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Income and wealth heterogeneity in the voluntary provision of linear public goods

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Abstract

This paper examines the effect of income and wealth heterogeneity in the voluntary provision of a linear public good. We use models of inequality aversion and altruism to predict behavior in our setting. Our results are not consistent with these models, however; our experimental results suggest that less wealthy subjects give the same absolute amount (and more as a percentage of their income) as the more wealthy.

JEL classification: C92; H41
Keywords: Linear public good; VCM; Income heterogeneity

1. Introduction

Public goods occupy an important part of consumers' lives and policy-makers' attention. Clean air, streetlights, and national defense affect consumers' daily lives. Policy-makers wrestle with questions surrounding the optimal level of public goods, whether they should be provided voluntarily or through some other mechanism, and the amount that individuals of different income levels should contribute to the public good.

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In this paper we experimentally investigate the voluntary provision of pure public goods when individuals' incomes (wealth) are heterogeneous. We use recent models of inequality aversion (Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999) and a model of altruism (Becker, 1974) to generate hypotheses for observed behavior. Generally these models predict that those with lower incomes or less wealth should give either less absolutely or a lower proportion of their income than the more favored. We find the opposite in our experiment: the poor contribute the same absolutely (or more as a percentage of their income) than their wealthier counterparts.[1]

This experiment models a pure public good; one that is non-rival and non-excludable. Non-rival means that for any given level of production, the use of the good by an additional consumer does not affect the utilization of the good by other consumers. Non-excludable means that it is either impossible or undesirable to exclude consumers from utilizing the good.[2]

Classic economic theory predicts that public goods will not be supplied voluntarily at optimal levels because of the presence of free riding associated with positive externalities. However, public television, the American Red Cross, and numerous other charities provide counterexamples to the traditional economic theory. Thus researchers have concluded that the traditional theory and the observed behavior deviate.

One explanation provided for this deviation involves non-traditional preferences. If consumers care not only about their own consumption (from the public good and their private consumption) but also about the consumption of others, then voluntarily contributing to provide public goods can be equilibrium behavior. Models of non-traditional preferences have included altruism (Becker, 1974), where an individual's utility function includes positively the consumption (or utility) of another; warm-glow altruism (Andreoni, 1995), where altruism is supplemented by additional utility from the warm glow of giving; and inequality aversion (Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999), where individuals dislike unequal net incomes or consumption. Models of inequality aversion have been demonstrated to successfully predict contribution behavior in previous linear public goods experiments.

However, the vast majority of this previous research has involved homogeneous players (exceptions are discussed in Section 2). In contrast, policy-makers are often concerned with the amount that individuals with different incomes will contribute toward public goods. In this paper we examine how individuals with heterogeneous period-by-period laboratory endowments (income) and different stocks of laboratory earnings (wealth) choose to voluntarily provide a linearly supplied, homogeneously valued public good.

[1] Income here is captured by the period-by-period tokens allocated to participants in the experiment (the endowment), and wealth by the accumulated stock of experimental earnings. Thus we assume that the subjects' naturally-occurring income or wealth is not affecting their decisions. For research that investigates the impact of real-world income/wealth on lab behavior, see Cardenas, 2002a,b.

[2] Goods can also be excludable but non-rival, such as a toll road during low traffic periods. The use of the road by one more car will not prevent other consumers from using it; however, the road is excludable because a toll must be paid in order to use it. These are typically called club goods. In addition, goods can be non-excludable but rival, such as a small public beach–as the beach becomes more crowded the enjoyment of being there diminishes. These are typically called congestion goods. A private good is both rival and excludable.

We use the Fehr and Schmidt (1999) model of inequality-aversion and the Becker (1974) model of altruism to generate hypotheses for our experimental setting. The inequality-aversion model predicts that individuals with higher incomes will contribute a higher percentage of their incomes to the public good than individuals with lower income, in an attempt to equalize earnings; while the altruism model predicts that individuals with higher incomes will contribute more absolutely to the public good than individuals with lower income.

Our results, however, are not consistent with either of these predictions. Instead, we observe that individuals with low incomes contribute the same absolute amount (a higher percentage of their income) to the public good than individuals with high incomes. Individuals' behavior, instead of equalizing earnings as the inequality-aversion predict, exacerbates them.

While this result is not consistent with the predictions of models of inequality-aversion in which higher-income donors give a higher percentage, empirical evidence also fails to support these theories. Data from the Social Welfare Research Institute at Boston College shows that in 2000, U.S. families with incomes under $125,000 (91.39% of families in the U.S.) gave an average of 2.34% of their income to charity. There was little variation of giving across incomes with the poorest families, those with incomes under $10,000 giving 2.25% (Giving USA, 2003).[3] Thus low-income families give the same percentage of their income as high-income families.

Section 2 briefly mentions previous public goods experiments that involve individual heterogeneity. Section 3 presents the models of inequality aversion and altruism and derives the hypotheses. Section 4 describes the experimental parameters and implementation. The results are presented in Section 5, and the paper concludes in Section 6.

2. Previous experiments

Ledyard (1995) provides an excellent survey of studies on the provision of public goods in an experimental setting. In this section, we describe previous experiments which have involved subject heterogeneity in some manner.

Our setting will involve a linear public good. In this setting, the value provided to individuals by the public good is a linear function of how much of the public good is provided. Thus the MPCR (the ratio of the private value of one unit of the public good to the private value of the private good needed to provide that unit) is constant. When the MPCR is less than one, the linear public good game has a unique equilibrium (assuming pure self-interest) of full free riding (zero contribution to the public good). When the MPCR is greater than $1/N$ (where N is the number of people who enjoy the public good), then the efficient outcome is full contribution to the public good. When both conditions are

[3] There are multiple types of charitable giving included in these gross statistics, including giving which supports public goods that the donor in part enjoys (e.g. giving to public radio), and giving to causes which are purely charitable, and which produce either no public goods or public goods which the donor does not himself consume. The VCM is clearly more applicable to the former, while dictator giving is likely to be a better model of the latter.

met, we say there is a *public good problem*, as the amount that would be voluntarily contributed in equilibrium is not societally efficient.

While many experiments have been run using this paradigm (in fields as diverse as political science, psychology, sociology and anthropology as well as economics), almost all have involved homogeneous actors. Participants in the experiment are arranged into groups and given equal incomes and MPCRs.

Two previous papers have explicitly used heterogeneous incomes in VCM experiments. Isaac and Walker (1988) examined the effect of communication in VCM games, in the presence of symmetric and asymmetric incomes. The authors found that levels of contributions in experiments with asymmetric incomes were less than levels of contributions in experiments with symmetric incomes, but the comparisons are made only after ten rounds of the VCM game with communication. Furthermore, this paper does not provide a comparison of how much the less-endowed and more-endowed subjects contributed. Kachelmeier and Shehata (1997) also used heterogeneous incomes in their experiment comparing behavior with and without monitoring in Canada, Hong Kong and China. However, they similarly do not report contributions of differently endowed subjects.

Two papers examine heterogeneity in VCM games along different dimensions. Fisher et al. (1995) examined behavior in a public goods setting in which subjects had identical incomes but heterogeneous *valuations* for the public good (different MPCRs). The study concluded that there was a strong effect of an individual's own valuation on his/her contribution to the public good.[4] Anderson et al. (2003) also examined the question of inequality and contributions to a linear public good. They induced inequality by offering participants different fixed payments via the show-up-fee for the experiment. Results indicated that group contributions decrease when show-up fees are asymmetric and known.

Two papers, Cardenas (2002a,b), have examined the effect of real wealth on cooperation in the experimental environment. In these experiments villagers in rural Columbia who knew each other and the level of the each other's real (outside) wealth were brought together in an experimental environment to explore how wealth heterogeneity would affect utilization of a common resource. Both papers found that increased inequality among the group members resulted in reduced levels of contribution.

Although we are the first to report on the impact of heterogeneous incomes on individual contributions in linear public good settings (VCMs), others have examined this question in nonlinear settings. While these experiments also involve public goods provision, they often have very different equilibrium predictions than the VCM. In a non-linear public good, the MPCR changes as the level of contribution changes. These games typically involve internal equilibria, where (assuming pure self-interest) groups should contribute some positive amount (which may be less than or equal to the social optimum). These games are thus often modeled as games of coordination as well as games of cooperation—the problem the group faces is not simply how much to contribute, but who should contribute how much in order to reach the equilibrium contribution.

[4] In common pool resource setting Cardenas et al. (2002) also introduced heterogeneity by varying the valuations of the private good. They found that individuals with higher valuations of the private good put less pressure on the common resource.

Three experimental papers have investigated the impact of heterogeneous incomes on voluntary provision of public goods in nonlinear settings. The first, Chan et al. (1996) used a continuous but non-linear public good. They found that an increase in income inequality led to higher overall contributions to the public good, as predicted by the (purely self-interested model of) Bergstrom et al. (1986).[5] A second paper by Chan et al. (1999) examined the effects of income heterogeneity on the provision of a non-linear public good with incomplete information and communication. They found that contributions of the heterogeneous groups were greater than the contributions of the homogeneous groups.

In a third paper, Rapoport and Suleiman (1993) used a threshold public good setting (a PPM).[6] In this setting, individuals voluntarily contribute to the public good. If enough contributions are collected the public good is provided; otherwise it is not. They found that heterogeneously endowed groups were less successful in the provision of the threshold public good than homogeneously endowed groups. Further, the study found that the players contributed the same percentage of their income to the public good regardless of that income level.[7]

One final paper uses yet a third public goods setting, that of a common pool resource. In their CPR study Hackett et al. (1994) found that open communication between differently endowed players increased the rents that the players earned. A more complete discussion of heterogeneity in CPR games can be found in Ostrom et al. (1994).

Thus while other research has addressed the impact of heterogeneity of incomes on group contributions in VCM games, we are the first to explicitly examine the effects of heterogeneous incomes on individual contribution behavior in these games.

3. Model and hypotheses

Models of pure self-interest cannot explain the contribution behavior typically observed in these settings as discussed in Ledyard (1995). However, a number of competing models have been developed which are consistent with observed behavior in these games.

The first type of model is altruistic. Becker (1974) models a utility function that is comprised of two elements: the actor's own wealth and the wealth of other members of the group. The utility function increases as the actor's wealth increases and as the wealth of the other group members increases. This model predicts that individuals with a high income will contribute more, in an absolute sense, to the public good than individuals with a low income. (See Appendix 2 for a proof)

[5] The Bergstrom, Blume and Varian model predicts that players with higher income should contribute more, and that such inequality should increase group contributions. Not all of the empirical findings of the paper agreed with the theoretical conclusion of this model. However, the authors did find that contributions of the heterogeneous groups were greater than the contributions of the homogeneous groups.

[6] Rondeau et al. (2003) in a meta-analysis of voluntary contribution (VCM) and provision point (PPM) mechanisms find that in general PPM increases total contributions and is more efficient than VCM.

[7] Other papers have examined heterogeneity in other aspects of the provision of non-linear public goods. Isaac et al. (1985) studied the effect of heterogeneous valuations of the public good on homogeneously endowed players in a non-linear but continuous setting. Croson and Marks (1999) investigated the provision of threshold public goods using players with heterogeneous valuations but homogeneous incomes.

The second type of model is inequality-aversion. Two recent papers model a decision-maker whose utility function increases in the equality of the payoffs of all the players. Fehr and Schmidt (1999) use a function where utility decreases (asymmetrically) when an actor earns either more or less than the average group payoff. Bolton and Ockenfels (2000) use a function that combines self-interest with concern for relative standing. These models have the same predictions in our setting–individuals with higher income or wealth should contribute a larger share of their income to the public good than those with lower income or wealth. (See Appendix 3 for a proof)

The experiment is designed to test the implications of these models. There are three hypotheses that will be tested in the experiment.

First, we predict that results from this experiment will be consistent with those in previous research. In particular,

H1. Group contributions will be positive but will decrease over the course of the experiment.

The second hypothesis comes from the altruism model above.

H2. Individuals with a high income will contribute a larger amount of their per-period income to the public good than subjects with a low income.

The third hypothesis comes from the inequality-aversion model above.

H3. Individuals with a high income will contribute a larger percentage of their per-period income to the public good than subjects with a low income.

4. Experimental parameters and implementation

The game used to test these hypotheses was based on the classic experiment of Isaac et al. (1984). As in that experiment, subjects were randomly arranged into groups of four. Each group played the game 10 times (with a known endpoint) with the same partners.

At the beginning of each round, each player received an income of tokens. These incomes stayed constant throughout the game and were common knowledge. Subjects then decided how many tokens to contribute to the public good. The language used in the instructions did not refer to contributions or public goods, but asked subjects to allocate tokens to one of two accounts: a group account and a private account (see Appendix 1 for a sample of the instructions and the subject sheet).

Parameters were chosen to be consistent with those used in previous experiments. For every token that a subject allotted to the private account, he received 1¢. For every token that the group allocated to the group account, each of the four subjects in the group received 1/2¢. The MPCR for this experiment is thus 1/2, as in previous studies (e.g. Andreoni, 1990; Croson, 1998).

At the end of each round the players received the following feedback:

- the number of tokens they contributed to the group account
- the average amount their group invested in the group account

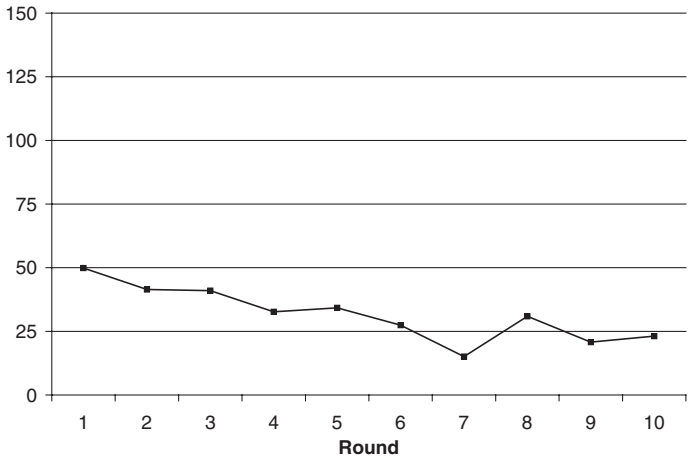

Fig. 1. Average group contribution.

- their earnings from the last round
- their earnings to date (wealth)
- the average wealth of the group to date.

We tested the effect of income (period-by-period endowment) on contributions. The information on wealth was provided so that the players could easily determine how they stood relative to the other participants. It was hoped that this information would help to amplify the social comparison aspects of the model.[8]

In the experiment two of the four players in each group had an income of 25 tokens, and two of the four players in each group had an income of 50 tokens, which they received in each period. Each player knew the income of the other players in his group. Each player knew that he was in a group of four players, two of whom had 50 tokens and two of whom had 25 tokens. The data included nine groups of four players, for a total of 36 subjects who played for ten rounds in fixed groups.[9]

The parameters chosen implement a linear public goods game: the socially optimal outcome is full contribution but the equilibrium (assuming pure self-interest) is fully free-riding. In contrast, if we assume preferences consistent with the altruism model, then we predict higher absolute contributions by the people with higher incomes than those with lower incomes. On the other hand, if the inequality aversion model is correct, we predict

[8] Some readers have suggested that this information makes the experiment contrived. However, we argue that most individuals who are part of a group know their relative wealth as compared with that of other members. Thus, it may be argued that this information imbues the experiment with a greater degree of external validity than it would otherwise have.

[9] We ran two other treatments with homogeneous incomes, one where each individual in the group had an income of 50 tokens and one where each individual in the group had an income of 25 tokens. That data include three groups of four players playing for ten rounds in each of these two treatments, for a total of 24 additional subjects.

Table 1
OLS regression results for heterogeneous groups (t-statistics)

	Round effect	Income effect		Wealth effect		Fair share
	Amount given (1)	Amount given (2)	Percent given (3)	Amount given (4)	Percent given (5)	Change (6)
Low income		1.606	0.110			−0.969
		(1.61)	(3.89)			(0.94)
Below avg wealth				1.097	0.163	
				(1.08)	(5.78)	
Difference						0.559
						(9.30)
Round	−0.751	−0.751	−0.022	−0.746	−0.021	0.202
	(4.32)	(4.33)	(4.47)	(4.30)	(4.44)	(1.02)
Intercept	15.156	15.983	0.337	14.417	0.282	−1.49
	(8.54)	(8.67)	(6.45)	(7.58)	(5.37)	(0.79)
Group dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	324
Adjusted R^2	0.2637	0.2670	0.2882	0.2640	0.3221	0.1949

either full free riding or positive contribution with a higher percentage of income contributed to the public good by people with a higher income.

5. Results

We first check that our data is consistent with those of previous experiments. Fig. 1 graphs group contributions over the 10 periods, pooling over income.

Consistent with previous experimental results, contributions begin high and decrease over time. Contributions in the first round of this experiment are lower than in previous experiments, perhaps due to the fact that incomes were (and were known to be) asymmetric. But the trend over time is statistically significant. A regression of individual contributions on round and including dummy variables for each group yields a significant negative coefficient on round ($\beta = -.751$, $p < .0001$, R^2 adj. $= .2637$), and is displayed in the first column of Table 1.[10]

Our main results of interest, however, focus on the impact of income heterogeneity on contribution decisions. We will present the data in aggregated form, but we will test our hypotheses using regression analyses with controls for each individual.

5.1. Income effects

Our second hypothesis, based on the altruism model, was that high-income subjects would contribute a larger absolute amount to the public good than low-income

[10] A regression of individual contribution in homogenous group on round and including dummy variable for each group yields a significant negative coefficient on round ($\beta = -.978$, $p < .0001$).

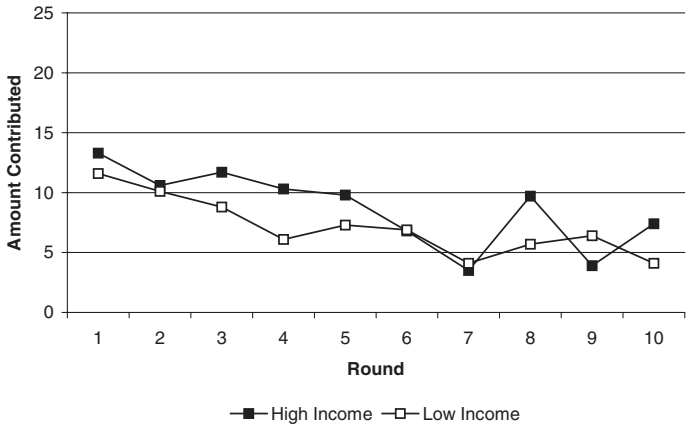

Fig. 2. Absolute amount of endowment contributed to the public good.

subjects. Fig. 2 graphs the absolute amount of income contributed in each of the 10 rounds.

This figure shows, in contrast to the hypothesis, that low income subjects give approximately the same absolute amount to the public good as high income subjects. We use a regression analysis, including a dummy variable for the income type (1 = low), a variable for the period number and other controls (column 2 of Table 1), and find that there are no significant effects for income. ($\beta = 1.606$, $p = .1076$, R^2 adj. = .2670).

Our third hypothesis was that high-income subjects would contribute a larger percentage of their income to the public good than low-income subjects. Fig. 3 graphs the average percentage of income contributed in each of the 10 rounds.

This figure shows, in contrast to the hypothesis, that low income subjects give a higher percentage of their income to the public good than high income subjects. Once again we

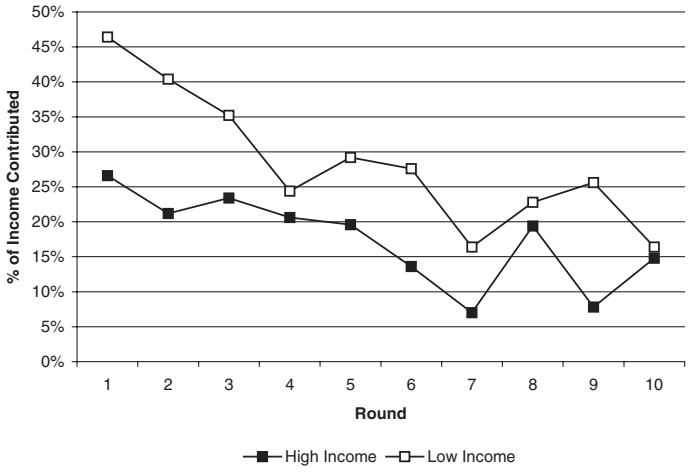

Fig. 3. Percent of endowment contributed to the public good.

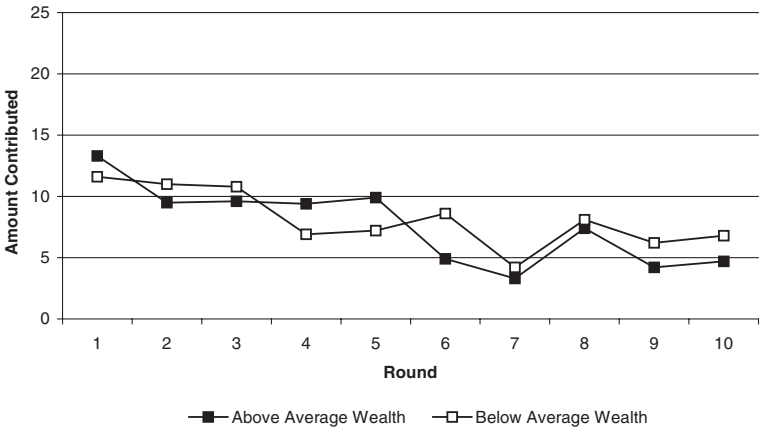

Fig. 4. Absolute amount of endowment contributed to the public good.

use a regression analysis (column 3 of Table 1), including a dummy variable for the income type (1 = low), a variable for the period number and group dummies, and find that contributions as a proportion of income by individuals with low income are significantly higher than those by individuals with high income ($\beta = .110$, $p < .0001$, R^2 adj. = .2882).

Why are the results not consistent with the predictions of altruism and inequality-aversion? One possibility is that we are measuring heterogeneity across the wrong dimension. Perhaps individuals are altruistic or inequality-averse not over income (represented by recurring endowment of tokens per period) but over wealth (the stock of accumulated earnings). Participants in our experiment knew their cumulative earnings (wealth) before making each decision. We thus generalize our statistical tests to compare the amount and proportion of income individuals contribute when they are more or less wealthy than the others in their group. Figs. 4 and 5 discussed below turn out to closely resemble Figs. 2 and 3, respectively, even though Figs. 4 and 5 concern wealth instead of income. While these figures theoretically could have diverged, in practice they did not.

5.2. Wealth effects

Fig. 4 shows the absolute amount of income contributed to the public good by subjects who are above and below the average wealth of the rest of the group. For the first round subjects with high incomes were coded as having above-average wealth (thus the first round's data is the same as that in Fig. 2). In subsequent rounds, the subjects' actual earning in the experiment up until that point were used in calculating their wealth position relative to the rest of the group, excluding the tokens they had in this round to allocate. Note that most of the time, subjects with high incomes also had high wealth. The proportion of the high-wealth subjects below who were with high income in each period averaged 81%.[11]

[11] In each period, the actual percentages were 100%, 77%, 81%, 79%, 83%, 79%, 80%, 79%, 77%, 79%.

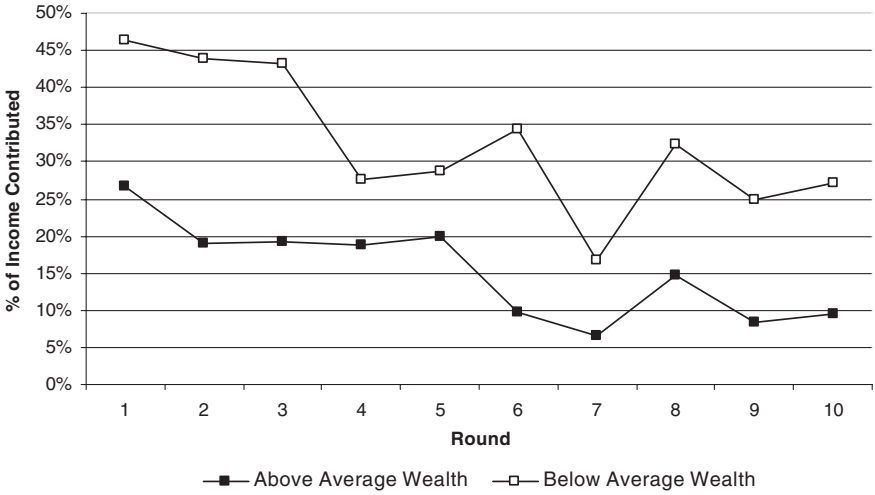

Fig. 5. Percent of endowment contributed to the public good.

This figure shows that low wealth subjects give approximately the same absolute amount to the public good as high wealth subjects. A regression analysis, including a dummy variable for the wealth (1 = low), a variable for the period number and other controls, finds that absolute levels of contributions between the two groups are not statistically different ($\beta = 1.097$, $p = .2820$, R^2 adj. = .2640) (see column 4 of Table 1).

Fig. 5 shows the average percentage of income contributed to the public good by subjects who are above and below the average wealth of the rest of the group.

This figure shows that low wealth subjects give a higher percentage of their income to the public good than high wealth subjects. A regression analysis in column 5 of Table 1, including a dummy variable for the wealth type (1 = low), a variable for the period number and other controls, finds that contributions as a proportion of income by individuals with low wealth are significantly higher than those by individuals with high wealth ($\beta = .163$, $p < .0001$, R^2 adj. = .3221).

This result is similar to the previous one and together they present a robust picture; less-advantaged subjects (whether measured by the recurring endowment of tokens per period [income] or by the stock of accumulated earnings [wealth]) contribute the same absolute amount (and thus a higher percentage), of their recurring income of tokens to the public good, contrary to predictions of models of inequality-aversion and altruism.

6. Conclusion

This paper builds on the experimental public goods literature by investigating the impact of heterogeneous income (period-by-period endowment) and wealth (accumulated earnings) in the voluntary provision of public goods. First, we replicate previous results from contexts of homogeneous income; contributions start high and decrease over time.

Next we analyze contributions as a function of the income of the players. Our results are not consistent with any of the pure self-interested model (which predicts full free-riding), models of altruism (which predict that those with higher income will contribute absolutely more to enjoy the benefits of others' consumption), or models of inequality-aversion, which predict that those with higher income will contribute a higher percentage of their income in order to equalize earnings. However, the results are not alone in contradicting the theory. Empirical data also fails to find that the wealthy give a higher percentage of their income than the poor. For example, the Social Welfare Research Institute finds that the percent of income contributed is stable or falls slightly as income rises—except for the extremely wealthy.

In our experiment, individuals with low incomes in a heterogeneous environment gave the same absolute amount (and hence a higher percentage of their income) to the public good, than individuals with high incomes. Similarly, those below the group's average wealth gave the same absolute amount (and hence a higher percentage of their income) to the public good than those above the group's average wealth.

There remains an open question of the motivation behind the behavior observed, since inequality-aversion and altruism are not consistent with our results. We believe, as suggested by Sugden (1984) that individuals are not averse to inequality *per se* but instead feel they must contribute their fair share to the public good. In our groups of four, this fair share might be interpreted as one-fourth the amount that the entire group contributes, independent of wealth or income. Disutility from not contributing one's fair share could induce low income and low wealth individuals to contribute the same absolute amount (and thus more as a percentage of their income) than those with high income or high wealth.

In order to test this hypothesis, we examine the subjects' change in giving patterns from one round to the next. At the beginning of each round subjects knew what absolute amount they had contributed to the public good and the amount contributed by their whole group in the last round. If this theory is correct, then in rounds where individuals gave less than 1/4 of the group contribution they should increase their contribution in the next round, and in rounds where they gave more than their fair share, they should decrease their contribution.[12]

For each round, we divide the total group contribution by four. We then subtract the subject's contribution from this fair share figure. If the subject contributed less to the public good than the group average, this number is positive and, if more, then this number is negative. We use this as the independent measure in our regression.

The dependent measure is the change in an individual's contribution from this round to the next. We use a regression analysis (column 6 of Table 1), including a dummy variable for the income type (1 = low), a control for the period number and group dummies. We find, as predicted, a significantly positive relationship between relative contribution in round t and the adjustment in contribution between round t and $t+1$. ($\beta = .559$, $p < .0001$, $R^2 = .1946$).[13] Our results thus support Sugden's

[12] We thank an anonymous referee for suggesting this analysis to us.

[13] A similar regression of individual contribution change using individuals in homogenous groups yields similar results ($\beta = .667$, $p < .0001$).

fair-share hypothesis. Note that this result is also consistent with the reciprocity hypothesis, suggested by Sugden and tested in Croson (1998). These results suggest the need for more models of conformity, reciprocity and/or norms to explain behavior in these experiments.

Clearly, this research is only a first step. As previous VCM literature has shown, there are a number of factors that can affect individual giving, including the number of players in the group, the MPCR, the pairing rule, communication, and the number of repetitions. The impact of all of these factors should be tested in the context of heterogeneous incomes, if only to provide robustness checks on our current understanding. Additionally, some of them might interact interestingly with heterogeneous incomes. For example, an anonymous referee suggested that an experiment using heterogeneous MPCRs and heterogeneous incomes might shed light on the universality of the fair share principle (or lack thereof). As always, more experiments are needed.

The question which originally motivated this research comes from the field; in environments of income heterogeneity who gives how much? Models of inequality aversion predict that wealthier individuals will give more; however, the data is more murky. Empirical evidence shows that people with lower incomes give the highest percentage of their income, those in the middle give the least and those with the highest incomes give somewhere in the middle (Andreoni, 2001). Our results also show that those with lower endowments (the poor) give more as a percentage than those with higher endowments (either the middle or the high).

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Appendix 1. Instructions[14]

Instructions:

This is an experiment in decision-making. The instructions are simple and, if you follow them and make good decisions, you may earn a substantial amount of money. This money has been provided by a research organization and will be paid to you in cash when the experiment is over. If you have any questions during the session, please raise your hand and someone will come to you to answer it.

[14] These instructions are based on Andreoni (1995).

In this session you will be randomly assigned to a group of four people. Each group of four will remain together throughout the session. The game is anonymous. This means that you will not know who is in your group, nor will the other members of the group know who you are.

You will interact with your group for ten rounds. At the beginning of each round, each member of your group will be given a specific number of tokens. Group members will invest these tokens to turn them into money. The tokens can be invested in one of two exchanges:

Individual exchange The individual exchange pays the investor 1¢ for each token invested in it. Notice that the amount you earn from the individual exchange is based only on your investment in it.

Group exchange The group exchange pays each member of the group (including the investor) 1/2 ¢ for each token invested in it. Notice that the amount you earn from the group exchange is based on the total invested in it by you and the other members of your group. For every token invested in the group exchange by *anyone* in the group, *everyone* in the group earns 1/2 ¢, regardless of their personal investment decision.

At the beginning of the experiment, you will be told the number of tokens each member of the group will have available to invest in each round. Note all group members may have the same number of tokens or group members may have different numbers of tokens. The number of tokens that a person receives does not vary from round to round. At the beginning of each round, each member of the group independently and privately decides how to invest their tokens. You (and the other members of your group) may choose to invest all of your tokens in the individual exchange, all your tokens in the group exchange, or some in each. However, you must invest all of your tokens in every round; tokens cannot be saved from round to round.

Three examples may help to clarify the earning structure.

Example 1. Suppose that there are 4 people in a group who each have 10 tokens. All the players decide to invest 10 tokens in the group exchange and zero tokens in the individual exchange. The total amount invested in the group exchange is 40 tokens.

Players 1, 2, 3, and 4 will each receive $0.20 ($0.00 from the individual exchange and $0.20 from the group exchange).

Example 2. Suppose that there are 4 people in a group who each have 10 tokens. All the players decide to invest 10 tokens in the individual exchange and zero tokens in the group exchange. The total amount invested in the group exchange is 0 tokens.

Players 1, 2, 3, and 4 will each receive $0.10($0.10 from the individual exchange and $0.00 from the group exchange).

Example 3. Suppose that there are 4 people in a group who each have 10 tokens. Players 1, 2 and 3 each decide to invest 5 tokens in the individual exchange and 5 tokens in the group exchange. Player 4 decides to invest 9 tokens in the individual exchange and 1 token in the group exchange. The total amount invested in the group exchange is 16 tokens.

Player 1 will receive $0.13 ($0.05 from the individual exchange and $0.08 from the group exchange).

Player 2 will receive $0.13 ($0.05 from the individual exchange and $0.08 from the group exchange).

Player 3 will receive $0.13 ($0.05 from the individual exchange and $0.08 from the group exchange).

Player 4 will receive $0.17 ($0.09 from the individual exchange and $0.08 from the group exchange).

At the beginning of each round you will be given a sheet of paper on which to record your investment decision. You may also keep a copy of your decision for your own records. The experimenter will then collect all investment decision sheets, calculate your earnings and return your investment decision sheet along with the following information:

the total amount invested in the group exchange for that round
the average amount invested in the group exchange for that round
the amount you earned that round
the total amount that you have earned so far
the average amount that members in your group have earned so far

In order to ensure that no communication between groups occurs, we ask that there be no talking or other communication during this session. You can feel free to read or study quietly, but if there is any unauthorized talking or communication you will be asked to leave the experiment and will forfeit your experimental earnings.

Are there any questions?

Subject sheet:
Date:
Player:
Round:
Endowment:
Endowments of other group members:
Amount invested in individual exchange:
Amount invested in group exchange:
Filled out by the experimenter:
Total amount invested in the group exchange for this round:
Average amount invested in the group exchange for this round:
Amount you earned this round:
Total amount you have earned during the game so far:
Average amount earned by the members in your group so far:

Appendix 2. Altruism

Assume:

$U=f(I_i)+h(G_i)$, where f and h are concave functions that increase at a decreasing rate, w.r.t. I and G, respectively. I_i represents the individual's income earned from his income and the public good. G_i represents the average wealth of the other individuals in the group.

In the experiment we have a four-person group comprised of two individuals with high incomes, and two individuals with low incomes, where the high income is denoted E_{h} and the low income is denoted E_{l}. Call the amount given to the public good by individual i $g_{i\mathrm{h}}$ when individual i has a high income and $g_{i\mathrm{l}}$ when individual i has a low income. g_{h} and g_{l} are the amount given to the public good by the other group members when they have a high income or low income, respectively. When the MPCR = 1/2 as in our experiment, then: $I_{\mathrm{h}} = E_{\mathrm{h}} - \frac{1}{2}g_{i\mathrm{h}} + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}$, and $G_{\mathrm{h}} = \frac{E_{\mathrm{h}}+2E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{h}}+\frac{1}{2}g_{\mathrm{h}}+g_{\mathrm{l}}}{3}$ in the case where individual i has a high income, and $I_{\mathrm{l}} = E_{\mathrm{l}} - \frac{1}{2}g_{i\mathrm{l}} + g_{\mathrm{h}} + \frac{1}{2}g_{\mathrm{l}}$, and $G_{\mathrm{l}} = \frac{2E_{\mathrm{h}}+E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{l}}+g_{\mathrm{h}}+\frac{1}{2}g_{\mathrm{l}}}{3}$ in the case where individual i has a low income.In both cases, this implies that the individual maximizes his utility such that: $\frac{\partial U}{\partial g_i}\left(g_i^*\right) = 0$. Thus, $\frac{\partial f}{\partial I_i} * \frac{\partial I_i}{\partial g_i} + \frac{\partial h}{\partial G_i} * \frac{\partial G_i}{\partial g_i} = 0$. This implies in the high income case,

$$\frac{1}{2} * \frac{\partial f}{\partial I_i}\left(E_{\mathrm{h}} - \frac{1}{2}g_{i\mathrm{h}}^* + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}\right) = \frac{1}{2} * \frac{\partial h}{\partial G_i}\left(\frac{E_{\mathrm{h}} + 2E_{\mathrm{l}} + \frac{3}{2}g_{i\mathrm{h}}^* + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}}{3}\right) \quad \text{Eq.1}$$

And in the low income case,

$$\frac{1}{2} * \frac{\partial f}{\partial I_i}\left(E_{\mathrm{l}} - \frac{1}{2}g_{i\mathrm{l}}^* + g_{\mathrm{h}} + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}\right) = \frac{1}{2} * \frac{\partial h}{\partial G_i}\left(\frac{2E_{\mathrm{h}} + E_{\mathrm{l}} + \frac{3}{2}g_{i\mathrm{l}}^* + g_{\mathrm{h}} + \frac{1}{2}g_{\mathrm{l}}}{3}\right) \quad \text{Eq.2}$$

Let

$$I_{\mathrm{h}}^* = E_{\mathrm{h}} - \frac{1}{2}g_{i\mathrm{h}}^* + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}$$

$$G_{\mathrm{h}}^* = \frac{E_{\mathrm{h}} + 2E_{\mathrm{l}} + \frac{3}{2}g_{i\mathrm{h}}^* + \frac{1}{2}g_{\mathrm{h}} + g_{\mathrm{l}}}{3}$$

$$I_{\mathrm{l}}^* = E_{\mathrm{l}} - \frac{1}{2}g_{i\mathrm{l}}^* + g_{\mathrm{h}} + \frac{1}{2}g_{\mathrm{l}}$$

$$G_{\mathrm{l}}^* = \frac{2E_{\mathrm{h}} + E_{\mathrm{l}} + \frac{3}{2}g_{i\mathrm{l}}^* + g_{\mathrm{h}} + \frac{1}{2}g_{\mathrm{l}}}{3}$$

Since f″<0 and h″<0, it follows that:

$$\frac{\partial f}{\partial I_i}\left(I_{\mathrm{h}}^*\right)<\frac{\partial f}{\partial I_i}\left(I_{\mathrm{l}}^*\right)\Leftrightarrow I_{\mathrm{h}}^*>I_{\mathrm{l}}^*, \qquad \text{Eq.3}$$

$$\frac{\partial h}{\partial G_i}\left(G_{\mathrm{h}}^*\right)<\frac{\partial h}{\partial G_i}\left(G_{\mathrm{l}}^*\right)\Leftrightarrow G_{\mathrm{h}}^*>G_{\mathrm{l}}^*, \qquad \text{Eq.4}$$

From Eqs. (1) and (2), at the utility maximizing point, we know, $\frac{\partial f}{\partial I_i}\left(I_{\mathrm{h}}^*\right)=\frac{\partial h}{\partial G_i}\left(G_{\mathrm{h}}^*\right)$ and $\frac{\partial f}{\partial I_i}\left(I_{\mathrm{l}}^*\right)=\frac{\partial h}{\partial G_i}\left(G_{\mathrm{l}}^*\right)$. Thus, it follows that

$$\frac{\partial f}{\partial I_i}\left(I_h^*\right)<\frac{\partial f}{\partial I_i}\left(I_{\mathrm{l}}^*\right)\Leftrightarrow\frac{\partial h}{\partial G_i}\left(G_{\mathrm{h}}^*\right)<\frac{\partial h}{\partial G_i}\left(G_{\mathrm{l}}^*\right) \qquad \text{Eq.5}$$

Notice, if $G_{\mathrm{l}}^*<G_{\mathrm{h}}^*\Rightarrow\frac{\partial h}{\partial G_i}\left(G_{\mathrm{l}}^*\right)>\frac{\partial h}{\partial G_i}\left(G_{\mathrm{h}}^*\right)$. This implies that $\frac{\partial f}{\partial I_i}\left(I_{\mathrm{l}}^*\right)>\frac{\partial f}{\partial I_i}\left(I_{\mathrm{h}}^*\right)$, which implies that $I_{\mathrm{l}}^*<I_{\mathrm{h}}^*$. This further implies that:

$$\frac{\partial f}{\partial I_i}\left(I_{\mathrm{h}}^*\right)+\frac{\partial h}{\partial G_i}\left(G_{\mathrm{h}}^*\right)<\frac{\partial f}{\partial I_i}\left(I_{\mathrm{l}}^*\right)+\frac{\partial h}{\partial G_i}\left(G_{\mathrm{l}}^*\right)\Leftrightarrow I_{\mathrm{h}}^*+G_{\mathrm{h}}^*>I_{\mathrm{l}}^*+G_{\mathrm{l}}^* \qquad \text{Eq.6}$$

So, following this logic, $I_{\mathrm{h}}^*+G_{\mathrm{h}}^*>I_{\mathrm{l}}^*+G_{\mathrm{l}}^*$ implies both:

1. $I_{\mathrm{h}}^*>I_{\mathrm{l}}^*$

2. $G_{\mathrm{h}}^*>G_{\mathrm{l}}^*$

We will use this logic in the following cases to derive the relationship between $g_{i\mathrm{h}}^*$ and $g_{i\mathrm{l}}^*$. Let us consider three cases. In all three cases we begin by considering what the other group members do in order to determine what individual i will do:

Case 1. The amount given to the public good by the group member(s) with the high income will be less than the amount given by the group member(s) with the low income plus the difference between the high and low income, that is:

$$g_{\mathrm{h}}<g_{\mathrm{l}}+(E_{\mathrm{h}}-E_{\mathrm{l}}).$$

By comparing $I_{\mathrm{h}}^*+G_{\mathrm{h}}^*$ to $I_{\mathrm{l}}^*+G_{\mathrm{l}}^*$, that is, $E_{\mathrm{h}}-\frac{1}{2}g_{i\mathrm{h}}^*+\frac{1}{2}g_{\mathrm{h}}+g_{\mathrm{l}}+\frac{E_{\mathrm{h}}+2E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{h}}^*+\frac{1}{2}g_{\mathrm{h}}+g_{\mathrm{l}}}{3}$ to $E_{\mathrm{l}}-\frac{1}{2}g_{i\mathrm{l}}^*+g_{\mathrm{h}}+\frac{1}{2}g_{\mathrm{l}}+\frac{2E_{\mathrm{h}}+E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{l}}^*+g_{\mathrm{h}}+\frac{1}{2}g_{\mathrm{l}}}{3}$, we find that $I_{\mathrm{h}}^*+g_{\mathrm{h}}^*>I_{\mathrm{l}}^*+G_{\mathrm{l}}^*$. From Eqs. (3)–(6), at the utility maximizing point, it follows that $G_{\mathrm{h}}^*>G_{\mathrm{h}}^*$, e.g.

$$\frac{E_{\mathrm{h}}+2E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{h}}^*+\frac{1}{2}g_{\mathrm{h}}+g_{\mathrm{l}}}{3}>\frac{2E_{\mathrm{h}}+E_{\mathrm{l}}+\frac{3}{2}g_{i\mathrm{l}}^*+g_{\mathrm{h}}+\frac{1}{2}g_{\mathrm{l}}}{3}$$

Simplifying this expression yields, $g_{i\mathrm{h}}^*-g_{i\mathrm{l}}^*>\frac{2(E_{\mathrm{h}}-E_{\mathrm{l}})+g_{\mathrm{h}}-g_{\mathrm{l}}}{3}$. We know $g_{\mathrm{h}}>g_{\mathrm{l}}+(E_{\mathrm{h}}-E_{\mathrm{l}})$. Thus, $\frac{2(E_{\mathrm{h}}-E_{\mathrm{l}})+g_{\mathrm{h}}-g_{\mathrm{l}}}{3}\geq 0$, when $E_{\mathrm{h}}\geq\frac{3}{2}*E_{\mathrm{l}}$. This condition is met in the experiment where $E_{\mathrm{h}}=50$ and $E_{\mathrm{l}}=50$. Thus, $g_{i\mathrm{h}}{}^*>g_{i\mathrm{l}}{}^*$, that is, the subject with a high income will contribute more to the public good than the subject with a low income.

Case 2. The amount given to the public good by the group member(s) with the high income will be greater than the amount given by the group member(s) with the low income plus the difference between the high and low income, that is:

$$g_h > g_l + (E_h - E_l).$$

In this case, by comparing $I_h^* + G_h^*$ to $I_l^* + G_l^*$, we find that $I_h^* + G_h^* < I_l^* + G_l^*$. From Eqs. (3)–(6), at the utility maximizing point, it follows that $I_h^* < I_l^*$, e.g.

$$E_h - \frac{1}{2}g_{ih}^* + \frac{1}{2}g_h + g_l < E_l - \frac{1}{2}g_{il}^* + g_h + \frac{1}{2}g_l$$

Simplifying yields $g_{ih}^* - g_{il}^* > 2(E_h - E_l) - g_h + g_l$. We know $g_h > g_l + (E_h - E_l)$. Thus, $2(E_h - E_l) - g_h + g_l \geq 0$ when $E_h \geq 2^* E_l$. This condition is met in the experiment where $E_h = 50$ and $E_l = 25$. Thus, $g_{ih}^* > g_{il}^*$, that is, the subject with a high income will contribute more to the public good than the subject with a low income.

Case 3. The amount given to the public good by the group member(s) with the high income will be equal to the amount given by the group member(s) with the low income plus the difference between the high and low income, that is: $g_h = g_l + (E_h - E_l)$. Finally, when $g_h = g_l + (E_h - E_l)$, by comparing $I_h^* + G_h^*$ to $I_l^* + G_l^*$, we find that $I_h^* + G_h^* = I_l^* + G_l^*$. From Eqs. (3)–(6), at the utility maximizing point, it follows that $I_h^* = I_l^*$, e.g. $E_{ih} - \frac{1}{2}g_{ih}^* + \frac{1}{2}g_h + g_l = E_{il} - \frac{1}{2}g_{il}^* + g_h + \frac{1}{2}g_l$. Simplifying yields $g_h^* - g_{il}^* = 2(E_h - E_l) - g_h + g_l$. We know $g_h = g_l + (E_h - E_l)$. Thus, $2(E_h - E_l) - g_h + g_l > 0$ when $E_h > E_l$. This condition is met in the experiment where $E_h = 50$ and $E_l = 25$. Thus, $g_{ih}^* > G_{il}^*$.

Altruism predicts, given the conditions in our experiment, that at the utility maximizing point the subject with a high income will contribute more to the public good than the subject with a low income, that is $g_{ih}^* > g_{il}^*$.

Appendix 3. Inequality aversion

To show this result we present a simplified version of the Fehr and Schmidt (1999) model. Consider a group of N individuals, who homogeneously value a linear public good and consume both the public good and a private good. Each individual has an income or income denoted E_i. Each unit of income contributed to providing the public good produces some amount of the public good, valued at v by each individual for each unit. Each unit of income privately consumed creates marginal value p for the individual alone. The MPCR is thus v/p, and a public good problem exists when $1/N < v/p < 1$.

Each individual must decide how to divide his income between contributing to the public good and enjoying private consumption. He can contribute any amount, g_i, to the public good, G, where g_i is less than or equal to E_i and $\Sigma g_i = G$. This leaves $X_i = E_i - g_i$ to be consumed via the private good. After all the players have made their allocations, each individual has a certain amount of wealth, $I_i = p * X_i + v * G$.

However, in these models the individual derives utility not only from his payoff but also from his position with respect to the other players. The individual dislikes obtaining a

higher payoff than other individuals or a lower payoff than other individuals. The utility function for a subject is given by:

$$U_i = I_i - \alpha_i * \max\{I_{\text{avg}} - I_i, 0\} - \beta_i * \max\{I_i - I_{\text{avg}}, 0\}. \quad (1)$$

The first term I_i is the individual's utility derived from his payoff as above. The second term measures the loss of utility from being below the group average, while the third term measures the loss of utility from being above the group average. The models assume that $\alpha_i > \beta > 0$ (that is, a subject would rather be above the group average than below it.).

If the α_i's and β_i's are sufficiently low, this model's predictions are the same as a self-interest model—full free riding. It is easy to understand this by examining the extreme case where they are set to zero. In this case the individual derives positive utility only from his wealth—his standing relative to the group does not affect his utility. Thus, the individual will maximize his utility by free-riding and not contributing to the public good.

Examining the first derivative with respect to g_i and assuming that the individual is above the group average, we find:

$$\frac{\partial U}{\partial g_i} = (p - v) - \beta_i \left(p - v - \left(\frac{P}{4} - v \right) \right)$$

If the β_i's are sufficiently high, $\beta_i \geq \frac{4}{3}\left(\frac{p-v}{p}\right)$, the subject will maximize his utility by dividing up his income such that the subject's payoff equals the group's average payoff.[15] In a heterogeneous group this maximization implies that an individual with a high income will contribute more of his income to the public good than an individual with a low income.

Imagine an environment where two players have high incomes, denoted E_{h}, and two players have low incomes, denoted E_{l}.

Case 1. Player A has a high income: Assume that player A believes that the other high income player will invest X^*E_{h} in the public good where $0 \leq X < 1$. Further, assume that player A believes that the low income players will invest Y^*E_{l} in the public good where $0 \leq Y < 1$. The group average will equal $\frac{2^*E_{\text{h}} + 2^*E_{\text{l}} + X^*E_{\text{h}} + 2^*Y^*E_{\text{l}} + g_{i\text{h}}}{4}$, where $g_{i\text{h}}$ is player A's contribution to the public good when he has a high income. Now, assuming $\beta_i \geq \frac{4}{3}\left(\frac{p-v}{p}\right)$, player A will maximize his utility by dividing up his income such that his payoff equals the group's average payoff, which implies $g_{i\text{h}} = \frac{2^*E_{\text{h}} - 2^*E_{\text{l}} + E_{\text{h}}^*X + 2^*E_{\text{l}}^*Y}{3}$. It easily follows that the percentage that he contributes to the public good is: $p_{i\text{h}} = \frac{2 - 2\left(\frac{E_{\text{l}}}{E_{\text{h}}}\right) + X + 2^*\left(\frac{E_{\text{l}}}{E_{\text{h}}}\right)Y}{3}$, where $p_{i\text{h}}$ is the percentage of player A's income contributed to the public good.

Case 2. Player A has a low income, E_{l}. He will maximize his utility by dividing up his income such that his payoff equals the group's average payoff, which implies $g_{i\text{l}} = \frac{2^*E_{\text{l}} - 2^*E_{\text{h}} + 2^*E_{\text{h}}^*X + E_{\text{l}}^*Y}{3}$, where $g_{i\text{l}}$ is player A's contribution to the public good when he has a low income. It follows that the percentage that he contributes to the public good is: $p_{i\text{l}} = \frac{2 - 2\left(\frac{E_{\text{h}}}{E_{\text{l}}}\right) + 2^*\left(\frac{E_{\text{h}}}{E_{\text{l}}}\right)X + Y}{3}$, where $p_{i\text{l}}$ is the percentage of player A's income contributed to the public good.

[15] This result is for groups of four which we use in this experiment. The generalized result is $\beta_i \geq \frac{N}{N-1}\left(\frac{p-v}{p}\right)$, where N is the number of individuals in the group.

In our experiment, $E_h = 2E_l$, this implies that given any beliefs by subject A concerning the giving patterns of the other players with high and low incomes that $p_{ih} \geq p_{il}$.[16] Thus, in a heterogeneous situation subjects with a high income will contribute a higher percentage of their income to the public good than subjects with a low income.

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[16] $p_{ih} = p_{il}$ only in the case where all subjects contribute everything to the public good or in the case where $X = 1$ and $Y = 0$. In all other cases, when $E_h = 2E_l$, p_{ih} is strictly than p_{il}.

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