An auction mechanism for public goods provision: an experimental study

Hichri, Pavel and Hichri, Walid

GREQAM

2008

GREQAM

Groupement de Recherche en Economie
Quantitative d'Aix-Marseille - UMR-CNRS 6579
Ecole des Hautes Etudes en Sciences Sociales
Universités d'Aix-Marseille II et III

Document de Travail

n°2004-31

Pavel Diev and Walid Hichri

An auction mechanism for public goods provision: an experimental study

An auction mechanism for public goods provision: an experimental study*

Pavel Diev[†] and Walid Hichri[‡]

26th May 2004

Abstract We experiment a new mechanism for the provision of a discrete public good: in a fixed period individuals can contribute several times; at any moment they can see the total amount collected; at the end of the period, the public good is provided if the amount covers the cost. We find that the ability of the mechanism to provide efficiently the public good decreases with the amount of the provision cost.

Résumé On expérimente un nouvel mécanisme de fourniture de bien public discret: les individus peuvent contribuer à tout moment durant un intervalle de temps fixé; à tout moment le montant total collecté est affiché aux individus; à la fin de l'intervalle de temps, le bien public est fourni si le montant collecté est suffisant pour payer le coût. Le principal resultat des expériences est que la capacité du mécanisme à fournir le bien public de manière efficace décroît avec le niveau du coût de production du bien public.

Keywords Public Goods, Experiments, Mechanism Design

Mots-clés Biens publics, Expériences, Mechanism Design

JEL Classification: C92; H41

*We are indebted to Christophe Deissenberg, Alan Kirman and Sylvie Thoron for their supervision and helpful comments. We also thank Jordi Brandts and Antoni Bosh for making the LeeX available for us, and the participants of the Workshop "Economie d'intéractions, réseaux et coalitions", 17 of May 2004, GREQAM, Marseille. The paper was submitted to Economics Letters with the title "Bidding for the Public Good: an Experimental Study".

[†]GREQAM, Université de la Méditerranée.

[‡]GREQAM, Univesité d'Aix-Marseille, Corresponding author: GREQAM, 2, rue de la Charité, 13002 Marseille, France, Tel: +33 (0)6 11 55 24 57, Fax: +33 (0)4 91 90 02 27, e-mail: hichri@ehess.vcharite.univ-mrs.fr.

1 Introduction

The literature of mechanism design on public goods searches "rules" that implement Pareto-efficient allocations. Many mechanisms were designed for situations with complete information. They produce efficient equilibrium outcomes by using a refinement for the Nash equilibrium concept. Bagnoli and Lipman (1989) design a very simple mechanism and show that the undominated perfect equilibria for this mechanism are efficient. Another exemple is Varian (1994) who uses the subgame perfection as an equilibrium refinement. However, the assumption of complete information is highly unrealistic. In fact, with complete information and free communication between individuals, we would expect that the Coase theorem would work (Coase (1960)).

What we propose here is an experiment of a modified version of the Bagnoli and Lipman (1989) voluntary contribution game. We drop out the assumption of complete information about preferences and we change the static environment by introducing the possibility for players, during a contribution period, to increase at any time their contribution for the public good. Also, the total amount collected is continuously displayed to individuals. As in Bagnoli-Lipman's study there is a discrete public good, individuals have heterogeneous willingness to pay (WTP) for it, and if the amount collected is less than the provision cost there is a refund. If the amount exceeds the cost, the extra-contributions are kept by the collector, contrary to Rondeau et al.(1999) where the extra-contributions are refunded. For a survey on the experimental study of different public good games, see Ledyard (1995).

We would like to observe the ability of the mechanism to produce efficient provision of the public good and the sensitivity of this ability depending on the provision cost level.

The fact that players can contribute several times in a period and see the total amount collected is a kind of communication between them. Players can send messages to other members of the group and signal their willingness to cooperate, which can make it easier to coordinate individual actions in comparison to the standard case where players contribute simultaneously and only once. In an experiment dealing with communication, Chan and al. (1999) show that communication increases coordination. In another experiment, Cason and Khan (1999) show that verbal communication is very powerful in increasing voluntary contribution levels.

Another interesting question is to see how contributions vary in each period, i.e., do subjects wait for the last seconds to contribute or do they contribute in the beginning of each period. On the individual level, we can be interested in the way contributions are related with the WTP, i.e. if people with hign WTP have higher contributions?

2 Theoretical design

Our design represents the willingness to pay for the public good, denoted π_i, as a certain number of tokens given to each member $i = 1, ..., n$ of a group. The production function is descrete: players have to contribute an amount that is at least equal to a threshold, c, for the public good to be realised.

Time in our design is continous as individuals can contribute at any moment and several times during the period. Denote the individual contribution at time t by $\alpha(t)$, and the total amount collected for the public good by $x(t) \equiv \sum_{i=1}^{n} \int_0^t \alpha_i(s)ds$. The outcome of the game is defined as the situation that prevails at the end of the contribution period, i. e. at the terminal date, denoted by T. We take the case where $\sum_{i=1}^{n} \pi_i > c$, which means that Pareto-efficient outcomes are characterized by $x(T) = c$. In other words, the social optimum for the group is to contribute an amount *exactly* equal to the threshold c.

It is easely established that Nash equilibrium outcomes are such that $x(T) \leq c$. To see this, suppose $x(T) > c$. Since $x(t)$ is continous and monotone by consrtuction, $\exists \bar{t} < T$ such that $x(\bar{t}) = c$. So, we have at least one i which contributes $\alpha_i(t) > 0$ in $t \in [\bar{t}, T]$. But in this case $\pi_i - \int_0^{\bar{t}} \alpha_i(s)ds > \pi_i - \int_0^{\bar{t}} \alpha_i(s)ds - \int_{\bar{t}}^{T} \alpha_i(s)ds$ which contradicts the fact that $\alpha_i(t) > 0$ for $t \in [\bar{t}, T]$ is a Nash equilibrium strategy.

On the other hand, suppose that at the neighbourhood of the end date, i.e. at $T^- = T - dt$ with $dt \to 0$, we have $x(T^-) < c$. Define the missing amout to provide the public good as $k = c - x(T^-)$. At the limit, we have a one shot simultaneous game and if there is no individual strategy $\alpha_i(T) = k - \sum_{j \neq i} \alpha_j(T)$ such that $\pi_i \geq \int_0^T \alpha_i(s)ds$, the Nash equilibrium outcome will be characterized by $x(T) < c$.

By cooperating individials can generate a surplus. The difference between c and the sum of the WTP ($\sum \pi_i - c$) is the maximal surplus that the individuals can generate.

We can have two possible benchmarks. The first one supposes that all the members of the group contribute the same amount to the public good, which gives $\overline{\alpha} = \frac{c}{n}$. We call this the *absolute solution.* This solution is compatible with individual rationality only if $\min(\pi_1, ..., \pi_n) \geq \frac{c}{n}$. In this case people with high WTP receive a larger part of the surplus.

The second case supposes that the contribution of each player is relative to his (her) WTP, i.e. if the WTP of a player is two times higher than the WTP of another player, then his contribution is two times higher. In this case, $\tilde{\alpha}_i = \frac{\pi_i}{\sum \pi_i} c$. Since we suppose $\sum \pi_i > c$, it is always compatible with individual rationality. We call this the *relative solution* which implies a more equal surplus sharing.

3 Experimental design

We make groups of four persons, $n = 4$. Two players are endowed in the beginning of each period with 100 tokens and the two others have 200 tokens, $\pi_i = \{100, 200\}$. We run two treatments. In the first one, the provision point, c, represents 60% of the sum of WTP ($\sum_{i=1}^{4} \pi_i = 600$) of all players of the group. In the second, it represents 80% of the sum of WTP, which means that the absolute solution is no longer a plausible outcome[1]. The contribution period is fixed to 90 seconds, $T = 90\,\text{sec}$.

The experiment was run in January 2004 at the LeeX (Laboratori d'Economia Experimental) at University Pompeu Fabra in Barcelona. Each treatment includes two sessions of approximatively one hour and a half. In each session we set three independent groups of four persons, which gives a total number of 24 subjects per treatment. All of them were students. This gives six independent statistical observations per treatment.

Each group played one practice period, followed by 20 paying periods. At the end of the period each subject was informed about the number of tokens he had earned. The number of players constututing the group and the number of periods of the game was common knowledge. At the end of the session, a questionnnaire was distributed to players.

The experiment was computerised. We used z-Tree as software, developped by Fischbacher (1999). In the beginning of each session subjects were placed randomly to each computer. Instructions of the experiment were read aloud by the experimenter. We made sure that they were well understood by all players before starting the game. Communication were not allowed.

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

4 Results

4.1 Low threshold treatment ($c = 360$)

Average contribution for all periods and for all groups is 361.98. This corresponds almost to the threshold and gives us an idea about average behavior. Neverthless, it does not allow us to know how many times the public good is realised. To do so, we construct an index, denoted I_{eff}, that mesures the ability of the mechanism to produce efficient provision of the public good. It represents the ratio of the number of times a group succeeds in contributing

[1]We mean an outcome that is compatible with individual rationality.

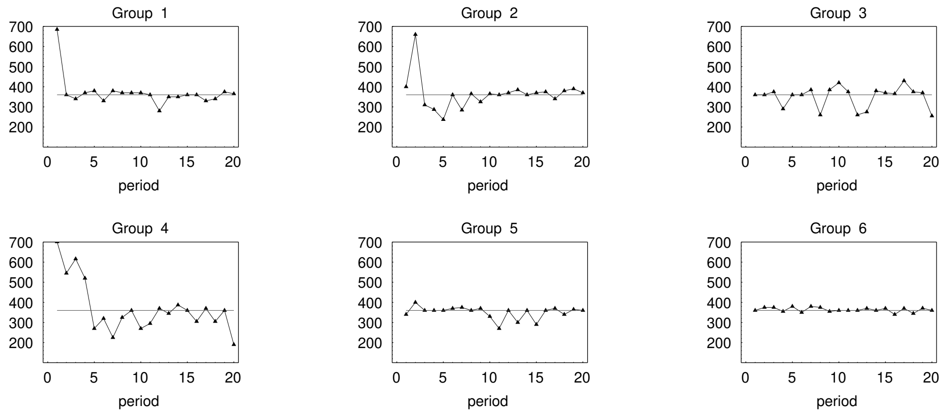

FIGURE 1: Contribution of each group for the 20 experimental periods in the low treatment.

a sufficient amount for the public good over the total number of playing periods. This index is computed in Table 1.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Mean
I_{eff}	0.65	0.70	0.75	0.50	0.70	0.75	0.68

TABLE 1: Ratio for the number of times the public good is realised over the total number of playing periods (low treatment).

Note that Pareto-efficiency require the amount contributed to be *exactly* the threshold, c. As shown in Figure 1 and contrary to the theoretical predictions, in many cases contributions exceed this threshold. We find that this occurs because at the end of the period (last 3 seconds), several members of a group contribute at the same time to complete the missing amount. However, except for the first five periods – usually considered as learning periods – the amount of extra-contribution is not large, as it can be seen in Figure 1 (an interesting extention of our mechanism is to stop contributions once the threshold was reached).

The analysis of the variation of contributions during the 90 seconds of each period may help us to understand the strategies followed by players. Gradstein (1992) shows that in a two period model of voluntary contribution with incomplete information, inefficiency occurs because of a delay in contributions. Although he uses a different production function, it is interesting to see if in our case, real subjects wait before contributing, as predicted in the Gradstein's study.

In Figure 2 we plot the mean contribution during one period for each of the 6 groups, after 15, 30, 45, 60, 75, and 90sec. This mean is calculated over the 20 observations of the 20 periods.

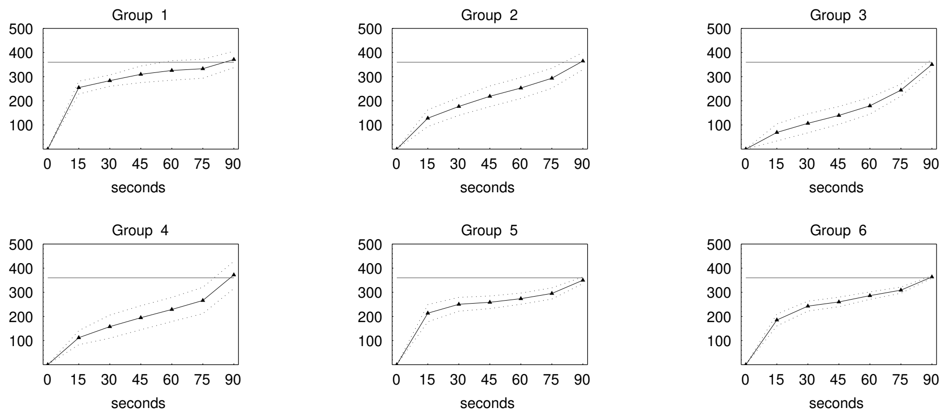

FIGURE 2: Mean contribution and confidence bounds during a period.

The results show that on average four groups (1,2, 4 and 6) succeed in reaching 360 at the end of the period. We can isolate two types of behavior. The first one shows an almost linear increase for the sum of average contributions. This concerns three groups (2, 3 and 4). In these groups, players contribute on average constant small amounts several times during all the period. Two of these groups (2 and 4) succeeded on average in realising the public good.

The three other groups (1, 5 and 6) behave differently, as their average sum of contributions increase clearly in the first 15 seconds of the period and continue to increase slowly in the rest of the time. This shows that players in these groups start by signaling their willingness to cooperate. On average, two of these three groups (groups 1 and 6) succeed in reaching 360.

There is an end-effect that concerns all the groups, even if it is not very significant, as contributions increase faster in the last intervall.

On the individual level, we observe that subjects with high WTP contribute more in absolute terms and less in relative terms (see Table 2). This is because in most of the cases subjects share the cost of provision equally. For example, in groups 4 and 5 the mean contribution in absolute terms for individuals with $\pi_i = 100$ is 84 and 81.4, respectively, and for individuals with $\pi_i = 200$ it is 91 and 100.4, respectively. In fact, the absolute solution (equal cost sharing) implies that each member pays $\bar{\alpha} = 90$ tokens, and the relative solution implies $\tilde{\alpha}_{100} = 60$ and $\tilde{\alpha}_{200} = 120$ tokens. The results suggests that individuals implicitly (without communication) reach an agreement of a nearly equal cost sharing.

Contribution	Absolute		Relative (% of π_i)	
	Mean	Std Dev	Mean	Std Dev
$\pi_i = 100$	71.59	35.61	71.59%	35.61%
$\pi_i = 200$	108.41	35.98	54.20%	17.99%

Table 2: Mean contribution as function of WTP (low treatment).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Mean
I_{eff}	0.05	0.25	0.45	0.25	0.35	0.05	0.23

Table 3: Ratio for the number of times the public good is realised over the total number of playing periods (high treatment).

4.2 High threshold treatment ($c = 480$)

In this second treatment, we decrease the surplus available to the group by increasing the level required for the public good provision. With $c = 480$, equal cost sharing implies that each individual pays $\bar{\alpha} = 120$, which is more than the initial endowment for individuals with $\pi_i = 100$. Intuitively, we expect that the public good must be realised less frequently, seeing that the set of cost sharing agreements compatible with the individual rationality of the players is more restricted. In other words, realising the public good requiers more contribution effort from individuals.

The results confirm our intuition. In fact, the ratio I_{eff} decreases from an averege value of 68% in the first treatment to an average of 23% in the second one (see Table 3). Although the average contribution for all periods and groups is 437.08 in this second treatment, which is superior to the average contribution in the previous one, it is not enough to realise the public good. Consequently, the increase of the threshold level increases contributions in absolute values, but reduces the efficiency of the mechanism. A similar result is found by Hichri (2004) in another context of a public good game.

The loss in the efficiency of the mechanism can be seen in Figure 3 where the group contributions are in most of the cases below the threshold of 480 tokens.

The variation of contributions in each group during the 90 seconds of each period is similar to that of the first treatment, as we still have the two types of behavior.

The analysis of individual contributions shows that, contrarily to the first treatment, individuals with high WTP contribute much more than those with low WTP in absolute terms, but still contribute less in relatives terms (see Table 4), which is not sufficient for the public good to be produced. In fact, the relative solution requires $\tilde{\alpha}_{100} = 80$ and $\tilde{\alpha}_{200} = 160$.

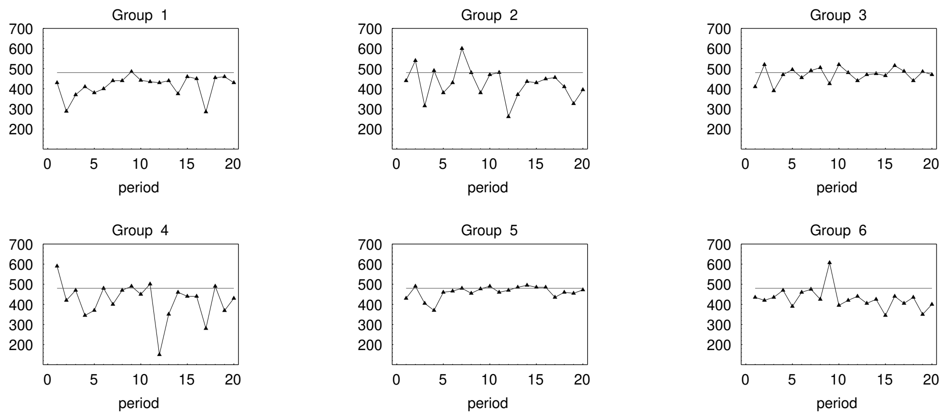

FIGURE 3: Contribution of each group for the 20 experimental periods in the high treatment.

Contribution	Absolute		Relative (% of π_i)	
	Mean	Std Dev	Mean	Std Dev
$\pi_i = 100$	76.75	46.68	76.75%	46.68%
$\pi_i = 200$	141.78	45.06	70.89%	22.53%

TABLE 4: Mean contribution as function of WTP (high treatment).

Thus, the failure to reach the threshold is partially due to individuals with high WTP who want to keep a larger part of the surplus. Replicating our experiment with the sum of WTP or the identity of contributors as commun knowledge may incite them to contribute more. Future research can consider this possibility.

References

[1] Bagnoli, M., and Lipman, B. L., (1989), "Provision of Public Goods: Fully Implementing the Core through Private Contributions", *Review of Economic Studies*, 56, 583-601.

[2] Cason, T. and Khan, F., (1999), "A Laboratory Study of Voluntary Public Goods Provision with Imperfect Monitoring and Communication," *Journal Of Development Economics*, 58, 533-52.

[3] Chan, K. S., Mestelman, S., Moir, R., and Muller, A. R., (1999), "Heterogeneity and the Voluntary Provision of Public Goods," *Experimental Economics*, 2, 5-30.

[4] Coase, R. H., (1960), "The Problem of Social Cost", *Journal of Law and Economics*, 3, 1-44.

[5] 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.

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

[7] Hichri, W., (2004), “Interior Collective Optimum In a Voluntary Contribution To a Public Goods Game”,*Applied Economics Letters*, 11, 135-40.

[8] Ledyard, J., (1995), “Public Goods: A Survey of Experimental Research”, in Kagel, J. and Roth, A. (eds.), *The Handbook of Experimental Economics*, Princeton University Press.

[9] Rondeau, D., Schulze, W. and Poe, G., (1999),“Voluntary revelation of the demand for public goods using a provision point mechanism”, *Journal Of Public Economics*, 72, 455-70.

[10] Varian, H. R., (1994), ”A Solution to the Problem of Extenalities When Agents Are Well-Informed”, *American Economic Review*, 84, 1278-93.

Appendix

These instructions are a translation from Spanish of the instructions that were distributed to subjects before the beginning of the experiment. They contain also a translation of the questionary that was distributed to them after the end of the game. The instructions presented here correspond to one of the two treatments tested (Low threshold treatment). Those relative to High threshold treatment were changed to reflect the difference with the first treatment concerning thelevel of the provision point.

Instructions to the Experiment

Welcome,

You will participate to 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 have already 6 euro that will be added to your earned money at the end of the experiment.

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

Each group will be composed of the same persons during all 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 approximatively one hour and a half. groups are independant and do not interact with each other.

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

In 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 gain of the hole session will be the sum of your gains from the 20 periods. The aim of the experiment is to win the maximum of points.

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

In each period, during one minute and 30 seconds, you can put at any mement and several times a part of the points you have in a urn. The total number of points you put in the urn and the sum of points that all the group 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 put in this urn is superior or equal to 360, each one wins the rest of points he still has. In the case where the number 360 is not reached, each one wins nothing and loose all the points he put in the urn and all the points he still has.

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 put in the urn is 300 (< 360), each person of your group wins zero.

*Suppose that you have 150 points and that you put 100 in the urn. If the sum of the points that your group 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 indicared on the computer screen.

This game will be repeated identiqually during all the periods of the game.

At the end of the experiment, you will be paid in cash and pravately. The total number of points you will win in the 20 periods of the experiment will be converted into euro at the rate of:

1 euro = 100 points

Illustration of the game distributed to subjects

In Figure 4 we present the schema of the game distributed to subjects.

Questionnaire distributed to subjects

Number of your computer:

Studies:

Level of Studies:

Gender:

1. Have you participated to experimental sessions before?
2. Have you understood the game and the instructions?
3. According to you, what was the aim of the experiment?
4. have you really tried to win?
5. What was you strategy?

6.What determinated your choices concerning the number of points you have put in the urn?

Screenshot

In Figure 5 we print the screen that individuals had seen during the experiment on theirs computers:

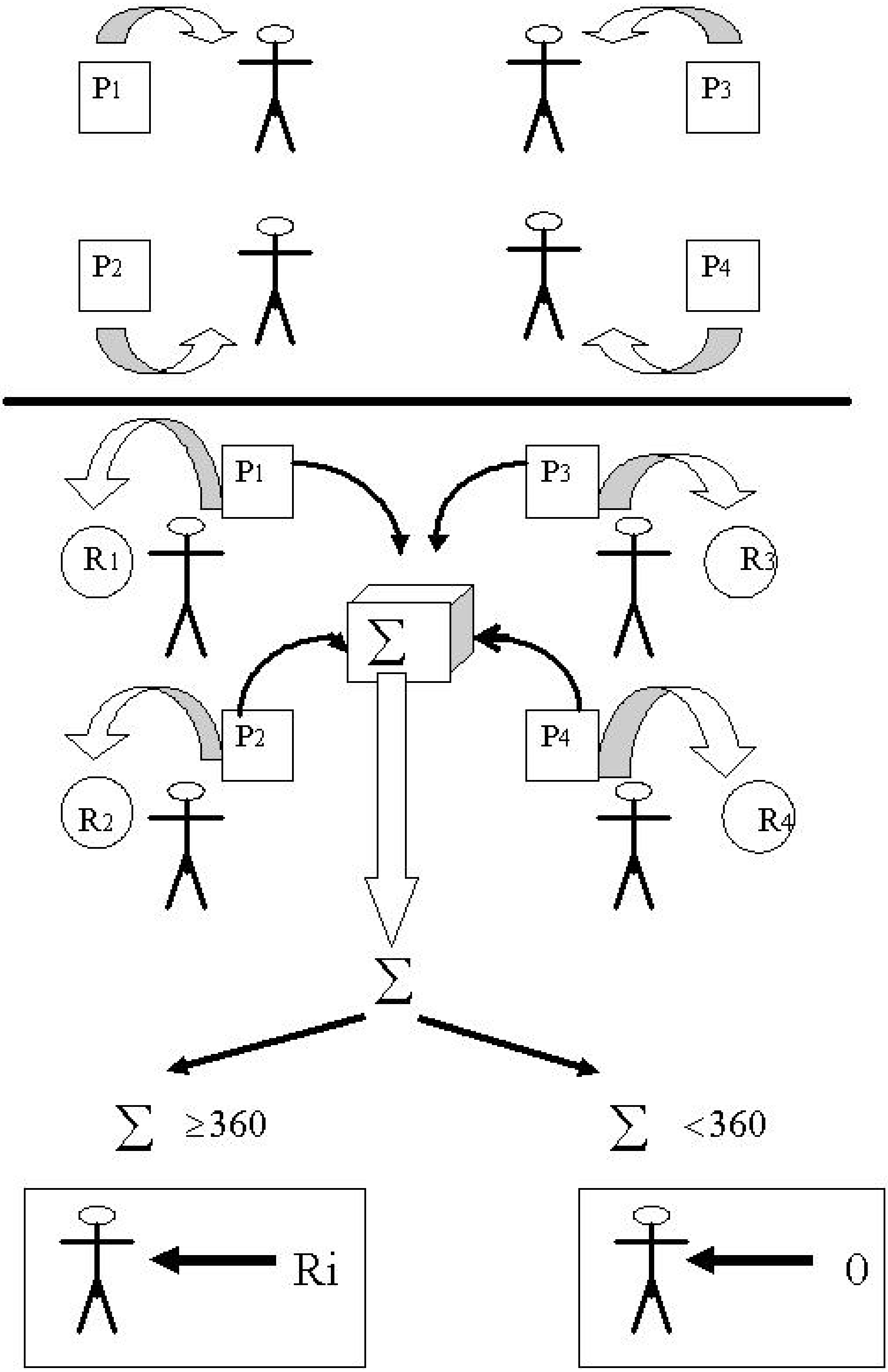

FIGURE 4: Illustration of the game.

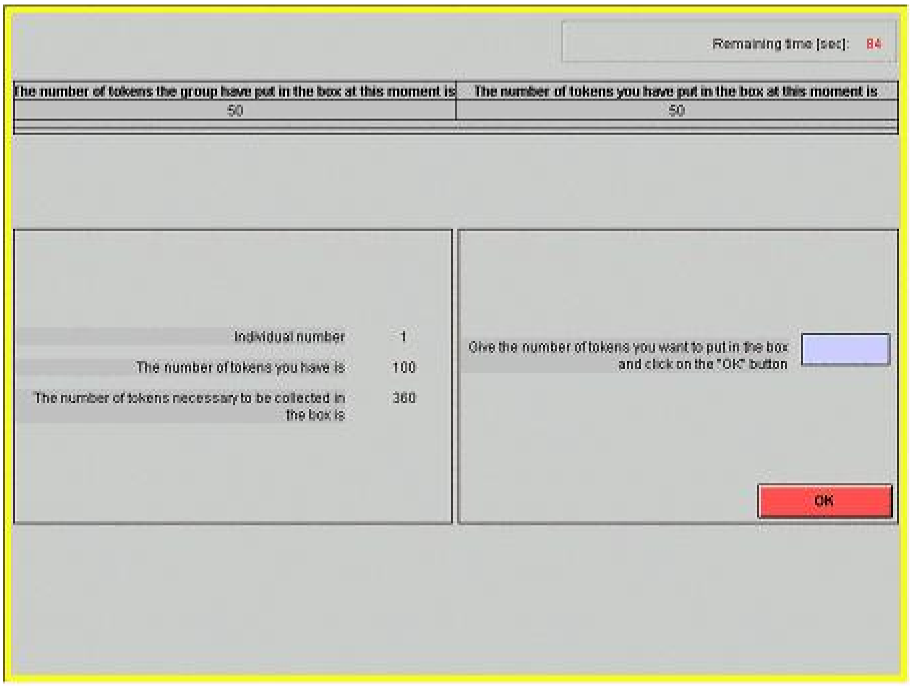

FIGURE 5: Screenshot (Software z-Tree).

Working Papers / Documents de Travail

Le GREQAM diffuse une série de documents de travail qui prend la suite de celle diffusée depuis 1982 par le GREQE. Cette série comporte 4 sous séries - respectivement : "théories", "applications", "méthodologie", "Tirés à part"

Certains papiers sont disponibles sous la forme de fichiers PDF. Adobe Acrobat vous permet de les lire, de les transférer et de les imprimer.

http://greqam.univ-mrs.fr/dt/dt.htm

Adresses du GREQAM

GREQAM
Centre de la Vieille Charité
2 Rue de La Charité
13002 MARSEILLE
tél. 04.91.14.07.70
fax. 04.91.90.02.27
E-mail : greqam@ehess.univ-mrs.fr

GREQAM/
LEQAM
Château La Farge
Route des Milles
13290 LES MILLES
tél. 04.42.93.59.80
fax. 04.42.93.09.68
E-mail : leqam@romarin.univ-aix.fr

GREQAM/
C.R.I.D.E.S.O.P.E.
Faculté d'Économie Appliquée
Bât. Austerlitz
15-19 Allée Claude Forbin
13627 Aix-en-Provence Cedex 1
Tel : 04 42 96 12 31
Fax : 04 42 96 80 00