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

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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
\[
\begin{align*}
   a_i, b_i &\in \{0,1,\ldots,20\} , \\
   a_i + b_i & = 20 , \quad i = 1,\ldots,4 
\end{align*}
\]

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):

\[
u_i^A(a_i) = 41 a_i - (a_i)^2
\]

(1)

Table 1 shows the additional payoff from any token allocated to
activity A and the cumulative payoff for any number of tokens allo-
cated 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 \( u_i^B(\text{Eb}_i) \), where \( \text{Eb}_i \) is the
amount of tokens used by the entire group for activity B. Each token
<table>
<thead>
<tr>
<th>token</th>
<th>payoff from that token (in ExCU)</th>
<th>cumulative payoff from all tokens used in A (in ExCU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>2nd</td>
<td>38</td>
<td>78</td>
</tr>
<tr>
<td>3rd</td>
<td>36</td>
<td>114</td>
</tr>
<tr>
<td>4th</td>
<td>34</td>
<td>148</td>
</tr>
<tr>
<td>5th</td>
<td>32</td>
<td>180</td>
</tr>
<tr>
<td>6th</td>
<td>30</td>
<td>210</td>
</tr>
<tr>
<td>7th</td>
<td>28</td>
<td>238</td>
</tr>
<tr>
<td>8th</td>
<td>26</td>
<td>264</td>
</tr>
<tr>
<td>9th</td>
<td>24</td>
<td>288</td>
</tr>
<tr>
<td>10th</td>
<td>22</td>
<td>310</td>
</tr>
<tr>
<td>11th</td>
<td>20</td>
<td>330</td>
</tr>
<tr>
<td>12th</td>
<td>18</td>
<td>348</td>
</tr>
<tr>
<td>13th</td>
<td>16</td>
<td>364</td>
</tr>
<tr>
<td>14th</td>
<td>14</td>
<td>378</td>
</tr>
<tr>
<td>15th</td>
<td>12</td>
<td>390</td>
</tr>
<tr>
<td>16th</td>
<td>10</td>
<td>400</td>
</tr>
<tr>
<td>17th</td>
<td>8</td>
<td>408</td>
</tr>
<tr>
<td>18th</td>
<td>6</td>
<td>414</td>
</tr>
<tr>
<td>19th</td>
<td>4</td>
<td>418</td>
</tr>
<tr>
<td>20th</td>
<td>2</td>
<td>420</td>
</tr>
</tbody>
</table>

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 \( i \):

\[
u_i^i(S_i) = 15 S_i \tag{2}\]

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

\[
u_i(a_i, S_i) = u_i^a(a_i) + u_i^s(S_i) \tag{3}\]

Using that, for each player \( i \), \( S_i = b_i + \sum_j b_j \) and \( b_i = 20 - a_i \), we can write \( u_i \) as

\[
u_i(a_i, \sum_j b_j) = 300 + 26 a_i - (a_i)^2 + 15 \sum_j b_j \tag{4}\]
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

<table>
<thead>
<tr>
<th></th>
<th>individual payoff (in ExCU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>per period</td>
</tr>
<tr>
<td>individual max*</td>
<td>1,369</td>
</tr>
<tr>
<td>social optimum</td>
<td>1,200</td>
</tr>
<tr>
<td>equilibrium</td>
<td>784</td>
</tr>
<tr>
<td>no contribution to B</td>
<td>420</td>
</tr>
</tbody>
</table>

* 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.

![Time path of average contributions to activity B](image)

**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 ($\chi^2$ 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 independ-
ent player groups

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

Table 4 yields, over all 48 subjects, the average token contribu-
tions 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)

<table>
<thead>
<tr>
<th>periods</th>
<th>1 - 5</th>
<th>6 - 10</th>
<th>11 - 15</th>
<th>16 - 20</th>
<th>21 - 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>average contribution</td>
<td>11.26</td>
<td>11.42</td>
<td>10.19</td>
<td>9.66</td>
<td>8.91</td>
</tr>
<tr>
<td>std.</td>
<td>5.47</td>
<td>5.48</td>
<td>5.16</td>
<td>4.98</td>
<td>4.32</td>
</tr>
<tr>
<td>over-contribution rate</td>
<td>32.77</td>
<td>34.00</td>
<td>24.54</td>
<td>20.46</td>
<td>14.69</td>
</tr>
</tbody>
</table>

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 percent, 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 ECU (33 Dutch Guilder) to 28,105 ECU (56 Dutch Guilder). The average payoff over all subjects is 22,357 ECU (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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