

Keser, Claudia

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**Institut für Höhere Studien (IHS), Wien
Institute for Advanced Studies, Vienna**

Reihe Ökonomie / Economics Series

No. 3

**VOLUNTARY CONTRIBUTIONS TO A PUBLIC
GOOD WHEN PARTIAL CONTRIBUTION
IS A DOMINANT STRATEGY**

Claudia Keser

Voluntary Contributions to a Public Good When Partial Contribution is a Dominant Strategy

Claudia Keser

Reihe Ökonomie / Economics Series No. 3

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Claudia Keser
University of Amsterdam and
Tinbergen Institute

CREED
Universiteit van Amsterdam
Roetersstraat 11
NL-1018 WB Amsterdam
Phone: +31-20-525-4110
Fax: +31-20-525-5283
e-mail: claudia@butler.fee.uva.nl

**Institut für Höhere Studien (IHS), Wien
Institute for Advanced Studies, Vienna**

Abstract

We present an experiment on voluntary contributions to a public good. The game has a dominant strategy solution in the interior of the strategy space. In the experiment we observe significant over-contribution. This result is similar to those of the typical corner solution experiments.

Zusammenfassung

Wir beschreiben eine experimentelle Untersuchung zu freiwilligen Beiträgen zu einem öffentlichen Gut. Das dem Experiment zugrunde liegende Spiel hat eine Lösung in dominanten Strategien, die im Inneren des Strategieraums liegt. Im Experiment beobachten wir signifikant überhöhte Beiträge. Dieses Experiment entspricht den Ergebnissen der typischen Experimente mit Randlösung.

Keywords

Experimental Economics, Public Goods

JEL Classification

C92, H41

1. Introduction

This paper presents the results of an experiment on voluntary contributions to a public good. The game is designed such that, in game-theoretic terms, it has a dominant strategy solution which lies in the interior of the strategy space. Each player's dominant strategy is to contribute part but not all of his endowment. This property results from declining marginal benefits from investment in the private good.

In the experiments, we observe contributions to the public good which are significantly above the dominant strategy solution. Initially, the over-contribution rate is about 33 percent; it declines to 15 percent in the last periods. This result is compatible with the well-known results of many corner-solution voluntary contributions experiments, where each player's dominant strategy is to contribute nothing to the public good (for a survey see Davis and Holt, 1993, or, Ledyard, 1993). In these experiments, one observes that at least initially significant contributions are made. Contributions typically amount to 30 to 70 percent of a player's endowment. However, Ledyard (1993) and Andreoni (1993a) argue that these contributions might not purely be due to 'altruism' or 'kindness' but to the fact that the dominant strategy lies at the corner of the strategy space. People might make mistakes. In the corner solution situation they can make them only in one direction. Thus, the observed contributions might simply result from error-making. Another reason might be that contributing nothing is considered as socially unacceptable. These arguments find support in several public goods experiments with non-cooperative Nash equilibria which lie in the interior of the strategy space, where subjects may err in two directions around the equilibrium (e.g. Andreoni, 1993b, Ostrom, Gardner and Walker, 1994). In many of these experiments, one observes that average behavior seems reasonably well described by the equilibrium solution. However, we have to take into account that the public goods games with Nash equilibrium solutions have a more complicated structure than the games with dominant strategy solutions. Andreoni (1993a) warns of the assumption that, in case of an interior Nash equilibrium, error making is averaged out of the aggregate contributions. This may mistakenly lead to an overstatement of the extent to which subjects understand the incentives for individual payoff maximization. Therefore, in the experiment presen-

ted in this paper, we analyze a voluntary contributions to a public good situation where it is not only a Nash equilibrium but also a dominant strategy for each player to contribute something. Subjects may err in both directions around the solution. Furthermore, the structure of the game is relatively simple to understand.

2. The game

The game belongs to the class of so-called Voluntary Contributions Mechanism (VCM) games. It is a 25-fold repetition of the following symmetric non-cooperative constituent game.

There are four players, each of whom is endowed with 20 tokens. These 20 tokens have to be allocated between two 'activities', called A and B. All tokens may be used for either activity or distributed between the two activities. Only entire tokens can be handled.

Let a_i be the number of tokens used for activity A by player i , and b_i the number of tokens used for activity B by player i , with

$$a_i, b_i \in \{0, 1, \dots, 20\}, \quad a_i + b_i = 20, \quad i = 1, \dots, 4$$

Activity A is a private activity to each player. The payoff earned from activity A by player i depends on the number of tokens player i uses for this activity. The payoff $u_i^A(a_i)$ from a_i tokens invested in activity A is determined by a quadratic function (which measures the payoff in ExCU, Experimental Currency Unit) :

$$u_i^A(a_i) = 41 a_i - (a_i)^2 \tag{1}$$

Table 1 shows the additional payoff from any token allocated to activity A and the cumulative payoff for any number of tokens allocated to this activity. If a player uses no token for activity A he gets no payoff from this activity.

Activity B is a public activity. The payoff from activity B to each player i depends on the total amount of tokens used by the entire group for this activity. It is denoted as $u_i^B(\Sigma b_j)$, where Σb_j is the amount of tokens used by the entire group for activity B. Each token

Table 1: Payoff from tokens used for activity A

token	payoff from that token (in ExCU)	cumulative payoff from all tokens used in A (in ExCU)
1st	40	40
2nd	38	78
3rd	36	114
4th	34	148
5th	32	180
6th	30	210
7th	28	238
8th	26	264
9th	24	288
10th	22	310
11th	20	330
12th	18	348
13th	16	364
14th	14	378
15th	12	390
16th	10	400
17th	8	408
18th	6	414
19th	4	418
20th	2	420

used by any member of the group gives each group member 15 ExCU (and thus yields a total of 60 ExCU for the group). Therefore, for each player i :

$$u_i^B(\Sigma b_j) = 15 \Sigma b_j \tag{2}$$

The total payoff to each player i from both activities, u_i , is the sum of the payoffs from both activities:

$$u_i(a_i, \Sigma b_j) = u_i^A(a_i) + u_i^B(\Sigma b_j) \tag{3}$$

Using that, for each player i , $\Sigma b_j = b_i + \Sigma_{j \neq i} b_j$ and $b_i = 20 - a_i$, we can write u_i as

$$u_i(a_i, \Sigma_{j \neq i} b_j) = 300 + 26 a_i - (a_i)^2 + 15 \Sigma_{j \neq i} b_j \tag{4}$$

The constituent game is repeated twenty-five times by the same group of four players. In the beginning of each of the 25 periods, each player of the group independently decides how to allocate the twenty tokens between the two activities. At the end of each period, each player is informed about the number of tokens used by the entire group for activity B and about his individual payoff from both activities in the current period. Then, the next period begins. The decision situation is exactly the same in each period. Each player knows that the game ends after 25 periods. The total payoff of the 25-period game is determined as the sum of the payoffs in each period.

3. Theoretical features of the game

In the constituent game it is, for each player, a dominant strategy to allocate 13 tokens to activity A and 7 tokens to activity B. Maximizing equation (3) with respect to a_i yields $a_i^*=13$, independent of what the other players in the group do. Table 1 shows that each of the first 13 tokens allocated by a player to his private activity yields him more than the 15 ExCU he could earn per token if allocated to the public activity. However, any token beyond the 13th allocated to his private activity A yields him less than 15 ExCU. Thus, the unique subgame perfect equilibrium of the 25-period game is for each player to contribute in each period 7 tokens to the public activity.

The efficient allocation, or the social optimum, requires that each group member contributes all of his tokens in the public activity B. The reason is that every token allocated to activity B yields the group as a whole more than what it would earn the individual player from his private activity.

Table 2 gives an overview of the resulting payoffs in the social optimum, in equilibrium and the maximum and minimum payoff that a player may earn. All players earn the minimum payoff if no player contributes anything to the public activity. The maximum payoff that a player may earn results if a player contributes 7 tokens while the three other players allocate all of their tokens to the public activity.

Table 2: Theoretical payoffs

	individual payoff (in ExCU)	
	per period	in game
individual max*	1,369	34,225
social optimum	1,200	30,000
equilibrium	784	19,600
no contribution to B	420	10,500

* The player contributes 7 tokens while the three other players contribute 20 tokens each to activity B.

4. Organization

The experiment was run in spring 1994 at the Center for Research in Experimental Economics and Political Decision Making (CREED) at the University of Amsterdam. It was organized in three sessions with sixteen subjects for each session. The subjects were recruited by posters around the department of economics. About two thirds of the subjects were students of economics or business administration. Among the remaining third, were mainly students of chemistry and urban planning. In each session, the subjects were randomly divided into four groups of four players to play once the 25-period game. They were instructed about the rules of the game and the use of the computer program through written instructions (available upon request). These instructions were distributed and read aloud by the experimenter. The understanding of these instructions was checked in a short computerized exercise program. Each subject had to go through this program individually. Then, the subjects played the 25-period-game. They took their decisions anonymously via computer terminals and did not communicate with each other in any other way. At the end of the session, each subject was privately paid in cash according to his success in the game. The exchange rate was 1 Dutch Guilder for 500 ExCU. A session lasted about two hours. The subjects faced no time limit when they took their decisions.

5. Results

Figure 1 shows the time path of the contributions made to the public activity B on average over all 48 subjects. We see that in each period contributions are above the dominant solution of 7 tokens. The average contribution over all players and all periods is 10.29 tokens with a standard deviation of 5.19. This corresponds to an average 'over-contribution rate' of 25 percent. The over-contribution rate is defined as the contribution rate if 7 tokens had been the minimum contribution.

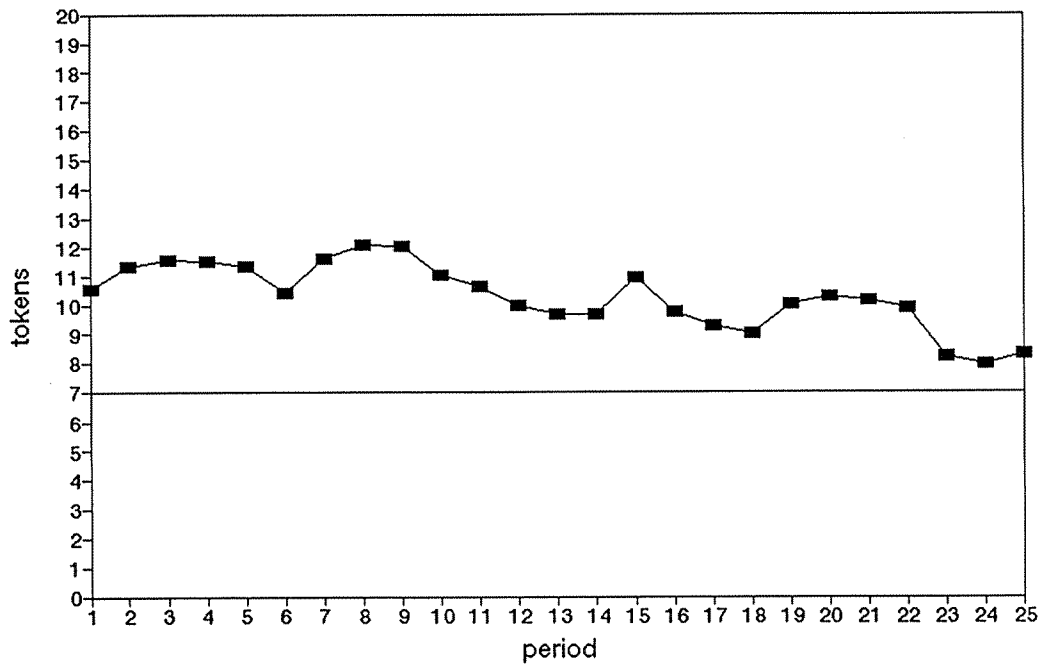


Figure 1: Time path of average contributions to activity B

Table 3 shows, for each independent player group, the average token contribution to activity B over all 25 periods, and separately for periods (1 - 10), periods (11 - 20), and periods (21 - 25). We see that the average contribution over all periods (1 - 25) is above 7

for each group. Thus, average contributions are significantly above the dominant strategy solution (χ^2 test for the null-hypothesis that there is no difference between the expected number of observations below and above 7; significance level of 1 percent).

Table 3: Average token contributions to activity B of the independent player groups

group	periods			
	1 - 25	1 - 10	11 - 20	21 - 25
1	9.95	9.83	10.23	9.65
2	10.75	11.25	11.13	9.00
3	10.11	12.15	9.05	8.15
4	8.98	8.93	9.60	7.85
5	11.36	13.65	10.48	8.55
6	10.89	12.30	10.20	9.45
7	15.07	18.93	13.00	11.50
8	9.28	10.03	8.78	8.80
9	7.65	7.88	7.18	8.10
10	12.67	12.98	12.98	11.45
11	8.62	9.15	8.40	8.00
12	8.14	9.05	8.08	6.45

Table 4 yields, over all 48 subjects, the average token contributions to activity B over five consecutive periods, from the first five periods to the last five periods of the game. We observe first a minimal increase and then slight but continuing decreases of the average contributions. These increases and decreases, however, are not significant (if we require a significance level of 5 percent, one-tailed sign test for the independent player groups). But from Table 3 we can conclude that there is a significant decrease from periods (1-10) to periods (11-20), and from periods (11-20) to periods (21-25). The significance level is 2 percent for a one-tailed sign test for the independent player groups.

Table 4 also gives, over each five consecutive periods and all 48 subjects, the average over-contribution rates. The initial over-contribution-rate is 33 percent; it declines to 15 percent in the last periods.

Table 4: Average token contributions to the public activity B (averages over all 48 subjects)

periods	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25
average contribution	11.26	11.42	10.19	9.66	8.91
std.	5.47	5.48	5.16	4.98	4.32
over-contribution rate	32.77	34.00	24.54	20.46	14.69

Figure 2 shows the distribution of the individual contributions to the public good of all 48 subjects in each of the 25 periods of the play (1200 decisions). The mode of all decisions is, with 27 per cent, at a contribution of 7 tokens. Note that four of the 48 subjects were dominant strategy players who always contributed 7 tokens to the public activity. Figure 2 shows other peaks at 10, 20 and 15. Below 7, contributions of zero and 5 were chosen most often. The median contribution is 9. 13 percent of all decisions are below 7, while 60 percent of all decisions are above 7.

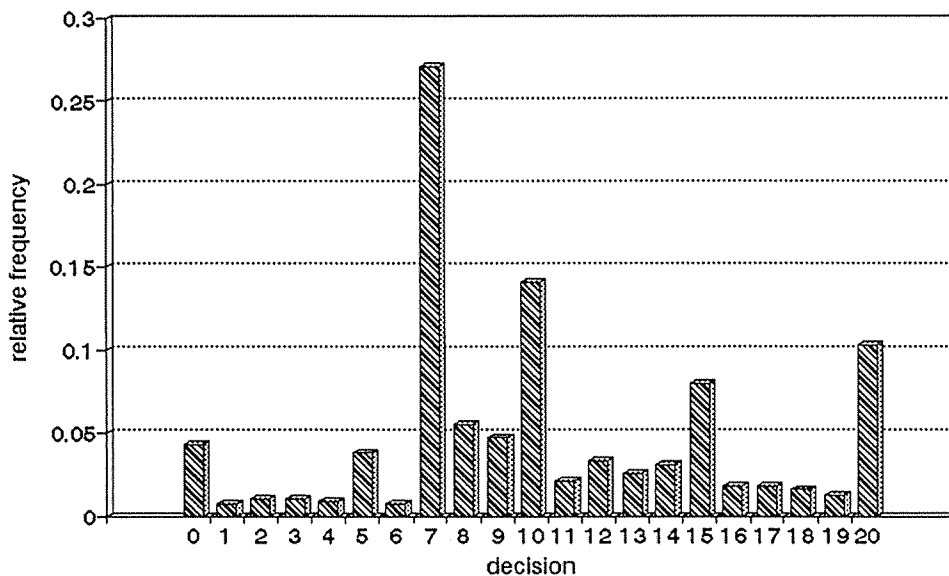


Figure 2: Distribution of individual contributions to activity B (48 subjects, 25 periods)

The realized payoffs range from 16,413 ExCU (33 Dutch Guilder) to 28,105 ExCU (56 Dutch Guilder). The average payoff over all subjects is 22,357 ExCU (45 Dutch Guilder). This means a 26.5 percent average efficiency gain over the equilibrium payoffs.

6. Conclusion

We observe an over-contribution rate of 33 percent in early periods which declines to 15 percent in the last five periods. This is consistent with the typical results found in corner solution experiments. If we assume that subjects might err in their decision-making and make errors equally likely above and below the dominant strategy, then the over-contribution observed in our experiment appears to result not from subjects' confusion. We suppose that the observed contribution above the dominant strategy results from many subjects' willingness to cooperate (see Keser, 1994).

Our result is different from the typical results in experiments with an interior Nash equilibrium, where the aggregate behavior often seems to be reasonably well described by the equilibrium solution. Thus, it supports Andreoni's (1993a) argument that the interior Nash equilibrium situations might be too complicated to assume away the possibility of error making and that one should not be too confident in what looks like equilibrium outcomes.

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Institut für Höhere Studien
Institute for Advanced Studies
Stumpergasse 56
A-1060 Vienna
Austria

Tel.: +43-1-599 91-0
Fax.: +43-1-597 06 35