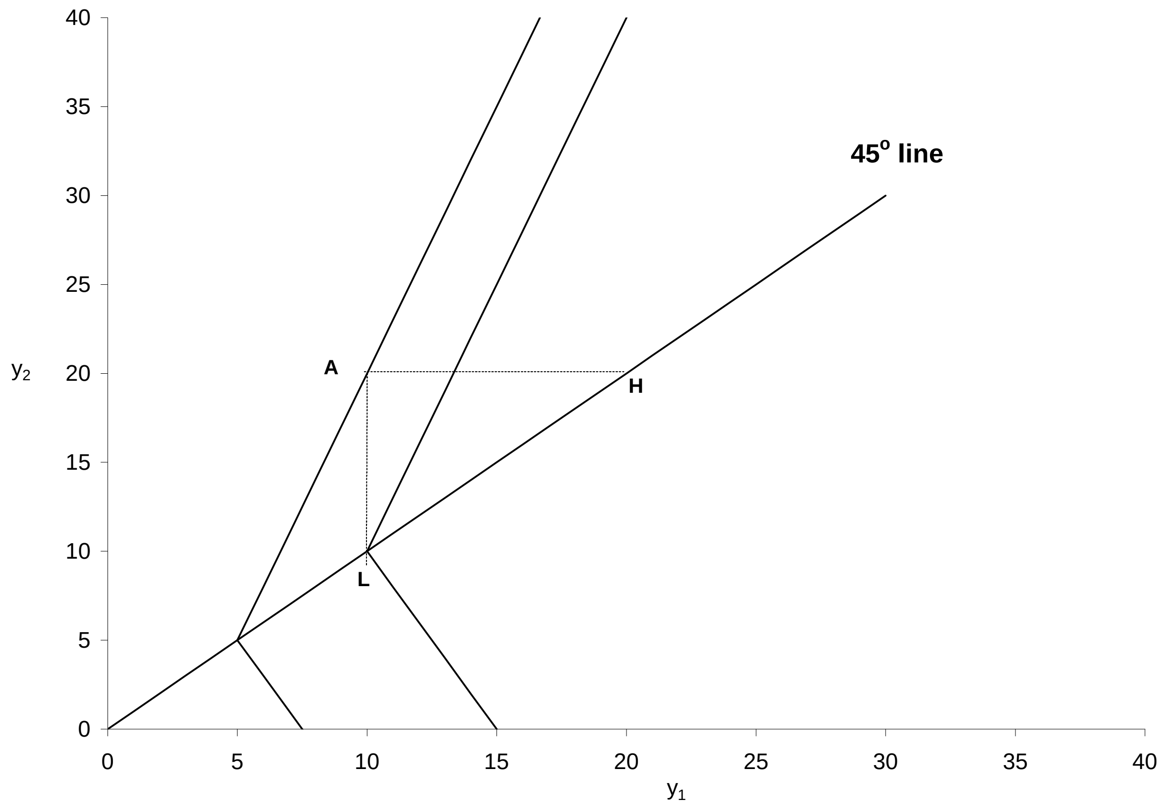

Figure 1: **Indifference curves for the inequity aversion model**

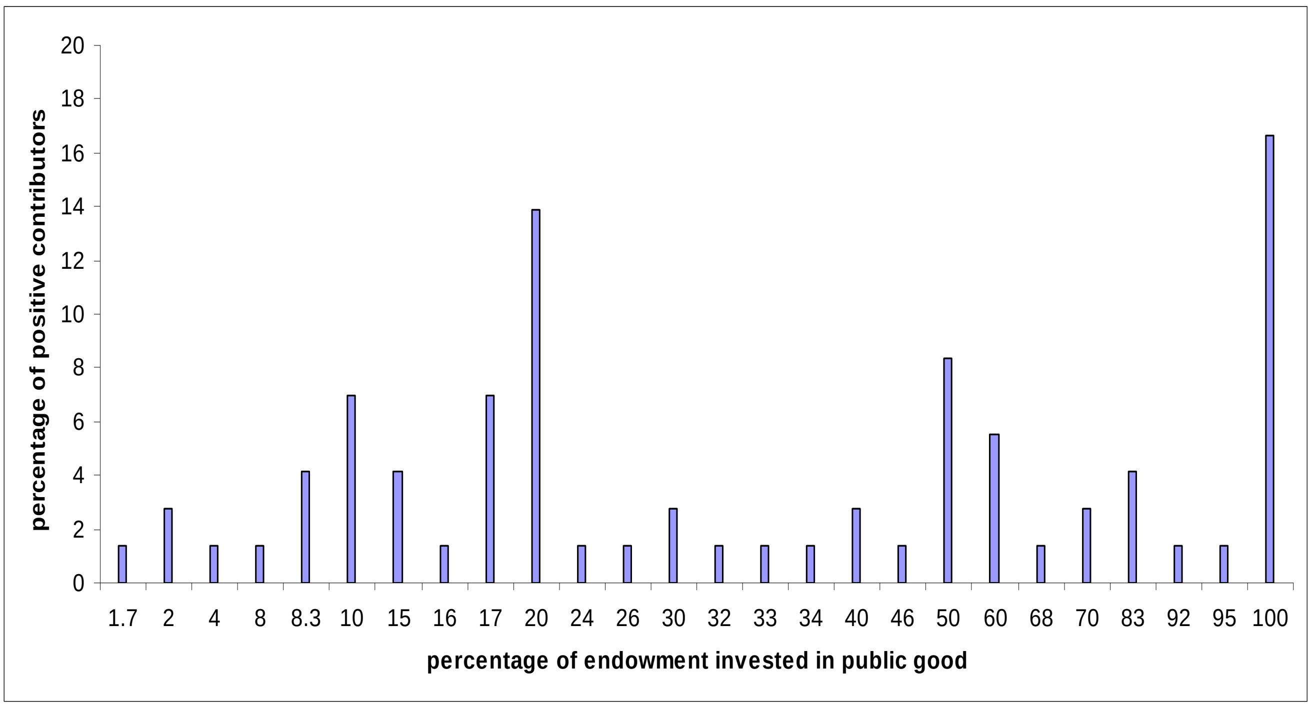

Figure 2: **Distribution of positive contributions**

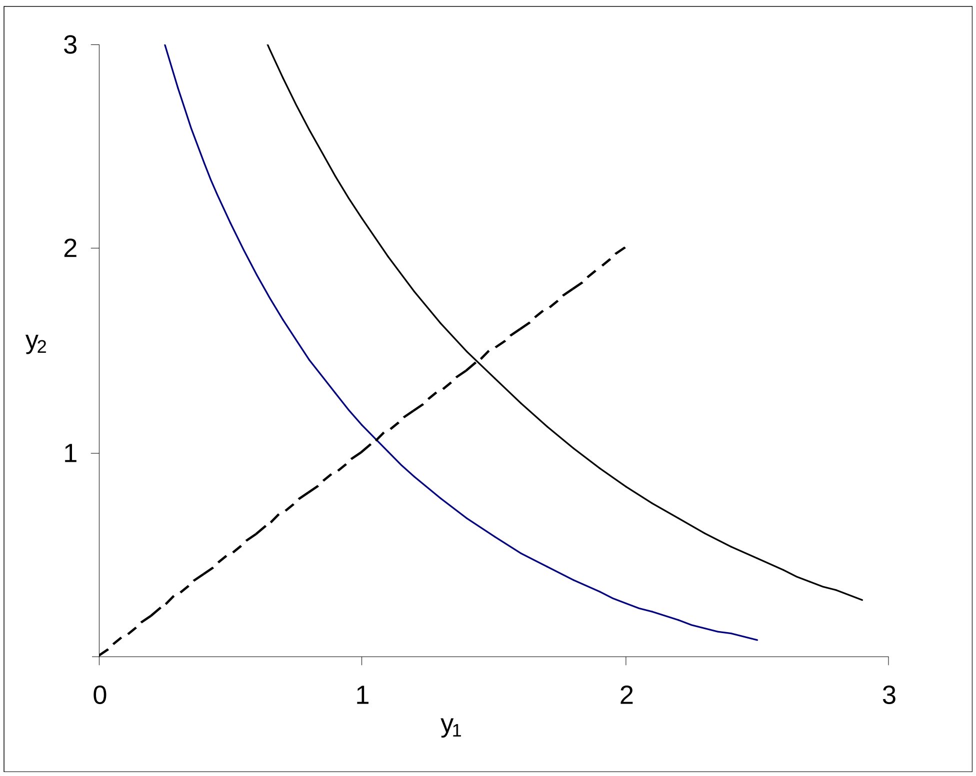

Figure 3: **Indifference curves for the egocentric other-regarding preferences**

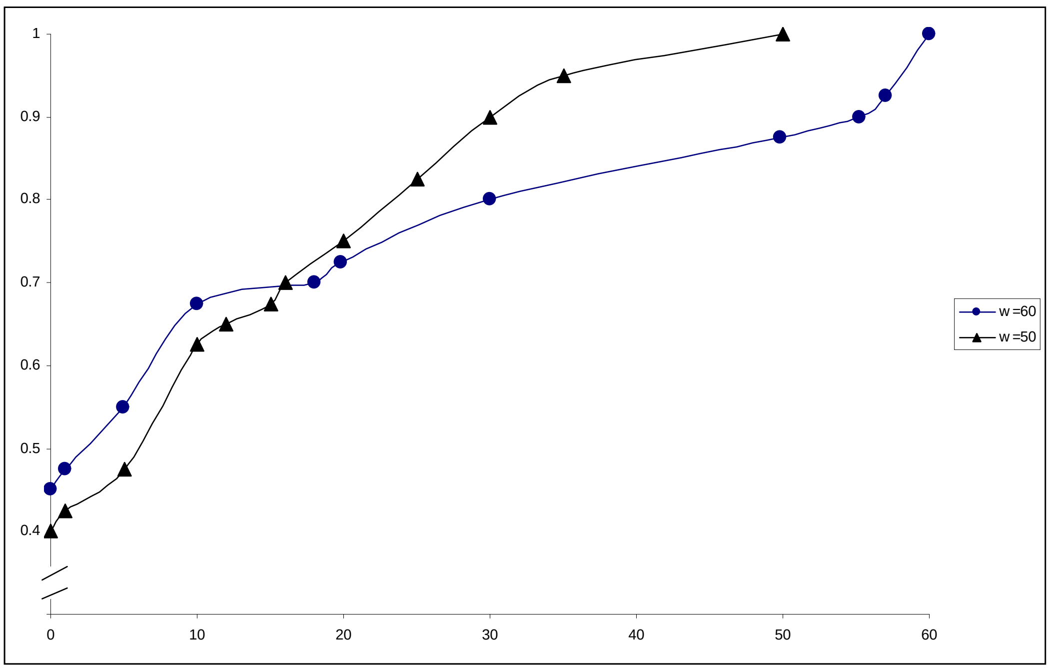

Figure 4: **Cumulative distributions of individual contributions when endowments are 50 or 60**