

Heterogeneity, Equity and Voluntary Contributions Toward the Provision of a Public Good

KENNETH S. CHAN

Department of Economics, McMaster University

Department of Economics and Finance, City University of Hong Kong

STUART MESTELMAN

Department of Economics, McMaster University

ROBERT MOIR

Department of Social Sciences (Economics), University of New Brunswick at Saint John

R. ANDREW MULLER

Department of Economics, McMaster University

Send correspondence to Stuart Mestelman, Department of Economics, McMaster University, Hamilton, Ontario, Canada, L8S 4M4 [telephone: 905-525-9140 x 23113; fax: 905-521-8232; e-mail: mestelma@mcmaster.ca]

Heterogeneity, Equity and Voluntary Contributions Toward the Provision of a Public Good

Abstract

Twenty-four laboratory sessions are conducted to evaluate the roles of communication, information and group heterogeneity when voluntary contributions determine the level of public good provision by small groups of individuals. Simple heterogeneity has one individual in a group having either greater endowment of resources or a greater preference for the public good than the others. Complex heterogeneity exists when one individual in a group has both higher income and greater preference for the public good. Information about income and preference distribution is a treatment variable, but proves to have no statistically significant impact on contributions or payoffs. Without communication, members of heterogeneous groups tend to coordinate more on equal contributions than predicted by a conventional public goods model. The distribution of payoffs within groups exhibits a strong interaction between communication and heterogeneity, leading to less equitable distributions of payoffs as heterogeneity becomes more complex. A model of equity theory helps to organize the results.

Keywords: Public goods, voluntary provision, heterogeneous agents, communication, information, equity

JEL Classification: H41, C92

1. Introduction

Naturally occurring voluntary charitable contributions arise in widely varying contexts. In general donors are heterogeneous, varying greatly both in their preferences concerning the charity and in their ability to contribute to it. They may have very good information about the preferences of other contributors or they may be operating *in the dark*. They may be members of a close-knit group who can discuss and co-ordinate their actions or they may be unknown to each other. All of these factors may have significant influence on their willingness to contribute funds and hence on the outcome of fundraising campaigns. Yet the way in which these factors act to promote or discourage voluntary contributions is not well understood. Improved understanding requires both theoretical and empirical work.

Charitable contributions are naturally modelled as voluntary contributions to a public good, even though charities may provide private goods to the recipients of their aid, because donors probably care chiefly about the level of charitable activity being carried out and this level is jointly supplied to all contributors. Linear public goods models are highly successful in capturing the social dilemma posed by free-riding. However, they are unrealistic in that the equilibrium and efficient outcomes require all participants to contribute either nothing or one hundred percent of their endowment to the public good. It is hard to believe either of these characterize the natural environment. Consequently it may be most appropriate to consider nonlinear public goods environments in which both the equilibrium and efficient outcomes lie in the interior of the contribution space.

At a theoretical level, several authors including Olson (1965) have conjectured that rich

individuals will contribute more to a public good than poorer individuals will, so that increasing inequality (i.e., increasing heterogeneity) in incomes may lead to increased provision of the public good. Bergstrom, Blume and Varian (1986) showed that this increased provision was an equilibrium outcome in a nonlinear public goods setting, but only when the income inequality is so severe that the non-negativity constraint on contributions is binding for poor individuals. When all participants are contributing positive amounts, small income redistributions should have no effect on aggregate contributions. This theory is developed in the context of full information and no communication. One might conjecture that communication should facilitate agreements to avoid free-riding and that incomplete information about others' preferences and incomes might reduce aggregate contributions by making it harder to coordinate on efficient contribution levels.

Experimental research on the issue is limited. Ledyard (1995, pp. 159-60) surveyed five public goods experiments (four linear and one non-linear, but all with Nash equilibria of zero contributions) that directly addressed the heterogeneity issue. On the basis of this survey, but warning that more research is needed, he conjectured that heterogeneity generally reduces aggregate contributions and that incomplete information generally raises them, especially when interacting with heterogeneity. In a study not included in the Ledyard survey, Isaac and Walker (1988) study voluntary contributions in a linear public good environment in which members of four-person groups have either the same or different endowments, information is complete or incomplete and communication is permitted before each decision round or not permitted. Isaac and Walker (1998, p. 598) observe that "levels of contributions in experiments with symmetric endowments tend to dominate those under conditions of asymmetric endowments" and "levels of contributions in experiments with complete information tend to dominate those under conditions

of incomplete information. But the effect is weaker than that related to distribution of endowments.” Ledyard’s conjectures and Isaac’s and Walker’s results pertain to underlying models in which equilibrium outcomes call for no voluntary contributions, whereas we have argued that voluntary contributions are best assessed within the context of a model which predicts some voluntary contributions.

In an earlier paper (Chan *et al.* 1999), we reported a systematic study of the effects of heterogeneity, communication, and information on *aggregate* voluntary contributions in a nonlinear environment. Groups of three members could be homogenous (all members had the same endowments and preference structures), heterogenous in endowments (one member had higher income than the other two), heterogenous in preferences (one member had a stronger preference for the public good) or heterogenous in both endowments and preferences. We referred to the last case as complex heterogeneity; the other two heterogeneous cases were termed simple heterogeneity. We varied the level of information (complete or incomplete) between subjects and the level of communication (no communication, communication every four decision rounds) within groups. Figures 1 and 2 summarize our findings.¹ In the case of complete information and homogeneous groups aggregate contributions were close to the Nash equilibrium

¹ Chan *et al.* (1999) analyse the variance in 48 observations: the mean contribution for each of the 24 groups across four rounds without communication (rounds 3-6) and across four rounds following communication (rounds 15-18). This permits a concise evaluation of all interactions in the design. The aggregate behaviour of contributions or payoffs for groups of subjects under the different simple heterogeneity treatments did not differ and were pooled into a single simple heterogeneity category (S Het) which is distinguished in Figure 1 from the homogeneous group category (Homo) and the complex heterogeneity category (C Het). The analysis of the 48 observations did not allow for the possible statistical dependence of the communication observations on the no communication observations. Supplementary tests on completely independent observations, which confirm these results, are reported in Chan *et al.* (1999).

of 21. Contrary to Ledyard's conjectures incomplete information had a small and weakly significant *negative* effect on contributions.² This was driven by the effect of information on homogeneous groups as shown in Figure 1. Heterogeneity had a small and weakly significant *positive* effect. As expected, communication had a large and highly significant positive effect. Unexpectedly there was a strong and very significant interaction between heterogeneity and communication. This is more clearly reflected in Figure 2 for which the data are pooled across information conditions. In the no communication treatment aggregate contributions generally rise as heterogeneity progresses from none to simple to complex. The positive effect of communication, while significant in all cases, is least for complex heterogeneity. In fact, communication adds so little to the contributions in the case of complex heterogeneity that total contributions actually decline in moving from simple to complex heterogeneity.

Since 1999, researchers studying heterogeneity and information in public goods environments have concentrated on linear public good environments. Marks and Croson (1999) and Rondeau, Schulze and Poe (1999) found no significant effects of different information conditions when provision point mechanisms were used to collect voluntary contributions for the provision of public goods. Cherry, Kroll and Shogren (2005) study income heterogeneity in a linear public good environment with complete information, and find contributions higher in homogeneous groups. Buckley and Croson (2006) study both wealth and income heterogeneity on voluntary contributions under complete information and find no significant effects on contribution levels. Levati, Sutter and Heijden (2005) study leadership in the provision of public

² Significance and weak significance refers to the p-value of an F-test on the main effects in an analysis of variance (5% and 10% level respectively).

goods using voluntary contributions with a linear public good environment. Information and heterogeneity in endowments, as well as types of leadership, are treatment variables. They find that providing leadership by example works well with complete information and homogeneous participants. Contributions fall with the introduction of heterogeneity and fall still further with incomplete information. The most novel of the recent papers studying heterogeneity in linear public good environments considers heterogeneity in attitudes. Participants in an experiment by Burlando and Guala (2005) are categorized as free-riders, cooperators and reciprocators and their voluntary contributions are compared when they participate in heterogeneous groups and when they participate in groups of individuals with common attitudes. The researchers find that contributions are greater in homogeneous groups.

Two papers addressing issues relating to common pool resources (CPRs) capture aspects of the non-linear public good environment presented in Chan *et al.* (1999). Margreiter, Sutter and Dittrich (2005) study voting in a CPR environment which includes agent heterogeneity as a treatment variable. They find no significant effect of heterogeneity. Cardenas, Stranlund and Willis (2002) investigate both agent heterogeneity and communication in a CPR environment. They find that heterogeneous agents generate a greater surplus than homogeneous agents both with and without communication (which itself increases the returns to agents). As well, they find that without communication, low income individuals extract less than the predicted Nash equilibrium quantity while high income individuals extract more. With communication, both reduce their extraction, and the difference between their extraction narrows. The results for the no-communication environment are comparable to those reported in Chan *et al.* (1997) for the non-linear public good environment, and the results for the communication environment are

comparable to the results that will be reported later in this paper.

Our task in this paper is to try to understand the patterns of *individual* behaviour that lead to this strong interaction between heterogeneity and communication. We examine both the contributions and payoffs earned by participants and the distributions of contributions and payoffs within the groups. Our analysis of the individual participant data suggests that some notion of equity in contributions may be responsible for the heterogeneity-communication interaction we observe in the aggregate data. We argue that many aspects of our results are consistent with the general principles of *equity theory* described by Walster *et al.* (1978). According to this theory people frequently attempt to secure outcomes that are equitable in the sense of equally sharing either the costs or the rewards of an action. In addition, the no-communication outcome may affect how notions of equity are implemented to generate our results. We find distributions of contributions becoming more equitable with communication and distributions of total payoffs become less equitable with increases in the complexity of heterogeneity. Finally, we offer a conjecture regarding a hierarchy of equity in this public good environment with communication, which focusses first on equity in contributions and then on equity in payoffs.

2. The Laboratory Environment³

In our laboratory environment, individuals in each group of three repeatedly allocated their token endowments to Market 1 (a private good market) or to Market 2 (a public good market).⁴

³ Much of this section is reproduced from Chan *et al.* (1999).

⁴ We chose a three-person environment for consistency with our earlier experiments. Bardhan's (1993) suggestion that small groups are more likely to coordinate successfully implies that using three-person groups allowing communication should increase the likelihood of optimal voluntary contributions regardless of the heterogeneity characteristics of the groups. Any heterogeneity effect will have to be strong if it is to be observed.

Subjects received written instructions which were also read aloud.⁵ All instructions were framed in neutral language. Allocations were restricted to integer values. Subjects were given tables showing their payoffs according to their own allocation and the allocation of the remaining subjects in the group. They reported their decisions and were informed of the results through a network of personal computers.

There were 22 decision rounds in each session, divided into five phases. The first phase consisted of six decision rounds, during which there was no communication among the subjects. The first two rounds were treated as practice periods and the data from them were not analysed. The remaining four phases consisted of four decision rounds each, preceded by limited face-to-face communication. At the end of 22 decision rounds, subjects were paid their accumulated payoffs, converted from laboratory dollars to Canadian dollars at a rate common to all participants that was announced at the beginning of the session.

Two information conditions were used. In the incomplete information condition subjects had no information about the individual endowments and payoff tables of other group members. In the complete information condition they knew both the endowments and payoff tables (preferences) of each of the other people in their group. In all cases subjects knew their own endowments, payoff tables, the total endowment of the group and when the session would end.

Each individual i had an endowment of w_i tokens. The lab dollar payoff to individual i , u_i , was derived from the function

$$u_i = x_i + \alpha_i G + x_i G \quad (1)$$

⁵ Instructions are reproduced in Chan *et al.* (1999). The payoff tables are posted at <http://socserv.mcmaster.ca/econ/mceel/papers/PGHet-PT.pdf>

where x_i is the allocation to the private good, $G = \sum_i g_i$, is the aggregate allocation to the public good, $g_i = w_i - x_i$ is the individual's allocation to the public good, and α_i is a parameter which characterizes individual preferences for the public good.

In our baseline homogeneity treatment, all agents have the same endowment and preference parameters. We refer to these agents as S-type individuals. Heterogeneity was introduced by making one agent (the D-type agent) different from the other two (the S-type agents). In our sessions the D-type agent either had a larger endowment than the others, a stronger preference for the public good or both. There were two levels of heterogeneity in endowments: same endowment (SE) with $w_i = 20 \forall i$, and different endowment (DE) with $w_1 = w_2 = 18$, $w_3 = 24$, and two levels of heterogeneity in preferences: same preferences (SP) with $\alpha_i = 9 \forall i$, and different preferences (DP) with $\alpha_1 = \alpha_2 = 6$, $\alpha_3 = 15$. In all treatments, the group endowment, W , was 60 tokens per period and the aggregate preference parameter $\alpha = \sum_i \alpha_i$ was 27. The two heterogeneity factors were combined with the information factor in a complete 2x2x2 factorial design replicated 3 times. All of this is summarized in Table 1.

[Insert Table 1 Here]

When communication was permitted, subjects with complete information were told that they were permitted to discuss anything they wished, other than physical threats or side-payments, for four minutes. Subjects were reminded that they had each others' payoff tables, which they could bring to discuss during the communication phases of the session. They were told that any agreements they reached during their discussion would not be enforced by the session monitor or by the computers. Subjects with incomplete information were only permitted to share qualitative information about their own payoffs. They could state that a contribution pattern increased or

decreased their payoff, but could not state the quantitative change. Recall that in these sessions subjects had only their own payoff tables. An invigilator attended each session to monitor and make notes regarding the discussion and to enforce the rules governing communication. No attempts to make side payments or threats occurred in any of the sessions.

3. Predictions

We will focus on individual contributions to the public good, on individual payoffs, and on two inverse measures of equity: inequality of contributions and inequality of payoffs as measured by their respective coefficients of variation. In a non-cooperative environment the best response function for individual i is given by

$$g_i = \max\left(\frac{w_i - G_{-i} + \alpha_i - 1}{2}, 0\right) \quad (2)$$

which is constrained to be non-negative. Assuming the constraint is not binding on any subject, setting $n = 3$ and summing over i we obtain

$$G = \frac{W + \alpha - 3}{4} \quad (3)$$

Aggregate contributions in equilibrium depend only on the aggregate group endowment, W , and the aggregate preference parameter, α . Given our experimental parameterization this is 21 tokens in all conditions. Using the equations from (2) for each of the three subjects, the individual Nash equilibrium contributions may be calculated for each type of subject in each of the four treatments. These equilibria are reported in Table 1 along with corresponding distribution of payoffs. The group optimum contribution is easily computed to be 43 tokens. Any combination of contributions totalling 43 will yield the same aggregate optimal payoff, but none of these combinations will be a

Nash equilibrium.

In a full-information, no-communication environment, the Bergstrom *et al.* model predicts that the non-cooperative equilibrium will prevail in all four heterogeneity conditions.⁶ All individuals in the homogeneous treatments will contribute 7 tokens to public good provision. If this is realized, the coefficient of variation of contributions made by participants in these groups, as a measure of equity, is 0. At the conventional equilibria outcome for simple heterogeneity treatments DE/SP and SE/DP, the coefficients of variations are 0.49 and 0.74. For complex heterogeneity, the coefficient of variation is 1.24. These reflect the widening distribution of predicted contributions from the triples {7, 7, 7} to {5, 5, 11} to {4, 4, 13} to {2, 2, 17}. The payoffs associated with these distributions are presented in Table 1 and reflect essentially perfectly equitable distributions of payoffs for each treatment.

The model offers no formal predictions for the effects of varying the level of information and introducing communication. Incomplete information makes it impossible for participants to compute the Nash equilibrium, and so any equilibrium tendencies might evolve more gradually than with complete information. Communication in this context is cheap talk. Agreements are not enforced by the experimenter. Any violations of agreements can only be enforced by retaliation in subsequent decision-rounds. However, previous experiments which introduce communication in voluntary contribution games tend to display increases in voluntary contributions from the no

⁶ These are homogeneity (SE/SP), also identified as Homo, two variants of heterogeneity in a single dimension (SE/DP and DE/SP), which will be referred to as simple heterogeneity (S Het), and one variety of heterogeneity in two dimensions (DE/DP), which will be referred to as complex heterogeneity (C Het).

communication baselines regardless of the information conditions.⁷ With communication, however, the impact of information may differ than without communication.

4. Results

Seventy-two subjects in 24 groups of three participated in a total of 14 sessions.⁸ Sessions were completed in less than ninety minutes. The average compensation for participating was \$27.75 (the range was \$19.00 to \$43.50; standard deviation was \$5.37). Data reported here are based on decision rounds 3 through 6 (the no communication rounds) and decision rounds 15 through 18 (the third set of decision rounds following a four minute period of communication).⁹

We focus on the effect of our treatment variables (subject type, incomplete information, heterogeneity and communication) on the level of individual contributions and payoffs and on the degree of inequality in contributions and payoffs within groups. As in Chan *et al.* (1999) we begin

⁷ Repeated communication raises contributions in the laboratory environments cited by Ledyard (1995) and Isaac and Walker (1988) find that eliminating communication results in reductions in voluntary contributions with both complete and incomplete information and homogeneous and heterogeneous groups.

⁸ The subjects in these sessions were recruited through notices posted across the McMaster University campus. Respondents became members of a pool of potential subjects who were invited to participate in different sessions conducted in the McMaster Experimental Economics Laboratory. By inviting members of the pool in alphabetical order we tend to control the inclusion of *good friends* as participants in the same group. In ten of the sessions there were two groups of 3 subjects; in the remaining four there was only one group. In the two-group sessions, the groups met in separate rooms and there was no interaction across the groups.

⁹ Chan *et al.* (1999) shows clear evidence of end-game effects in the fifth, and last, phase and increasing contributions over the second through fourth phases. This motivates the decision to focus on the last four periods of the first phase (rounds 3 through 6) and on the fourth phase (rounds 15 through 18) when analysing the data.

with a fully saturated analysis of variance in each of these outcomes.¹⁰ We then tested and retained the hypothesis of equivalence between the SE/DP and DE/SP treatments.¹¹ Consequently we conducted further analysis using a restricted model with three levels of heterogeneity: homogeneity, simple heterogeneity (one-dimensional heterogeneity in either endowments or preferences), and complex heterogeneity (two-dimensional heterogeneity in both endowments and preferences). The pooled data constitute a 3x2x2x2 factorial design in heterogeneity, communication, subject type, and information. We analysed these data using ANOVA methods as a convenient presentation of a general linear regression model on categorical variables. We then tested and retained the hypotheses that the information condition did not have a significant influence on contributions, payoffs, and the coefficients of variation of contributions and payoffs.¹² F-tests reported in this

¹⁰ This is equivalent to a categorical regression with dummy variables for different endowment, different preferences, incomplete information, and all of their interactions to the fourth order, plus dummy variables for 71 of the 72 subjects (for individual contributions and payoffs) and 23 of the 24 groups (for coefficient of variation of contributions and payoffs).

¹¹ We tested the equality of the DE/SP and SE/DP effects by estimating a restricted model of variance for the four dependent variables in which we specified three levels of heterogeneity: none (SE/SP), simple heterogeneity (SE/DP or DE/SP) and complex heterogeneity (DE/DP). In no case was the restriction significant. For contributions and payoffs the F-statistics were 0.443 and 0.604 respectively. The critical value of the F-statistic at the 5% level of significance with $\nu_1 = 4$ and $\nu_2 = 86$ degrees of freedom is greater than 2.47. For the coefficients of variation of contributions and payoffs the F-statistics were 0.866 and 2.02 respectively. The critical value of the F-statistic at the 5% level of significance with $\nu_1 = 2$ and $\nu_2 = 32$ degrees of freedom is greater than 3.23.

¹² We tested the significance of the information condition by estimating a restricted model of variance for the four dependent variables in which we omitted the information condition, pooling data across the complete and incomplete information conditions. In no case was the restriction significant. For contributions and payoffs the F-statistics were 0.304 and 0.257 respectively. The critical value of the F-statistic at the 5% level of significance with $\nu_1 = 5$ and $\nu_2 = 82$ degrees of freedom is greater than 2.30. For the coefficients of variation of contributions and payoffs the F-statistics were 0.421 and 1.134 respectively. The critical value of the F-statistic at the 5% level of significance with $\nu_1 = 3$ and $\nu_2 = 30$ degrees of freedom is 2.92.

section are derived from the analyses of variance based on models with the independent variables heterogeneity, communication, subject type and their interactions and include dummy variables for subject or group effects.¹³

4.1. Contributions

Results for contributions are illustrated in Figures 3 and 4. Figure 3 summarizes mean per period contributions by heterogeneity category, subject type, and communication conditions. Figure 4 summarizes the coefficients of variation (COV) of contributions within a group by heterogeneity category and communication conditions. The COV is an inverse measure of equality in contributions.¹⁴

Moving from left to right across Figure 3 within a heterogeneity category, the first two bars for each heterogeneity treatment identify the mean contribution for S-type participants in a group. The third and fourth bars identify values for the D-type participants. In homogeneous groups (Homo) there are only S-type individuals. In the simple (S Het) and complex heterogeneity (C Het) categories there are both S- and D-types. White bars and lightly shaded bars identify non-communication periods and black and darkly shaded bars identify communication periods. The short bold horizontal bars identify the predicted non-cooperative Nash equilibrium contribution for

¹³ All ANOVA tables produced for this paper are posted at <http://socserv.mcmaster.ca/econ/mceel/papers/PGHet-ANOVA.pdf> and the data used to generate Figures 3-6 and all summary statistics reported in the text of this paper are posted at <http://socserv.mcmaster.ca/econ/mceel/papers/PGHet-DS.pdf>

¹⁴ The coefficients of variation were computed as $\sqrt{\frac{\sum_i^3 (\mu_i - \bar{\mu})^2 / 2}{\bar{\mu}}}$ where μ_i is the mean contribution per period of individual i averaged over all the periods in the current phase and $\bar{\mu}$ is the mean of the μ_i for each group in the current phase.

each participant type.¹⁵ In Figure 4, white bars denote no-communication periods and black bars denote communication periods.

[Insert Figures 3 and 4 Here]

Inspection of Figure 3 suggests that communication increases contributions, that D-type individuals contribute more than S-type individuals and that more contributions are made by heterogeneous groups than are made by homogeneous groups. These observations are supported by an analysis of variance. The first-order effects of communication and subject type are significant ($p = 0.000$ and $p = 0.007$). While the first-order effect of heterogeneity is not statistically significant ($p = 0.465$), the interaction of heterogeneity and communication is strongly significant ($p = 0.000$), and the three-way interaction of heterogeneity, communication and subject type is strongly significant ($p = 0.019$). The significant two-way interaction captures the difference between contributions across heterogeneity treatments with and without communication displayed in Figure 2 and reported in Chan et al. (1999).

The interaction between communication and subject type is not significant ($p = 0.249$), indicating that the difference between average S-type individual contributions and D-type individual contributions is not significantly affected by communication (these differences are 3.49 tokens with no communication and 3.25 tokens with communication). The three-way interaction, however, indicates that the patterns of these differences across heterogeneity treatments is significant. In this comparison, the mean difference in contributions made by D-types over S-types with no communication *increases* from 2 tokens under S Het to 6.7 tokens under C Het. With

¹⁵ The predictions for the {S-types, D-types} in the SE/DP and DE/SP treatments are {5,11} and {4,13} respectively. Because there are equal numbers of observations of each treatment, the prediction reported in Figure 2 for S Het is {4.5,12}.

communication the mean difference *falls* from 3.71 tokens under S Het to 1.84 under C Het. The reduction in this difference is associated with a reduction in contributions by D-type individuals in C Het groups with communication relative to what was contributed in the absence of communication. This result helps provide an explanation of the anomalous result reflected by the aggregate data in Figure 2. This will be discussed in Section 5.

In heterogeneous groups and in the absence of communication, individuals with high endowments or strong preferences for the public good contribute less than the conventional Nash equilibrium predictions for their types. Individuals with low endowments or weak preferences contribute more. This is clear from Figure 3. These outcomes result in more equitable distributions of contributions within heterogeneous groups than predicted by the conventional public good model.

The data for coefficients of variation for contributions are summarized in Figure 4. The coefficients of variation associated with Nash equilibrium outcomes are 0, 0.62 and 1.24 for the Homo, S Het and C Het heterogeneity treatments. The coefficients of variations reported in Figure 4 under no communication are 0.403, 0.347 and 0.494. While homogeneous groups display equity measures which suggest less equitable distributions than the Nash outcome would yield, heterogeneous groups are generating distributions of contributions which are more equitable than those predicted by the conventional public good model. It is particularly interesting that even though the total contributions made by homogeneous groups are, on average, very close to the predicted level, the distribution of contributions within groups are considerably more dispersed. With communication, the equity measures for the Homo, S Het and C Het treatments fall to 0.081, 0.183 and 0.230. This communication effect is statistically significant ($p < 0.001$).

The results for heterogeneous groups with no communication are consistent with the predictions of the equity theory model presented in Chan *et al.* (1997) rather than those of the conventional public good model presented by Bergstrom *et al.* (1986). There also may be a notion of equity that drives the contribution decisions of participants when they may communicate. Discussion will be directed towards this in Section 5.

4.2. Payoffs

Results are illustrated in Figures 5 and 6. Figure 5 summarizes mean per period payoffs by heterogeneity category, subject type, and communication conditions. Figure 6 summarizes the coefficients of variation (COV) of payoffs within a group by heterogeneity category and communication conditions.

Moving from left to right across Figure 5 within a heterogeneity category, the first two bars for each heterogeneity treatment identify the mean payoffs for S-type participants in a group. The third and fourth bars identify values for the D-type participants. In homogeneous groups (Homo) there are only S-type individuals. In the simple (S Het) and complex heterogeneity (C Het) categories there are both S- and D-types. White bars and lightly shaded bars identify no-communication periods and black and darkly shaded bars identify communication periods. The faint dotted lines across Figure 5 identify the individual Nash equilibrium payoffs in the no-communication sessions (475 lab dollars) and the symmetric individual optimal payoffs in the communication sessions (636 lab dollars). The Nash equilibrium payoffs reflect the income neutrality inherent in the Bergstrom *et al.* public good model.

[Insert Figure 5 Here]

The patterns of individual payoffs in Figure 5 suggest that communication increases payoffs

and that D-type individuals earn more than S-type individuals. The main effect of communication is strongly significant ($p = 0.000$) as average per person profit rises by 25 percent from 475 to 595 lab dollars with communication. The main effect of type is weakly significant ($p = 0.109$); D-type individuals earn, on average, 178 lab dollars more than S-type individuals (489 versus 667).

In the absence of communication, the average payoff to individuals in Homo, S Het and C Het treatments is 449, 458 and 536 lab dollars respectively. With communication, these rise to 570, 624 and 560 lab dollars. The average payoff in C Het groups rises, but is no longer greater than the payoffs to individuals in homogeneous or simple heterogeneity groups. This interaction between communication and heterogeneity is significant ($p = 0.010$) and mirrors the pattern of group contributions in Figure 2. There is also a significant interaction between communication and subject type ($p = 0.013$). This is reflected by an increase in the difference between payoffs to S-types and D-types with communication of nearly 60%. The average difference in the absence of communication is 138 lab dollars. This rises to 218 lab dollars with communication. Driving this result is the increase in payoffs to both S-type and D-type individuals in all groups except for S-type individuals in C Het groups (see Figure 5).

Figure 6 shows mean coefficients of variation for payoffs by heterogeneity categories and communication conditions. White bars denote no-communication periods and black bars denote communication periods. Pooled across communication conditions, payoffs are least unequal in the homogeneous condition ($COV = 0.095$) and most unequal in the complex heterogeneity condition ($COV = 0.280$). There is a significant interaction between heterogeneity and communication ($p = 0.045$). Communication is associated with increased inequality of payoffs in the C Het category (from 0.223 to 0.327) and reduced inequality in the Homo category (from 0.145 to 0.043).

[Insert Figure 6 Here]

The results displayed in Figure 6 reflect those shown in Figure 4. The dramatic reduction in inequality in the distribution of contributions resulting from communication among members of homogeneous groups leads to a reduction in payoff inequality in these groups. In the groups characterized by complex heterogeneity, the distribution of contributions also became substantially more equitable. This is reflected in the more inequitable distribution of payoffs. High endowment individuals with relatively greater preferences for the public good keep more resources for private consumption and increasingly free-ride on the other members of their groups, gaining increased payoffs from the increased provision of the public good and from their increased consumption of private goods. The S-type individuals find their total payoffs marginally less than in the no-communication periods. The role of preferences for equity in creating these payoff distributions is discussed in Section 5.

5. Discussion and Conclusions

This paper reports effects on both individual contributions to and individual payoffs from voluntary contributions to public good provision in a non-linear environment under alternative conditions of communication, information and the heterogeneity of contributors. We find that providing all participants in a group with information on each individual's endowment and payoff table does not significantly affect the contributions made by individuals in three-person groups regardless of whether they are able or not able to communicate with each other. A possible extension of this research is to consider comparable environments and in addition provide the specific contributions of each participant after each complete information decision-round rather than only the total contributions from the group.

When potential contributors are unable to communicate, the resulting patterns of mean contributions by subject type do not conform to the predictions of the conventional non-linear public good model as developed by Bergstrom *et al.* (1986), even though they tend to conform on aggregate. The S-type individuals in heterogeneous groups tend to over-contribute and the D-type individuals tend to under-contribute. This behaviour was first identified in non-linear public goods environments by Chan *et al.* (1996). They conjectured that notions of equity might underlie this type of outcome, and presented an alternative to the conventional public good model which predicted Nash equilibria consistent with the outcomes they observed. Chan *et al.* (1997) tested this model against the conventional model and supported a public good model which included a notion of equity that had been presented earlier in the psychology literature by Walster *et al.* (1978). This notion of equity may provide an explanation for the pattern of contribution behaviour that emerged with communication, resulting in the increasingly inequitable distributions of payoffs as heterogeneity became more complex.

Chan *et al.* (1997) conjectured that an additive *equity* term augmented the induced payoff schedule presented to the participants in their sessions. The equity term reduced the *psychic* payoff of an individual from that associated with his lab dollar payoff whenever the individual's contribution relative to his endowment differed from the share of the group's total contribution from its total endowment.¹⁶ In the experiment reported here, whether information was complete or incomplete, each individual could always obtain these ratios. The data indicate that the information treatment did not have a significant influence on contributions or payoffs, and the pattern of

¹⁶ The predictions presented in Chan *et al.* (1997) would be unchanged if individuals compared their actual contributions with mean individual contributions rather than their contributions relative to their endowments with total contributions relative to total endowments.

relationships described below are reflected in both information treatments. A conjecture which follows from the data supports a hierarchical notion of equity in the presence of communication. If pre-communication contributions are relatively equitable, individuals seek to focus on equity in payoffs. If pre-communication contributions are not equitable, individuals focus on increasing equity in contributions.

When group members are permitted to communicate and communication is not binding, the Nash equilibria are unchanged. It is possible, however, that the distribution of contributions across members of a group at the start of communication will be important in determining the contributions which will emerge from communication.

In this experiment, communication in homogeneous groups would likely reveal the relative unequal distribution of contributions that are reflected by the coefficients of variation in Figure 4. Communication leads to more equitable distributions of contributions. Because individuals have the same payoff schedules, this leads to more equitable distributions of payoffs. See Figure 6.

Prior to the start of communication in the groups characterized by heterogeneity in a single dimension, contributions are relatively more equitable than are predicted by the public good model which does not incorporate notions of equity (the mean coefficient of variation of contributions is 0.35 as compared to the predicted 0.62). The average contribution of S-type individuals is 6.32 tokens (as compared to the predicted 4.5) and the average contribution of D-type individuals is 8.32 (as compared to the predicted 12). Because the differences in contributions of these two types of individuals were relatively small, it may have been easy for them to agree, through communication, that they should both increase their contributions in order to increase their payoffs. The resulting outcome leads to more contributions and no change in the distribution of payoffs

across members of these groups. Average contributions of the S-types rose to 11.81 tokens and for the D-types, 15.52. Before communication, the average coefficient of variation of payoffs was 0.16 and after communication it was 0.17. Contributions which were relatively equitable before communication generated increased contributions by everyone.

Prior to the start of communication in the groups characterized by heterogeneity in two dimensions, contributions are clearly unequal. The average contribution of S-type individuals is 6.61 tokens (as compared to the predicted 2) and the average contribution of D-type individuals is 13.38 (as compared to the predicted 17). Both deviate from the conventional Nash prediction in the direction predicted by the model with equity considerations. However, the difference in contributions of these two types of individuals was not relatively small. The D-type individuals contributed on average twice what the S-types contributed. Even though the individuals may have recognized that increased contributions would result in a greater provision of the public good, it may not have been easy to negotiate uniform increases in contributions by both types of individual. The differences in no-communication contributions may have created an environment in which increasing the equality of contributions was a very important outcome of communication. This is what happened. The gap between S-type and D-type contributions fell from 6.77 to 1.84 as the total contributions rose from 26.6 tokens to 30.5 tokens. This was caused by the S-types increasing their contributions to 9.54 and the D-types lowering their contributions to 11.38. The result was a substantial narrowing of the coefficients of variation of contributions from 0.49 to 0.23, and an increase of the coefficients of variation of payoffs from 0.22 to 0.34. The distribution of contributions is more equitable following communication, while the distribution of payoffs becomes more inequitable.

When heterogeneity is complex, it is the failure of both the S-types and D-types to increase their contributions in the face of communication that results in the anomalous result in total contributions with and without communication that is shown in Figure 2. The conjecture that equity (or near equity) in contributions is important as a starting point for individuals to focus on payoffs in these environments is suggested by this data. This provides a rationalization for the emergence of the aggregate result that was *surprising* and of the anomalous reversal of fortunes of the S-type individuals following communication. These results suggest a new experiment designed specifically to test the conjecture within the voluntary contribution environment described here that individuals may first address equity in contributions and then in payoffs.

As part of the new design, recording the discussions of participants in communicating groups may provide evidence to support the conjecture that the outcomes of no-communication rounds are important in determining the direction in which communication drives group outcomes. In particular, an experiment which does not have a no-communication phase may lead to different results across heterogeneity treatments.

If there is anything for the practical policy maker to take away from this experiment, it is that individuals in small groups are remarkably resourceful in their ability to generate processes for coordinating their activities for increasing their surpluses through voluntary contributions of resources to provide group benefits *even if they do not have a way of identifying the optimal (surplus maximizing) allocation of resources.*

When members of the small groups in this experiment knew their own endowments and potential payoffs and the total endowments and contributions of their group, the homogeneous groups increased their aggregate surpluses from 71 to 90 percent of the potential optimum after

three rounds of communication. For heterogeneous groups the increase was from 76 to 95 percent of the optimum. Communication, which brought increased payoffs and increased equity in contributions may lead, however, to increased inequity in payoffs for the groups characterized by a large degree of heterogeneity. If this result can be replicated for larger groups and different forms of complex heterogeneity, it would support fund-raising strategies which concentrate on reducing the heterogeneity of target groups of voluntary contributors.

Acknowledgements

The authors acknowledge the financial support of Environment Canada (through a grant to the McMaster University Eco-Research Program for Hamilton Harbour) and of the Social Sciences and Humanities Research Council of Canada (through a grant to Chan and Mestelman). We are particularly appreciative of the detailed constructive comments we received from Doug Davis.

References

- Bardhan, P. (1993). "Symposium on Management of Local Commons." *The Journal of Economic Perspectives*. 7, 87-92.
- Bergstrom, T. C., Blume, L. E. and Varian, H. R. (1986). "On the Private Provision of Public Goods." *Journal of Public Economics*. 29, 25-49.
- Buckley, E. and Croson, R. (2006). "Income and Wealth Heterogeneity in the Voluntary Provision of Linear Public Goods." *Journal of Public Economics*. 90, 935-955.
- Burlando, R. M. and Guala, F. (2005). "Heterogeneous Agents in Public Goods Experiments." *Experimental Economics*. 8, 35-54.
- Cardenas, J. C., Stranlund, S. and Willis, C. (2002). "Economic Inequality and Burden-sharing in the Provision of Local Environmental Quality." *Ecological Economics*. 40, 379-395.
- Chan, K. S., Mestelman, S., Moir, R. and Muller, R. A. (1996). "The Voluntary Provision of Public Goods Under Varying Income Distributions." *Canadian Journal of Economics*. 29, 54-69.
- Chan, K. S., Mestelman, S., Moir, R. and Muller, R. A. (1999). "Heterogeneity and the Voluntary Provision of Public Goods." *Experimental Economics*. 2, 5-30.
- Chan, K. S., Godby, R., Mestelman, S. and Muller, R. A. (1997). "Equity Theory and the Voluntary Provision of Public Goods." *Journal of Economic Behavior and Organization*. 32, 349-364.
- Cherry, T. L., Kroll, S. and Shogren, J. F. (2005). "The Impact of endowment Heterogeneity and Origin on Public Good Contributions: Evidence from the Lab." *Journal of Economic Behavior and Organization*. 57, 357-365.

- Isaac, R. M. and Walker, J. M. (1988). "Communication and Free-Riding Behavior: The Voluntary Contribution Mechanism." *Economic Inquiry* 26, 585-608.
- Ledyard, J. (1995). "Public Goods: A Survey of Experimental Research." In John Kagel and Alvin Roth (eds.), *The Handbook of Experimental Economics*. Princeton, NJ: Princeton University Press, 111-194.
- Levati, M. V., Sutter, M. and van der Heijden, E. (2005). "Leading by Example in a Public Goods Experiment with Heterogeneity and Incomplete Information." Discussion Papers on Strategic Interaction No. 17-2005. Max Planck Institute of Economics. Jena, Austria.
- Margreiter, M., Sutter, M. and Dittrich, D. (2005). "Individual and Collective Choice and Voting in common Pool Resource Problem with Heterogeneous Actors." *Environmental and Resource Economics*. 32, 241-271.
- Marks, M. B. and Croson, R. T. A. (1999). "The Effect of Incomplete Information in a Threshold Public Goods Experiment." *Public Choice*. 99, 103-118.
- Olson, M. (1965). *The Logic of Collective Action*. Cambridge, MA: Harvard University Press.
- Rondeau, D., Schulze, W. D. and Poe, G. L. (1999). "Voluntary Revelations of the Demand for Public Goods Using a Provision Point Mechanism." *Journal of Public Economics*. 72, 455-470.
- Walster, E., Walster, G. W. and Berscheid, E. (1978). *Equity Theory and Research*. Boston, MA: Allyn and Bacon.

Table 1. Experimental Design: Parameterization, Nash Equilibria and Sessions Per Treatment^a

	Same Endowment ($w_i = 20$ for $i = 1, 2, 3$)		Different Endowment ($w_i = 18$ for $i = 1$ and 2 , $w_3 = 24$)	
	Same Preferences ($\alpha_i = 9$ for $i = 1, 2, 3$)	Different Preferences ($\alpha_i = 6$ for $i = 1$ and 2 , $\alpha_3 = 15$)	Same Preferences ($\alpha_i = 9$ for $i = 1, 2, 3$)	Different Preferences ($\alpha_i = 6$ for $i = 1$ and 2 , $\alpha_3 = 15$)
<i>Contributions</i>				
Individual Nash	{7, 7, 7}	{4, 4, 13}	{5, 5, 11}	{2, 2, 17}
COV ^b	0.00	0.74	0.49	1.24
Group Nash	21	21	21	21
Group Optimum	43	43	43	43
<i>Payoffs</i>				
Individual Nash	{475, 475, 475}	{478, 478, 469}	{475, 475, 475}	{478, 478, 469}
COV ^b	0.00	0.01	0.00	0.01
Group Nash	1425	1425	1425	1425
Group Optimum	1909	1909	1909	1909
Comp Info Sessions	3	3	3	3
Inc Info Sessions	3	3	3	3

^a The parameters identified above are the subject's preference parameter for the public good, α_i , and the subject's endowment for each decision round, w_i . If the value of either of these parameters increases, then the subject's return to public good consumption or the subject's endowment in each decision round increases. Also note that the Nash equilibria contributions are independent of the information condition. In heterogeneous environments, individuals 1 and 2 are the S-type individuals and individual 3 is the D-type individual.

^b Coefficient of variation

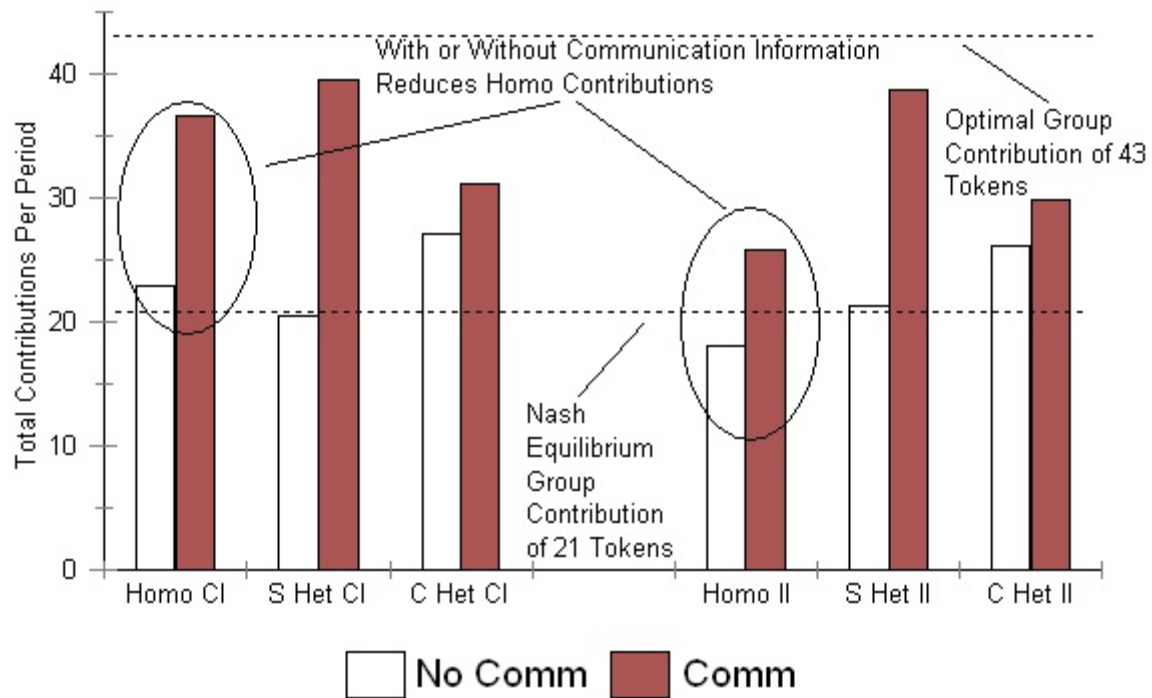


Figure 1. **Mean Total Contributions per Period by Heterogeneity, Communication and Information.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). CI denotes complete information. II denotes incomplete information. Comm denotes communication and No Comm denotes no communication.

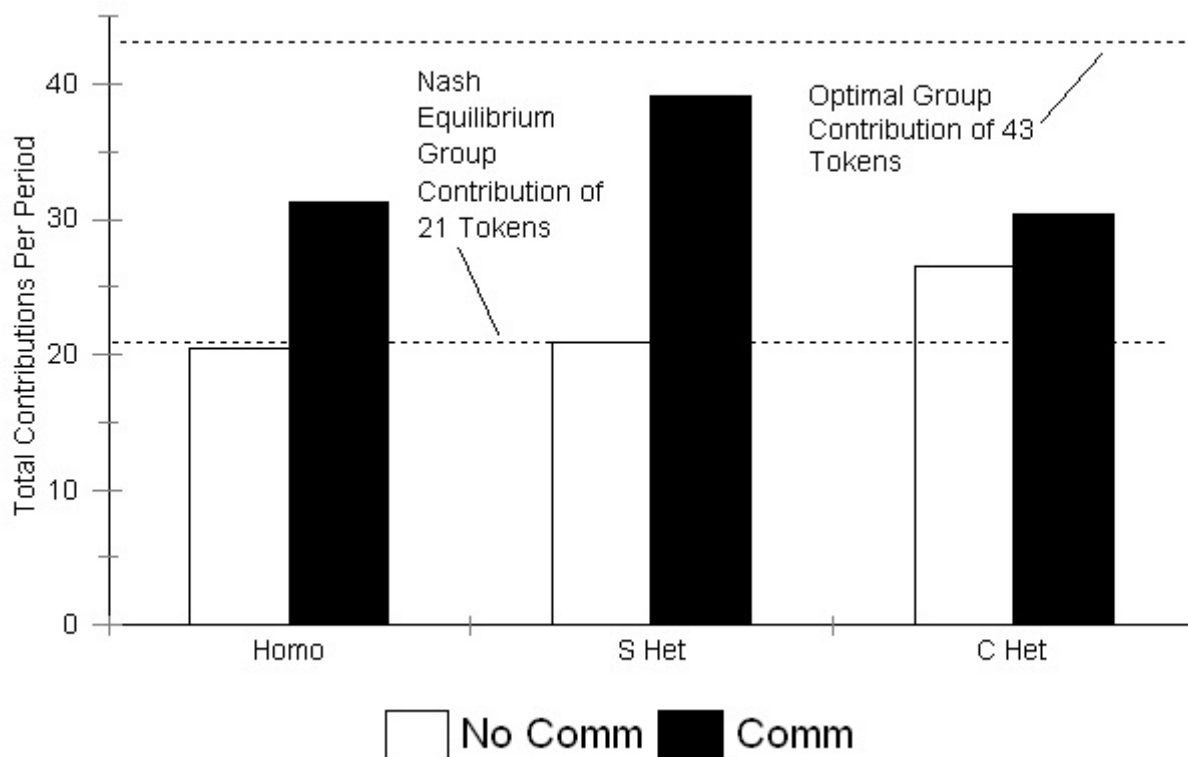


Figure 2. **Mean Total Contributions per Period by Heterogeneity and Communication.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). No Comm denotes no communication. Comm denotes communication.

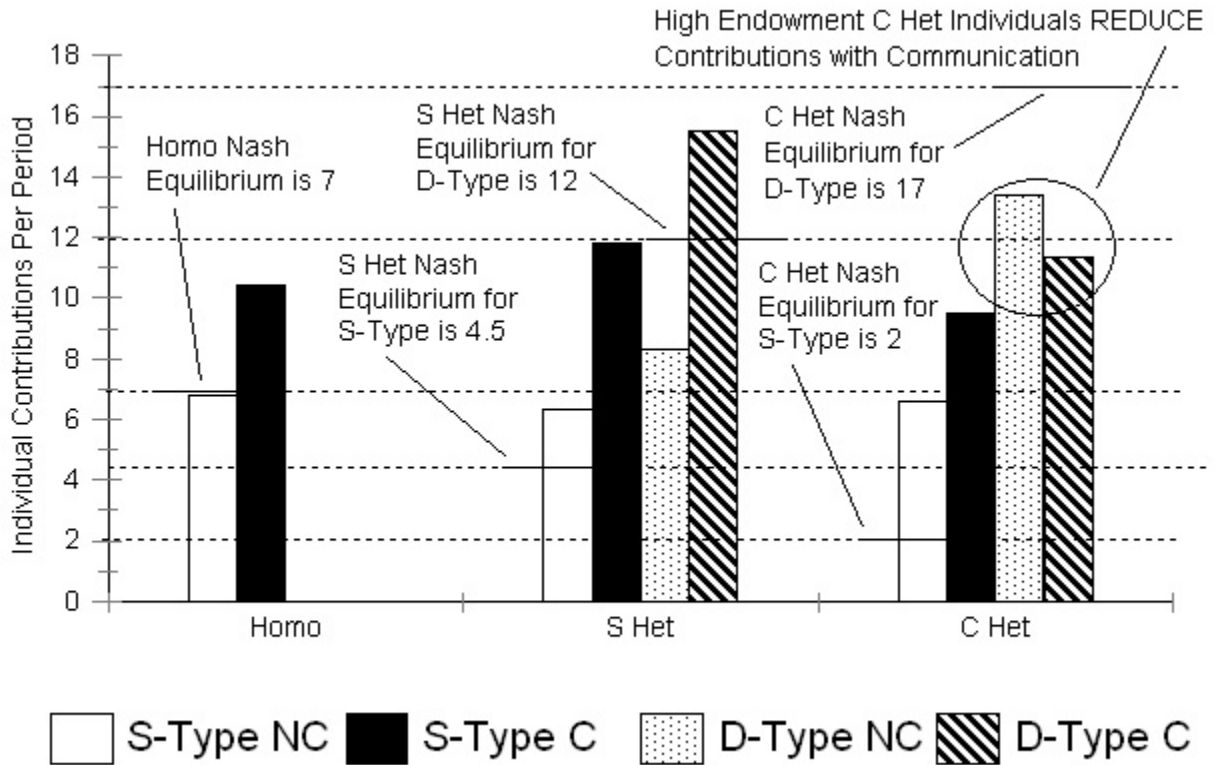


Figure 3. **Mean Individual Contributions per Period by Type, Heterogeneity and Communication.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). NC denotes no communication. C denotes communication.

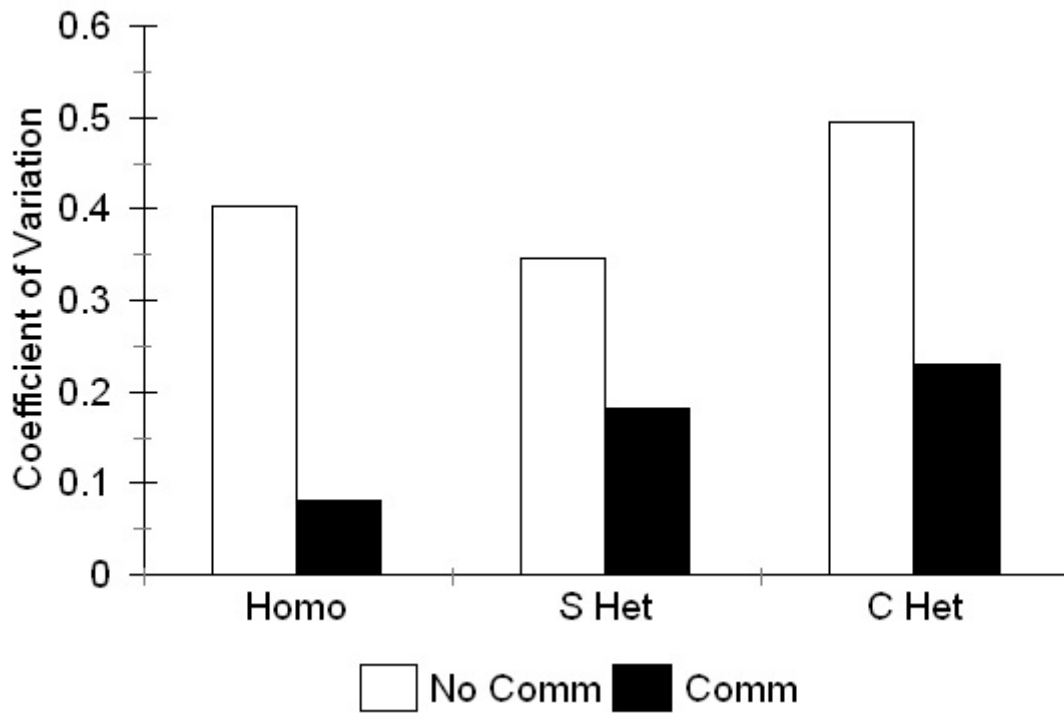


Figure 4. **Mean Coefficients of Variation for Contributions by Heterogeneity and Communication.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). No Comm denotes no communication. Comm denotes communication.

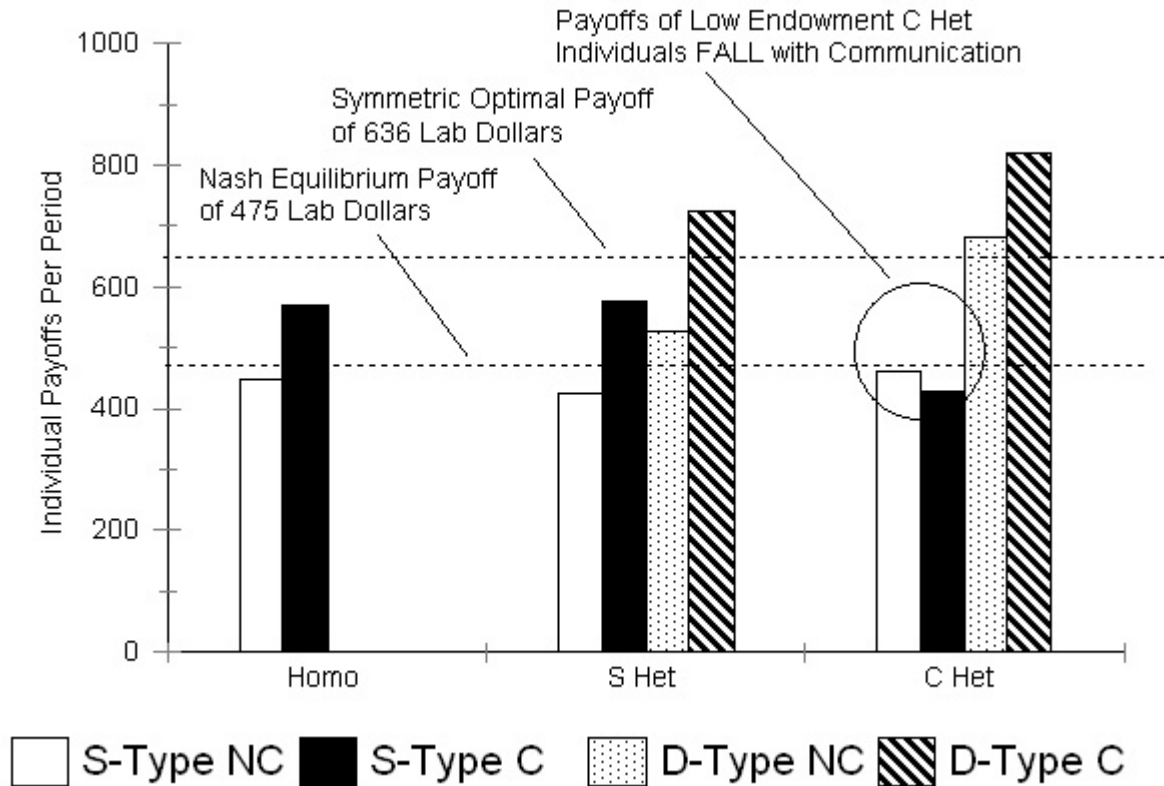


Figure 5. **Mean Individual Payoffs per Period by Type, Heterogeneity and Communication.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). NC denotes no communication. N denotes communication.

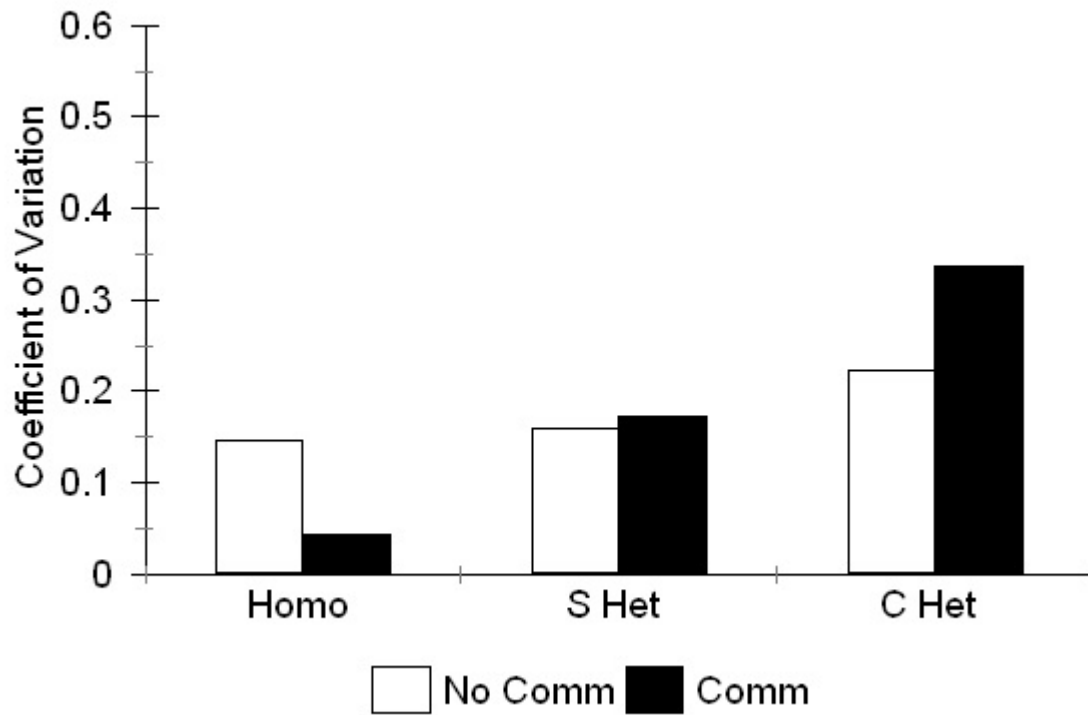


Figure 6. **Mean Coefficients of Variation for Payoffs by Heterogeneity and Communication.** Homo denotes homogeneous groups, S Het denotes groups with simple heterogeneity and C Het denotes groups with complex heterogeneity (heterogeneity in two dimensions). No Comm denotes no communication. Comm denotes communication.