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Mobility and Cooperation: On the Run*

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Résumé / Abstract

Lorsque les sujets peuvent changer de groupes dans les expériences sur les contributions volontaires aux biens publics, nous observons que les sujets plus coopératifs délaissent les sujets moins coopératifs. De plus, ces derniers essaient de joindre les groupes coopératifs pour profiter comme resquilleurs de leurs contributions.

In public goods experiments where subjects may change groups, we observe a continual flight of the more cooperative subjects away from the less cooperative ones. The less cooperative subjects attempt to enter cooperative groups in order to free-ride on their contributions.

Mots Clés : Biens publics, hypothèse de Tiebout, migration, économie expérimentale

Keywords: Public goods, Tiebout hypothesis, migration, experimental economics

JEL: C92, H41

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1. Introduction

The provision of public goods is one of the most important topics in public economics. In his path-breaking paper, Tiebout (1956) challenged the conjecture by Musgrave (1939) and Samuelson (1954) that public goods cannot be allocated efficiently. Tiebout demonstrated that public goods might be efficiently allocated if agents are fully mobile and can move to those communities that best satisfy their preferences. Tiebout's model has since been extended in many ways to examine the performance of various political institutions.[1] While this literature is about the *public* provision of goods, there is another literature on the *private* provision of public goods.[2] Besides theoretical models, we find many experimental investigations on voluntary contributions to the provision of public goods (for surveys see, for example, Davis and Holt 1993 or Ledyard 1995). The experiments show that, on average, subjects contribute more to public goods than theoretically predicted but less than would be socially efficient. Individual behavior varies considerably. At the extremes, we observe subjects who always free-ride on the contributions of others and subjects who always contribute their whole endowment to the public good.

In this paper, we present an experiment which examines voluntary contributions to public goods in a kind of Tiebout world. Each agent belongs to a community but has the opportunity to migrate to another community or create a new one. We observe that, although migration is costly, agents frequently migrate to other communities. This supports Tiebout's fundamental "voting with the feet" assumption. In our experiment, migration is going on all the time. We do not observe the evolution of stable communities. The observed contribution level is significantly above the theoretical prediction and, thus, closer to the socially efficient level.

Our experiment allows us to obtain a better understanding of individual decision-making than in previous public goods experiments without migration. In our experiment, the more cooperative subjects are continually on the run from the less cooperative ones. However, the less cooperative ones keep following them around. Thus, both free-riding and cooperating appear to be active principles in the sense that free-riders seek the contributions of others to take advantage of and that cooperators try to form groups with other cooperators.

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1 For a survey of the related empirical literature see Dowding, John and Briggs 1994.

2 There is some literature modeling Tiebout-like migration between different communities that utilize either public or private procedures for the provision of public goods (see Lagunoff 1997, or Glomm and Lagunoff 1997).

2. The game

Our experiments involve a dynamic game which is based on a population of nine players. Each player in this *population game* interacts in a sequence of 30 *n-player public good games*, with $1 \leq n \leq 9$. The actual size n of each public good game is determined by the players themselves in each round of the dynamic game.

In the symmetric *n-player public good game*, each of the n players is endowed with 10 tokens to be allocated between two alternatives, called A and B. Alternative A is private: each token allocated to alternative A yields the player a return of 1 Experimental Currency Unit (ExCU). Alternative B is public: each token allocated to alternative B by any of the n players yields each player in the group an individual return of k(n) ExCU. The individual return k(n) depends on the group size n, as presented in Table 1. We have chosen the actual values for k(n) to satisfy the following constraints. The individual return per token k(n) is smaller than 1, the return per token in the private alternative A. However, the return per token to the entire group $r(n) = nk(n)$ is greater than 1 (for $n > 1$). These constraints imply the typical public good properties: (1) contribution to the private alternative maximizes one's individual profit but (2) leads to an undesirable outcome for the group. Further constraints cause the individual return k(n) to decrease while the group return r(n) increases with the group size n.[3] This implies that a token contributed to the public good in a large group yields a lower individual but higher group return than in a small group.

The *population game* begins with a first round of interaction in 3-player public good games. In this round, the nine players of the population are randomly assigned to three separate groups of three players each to play the public good game once. From the second round on, each round is divided into two stages. In the first stage, each player decides whether he wants to stay with his group, switch to one of the other groups that existed in the previous round, or create a new group. Switching to another group or creating a new group incurs costs of 5 Experimental Currency Units (ExCU) to the player. In the second stage, he makes a contribution to the public good decision within his new group of n players. If in the first stage of a round a player has created a new group he forms a 1-player group during the second stage of the current round.

3 Note that a *pure* public good can be characterized by nonrivalry in consumption. Thus, group size has no effect on the individual return. Isaac and Walker (1988), however, consider an *impure* public good "which can be jointly consumed but in which increases in group size tend to diminish the marginal benefit to all consumers." See also Olson (1965) for a discussion of group size and public goods provision.

In the beginning of the first stage, when a player makes his group adherence decision, he knows the sizes, total and average group contributions to alternative B, and the per capita returns from alternative B of all groups in all prior rounds in which they existed. He is also informed about his personal payoff in the prior rounds. This information is always available. Each group can be identified by its identification number. In the beginning of the second stage of each round, before making his contribution decision, each player is informed about the size n of his new group.

A player's payoff in a round results from his success in the second-stage public good game, minus mobility costs if he changed groups in the first stage. The payoff of all 30 rounds is added up to determine the player's total payoff in the population game. All players know the conversion rate with which the population game payoff is converted into cash payment. The players have complete information about the rules of the game.

The n-player public good game has a *game-theoretic solution* in dominant strategies. Since for any group size n, the individual return per token in alternative A is always larger than the individual return per token in alternative B, it is a dominant strategy for each player to contribute all of his token endowment to his private alternative A and nothing to the public alternative B. Thus, solving the 30-round population game by backward induction, we find that in the unique subgame perfect equilibrium, in each round, each player should contribute all of his token endowment to his private alternative A and nothing to the public alternative B. Furthermore, he should never change his group because in doing so he would only incur costs.

Since for any group with more than one member the group return from a token in alternative B is greater than 1, the solution in dominant strategies does not maximize the payoff to the entire group. The group optimum of the n-player public game (with $n > 1$) is achieved if each player contributes all of his token endowment to the public alternative. As the group return per token, $r(n)$, is increasing in n, in each round of the dynamic game, the population of nine players is best off if they are all in one group of nine players to play the public good game and contribute all of their tokens to the public alternative B.

3. The experiments

The experiments were conducted as computerized experiments at the University of Karlsruhe. Subjects were 90 students from various departments who had never participated in a public goods experiment before. We organized 5 experimental sessions with 18 subjects each. In each session we ran two independent population game experiments at the same time.[4] No subject could identify who the other 8 members in his population were. Subjects made their decisions privately at computer terminals. They were not allowed to communicate in any other way. Before the experiment started, written instructions (available upon request) were distributed and read aloud. Then, to make sure that everybody had understood the rules of the game, each subject had to answer some questions regarding the instructions. The questions were presented one by one at his computer screen. After the experiment, each subject was paid according to his individual earnings in the experiment. The conversion rate was 6 pfennigs (0.06 German marks, DM) per ExCU. The earnings ranged from DM 20.80 to DM 45.60; the average earning was DM 30.20 for about two hours.

4. Results

Fig. 1 shows the time path of average contribution to the public good (contribution B) over all 90 subjects. The time path shows the typical slight downward trend. The average contribution to the public good over all rounds is 5.17 (standard deviation 4.14). This is more than half of the endowment and, thus, relatively high. Zero contribution and contribution of the whole endowment occur both with a frequency of about 30 percent.

A fair amount of movement takes place. On average, we observe 41 group changes per population game. This corresponds to 1.4 group changes per round in a population. The average group size is 4.6. Groups of nine exist, on average, during 7 of 30 rounds.

In total, we observe the creation of 32 new groups. In 21 of the new groups, the single subject contributes all of his endowment to the public good while in 8 of the new groups the single subject contributes nothing to the public good. In three of the new groups we observe partial contribution (2, 8, and 9 tokens). Contribution to the public good neither maximizes the subject's own current profit nor brings a return for any other subject. We interpret such a behavior as a form of signaling one's willingness to cooperate. This confirms the result of a strategy experiment by Keser (1997) where subjects designed complete behavioral plans for playing a repeated 4-player public good game.

We observe a continual growing and splitting of groups: Groups with a relatively high contribution level tend to grow, but once they are growing, contributions decrease and the groups begin to split. New groups arise and the dynamics go on.[5] To give statistical support to this description of the group dynamics, we apply nonparametric statistics, following Siegel (1987). We can show that a group tends to grow because of its high contribution level (Result 1). However, once it is growing, its contribution level tends to decrease (Result 2). A decreasing contribution level then causes members to leave the group (Result 3).

Result 1: *Groups with a relatively high contribution level tend to grow, while groups with a relatively low contribution level tend to shrink.*

We consider the contribution level to the public good *before* a group grows, remains unchanged, or shrinks in size. In the aggregate over all populations, the contribution level of groups that attract members is higher than the contribution level of groups that do not change in size. Furthermore, the contribution level of groups that do not change in size is higher than the contribution level of groups that lose members. With a sign test based on the independent populations we can show that these differences are significant at the 1 percent level (two-sided test).

Result 2: *If, from the previous to the current round, the size of a group has remained unchanged or has increased, the contribution level of that group tends to decrease in the current round.*

We consider the change in contribution *after* a group has grown, remained unchanged, or shrunk in size. In cases where a group has grown or remained unchanged in size, we observe, on the

4 This yields us 10 independent observations in total.

5 A computer program showing the dynamics of group size and contribution level for each independent population can be found at http://www-vwl3.wiwi.uni-karlsruhe.de/vwl3/selbstbedienungsladen.html.

average, significant decreases in contribution. Applying a sign test, in both cases, we can reject the null hypothesis that the contribution tends to increase or decrease with equal probability at the 5 percent significance level (two-sided test). In cases where a group has shrunk, we observe, on the average, a small increase in contribution. However, we cannot reject the null hypothesis.

Result 3: *A group tends to shrink or remain unchanged in size after it has shown a decreasing contribution level.*

We consider the change in contribution *before* a group grows, remains unchanged, or shrinks in size. In general, groups that shrink or remain constant have suffered a decrease in contribution level, whereas those that grow have experienced an increase in contribution level. Applying a sign test, we may reject the null hypothesis that the contribution is equally likely to have increased or decreased before a group shrinks (5 percent level, one-sided) and before a group remains unchanged in size (5 percent, one-sided). However, we cannot reject the null hypothesis in the case of a group that grows.

4. Individual behavior

We base the analysis of individual behavior on the following measures for each individual subject:

Contribution level: his average contribution to the public alternative over all 30 rounds.

Old group size: the average size of groups before he leaves them, if he ever changes a group.

New group size: the average size of groups before he joins them, if he ever joins another group.

Old group deviation: the average difference of the subject's own contribution from the average group contribution in the round before he leaves a group, if he ever leaves a group.

New group deviation: the average difference of the subject's own current contribution from the average contribution in the previous round of the group

	that he has just joined, if he ever joins a group.
Frequency of group change:	number of times he decides to change to another group or to create a new one.

In the following, we consider a subject's contribution level as an indicator of his cooperativeness. A subject with a higher contribution level is considered to be more cooperative than a subject with a lower contribution level.[6] We can show that the more and less cooperative subjects show different group-changing behavior. This difference is not observed in the frequency of group change.[7] It shows, however, in the point of time at which groups are changed. The more cooperative subjects tend to leave groups earlier as they tend to leave larger groups than the less cooperative subjects (Result 4). Furthermore, the more cooperative subjects join smaller groups than the less cooperative ones, who join groups that have already undergone growth (Result 5). This supports the interpretation of the more cooperative subjects being on the run from less cooperative subjects. The less cooperative subjects, however, are continually following them around. Finally, we show that the behavior of subjects with a higher contribution level may be considered as cooperation while the behavior of subjects with a lower contribution level may be considered as free-riding (Result 6). This is based on the observation that a subject with a higher contribution level tends to contribute more than the others he is interacting with while a subjects with a lower contribution level tends to contribute less than the others he is interacting with.

Result 4: *Subjects with a higher contribution level tend to leave larger groups than subjects with a lower contribution level.*

The Spearman rank correlation coefficient between the contribution level and the old group size

6 We think that this measure is quite reasonable, as we have evidence that the variety in subjects' contribution behavior almost uniformly covers the whole spectrum. At the extremes, let us consider to be free-riders all those who make zero contributions in more than half of all rounds and cooperators all those who make full contributions in more than half of all rounds. By this definition we identify 23 free riders and 23 cooperators. Together they represent about half of the total of 90 subjects. The median of the contribution levels of all 90 subjects is 5.20; the average is 5.17.

7 We apply a median test for the null hypothesis that the frequency of group change is independent of the contribution level. The null hypothesis cannot be rejected (p-value of 82.2 percent). The rank correlation coefficient between the contribution level and the frequency of group change is -0.121 and thus not significantly different from zero.

is significantly positive at the 1 percent level; it is 0.415.

Result 5: *Subjects with a higher contribution level tend to change to smaller groups than subjects with a lower contribution level.*

The Spearman rank correlation coefficient between the contribution level and the new group size is -0.390; it is significantly negative at the 1 percent level.

Given the above described group dynamics (a group grows, contributions in this group decrease, group members leave, and a new group grows) we deduce from Results 4 and 5 that subjects with a higher contribution level tend to leave groups earlier than subjects with a lower contribution level. They also tend to join groups earlier than subjects with a lower contribution level.

Result 6: *The behavior of subjects with a higher contribution level may be considered as cooperation while the behavior of subjects with a lower contribution level may be considered as free-riding.*

We consider individual behavior as cooperation if for a subject the old group deviation and the new group deviation is nonnegative, and we consider individual behavior as free-riding if for a subject the old group deviation and the new group deviation is negative.

The Spearman rank correlation coefficient between the contribution level and the old group deviation is significantly positive at the 1 percent level; it is 0.658. Furthermore, we classify subjects with respect to their contribution level, below median or not, and their old group deviation, negative or not. Applying a median test, we are able to reject the null hypothesis at the 1 percent significance level. We conclude that subjects with a higher contribution level tend to leave groups after they have contributed at least as much as the group average, while subjects with a lower contribution level tend to leave groups after they have contributed less than the group average.

The Spearman rank correlation coefficient between the contribution level and the new group deviation is 0.650, significantly positive at the 1 percent level. Furthermore, we classify subjects with respect to their contribution level, below median or not, and their new group deviation, negative or not. Applying a median test, we can reject the null hypothesis at the 1 percent significance level. We conclude that subjects with a higher contribution level tend to join groups with a positive deviation while subjects with a lower contribution level tend to have a negative deviation when they join new groups.

5. Conclusion

We have presented an experiment where subjects interact in a repeated public goods game environment that allows them to move to other groups or create new groups. We observe that more cooperative subjects are on the run from less cooperative ones who follow them around. A plausible explanation for the more cooperative subjects' flight is that free-riders, if they join a group of cooperative subjects, harm the other group members. This results from the decrease of the individual return per token contributed to the public good with each additional group member.

Our design with mobility has the advantage, compared to the traditional experiments on voluntary contributions to a public good, that it brings to light features of individual decision-making principles that remain largely hidden in the traditional experiments. The major conclusion that we can draw out of these results is that both free-riding and cooperating are active principles.

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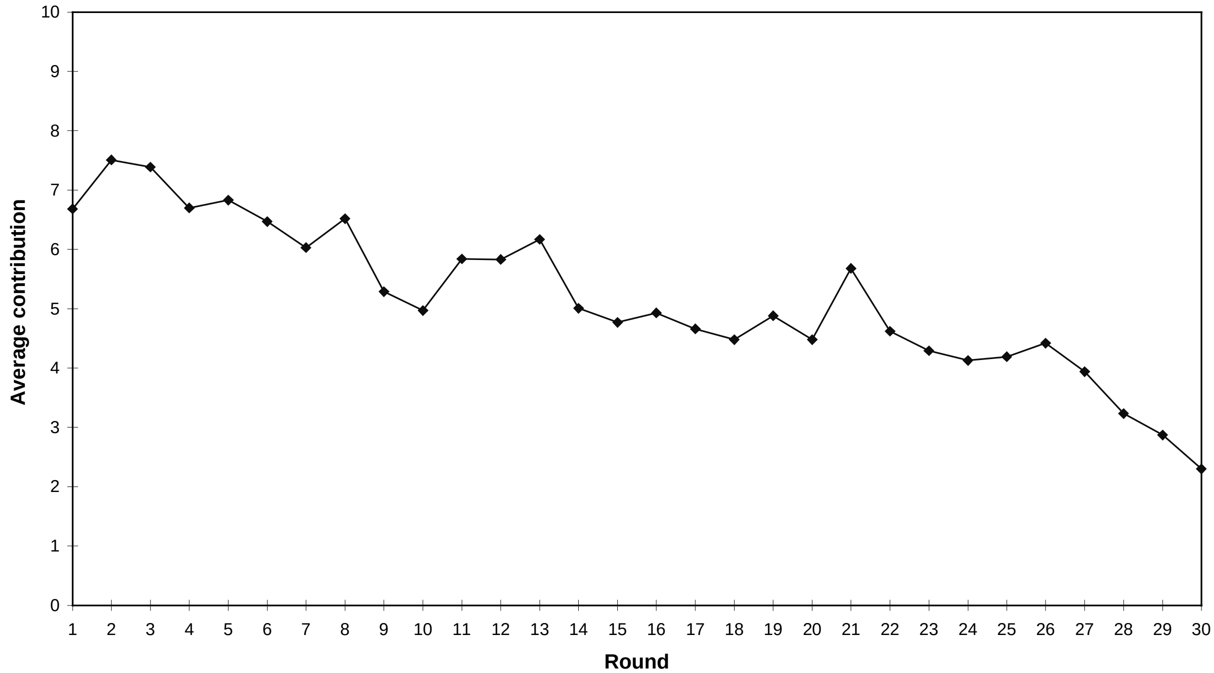

Fig. 1. Time path of the average contribution to the public good

Table 1. Individual return per token contributed to alternative B, k(n), and group return per token contributed to alternative B, r(n)

	number of group members, n								
	1	2	3	4	5	6	7	8	9
k(n)*	0.7	0.65	0.6	0.55	0.5	0.45	0.4	0.36	0.33
r(n)	0.7	1.3	1.8	2.2	2.5	2.7	2.8	2.9	3.0

* Determined as k(n) = r(n)/n, rounded to two digits in this table.

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