Partners and strangers in non-linear public goods environments

Stuart Mestelman
McMaster University
Hamilton, Ontario, Canada

26 February 2004

Abstract

Data from three non-linear public goods experiments provide evidence that the random reassignment of participants to groups during a session does not have a significant effect on voluntary contributions as compared with voluntary contributions made by participants in groups whose members do not change over the session in which they participate. This extends the literature considering the effects of random rematching members of groups in voluntary contribution games beyond those with linear payoff functions.

Keywords: Non-linear public goods, experiments, partners, strangers.

JEL classification: C92

Send Correspondence to

Stuart Mestelman
Department of Economics
McMaster University
Hamilton, Ontario L8S 4M4
Canada

Phone: 905-525-9140 x23822
e-mail: mestelma@mcmaster.ca

Partners and strangers in non-linear public goods environments

1. Introduction

Andreoni (1988) first introduced the partners and strangers treatments in voluntary contribution games in an attempt to understand the relatively small effect that repetition had on increasing free riding in linear public goods games conducted by Isaac and Walker (1988). Andreoni was interested in whether reputation effects were responsible for keeping voluntary contributions above the single-shot dominant strategy of no contribution. Andreoni's conjecture (Andreoni and Croson, 2002) was that "if reputations matter, then partners [a set of subjects who played together in finitely repeated games] should cooperate more than strangers [a set of subjects who played in a repeated single-shot games]." This is the strategies hypothesis.

Andreoni considers strategic play and learning as explanations for the pattern of decay in voluntary contributions found in linear public goods environments. According to his strategies hypothesis strategic play in partners groups will keep contributions from falling. This may occur either because individuals are attempting to keep others who are making contributions from learning to free-ride, or because individuals are concerned that others will respond to free-riding behaviour by free-riding themselves. However, as the end of the game is approached, there is less of an incentive to avoid free-riding, and voluntary contributions decline (Croson, 1996). In strangers groups, individuals have no reason to believe that they can affect the behaviour of others in their group, because group membership changes after each decision round. Under this condition, the dominant strategy should prevail. Learning results in the gradual decline of voluntary contributions as individuals learn how to play the dominant strategy "over time". But all participants do not come to this realization at the same time (Croson, 1996). Therefore, the decline in voluntary contributions occurs over a number of periods.

Andreoni (1988) fails to support either his strategies or learning hypotheses. Strangers are more cooperative than partners and an unexpected restart of both partners and strangers environments results in an increase in contributions, which is inconsistent with the learning hypothesis that the continual decay over time will not be affected by the restart. Croson (1996) conducts an experiment which nearly replicates Andreoni's design, and is able to conclude that the strategies hypothesis can be supported.[1] Where Andreoni's strangers groups contributed more than his partners groups over the first ten periods of play, Croson's partners groups contributed more than her strangers groups. Croson's results are consistent with the strategies hypotheses.

Andreoni and Croson (2002) survey experiments which consider partners and strangers treatments in linear public goods settings and discover that the results regarding whether partners contribute more than strangers are generally inconclusive. Of nine papers surveyed, three show partners contributing more than strangers, two show the reverse, and two show neither out-contributing the other. The remaining two papers have subject pools represented by participants in six different countries. These papers find that partners dominate in sessions run with Italian and U.S. participants, strangers dominate in sessions with U.K. and Spanish participants, and neither dominates in sessions with Japanese and Dutch participants.

This paper contributes to the data accumulating on the impact of the partners and strangers treatments in public goods environments. The data reported here were generated in

[1] Replication is close, but not precise. Croson (1996) uses four person groups and Andreoni (1988) uses five person groups. Croson's linear payoff function has the same marginal per capita return to the group activity as does Andreoni's and the same marginal return to the private activity.

three experiments in which participants had identical endowments to allocate between a private and group activities and identical payoff functions. The difference between these environments and those reported in Andreoni and Croson (2004) is the form of the payoff function. Rather than a payoff function of the form

$$\Pi_i = (e_i - g_i) + A(g_i + G_{-i}) \qquad (1)$$

where e_i is individual i's endowment in tokens, g_i is individual i's contribution to the group activity, G_{-i} is the total group contribution to the public good *excluding* i's contribution (and $g_i + G_{-i} = G$), and 0 # A # 1, the payoff function is

$$\Pi_i = (e_i - g_i) + B(g_i + G_{-i}) + C(e_i - g_i)(g_i + G_{-i}) \qquad (2)$$

where B, C > 0.

The payoff function represented by equation (1) yields a Nash equilibrium $G^N = 0$ and an optimum $G^* = Ne_i$, where N is the number of individuals in a group. The optimal allocation is not a Nash equilibrium. The payoff function represented by equation (2) is parameterized to yield an Nash equilibrium $G^N > 0$ and an optimum $G^N < G^* < Ne_i$. Because it is possible for participants in this environment to make voluntary contributions that are less than the individual Nash equilibrium contribution, overall contributions may be less than the group Nash equilibrium unlike the outcome in linear public good environments in which voluntary contributions are necessarily greater than or equal the group Nash equilibrium contribution. This may result in differences between voluntary contributions by partners and strangers in non-linear public goods environment than in linear environments.[2]

---

[2] Another difference between the linear and the non-linear environments described above is the presence of a dominant strategy in the linear environment but not in the non-linear environment.

The data from the sessions reported here generally support a null hypothesis that there is no difference in the volunatry contributions made in partners and strangers environments. However, there is still evidence that is consistent with the results reported by Croson (1996).

2. The Laboratory Environment

The data presented here come from three experiments (Chan *et al*., 1996, 1997, 2002) which induce the same payoff functions for participants in baseline treatments (other treatments varied among the experiments). The payoff function given by equation (2), with B = C = 1.

The baseline treatments considered three-person groups of contributors with endowments of twenty tokens each per decision round. Payoffs were induced with a complete payoff matrix and all participants knew that everyone in their groups had the same twenty token endowment and the same payoff table. The Nash equilibrium is unique for the group (G = 15) and for the individual (g_i = 5). The optimal allocation is unique (G = 31) and any combination of individual contributions adding to 31 will generate the same total payoff to the three-person group. The optimal allocation is not a Nash equilibrium outcome. Similarly free-riding, in the sense that an individual makes no contribution to the group activity, cannot be sustained as an Nash equilibrium outcome.

The participants make voluntary contribution decisions for fifteen rounds. They know how many rounds they will play. The sessions were conducted between 1992 and 1994. Token payoffs were converted into Canadian dollars are the end of a session and participants were paid privately. Payoffs ranged between $15 and $25 with a mean of approximately $20 and a standard deviation of about $1.50.[3]

[3] Specific details of these sessions can be found in Chan *et al.* (1996, 1997, 2002).

The partners environment was used in Chan *et al.* (1996). This experiment contributes data from fifteen participants in five groups. The groups remained together for fifteen decision rounds, but the participants did not know who were the other members of their groups. The strangers environment used in Chan *et al.* (1997) contributes data from twelve participants who were reassigned to three-person groups in each of fifteen decision rounds. Chan *et al*. (2002) contributes data from sixty participants who were reassigned to three-person groups in each of fifteen decisions rounds. In this within-subject design, participants experienced a variety of treatments, however each participant experienced the baseline treatment at least four times during the last twelve decision rounds and once during the first three decisions rounds.[4]

3. The Data

The unit of observation for the comparison of the partners and strangers treatments is the contribution made by the three-person groups in each period. The individual per period contribution is not an appropriate unit of observation in the partners treatment because of the interdependence of individuals within groups over time. Although it is possible to calculate the average contribution of a group over a session for partners, it is not possible to calculate a comparable measure for the strangers treatment, because the individuals are reassigned to groups each period. Accordingly, the unit of observation will be the group in a period. Each partnered group provides an independent observation in a period, and the assumption underlying the strangers treatment is that, because of the reassignment of individuals to groups, the group contributions in the strangers treatment will be independent of one another.

[4] The analyses in Chan et al. (1996, 1997, 2002) used data from the last twelve decisions rounds. Participants were paid according to their decisions in the first three rounds, but these were treated as learning rounds and not included in the analyses of data.

The data from the three experiments are summarized in Table 1. The means and standard deviations of the group contributions by treatment and period are reported along with the number of observations in each period and p-values for exact randomization tests of the difference in per period treatment means. The contribution data are reported as the percentage of the gap between the Nash equilibrium group contribution (15 tokens) and the optimal group contribution (31 tokens) that is realized by the group. As an example, in period 8 the partners groups contributed, on average, more than the Nash equilibrium, by 18.75 percent of the difference 15 and 31 tokens. The strangers groups, however, contributed less than the Nash equilibrium contribution by 10.23 percent of the difference between 15 and 31 tokens. An exact randomization test on the difference between 18.75 and -10.67, using the five partners groups and the six strangers groups supports the null hypothesis that there is no difference between the mean of the partners groups and the mean of the strangers groups against the alternative that the means are different (p = 0.249).

The data can be easily summarized. Generally, partners contribute more towards the public good than do strangers. In all but one of the periods from 4 through 15 the partners contribute more on average than do the strangers. This is consistent with the Andreoni conjecture. However, only in one period, period 14, do the partners contribute significantly more than the strangers. Greater contributions by partners, but not significantly greater, is consistent with Croson's finding in a linear public good environment.

Croson (1996, p. 30) reports partners contributions being more variable than strangers. This is based on the distribution of individual contributions. A difficulty with using the distribution of individual contributions in a partners environment is that in any given period, the contributions of individuals who are partners are not independent. This makes the estimate of the standard deviation in this case suspect. Using group contributions, however, a comparable result emerges in the non-linear environment described here. The contributions of partners groups are more variable than are those of strangers groups. From the sixth through fifteenth periods the standard deviation of the partners groups exceeds that of the strangers group. This is consistent with a strategies hypothesis. Individuals in strangers groups have no reason to expect any signals they send in one period to have any effect on the behavior of the individuals with whom they interact in the next period. Because of the reassignment of group members, reputations cannot be established and cooperative behavior of group members in one period cannot be rewarded in the next. Individuals in strangers environments have the incentive to move towards the Nash equilibrium outcome fairly quickly. In partners groups, successful cooperation may emerge. If it does not, the likely outcome is convergence towards the Nash equilibrium. If there is any successful cooperation, this will lead to group contributions which are higher than the Nash outcome associated with non-cooperative behavior. This could reveal itself in the data as higher mean group contributions from the partners group than from the strangers group and a higher standard deviation of the group contributions from partners than from strangers.

One of the five groups of partners whose data is included here was able to cooperate and maintain a group contribution of 30 tokens from period 5 through 15. If we exclude this data from the partners groups, the mean contribution will fall and the standard deviation of the partners contributions will look very similar to that of the strangers group (instead of exceeding the strangers standard deviation in every period from 6 through 15, in four of the ten periods, this is reversed).

Finally, the means and standard deviations included in Table 1 permit a parametric test of the null hypothesis that group contributions equal the Nash equilibrium prediction of 15 tokens. From period 4 through 15, the only period in which the null hypothesis that the partners groups contribution equals 15 can be rejected in favour of the alternative that contributions exceed the Nash equilibrium is in period 4. For the strangers group this occurs only in period 9. One difference between the linear public good environment and the non-linear environment is the extent to which the Nash equilibrium characterizes the group outcomes. A simple average across the 10 periods prior to a restart, based on the figures presented in Andreoni and Croson (2004), suggest that the mean contribution of partners and strangers groups is between 30 and 40 percent of the difference between the Nash equilibrium and the optimal contributions in their linear public goods environments. In the sessions reported here, over the first ten periods, the contributions from partners and strangers groups is between 9 and 18 percent of the difference between the Nash equilibrium and the optimal contributions. This counts under-contributions as zero. Otherwise, this will bring the mean even closer to the Nash equilibrium. Generally, the Nash equilibrium organizes the data better in the non-linear environment than in the linear environment.

4. Concluding Comments

The data from Chan *et al*. (1996, 1997, 2002) provide evidence to extend the observations about partners and strangers treatments in laboratory public goods environments. When participants are provided with non-linear payoff functions which permit interior Nash equilibria, Nash equilibrium predictions tend to organize the group contributions better than they do in linear environments, when strong free-riding (making no voluntary contributions) is the Nash equilibrium prediction (this was first shown in Andreoni, 1993, and confirmed in Chan *et al.*, 1996, 1997, and 2002 for homogeneous groups).

The data presented here do not provide statistically significant evidence of a partners or strangers effect on voluntary contributions to public goods when payoff functions are non-linear, but they do provide some support for the conjecture made by Andreoni (1988) that we might expect to see strategic cooperative behavior from participants in the partners environment that will not emerge in the strangers environment. It is the cooperative behavior from one group of participants in the partners treatment in the data reported here that drives the differences that appear to exist in these data. Even though the sample is small, these data suggest that Andreoni's original conjecture regarding strategic behavior and its role in maintaining contributions above the conventional Nash equilibrium in a public good environment may be important. Accordingly, it supports the conclusion by Andreoni and Croson (2004) that "it seems only prudent that if a prediction is based on a single-shot equilibrium, then a Strangers condition will be most appropriate."

Acknowledgements

The author thanks Neil Buckley and Andy Muller for their discussion on this topic and the McMaster Arts Research Board and Environment Canada for the resources which funded the public goods sessions summarized in this paper.

References

Andreoni, J., 1988. Why free ride? Strategies and learning in public goods experiments, Journal of Public Economics 37, 291-304.

Andreoni, J., 1993. An experimental test of the public goods crowding-out hypothesis, American Economic Review 83, 1317-1327.

Andreoni, J. and R. Croson, 2004. Partners versus strangers: Random rematching in public goods experiments, in: C. R. Plott and V. L. Smith, eds., Handbook of Experimental Economics Results (Elsevier, The Netherlands), forthcoming.

Chan, K. S., R. Godby, S. Mestelman, and R. A. Muller, 2002. Crowding-out voluntary contribution to public goods, Journal of Economic Behavior and Organization 48, 305-317.

Chan, K. S., R. Godby, S. Mestelman, and R. A. Muller, 1997. Equity theory and the voluntary provision of public goods, Journal of Economic Behavior and Organization 32, 349-364.

Chan, K. S., S. Mestelman, R. Moir, and R. A. Muller, 1996. The voluntary provision of public goods under varying income distributions, Canadian Journal of Economics 29, 54-69.

Croson, R. T. A., 1996. Partners and strangers revisited, Economics Letters 53, 25-32.

Isaac, M. R. and J. M. Walker, 1988. Group size effects in public goods provision: The voluntary contributions mechanism, Quarterly Journal of Economics 53, 179-200.

Table 1 Means and Standard Deviations of the Percent of the Gap between the Optimal Contribution and the Nash Equilibrium Contribution that is Realized by Each Group in Each Period by Treatment and Numbers of Observations and p-values of Exact Randomization Tests for the Difference in Means by Period

	Period														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Partners															
Mean	33.75	18.75	-10.00	31.25	23.75	5.00	16.25	18.75	31.25	5.00	20.00	17.50	16.25	28.75	1.25
St. Dev.	62.70	47.27	40.04	14.25	38.61	49.43	51.93	47.60	40.31	47.50	70.98	40.77	44.83	34.14	50.94
Groups	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Strangers															
Mean	52.08	28.91	10.42	4.55	-3.41	13.13	-6.82	-10.23	15.63	1.14	4.55	-11.25	-7.95	-9.660	-11.25
St. Dev	28.45	34.93	47.62	29.69	41.32	41.97	31.70	35.58	19.42	18.62	32.21	31.10	22.31	20.88	16.01
Groups	8	4	8	7	7	6	7	7	6	6	7	7	6	7	7
p-values for exact randomization tests of the difference in means	0.474	0.723	0.464	0.113	0.283	0.797	0.347	0.249	0.394	0.793	0.587	0.237	0.264	0.011	0.577