E C O N O M I C S B U L L E T I N

Dynamic voluntary contributions to a discrete public good: Experimental evidence

Pavel Diev
Banque de France

Walid Hichri
University of Lyon, CNRS, GATE

Abstract

We experiment a mechanism for the provision of a discrete public good where individuals are allowed to update upwards their contribution during a fixed time interval. Experimental evidence shows that subjects increase their contributions in order to finance the cost of the good. The public good is financed more frequently when its cost is low relative to the social ability to pay.

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1 Introduction

Let us consider the following example of a real situation captured by our framework. Ph.D. students in a research lab want to jointly buy a new workstation. In order to buy it at a special rate they must order it before the end of the week. During the week students can at any moment give cash towards the purchase of the machine. The director of the lab collects the money in cash and announces the total amount collected each time he receives a new payment. A student that has already given some amount of money can give another one at any time. At the end of the week, if the amount collected covers the cost, the workstation is bought. If the total amount is larger than the cost, the director can use the extra amount as he pleases (no refund of extra contributions). If the total amount is less than the cost (the provision point is not met) then the director spends the contributed money on his own dinner (or party or vacation) without inviting the students to participate (assuming the students don't have positively or negatively altruistic feelings about the director dining on their money). In this paper we describe an experiment for this situation.

According to theory, dynamic structure of contribution to a public good cannot, in itself, lead to an efficient outcome, see Fersthman and Nitzan (1991), Admati and Perry (1991), Gradstein (1992). The reason for negative results is that the introduction of dynamics allows individuals to free ride upon future contributions. This can be counteracted by assuming some form of punishment for free riders. For example, Marx and Matthews (2000) assume that individuals commit to stop contributing if some individual contributes zero in the current period. In our paper, the punishment stems from the introduction of a fixed contribution period and a discrete public good, i.e., there is no benefit from contributing if a given total amount is not reached and individuals cannot delay their contribution indefinitely if they want to obtain some positive gain.

With regard to the experimental analysis of dynamic public goods games, the experiment in our paper presents similarities and differences in comparison to experimental literature. Dorsey (1992) is interested in the relationship between the production technology of a public good and the amount collected, while we are mainly concerned with the efficient provision of a discrete public good. As in our paper, Dorsey allows the individuals to update their contribution during a fixed period. He uses linear public good production technologies which are continuous save for the following: if a given minimum amount of total contributions is not reached, the good is not provided at all, but the individuals are not refunded. There are two types of possible updates: increasing or decreasing contributions. All individuals are originally given the same amount of (experimental) money, i.e., they have identical endowments, or Ability to Pay (ATP). By contrast, in our paper, we allow only increasing updates. We have a binary production function: either the good is produced, or it is not produced at all. Moreover, individuals are originally given different amounts of (experimental) money,

i.e., they have heterogeneous endowments, or ATP. The amounts of these endowments are private information.

Other related experimental papers are Levati and Neugebauer (2004) and Güth et al. (2002). Levati and Neugebauer (2004) experiment a situation where individuals are allowed to increase their contributions at a fixed rate (English clock mechanism) and can decide to stop contributing (i.e. exit the game) at any moment and never contribute again. Obviously, this does not give them a chance to reconsider their contributions once they have decided to stop contributing. Levati and Neugebauer (2004) assume identical ATP, which is common knowledge to all the players, and a linear production function. Güth et al. (2002) extend this framework by allowing different ATP, which is also common knowledge to all players, increasing/decreasing contributions and three types of production technologies (weakest link, average contributions and best shot). Furthermore, as in our experiment, individuals can increase/decrease their contribution by any amount. Each individual can observe the amount contributed by the other members of the group. In contrast, in our paper, an individual can only observe the total amount contributed, but not each individual's contribution. To our knowledge, dynamic voluntary contributions to a discrete public good with private information on ATP have never been examined in experimental literature.

2 Experimental design

The experiments are conducted using groups of four subjects ($n = 4$). Two of these subjects are endowed with 100 tokens (i.e. experimental currency units) and the other two with 200 tokens. Thus, the Ability to Pay of an individual i is $ATP_i = \{100, 200\}$. The endowments are private information. As in Hichri (2004), we run two treatments with different levels of social surplus. In the first treatment the provision cost of the public good, c, represents 60% of the sum of the individual ATP ($\sum_{i=1}^{4} ATP_i = 600$), i.e., the provision point is 360 tokens[1]. .In the second treatment, the cost c represents 80% of the sum of the ATP, i.e., 480 tokens[2]. The time interval for contribution, T, is fixed at 90 seconds.

In this experiment, individuals do not earn anything if the provision point is not reached. When the sum of contributions of one group exceeds the provision point, each individual earns the difference between his or her endowment ATP_i and his or her contribution x_i to the public good. The payoff π_i of individual i is calculated as follows:

$$\pi_i = d.(ATP_i - x_i)$$

[1]Note that in the first treatment, equal cost sharing implies that every subject has to pay 90 tokens, which is compatible with individual rationality, as individual endowments are higher than 90.

[2]In the second treatment, equal cost sharing implies that every subject has to pay 120 tokens, which is not compatible with individual rationality, as two of the four players are endowed with only 100 tokens.

where $x_i \geq 0$ is the amount given by i to the public good, and d is a dummy parameter ($d = 1$ if the provision point is reached, and $d = 0$ if not).

We make sure while programming the experiment that individual contributions are systematically refused when they are negative. In such a case, the program sends a warning message and asks for a positive amount. However, individuals are able to contribute an amount that is higher than their initial endowment. In fact, we choose not to reduce contributions to the amount that warrants a positive payoff for individuals, as we suppose that individuals may be willing to lose money to allow the public good to be realized. On the other hand, this also gives us an opportunity to see whether individuals have understood the game, as the rationality of players implies that their contributions should not exceed their initial endowments.

The experiment was run in January 2004 at LeeX (Laboratori d'Economia Experimental), at University Pompeu Fabra in Barcelona. Each treatment included two experimental sessions of about one hour and a quarter. In each session we set three independent groups. This gives six independent statistical observations per treatment and requires 24 subjects per treatment (48 subjects for the whole experiment). All of them were students selected randomly on the campus.

Each group played one practice period, followed by 20 paying periods. At the end of each period, each subject was informed about the number of tokens he had earned. The number of subjects n in a group, the provision cost, c, the length of the time interval, T, and the number of experimental periods were common knowledge. At the end of the session, a questionnaire was distributed to subjects.

The experiment was computerized. We used z-Tree software, developed by Fischbacher (1999). At the beginning of each session, subjects were randomly assigned a computer. The experimenter read the instructions[3] aloud. All the questions were answered publicly. During the experiment, communication was totally forbidden. We made sure that the game was well understood before beginning each session.

Subjects were paid privately and in cash at the end of the experiment. The payment of a player was equal to the amount of tokens he won converted into euros at the rate of 100 tokens = 1 euro, plus 6 euros as show up fees.

3 Results

We are primarily interested on the ability of the mechanism to efficiently provide the public good. A second question is: how do individuals behave during the interval of 90 seconds; in particular do they increase their contributions? To study the efficiency of the mechanism,

[3]See the Appendix for the instructions given to individuals before the beginning of the experiment.

we examine the total amount of contributions after 90 seconds and we construct an index, denoted Ef, representing the ratio of the number of times a group succeeded in contributing a sufficient amount to provide the public good ($\sum_{i=1}^{4} x_i \geq c$) over the total number of experimental periods.

3.1 Low threshold treatment ($c = 360$)

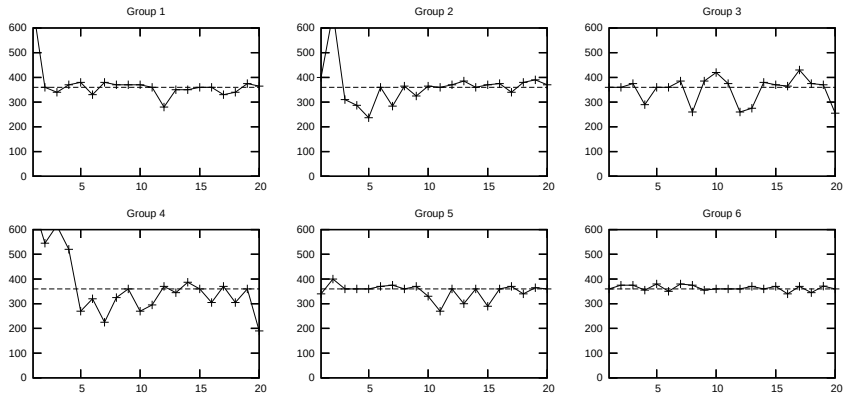

Figure 1: Contribution of each group over the 20 experimental periods (low treatment)

Table 1: Efficiency ratio (low treatment)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Average
Ef	0.60	0.80	0.73	0.40	0.67	0.73	0.66

From Figure 1 we observe that in the first experimental periods some subjects (groups 1, 2 and 4) contributed large amounts, higher than their ATP for instance. As we observe this behavior only in the first periods, we can assume that the reason for such behavior is the fact that they did not understand the game, which excludes the idea that individuals may be irrational and altruistic and willing to make negative profits. Because their payoff was negative, they quickly learned not to contribute more than their ATP. Thus, we discounted the first 5 periods from the analysis of the results, considering them as learning periods. The ratio Ef was computed over the 15 last periods.

We observe that the total amount of contributions is close to the cost of provision, even if it is less than c in some periods or slightly more than c in other periods. When the amount exceeded the cost of provision, we discover that this is because at the end of the period (in

the last 3 seconds) several individuals contributed simultaneously in order to complete the project. On average the public good was financed 65.5% of the time.

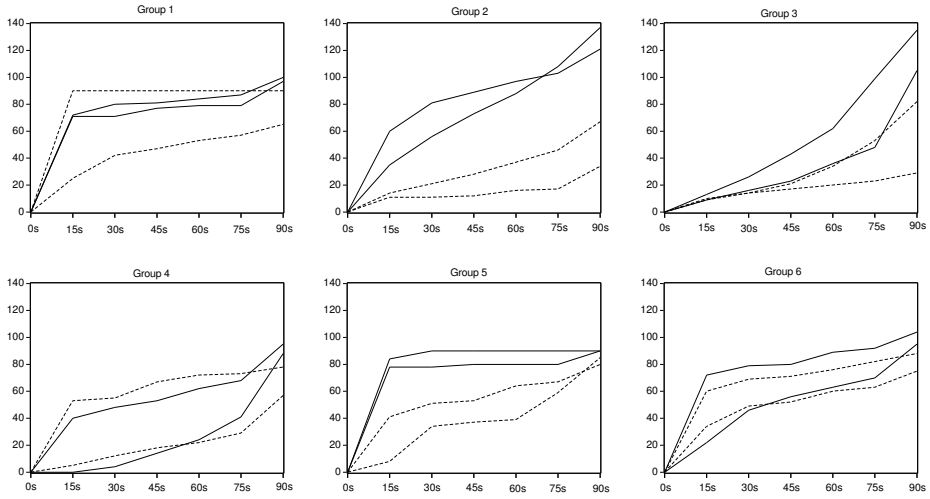

Figure 2: Individual contributions during a period (low treatment)

Turning to individual behavior, Figure 2 reports the average contribution of each individual during a period, i.e., after 15, 30, 45, 60, 75 and 90 seconds. This average is calculated over the last 15 periods. As shown in Figure 2, all subjects increased their contribution within the time interval of 90 seconds. This behavior suggests that they had incentives to reach the provision point. Intuitively, the only way to obtain a positive payoff is to contribute a total amount that is greater than c. Acting in favor of this objective requires that subjects have to increase their individual contribution. Two main behavior patterns may be distinguished: (1) individuals who contributed large amounts during the 15 first seconds and contributed only slightly thereafter; (2) individuals who contributed low amounts during the first 75 seconds and contributed large amounts during the last 15 seconds. There were also individuals who followed a mixture of these two behavior patterns.

We also observed that subjects with low ATP ($ATP_i = 100$; dashed lines) contributed on average 69% of their ATP, while subjects with higher ATP had a relative contribution equal to 52%. This could be explained by a tendency towards equal cost sharing observed in groups 5 and 6 (all members contributed nearly 90 tokens regardless of their ATP), even if some individuals were better endowed. In groups 2 and 3 this tendency was mitigated by the behavior of one individual with low ATP who committed to low contributions.

Table 2: Efficiency ratio (high treatment)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Average
Ef	0.07	0.20	0.47	0.27	0.40	0.07	0.25

3.2 High threshold treatment ($c = 480$)

As an alternative interpretation of the experiment, the time interval T can be seen as a bargaining period in which a cost-sharing agreement might be found. A benchmark agreement in such a bargaining situation is to share the cost equally. As we saw in the previous section, there is a tendency towards equal cost sharing in some groups. What will happen if equal cost sharing is not compatible with the individual rationality of some individuals? What if the equal sharing rule supposes that subjects must give more than their initial endowment? The aim of the second treatment is to give insights to these questions.

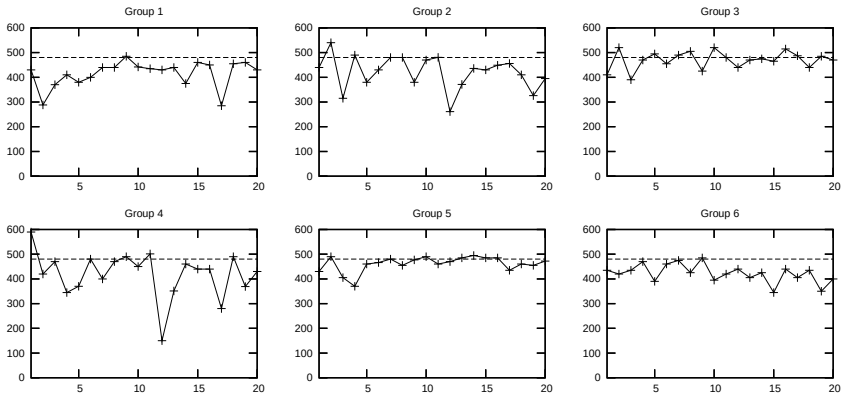

Figure 3: Contribution of each group over the 20 experimental periods (high treatment)

The results can be seen in Table 2 and Figure 3. We observe that the amount of contributions exceeds the provision point less frequently. On average, the public good is financed 24.7% of the time. In other words, subjects have more difficulty in finding a cost-sharing agreement. Intuitively, the reason might be that the set of agreements compatible with individual rationality is now restricted, making it harder to reach an agreement. Indeed, if the number of agreements that can be explored by a group during a given time interval is fixed, determined by an individual's cognitive capacities for instance, restricting the set of possible agreements automatically means that the chances of finding an agreement during a fixed time interval are decreased.

However, we still observe that the amount of contributions is close to the provision point and that in some groups and periods individuals are able to finance the public good. This

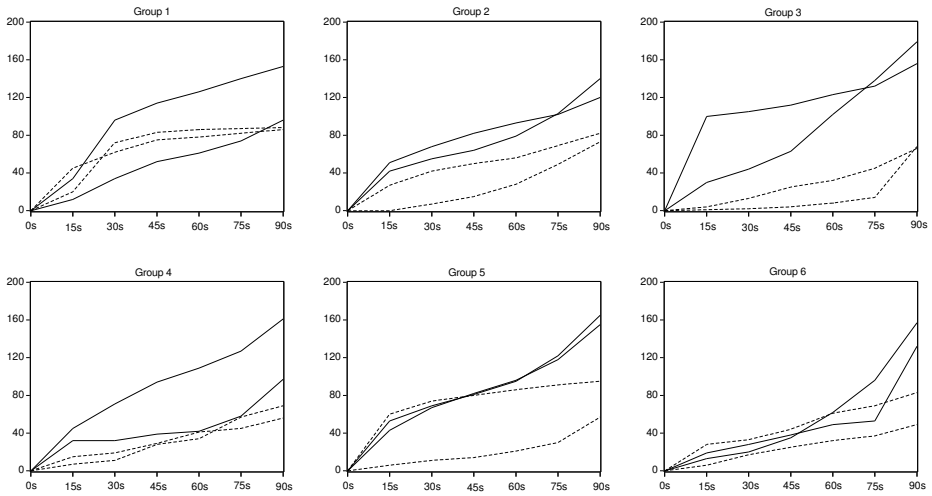

Figure 4: Individual contributions during a period (high treatment)

means that the incentives to finance the public good are still present. This can be recognized from Figure 4, where we can see that subjects are increasing their contributions during the contribution time interval. We also observe that subjects with low ATP ($ATP_i = 100$; dashed lines) contributed on average almost the same relative amount as subjects with high ATP, 72% and 71% respectively. This indicates that subjects understood that equal cost sharing was not possible, but they did not have enough time to find a different cost-sharing agreement, leading to less frequent provision of the public good[4]. Obviously, one can test whether the replication of these treatments with an increase of the contribution interval would improve the efficiency of the mechanism. This is for future research to determine.

4 Conclusion

Experimental results have to be interpreted with great caution as they are sensitive to the design of the protocol and provide a limited number of independent observations, which makes general conclusions impossible. Nevertheless, the experimental evidence we provide in this paper shows that using a dynamic voluntary contribution mechanism to provide a discrete public good in the presence of a provision point would produce incentives for the individuals to increase their contribution. This behavior could be explained by the intuition

[4]For comparison, we note that in Dorsey's (1992) experiments the time interval was fixed at 180 seconds, i.e. twice the amount of time given in our experiment.

that it is in the interest of each individual to act in favor of the objective of providing the public good, as subjects do not make a profit if the provision point is not reached. In other words, we have a situation whereby, when acting in favor of his/her own interest, an individual also acts in favor of society's interest. Sharing contributions equally when subjects are endowed with different amounts is not always possible, according to our results, as it depends on the level of the provision point. Finally, when given a time interval within which increasing contributions is possible, subjects either contribute at the beginning of the period, or wait until the end in the hope that the others will increase the sum of contributions to the provision point.

References

[1] Admati, A. R. and Perry, M., (1991), Joint Projects without Commitment, *Review of Economic Studies*, 58, 259-76.

[2] Dorsey, R. E., (1992), The voluntary contributions mechanism with real time revisions, *Public Choice*, 73, 261-82.

[3] Fershtman, C. and Nitzan, S., (1991), Dynamic Voluntary Provision of Public Goods, *European Economic Review*, 35, 1057-67.

[4] Fischbacher, U., (1999), z-Tree -Zurich Toolbox for Ready made Economic Experiments-Experimenter's Manual, Working Paper, 21, Institute for Empirical Research in Economics, University of Zurich.

[5] Gradstein, M., (1992), Time Dynamics and Incomplete Information in the Private Provision of Public Goods, *Journal of Political Economy*, 100, 581-97.

[6] Güth, W., Levati, V. and A. Stiehler (2002), Privately Contributing to Public Goods over Time -An Experimental Study-, Discussion Papers on Strategic Interaction 2002-01, Max Planck Institute of Economics, Strategic Interaction Group.

[7] Hichri, W., (2004), Interior Collective Optimum in a Voluntary Contribution to a Public Goods Game, *Applied Economics Letters*, 11(3), 135-40.

[8] Levati, V. and Neugebauer, T., (2004), An Application of the English Clock Market Mechanism to Public Goods Games, *Experimental Economics*, 7, 153-69.

[9] Marx, L. M. and Matthews, S. A., (2000), Dynamic Voluntary Contributions to a Public Project, *Review of Economic Studies*, 67, 327-58.

Appendix

These instructions are translated from the Spanish instructions that were distributed to subjects before the beginning of the experiment and correspond to one of the two treatments we are testing (Low threshold treatment).

Instructions:

Welcome,

You will participate in an experiment that will allow you to earn money. The amount you will win will be given to you at the end of the experiment. Independently of the game, you already have EUR 6 that will be added to any money you win during the experiment.

As shown in the following illustration of the game, the groups in the experiment will be randomly formed with four people per group (you and three other people). The identity of the other three group members will not be revealed to you.

Each group will be composed of the same people during the experiment. The latter is formed of one practice period that will not be considered when computing your gains, and 20 remunerated periods. The session will last approximately one hour and a half. Groups are independent and do not interact with each other.

You are not allowed to communicate with anyone in the room during the session. If you have any questions at any moment, please raise your hand and the experimenter will answer your questions privately. Any communication will lead to your exclusion from the room without any payment.

During each period, you have to take a decision and your payoff will depend on this decision and on those of the other members of your group. Your total gains from the session will be the sum of your gains from the 20 periods. The aim of the experiment is to win the maximum number of points.

At the beginning of each period, you will see the number of points you have on the computer screen. This number is private information and may be different from the number assigned to the other members of your group. You will have the same number at the beginning of each period in the game (20 periods).

During each period, lasting one minute and 30 seconds, at any moment and several times you can place a share of the points you have in an urn. The total number of points you have put in the urn and the sum of points that the group has put in this urn will be indicated continuously on the computer screen.

At the end of the period, if the sum of the points that all the members of the group have put in this urn is above or equal to 360, each group member wins the remainder of points he/she still has. If the number 360 is not reached, all group members lose all the points they have put in the urn and all the points they still have at the end of the period.

Example:

* Suppose that you have 150 points and that you put 100 points in the urn. If the sum of the points that your group has put in the urn is 300 (< 360), each group member loses all of their points.

* Suppose that you have 150 points and that you put 100 in the urn. If the sum of the points that your group has put in the urn is 400 (≥ 360), you win 150 - 100 = 50 points.

At the end of each period, the points you win during this period will be indicated on the computer screen.

This game will be repeated identically during all the periods of the game. At the end of the experiment, you will be paid in cash and privately. The total number of points you will win in the 20 periods of the experiment will be converted into euros at the rate of:

1 euro = 100 points