Submission Number: PET11-11-00329

The timing of contributions to public goods

Miguel A. Sanchez villalba
University of Alicante

Silvia Martinez gorricho
University of Alicante

Abstract

We propose an incentive mechanism based on a time dependent subsidy scheme as a way of financing public goods. We tested -and found support for- the theoretical predictions of the model by means of a computer-based experiment. The theoretical model and the supporting experimental evidence both suggest the mechanism is an efficient and equitable means to finance public goods through voluntary contributions. In policy terms, and beyond the efficiency and equity considerations, the mechanism would be easy to implement and run given its simplicity and self-sufficiency.

The authors thank Giovanni Ponti and Adam Sanjurjo for helpful comments and suggestions. All remaining errors are ours. Financial support from SEJ 2007-62656 and from IVIE7-10I is gratefully acknowledged.
Submitted: April 12, 2011.

The Timing of Contributions to Public Goods*

Miguel A. Sánchez Villalba
University of Alicante

Silvia Martínez Gorricho
University of Alicante

September, 2010
PRELIMINARY VERSION
Please do not quote without the permission of the authors

Abstract

We propose an incentive mechanism based on a time dependent subsidy scheme as a way of financing public goods. We tested –and found support for– the theoretical predictions of the model by means of a computer-based experiment. The theoretical model and the supporting experimental evidence both suggest the mechanism is an efficient and equitable means to finance public goods through voluntary contributions. In policy terms, and beyond the efficiency and equity considerations, the mechanism would be easy to implement and run given its simplicity and self-sufficiency.

Keywords: Public Goods; Voluntary Contribution Mechanism; Subsidy Schemes; Laboratory Experiments;

JEL Classification: C72; C92; H41

*The authors thank Giovanni Ponti and Adam Sanjurjo for helpful comments and suggestions. All remaining errors are ours. Financial support from SEJ 2007-62656 and from IVIE7-10I is gratefully acknowledge.

1 Introduction

Pure public goods possess the feature that they are nondepletable (consumption by one individual does not affect the supply available for other individuals) and nonexcludable (exclusion of an individual from the benefits of a public good is impossible). These characteristics of public goods imply that its private provision creates a situation in which positive externalities are present: a consumer's private contribution to the provision of the public good provides a direct benefit not only to the consumer herself but also to every other consumer, independently of whether they are providers of the public good or not. The failure of each consumer to internalize the benefits conferred upon all other consumers of her public good provision is often referred as the free-rider problem: each consumer has an incentive to enjoy the benefits of the public good provided by others while withholding her own contribution.

The standard mechanism for the private provision of a public good, called the voluntary contribution mechanism (VCM) (first studied by Olson (1965)), relies on voluntary contributions. The standard voluntary contribution mechanism is usually modeled in the literature as the Prisoner's Dilemma game. This mechanism does not have the ability to overcome the free rider problem since it results in a systematic underprovision (low levels of public good contributions are a dominant strategy for each player) of the public good when it is socially desirable[1].

Numerous fund-raising mechanisms or institutions have been proposed in the literature to elicit socially optimal levels of public good contributions. Theoretically, sophisticated efficient allocation mechanisms or mechanisms based on tax-subsidy schemes and penalties have been designed to solve or mitigate the free-rider problem (eg. Groves and Ledyard (1977), Walker (1981), Boadway et al. (1989), Roberts (1992), Varian (1994a,b), Andreoni and Bergstrom (1995), Falkinger (1996)). In practice, however, these schemes are either complex and difficult to implement, and/or have generally failed to achieve socially optimal contributions levels and/or require a degree of coercion that are not available to private organizations, such as charities, and therefore, cannot be implemented by these organizations[2].

Scholars have recently begun to explore the effectiveness of less coercive mechanisms, including step-level provision points, auctions, contests and lotteries.

The underprovision problem of the VCM can be remedied by the introduction of a step-level provision point (a commonly known minimum threshold that contributions must meet or surpass for the public good to be provided to all members (Andreoni (1998)). With the provision point, the VCM is typically modeled by the game of Chicken, also known as the "Battle of the Sexes"[3]. There are no dominant strategies in this game and the zero contribution equilibrium is Pareto dominated by a positive-contribution equilibrium. However, coordination problems arise due to the multiplicity of positive-contribution equilibria. These equilibria form a set which cannot be Pareto ranked and create a conflict called the "cheap riding" problem[4] since it provides individual incentives to attempt to obtain an equilibrium outcome with unequal distribution of contributions. Furthermore, assurance problems (the fear of having one's contribution wasted if the provision point is not met) also develop in this framework. Suppose that contributing all the aggregate wealth is socially desirable. In this case, if the provision point is set equal to the aggregate wealth, then the efficient equilibrium outcome becomes a focal point in which the"cheap rider" problem does not arise but the monetary risk from the assurance problem becomes the greatest. This is because this highest provision equilibrium is unstable: small departures from equilibrium contributions

[1] Refer to the classical paper by Bergstrom, Blume and Varian (1985) for further discussion on the relevance of this model. Ledyard (1995) provides a good survey of the experimental evidence.

[2] Individuals are assumed not to have the right to opt out of the mechanism, that is, these mechanisms are not individually rational.

[3] In this game, players agree that it is better to cooperate than not to cooperate but they disagree about the best outcome.

[4] This term was introduced by Isaac, Schmidtz and Walker (1988).

by one participant causes the best response for the other participants to jump to zero contribution. The inefficient zero contribution equilibrium outcome is stable instead. Schmidtz (1987) proposes an institution, known as the conditionally binding assurance contract which combines a provision point feature with a money-back guarantee (contributions are returned if the provision point is not met). Adding full refunds does not solve the "cheap rider" problem. Furthermore, if the provision point is not set equal to the aggregate wealth, although the assurance problem is eliminated, the fear of having one's contribution partially wasted if the provision point is surpassed by total contributions is still an issue. Nonetheless, if the provision point is set equal to the aggregate wealth, then full contribution to the public good becomes a dominant strategy and despite the existence of multiplicity of equilibria, the full contribution equilibrium is the only strict Nash equilibrium. Isaac, Schmidtz and Walker (1988) show that the money-back guarantee must be complete and credible for it to be successful in promoting the provision of public goods in an environment characterized by the assurance problem[5].

Lotteries obtain higher levels of public goods provision than a voluntary contributions mechanism because the lottery rules introduce additional private benefits from contributing (Morgan (2000))[6]. When a consumer purchases raffle tickets, she reduces the chances of winning of all other bettors. This extra negative externality component compensates for the positive externality mentioned above, reducing the gap between the private and social marginal benefits of contributions. Hence, lotteries tend to mitigate the tendency for agents to free ride. As Morgan points out, fixed-prize lotteries are seen to be subsidies that are nonlinear[7] in the amount rebated for contributions to the public good. The lottery fixed-prize can be seen as the stipulated total rebate amount set aside from total contributions. Each individual receives a rebate share that is proportional to her contribution to the public good relative to total contributions[8]. Morgan argues that pari-mutuel lotteries (the prize amount is a stipulated constant fraction of the total wagers) dilute the negative externality component and do not increase public good provision relative to the standard voluntary contribution mechanism.

Our model is one of a complete information (agents are homogeneous) in a static framework. A variation of the pari-mutual lottery is proposed as a public good provision mechanism[9] in this paper and its superiority with respect to the fixed-prize lottery advocated by Morgan is theoretically proved. The total rebate (prize) amount is made endogenous by being made equal to a nonlinearly decreasing fraction of the total contribution. The private provision of public good is modeled by the Stag Hunt game[10]. Our mechanism is individual rational, fully self-financing (budgetary illusion is excluded) irrespectively of whether subjects are in or out of equilibrium, and it does not require a credible commitment by the agency to fully refund contributions. In fact, the proposed scheme, if properly designed, requires zero payments made in equilibrium by the agency. Furthermore, if full contributions are socially desirable, then the mechanism can be designed such that full contribution is a weakly dominant strategy for each agent and the public good provision consists of the aggregate wealth (full contributions). This feature makes this mechanism dominate other proposed mechanisms such as auctions[11] and contests (Faravelli (2008)).

[5] A money-back guarantee is also assumed in mechanisms based on lotteries (Morgan (2000)). If the wagers are insufficient to cover the cost of the prize, then the charity is assumed to call off the raffle and return each bettor's wager.

[6] Experimental evidence on lotteries and auctions as methods to finance public goods is reported by Morgan and Sefton (2000), Orzen (2005), Schram and Onderstal (2007), Lange et al. (2007) and Lim and Matros (2009)

[7] The literature examines linear subsidy schemes to private spending that are financed through taxation. In addition to the papers cited above refer, for example, to Roberts (1987),(1992)?

[8] Morgan employs the ratio form of the Contest Success Function (Tullock (1967, 1980)) with the "mass effect parameter" set equal to one. Refer to Hirshleifer(1989) for a comparison analysis of this success function relative to the difference form one.

[9] Refer to Martínez-Gorricho et al (2010) for a generalization of the proposed mechanism that can be applied to a static framework with heterogeneous agents.

[10] In this game, players not only agree that it is better to cooperate than not to cooperate but they also agree about the best outcome.

[11] The first-price all pay auction with complete information has been used extensively in the literature. The

Gradstein (1992) argues that the dynamics of the provision of public goods should also be taken into consideration. According to this author, the standard inefficiency result is not only to underprovision in quantity terms of a public good but also to a delay in its provision. Thus, he urges that any discussion of government intervention should address two issues simultaneously by trying to induce both larger and quicker contributions. The timing of contributions is an artifact used in our model to generate price discrimination through a time dependent subsidy scheme in order to avoid delays in contributions. Each agent simultaneously decides not only whether to contribute but also when to make her pledge without observing the decisions made by her counterparts.

Experimental data from voluntary contribution public goods environments report a frequent use of strictly dominated strategies. The persistence of cooperation in public good experiments is a well known phenomenon in the literature[12]. Subject's public contributions are much greater than predicted by standard economic theories of free-riding and these contributions decay over the course of multiple-round games[13]. Note that agents also often fail to contribute when it is in their own interest to do so (Saijo and Nakamura (1995)[14], Palfrey and Prisbrey (1997)). From there, the importance of testing our theory in the laboratory.

Our theory provides several testable predictions. We evaluate our theoretical conjectures via a series of experimental treatments that examines the contribution decisions of agents across a number of settings. We ran 6 treatments (all of them using neutral terminology):

- one standard VCM treatment to be used as benchmark for comparison (treatment VCM),
- another one in which rebates were a function of the absolute time of contribution (treatment E),
- four other treatments in which rebates were a function of the relative time of contribution, each one of them presenting a different combination of exogenous and strategic risk levels, namely
  - one in which both types of risk were strictly positive and that was used as the basis for comparison with all other treatments (treatment B or $Base$),
  - one in which the exogenous risk was as in the B treatment and the strategic risk was eliminated (treatment D), meaning that "contribution" became a (weakly) dominant strategy,
  - one in which the strategic risk was as in the B treatment and the exogenous risk was eliminated (treatment A), meaning that every contributor received the same rebate,
  - finally, one in which both the exogenous and the strategic risk were eliminated (treatment C), which meant that this treatment was, a priori, the best of them all.

Our hypotheses were such that we could order treatments in terms of their performance (number of contributors and net contributions per capita): we expected C to be better

exists no pure strategy Nash equilibrium and a complete characterization of its equilibria appears in Baye et al. (1996). Barut and Kovenock (1998) study symmetric multiple prize all-pay auctions with complete information. Goeree et all (2005) propose a class of lowest-price all-pay auctions which involves both an entry fee and a reserve price as an optimal fund-raising mechanism in an incomplete information setting.

[12] Several explanations have been offered in the literature for why there is so much cooperation: kindness (altruistic preferences, warm-glow preferences) and "confusion" or decision error. Both explanations bias contributions upwards. See Palfrey and Prisbrey (1997) and Anderson et al. (1998)

[13] Subjects generally begin by contributing about half of their endowments to the public good. As the game is iterated, the contributions "decay" toward the dominant strategy level and stand at about 15-25% of the endowment by the tenth iteration (Isaac and Walker (1988). The declines in contributions might be consistent with learning and endgame effects.

[14] Saijo and Nakamura do not justify their results by arguing confusion but by arguing the presence of many spiteful subjects, those who free ride in order to maximize ranking.

than A and D (lower risk) and B to be worse than A and D (higher risk), but we did not know what to expect from the comparison between A and D. Also, we expected E to be equivalent to the VCM (no externality) and both of them to be worse than B (externality). Our hypotheses can therefore be represented as follows:

$$C \succ best\{A,D\} \succcurlyeq worst\{A,D\} \succ B \succ E \sim VCM \tag{1}$$

Our empirical results support almost every one of our hypotheses: we obtained the following ordering of the treatments in terms of their performance

$$C \sim A \succ D \sim B \succ E \sim VCM \tag{2}$$

That is, the only two hypotheses that were rejected were that $C \succ A$ and that $D \succ B$. In both cases, the intuition behind the hypothesis was that the strategic risk in the treatment on the left-hand side was lower than in the one on the right-hand side. Empirical evidence seems to reject, therefore, the idea that people care about strategic risk. It is quite a surprising result, and we do not have a definitive explanation for this "anomaly". Our best shot at it is based on the idea that, when making risky decisions, some people seem not to weight their payoffs using the associated probabilities but they simply "count" the number of "good" outcomes (in which the person "wins" and gets extra money) and the number of "bad" outcomes (in which the person "loses" and has to pay/give up some money) and then they simply choose the option with the highest number of "good" outcomes (see, for example, Sánchez Villalba (2009) for a case in which such rule of thumb seems to be followed).

On the other hand, the experimental evidence seems to also categorically determine that $A \succ D$, which is consistent with the results in the previous paragraph and implies that changes in the exogenous risk are more important than changes in the strategic risk.

The paper is organized as follows. A simple version of the more general public game presented in Martínez-Gorricho et al. (2010), with homogeneous agents and complete information is formalized in section 2. Section 3 compares private provision via the proposed mechanism with other mechanisms proposed in the literature, such as fixed-prize lotteries and auctions. Experimental designs and tests of many implications of the theory are introduced in section 4. Section 5 presents the results of our experiments. Section 6 concludes with a discussion of directions for future research. Proofs are contained in the Appendix.

2 The Model

Consider a very simple simultaneous linear public game with N homogeneous and risk neutral expected utility maximizers agents. Each consumer i consumes an amount of x_i of the private good and donates an amount $g_i \geq 0$ to the supply of the public good. The total supply of the public good, $G = \sum_{i=1}^{N} g_i$, is the sum of the contributions of all individuals. Each player's preferences are represented by the payoff function: $u_i(x_i, G) = x_i + \gamma G$, where $\gamma \in \left(\frac{1}{N}, 1\right)$ is the marginal per capita return (MPCR). Each individual i is endowed with wealth w which she allocates between the private good x_i and his gift g_i. Let G_{-i} denote the sum of all gifts by consumers other than i.

A Nash equilibrium in this model is a contribution profile g^* such that for every player i, (x_i^*, g_i^*) solves

$$\max_{x_i, g_i} \; u_i(x_i, g_i + G_{-i}^*) = x_i + \gamma(g_i + G_{-i}^*)$$

$$st. \; x_i + g_i = w$$

$$0 \leq x_i \leq w,\ 0 \leq g_i \leq w$$

Although there does not exist an explicit cost of investing in the public good by contributing a positive amount, there exists an implicit opportunity cost in terms of foregone private consumption. Given that $\gamma < 1$, each individual's opportunity cost of contributing to the public good exceeds the marginal return of investing in the public good. Clearly, not contributing to the public good strictly dominates any player's other action. Therefore, the unique equilibrium predicted contributions induced by the Voluntary Contribution Mechanism (VCM) are null, and as a result, the public good is not provided in equilibrium.

On the contrary, the social optimum contribution profile $\hat{g}$ solves:

$$\max_{\{g_i\}} \sum_{i=1}^{N} u_i(w - g_i, G) = Nw - G + \gamma NG$$

$$st.\ 0 \leq \sum_{i=1}^{N} g_i \leq Nw$$

Given that $N\gamma > 1$, if $\hat{G} = Nw$, then social payoffs are maximized. All aggregate wealth to be contributed to the public good is the socially efficient outcome.

Our environment is characterized by extreme free riding when in fact, the public good is socially desirable. The VCM results in a systematic underprovision of the public good relative to the first-best allocation. Our goal for this paper is designing a mechanism that induces both larger and quicker contributions to the supply of the public good.

3 Subsidy Scheme Mechanisms

In this section, different budget balancing subsidy schemes are analyzed. We introduce an extra dimension in the consumer's problem, called "the timing of contributions". Now, each agent simultaneously decides not only whether to contribute or not and by how much, but also *when* to make her pledge without observing the decisions made by the other agents. Note that the game continues to be a static game. The timing of contributions is a simple artifact that allows us to generate price discrimination through a time dependent subsidy scheme. Specifically, the opportunity cost of contributing to the supply of the public good is lowered for earlier contributions.

Given the added complexity introduced by the time variable and the subsidies, we focus on a simpler version of the game characterized by binary contributions only: each agent must decide privately whether to "contribute" (C) her total endowment to the public good or "refrain from contributing" (R). Define the following contribution index variable:

$$\kappa_i = \begin{cases} 1 & \text{if player } i \text{ chooses } C \\ 0 & \text{if player } i \text{ chooses } R \end{cases}$$

Let $\kappa \in \{0,1\}^N$ be a profile of contribution indexes. Let time be a continuous variable that starts at 0 and runs indefinitely. Let t_i denote player i's contribution time: the time at which player i chooses to contribute to the public good if (he decides to do) so. Let $t \in R_+^N$ be a profile of contribution times. Define $T^C(t)$ as the contributors' contribution time set for a given profile of contribution times, that is, the collection of contribution times by contributors only given t. Thus, $t_i \in T^C(t)$ if and only if $\kappa_i = 1$. Let n denotes the number of contributors and equals the cardinality of the contributors' contribution time set $T^C(t)$. Each player's action space is $\{C, R\} \times R_+$. Player i's preferences are represented by the payoff function:

$$u_i(\kappa, t) = s_i(\kappa, t) + (1 - \kappa_i)w + \gamma \left(\sum_{j=1}^{N} \kappa_j w - \sum_{j=1}^{N} s_j(\kappa, t) \right)$$

where $s_i(\kappa, t)$ denotes the total subsidy (instantaneous cash rebate) obtained by player i in the game. The public good provision is given by the sum of all gifts in excess of the total subsidy payments. These subsidies are assumed to be bounded above by the wealth endowment: $s_i(\kappa, t) \leq w$ for all (κ, t) profiles. This guarantees that the mechanism is self-financing. For individuals to have the right to opt out of the mechanism, $s_i(\kappa, t) \geq 0$ if $\kappa_i = 0$. In order to maximize the total net contributions to the public good, $s_i(\kappa, t) = 0$ if $\kappa_i = 0$.

3.1 The Absolute Time Subsidy Scheme

Under the Absolute Time Subsidy Scheme (ATSS), the subsidy function faced by player i is a function that is only dependent on the contribution time chosen by player i. This scenario resembles a "for a limited time only" market sale promotion. This type of promotion has been taken place some time ago in the province of Tucumán (Argentina), where the taxpayers were waived one of the bimonthly instalments of the property tax if they were paid altogether a the beginning of the fiscal year. Another example that demonstrates that this kind of promotion is very popular and spread around the world, refers to waived fees applied to early registrations for a scientific conference.

Formally, $s_i(\kappa, t) = \kappa_i \cdot \delta(t_i)$, where $\delta(\cdot)$ is a monotonically decreasing function in player i's contribution time, being strictly decreasing at some instant in time. Therefore, player i's preferences are represented by the payoff function:

$$u_i(\kappa, t) = \kappa_i \cdot \delta(t_i) + (1 - \kappa_i)w + \gamma \sum_{j=1}^{N} \kappa_j (w - \delta(t_j))$$

The final term represents the payoff from the public good.

Under the Absolute Time Subsidy Scheme, then a unique (pure strategy) Nash equilibrium outcome exists in the linear public good game and it is characterized by a null provision of the public good.

Proof. A Nash equilibrium in this model is contribution index and time profile (κ^*, t^*) such that for every player i, (κ_i^*, t_i^*) solves

$$\max_{\{\kappa_i, t_i\}} u_i(\kappa, t) = w - (1 - \gamma)\kappa_i(w - \delta(t_i)) + \gamma \sum_{j \neq i} \kappa_j^*(w - \delta(t_j^*))$$

If $\delta(0) < w$, then $w - \delta(t_i) > 0$ for all t_i and given that $\gamma < 1$, "refrain from contributing" (R) is the *unique* best *first component* response of each player to any other players' strategies. If $\delta(0) = w$, let $\tilde{t}$ be the largest time instant for which the subsidy obtained by any player is equal to the wealth endowment: $\delta(t_i) = w$ if and only if $t_i \leq \tilde{t}$. The strategy "refrain from contributing" ($\{R, t_i\}$ $\forall t_i$) continues being a best response to any other players' strategies.

Furthermore, “contribute at a time instant not larger than $\tilde{t}$ " ($\{C, t_i\}$ for $t_i \leq \tilde{t}$) is also a player i's best response to the other players' strategies. No further best responses exist. As a result, in any (pure strategy) Nash equilibrium outcome, the sum of all gifts does not excess the total subsidy payments so that the public good is not provided in equilibrium. ■

This mechanism is completely ineffective at mitigating the extreme free-riding problem. It keeps being a pervasive outcome of the public good game.

3.2 The Relative Time Subsidy Scheme

If properly designed, a time-dependent price discrimination subsidy scheme could be successful in promoting the provision of the public good by generating a negative externality via competition among contributors to get the rebates. This artificially generated negative externality helps reducing the gap between the private and socially marginal benefit of contribution. This mechanism can be modeled as a (within-group) tournament game being the subsidy payments the prizes awarded. Each contributor is paid a rebate based on how her contribution time ranks in comparison to the other contributors' contribution times. The agent with the shortest contribution time among contributors gets the highest rebate. Rebates are weakly decreasing in rank so that the contributor with the largest contribution time gets the lowest (non-necessarily positive) rebate. The tie-breaking rule is such that players contributing at same time share the subsidies equally in expected terms. This scenario is a variation of the popular “while stocks last" market sale promotion in which the first contributors get a positive discount. However, we allow the discount rate (rebate) not be necessarily uniform for these earlier contributors.

Formally, define the “earlier contribution times set" relative to a given alternative or contribution time $t_i \in T^C(t)$ by a given contributor i as a subset of all contribution times in $T^C(t)$ such that t_i is the largest contribution time in $T^C(t)$:

$$\underline{T_i^C(t)} \equiv \left\{t_j \mid t_j \in T^C(t) \text{ and } t_i > t_j\right\} \text{for all } t_i \in T^C(t)$$

Similarly, define the “no later contribution times set" relative to a given alternative or contribution time t_i in $T^C(t)$ by a given contributor i as a subset of all contribution times in $T^C(t)$ such that no contribution time $t_j \in T^C(t)$ is larger than contribution time $t_i \in T^C(t)$:

$$\overline{T_i^C(t)} \equiv \left\{t_j \mid t_j \in T^C(t) \text{ and } t_i \geq t_j\right\} \text{for all } t_i \in T^C(t)$$

We construct the rank position of each contributor by assigning to each contributor an integer number which is equal to the cardinality of her “earlier contribution times set" plus one. That is,

$$\underline{r_i} \equiv rank(t_i) = 1 + \#\underline{T_i^C(t)} \text{ for all } t_i \in T^C(t)$$

Similarly, define

$$\bar{r_i} = \#\overline{T_i^C(t)} \text{ for all } t_i \in T^C(t)$$

Let $e_j \in R_+^N$ be the j^{th} column vector of the $(N \times N)$ identity matrix I. Let $\delta \in R^N$ be a row vector of rebates such that $w \geq \delta_j \ \forall j = 1, ..., N$ and that $\delta_j \geq \delta_{j+1} \ \forall j = 1, ..., N$ with strict inequality for at least $j = 1$. The expected subsidy obtained by any agent i is given by:

$$s_i(\kappa,t)=\begin{cases}\delta e_{\underline{r_i}} & \text{if } \kappa_i=1 \text{ and } \underline{r_i}=\overline{r_i}\\ \left(\frac{1}{\bar{r_i}-\underline{r_i}+1}\right)\sum_{j=\underline{r_i}}^{\bar{r_i}}\delta e_j & \text{if } \kappa_i=1 \text{ and } \underline{r_i}<\overline{r_i}\\ 0 & \text{if } \kappa_i=0\end{cases}$$

Player i's payoff function can be written as:

$$u_i(\kappa,t)=w-(1-\gamma)(\kappa_i w-s_i(\kappa,t))+\gamma\left(\sum_{j\neq i}\kappa_j w-\sum_{j\neq i}s_j(\kappa,t)\right)$$

Note that this tournament game is not a zero-sum game since rebates are only earned by early contributors. This non zero-sum nature creates incentives for cooperation in terms of contributions to the public good. On the other hand, there are no incentives for any cooperation or reciprocality in the timing of contributions. If there are at least two contributors, and given that someone will end up getting the highest rebate, all contributors will try to get it.

Under the Relative Time Subsidy Scheme, if at least two agents contribute to the public good in any Nash equilibrium, all contributors must contribute at time zero.

Proof. The proof is by contradiction. Suppose not so that $1<n\leq N$ players choose to contribute to the public good at different time instants. Let focus first on the last player in contributing. If she contributed in a time instant different from the penultimate agent in contributing, she would be strictly worse off contributing than refraining from contributing since $\delta_n<w$. Hence, if she contributes to the public good, she must do so at the same time as the penultimate contributor. Now, lets partition the set of contributors according to their contribution times. If the partition (collection of subsets of the contributors set) contains at least two sets, let focus on any player who is not a member of the subset characterized by the shortest contribution time. Given that $\delta_1>\delta_j\ \forall j=2,...,N$, this player can obtain a strictly higher expected payoff if she deviates by choosing a contribution time such that no player contributes to the public good earlier than her. As a result, all contributors must contribute at the same time instant. Suppose they contribute at a time moment different from zero. Then, any player can obtain a strictly higher expected payoff if she deviates and chooses a contribution time of zero, thus becoming the first contributor earning the rebate δ_1. ■

Assuming existence, we could try to characterize the potential Nash equilibria of the game. It is clear that if all other agents refrain from contributing to the public good and $\delta_1<w$, the unique best *first component* response of any player to the other players' strategies is refraining from contributing and as a result, the public good is not privately provided in equilibrium. If all other agents refrain from contributing to the public good and $\delta_1=w$, then any possible strategy is a best response to the other players' strategies. We have a continuum of equilibria also characterized by a null private provision of the public good. Suppose now at least one player chooses to contribute to the public good ($1\leq n\leq N$). Can this outcome be supported in a Nash equilibrium? Suppose so. Given the above lemma, let $\bar{\delta}_{n^*(\delta)}$ denote the expected rebate obtained by any contributor in equilibrium in the game given δ: $\bar{\delta}_{n^*(\delta)}\equiv\frac{1}{n^*}\sum_{j=1}^{n*}\delta_j>\delta_{n^*(\delta)}$ where $n^*(\delta)$ denotes the number of contributors in equilibrium given δ. The necessary condition for any given contributor not willing to deviate and refrain from contributing is:

$$\gamma(w-\delta_{n^*(\delta)})\geq w-\bar{\delta}_{n^*(\delta)}\ \Leftrightarrow\ \bar{\delta}_{n^*(\delta)}\geq(1-\gamma)w+\gamma\delta_{n^*(\delta)}\tag{3}$$

This condition specifies a lower bound for the expected rebate obtained by any contributor in any equilibrium of the game. This lower bound corresponds to a particular convex combination of the wealth endowment and lowest rebate earned by a contributor being the convex combination parameter the MPCR. The condition can be interpreted in the following terms: the opportunity cost of contributing to the public good for a contributor (given by $w - \bar{\delta}_{n^*(\delta)}$) cannot exceed the gains obtained from her contribution (given by $\gamma(w - \delta_{n^*(\delta)})$).

If there were no contributors in equilibrium, the additional necessary condition must be satisfied for these no contributors not willing to deviate and contribute to the public good:

$$\gamma(w - \delta_{n^*(\delta)+1}) \leq w - \bar{\delta}_{n^*(\delta)+1} \;\Leftrightarrow\; \bar{\delta}_{n^*(\delta)+1} \leq (1-\gamma)w + \gamma\delta_{n^*(\delta)+1} \tag{4}$$

This condition specifies an upper bound for the expected rebate that would obtained any contributor in any equilibrium of the game if a non contributor deviated and decided to contribute to the public good.

Given the parameter values of the model, it is possible to characterize many rebate vectors that satisfy these upper bound and lower bound conditions. As a result, multiplicity of Nash equilibrium follows.

Under the Relative Time Subsidy Scheme, multiple (pure strategy) Nash equilibrium outcomes might exist in the linear public good game characterized by multiple public good provision levels.

For any rebate vector $\delta \in R^N$, the equilibrium social welfare is given by:

$$\sum_{j=1}^{N} u_i(\kappa^*, 0) = Nw + (N\gamma - 1)n^*(\delta)(w - \bar{\delta}_{n^*(\delta)})$$

The private provision of public good is given by the equilibrium net contributions to the public good $n^*(w - \bar{\delta}_{n^*(\delta)})$ while the percentage of total net contributions to the public good over aggregate wealth is given by $\frac{1}{Nw}n^*(w - \bar{\delta}_{n^*(\delta)})$.

Our main task is designing the rebate vector that provides the highest well being in equilibrium. It is clear that the greater the private provision of the public good, the better off are the players. In order to maximize welfare and achieve the equilibrium outcome closest to the first best we should choose a rebate vector δ^* such that all players contribute in equilibrium: $n^*(\delta^*) = N$. The necessary condition for this to be satisfied is that $\delta^*_N \leq \frac{\sum_{j=1}^{N} \delta_j - N(1-\gamma)}{N\gamma - 1}$. This condition establishes an upper bound for the lowest rebate provided. In order to maximize welfare, it should not be positive. In principle, we could set up it to be negative. If we constrained it to be nonnegative, then we obtain that social welfare is given by $N[1 + (N\gamma - 1)\gamma]w$ so that it is increasing in both population size and the MPCR. Total net contributions are given by $N\gamma w$ while the percentage of contributions over aggregate wealth is given by γ. We could also design this rebate vector such that no other partial contribution equilibrium exists with $1 \leq n^*(\delta) < N$. By doing this, we reduce any possible coordination issues that agents might face when playing the game. As a result, if properly designed, the Nash equilbrium outcomes in the linear public good game could be reduced to two: one in which all players contribute and there is no delay in equilibrium and one in which no one contributes to the public good. The first equilibrium outcome corresponds to a Nash equilibrium that Pareto dominates any Nash equilibrium characterized by a zero public good provision, becoming a focal equilibrium to be played in the game. Furthermore, we could also design it in such a way that it satisfies the Risk Dominance refinement.

Under the Relative Time Subsidy Scheme, if the subsidy scheme is properly designed, there is a unique Nash equilibrium with positive public good level provision and it is characterized by no delay and by all players being contributors to the public good. This equilibrium Pareto dominates the equilibrium outcome in which the public good is not privately provided.

Our main results from this section are that a RTSS can be designed in a way such that:

1. There is no delay in equilibrium: Instant contributions are generated by this mechanism even when agents are extremely patients, that is, players do not discount future payoffs.
2. All agents contribute their entire endowment in equilibrium
3. The Nash equilibrium outcome Pareto dominates the equilibrium outcome generated by the VCM.

Some comparisons can be performed relative to other suggested mechanisms in the literature such as the fixed-prize lottery mechanism suggested by Morgan(2000).

The payoff of any player who participates in the lottery is given by: $u(x_i, g_i) = w - g_i + \left(\frac{g_i}{g_i + G_{-i}}\right) R + \gamma(\sum_{j=1}^{N} g_j - R)$ where R is the fixed-prize set apart from gross contributions to the public good. It can be shown that our mechanism outperforms Morgan's mechanism in all welfare criteria cited above for all values of R. Thus, our mechanism which can be interpreted as a parimutuel lottery with rebates being a non uniform percentage of total bets is superior to any fixed prize lottery.

4 Experiment design

The experiment took place on the 7 and 8 of October 2010, at the LaTEX computer laboratory (University of Alicante, Spain). 144 participants were recruited from the pool of students that attend the University of Alicante and were allocated to sessions according to their time preferences.[15] No person was allowed to participate in more than one session.

The experiment consisted of 6 sessions and 6 treatments, namely, A(verage), B(ase), C(ertain), D(ominant), E(xogenous time) and VCM (voluntary contribution mechanism). Sessions lasted between 90 and 120 minutes. Participants were allowed into the lab according to their arrival time and they entered and freely chose where to sit. They were not allowed to communicate for the entirety of the session and could not see other people's screens.

In each session instructions were read aloud by the instructor and, in order to ensure their correct understanding, the participants were asked to complete a "short quiz" (shown in appendix A; correct answers and the rationale for them were provided by the instructor after a few minutes). For the same reasons, participants then played two "trial" (practice) rounds whose outcomes did not affect their earnings. After each of these first three stages the instructor answered subjects' questions in private. The experimental rounds (12 per treatment) were then played, and after that, subjects completed a questionnaire with information regarding personal data and the decision-making process they followed. Finally, each participant was paid an amount of money consisting of a fixed amount (1.50 €) and a variable component equal to the earnings obtained in one of the rounds, randomly chosen using an urn with balls. The exchange rate used to translate experimental currency ("pesetas")[16] into money was

$$100 \text{ "pesetas"} = 10 \text{ €} \tag{5}$$

and the average person was paid 14.48 €.

In each session, the 24 participants were grouped into three 8-member matching groups, that remained fixed throughout the session. In each round, subjects in a matching group were randomly grouped into two 4-person groups.

[15] Between four and six "reserve" people were invited to each session and some of them had to be turned down because the target number of participants (24 per session) was reached. Each one of them was paid the 5€ show-up fee before being dismissed.

[16] This is the traditional "experimental currency" used in the LaTEX laboratory.

Each experimental round consisted of three stages: the "Scenario calculator", where a player could try different combinations of her own and the members of her group's choices and see how they impact on her payoffs; the "Choice" one, where participants had to make a decision that would affect their payoffs, and the "Feedback" one, where they got information about the round outcome.

In the "choice" stage a one-shot game was played. Each player was endowed with 100 "pesetas" and had to allocate them to one of two possible "activities" (Y or Z) interpreted as *(Gross) Contribution* and *No Contribution*, respectively.[17] We talk here of *gross* contribution rather than just plain contribution because in some cases contributors are entitled to a *subsidy*, which means that their net contribution differs from (are lower than) their gross contributions. Formally, $k_i \in \mathcal{K} := \{100, 0\}$, where k_i is the (gross) contribution decision of player i and it takes the value 100 (resp., 0) when she dedicates her entire endowment to activity Y (resp., Z).

In some of the treatments they also had to choose *when* to make their gross contribution (in the case of choosing Y). Formally, $t_i \in \mathcal{T} := \{1, 2, 3, 4\}$, where t_i is the moment in time at which player i dedicates her endowment to activity Y (economically, the moment in time at which she (gross) contribute her endowment to the provision of the public good).

We restrict the values that k_i can take because we are mostly interested in analysing the effect of time on contribution decisions. Thus, we reduced the contribution choice to an "all or nothing" question, so that deciding *how much to contribute* was a relatively simple issue and people could concentrate on the *when to contribute* dimension. Note that the presence of subsidies does, in fact, relax this restriction because those who benefit from a subsidy can, at the end of the day, enjoy some private consumption even though they (gross) contributed their whole endowment.

A player i's payoff y_i is therefore determined by her own decision profile $\mathbf{d}_i = (k_i, t_i) \in \mathcal{D} := \mathcal{K} \times \mathcal{T}$ and the decision profiles of the other 3 people in her group $\mathbf{d}_{-i} \in \mathcal{D}^3$.Formally,

$$y_i := y(\mathbf{d}_i, \mathbf{d}_{-i}) \tag{6}$$

Furthermore, since the time of contribution t_i only matters when the player (gross) contributes her endowment (i.e., when $k_i = 1$, if the person does not contribute her payoff is independent of t_i), we can reduce the decision profile $\mathbf{d}_i$ to a scalar variable "choice" $c_i := k_i \cdot t_i$. Thus, the previous equation becomes

$$y_i := y(c_i, \mathbf{c}_{-i}) \tag{7}$$

More explicitly, the payoff function is

$$y_i = x_i + \gamma G \tag{8}$$

where y_i is the total payoff of player i in a round, x_i is her private consumption for the round, $G := \sum g_i$ is the aggregate level of *net* contributions g_i in the group, and $\gamma \in (0, 1)$ is the constant "marginal per capita rate" (MPCR) at which contributions are transformed into payoffs.[18] Note that every person consumes the same amount of public good, which reflects the fact that the public good is both non-rival and non-excludable (that is, it is a

[17] The assumption of a degenerate income distribution is a first approach to the problem. We leave the question of how non-degenerate income distributions affect the subsidy mechanism open for future investigation. Our preliminary results suggest, however, that the mechanism can be easily modified in the presence of said distributions.

Nevertheless, that there is a very important application for the case of degenerate income distributions, namely, collective choice problems in which every person has one vote (hence, analogous to situations in which everyone has the same income) and part of the money collected is redistributed to the voters (analogous to subsidies being paid to players).

[18] In the experiment, the variables were labeled neutrally: y_i as "Result", x_i as "Component A", and γG

pure public good). Instructions highlighted the fact that different people could get different levels of private consumption x_i (component A) but γG was the same for everyone.

The player's budget constraint is:

$$x_i + g_i = w_i \tag{9}$$

so that her private consumption is given by:

$$x_i = w_i - g_i \tag{10}$$

Net contribution g_i is, in turn, equal to the player's gross contribution $k_i \in \{0, w_i\}$ minus the subsidy she receives $s_i \in [0, k_i]$:

$$g_i = k_i - s_i \tag{11}$$

Note that g_i cannot be negative: the subsidy cannot be negative and cannot exceed the amount (gross) contributed. This assumption implies that the system is self-financing: the designer *always* counts with enough money as to pay the subsidies and does not need to use her own money in any case. It can be said that bankruptcy is not possible. The actual functional form of the subsidy depends on the treatment considered, but its general form is

$$s_i = s\left(c_i, \mathbf{c}_{-i}\right) = s\left(k_i, t_i, \mathbf{k}_{-i}, \mathbf{t}_{-i}\right) \tag{12}$$

that is, it depends on the choices of the person (k_i, t_i) and on the choices of the other members of the group.

When a person contributes (choses activity Y), she becomes eligible for a subsidy. The impact of the subsidy is (at least) twofold:

1. On the one hand, it decreases the person's (net) contribution g_i and so, *ceteris paribus*, the person's public good consumption γG (second term of equation 8) and payoff y_i.
2. On the other hand, it increases the person's private consumption x_i (first term of equation 8) and, hence, the payoff of the person y_i.

The payoff function can therefore be re-written as

$$y_i = x_i + \gamma\left(W - X\right) = x_i + \left(\gamma W - \gamma X\right) \tag{13}$$

where $W := \sum w_i$ is the total wealth of the group and $X := \sum x_i$ is the total private consumption of the group. This formula is the one that was used in the instructions for the treatments (see appendix): x_i corresponds to "Component A" and $(\gamma W - \gamma X)$ to "Component B". In the experiment the MPCR is set equal to 0.6 (not different from the values frequently used in the literature –see, for example, XX and XX) and $w_i = 100$ for every player, so that $W = 400$ and "Component B"$= 0.6 \cdot 400 - 0.6 \cdot \sum x_i = 240 - 0.6 \cdot$ (sum of components "A" of the members of the group), which is exactly the formula used in the instructions (see appendix). Instructions highlighted the fact that different people could get different levels of private consumption x_i (component A) but $\gamma G = \gamma W - \gamma X$ was the same for everyone.

The participant's submission of her decision (k_i and t_i) ends the "Choice" stage and give way to the "Feedback" one, in which the person was informed about her choices, the information

as "Component B".

The assumption of a linear payoff function is frequently used in the literature (see NN, NN among others) and implies a corner solution. Thus, restricting attention to $k_i = 0$ and $k_i = 100$ is not an *assumption*, but a *consequence* of using a linear payoff function.

necessary to compute the subsidy, both her private and her public consumption, and her payoff for the round. At no stage was a subject given any information about the choices or outcomes of any other participant (at least not explicitly, though they could infer them in some scenarios).

By clicking on the "Continue" button, participants exited the "Feedback" stage and moved on to the next round (if any was left). Rounds were identical to each other in terms of their structure (Scenario calculator, Choice and Feedback stages) and rules (payoff computations, matching protocols), but may have differed in the *realised* values of the random variables (allocation of people to groups, tie breaking results). Participants were told explicitly about this and informed that each round was independent from every other one.

4.1 Treatments

The experiment's treatments were defined according to the subsidy function used.

1. The first case to consider is the "no subsidy" one: $s_i = 0$ always. This is the standard voluntary contribution mechanism. Whatever is (gross) contributed is also (net) contributed: $g_i = k_i$. This is the setup we used in the VCM treatment.
2. Alternatively, we could consider cases in which the subsidy was strictly positive at least in some scenarios. In particular, we made the subsidy be a function of (among other possible variables) the *time* at which the player contributed. There are, however, two ways in which time can be used to determine the size of subsidies:
   (a) Time of contribution could be measured in "absolute" terms, meaning that the subsidy would be a function of the exact day/hour/minute/second at which the contribution was made: $s_i = s(k_i, t_i; \mathbf{k}_{-i})$. This implies that everyone who contributed on, say, October 20^{th} would receive the same subsidy. It also implies that time affects the size of the subsidy that I get *only* via my *own* time of contribution. This setup is the one used in treatment E(xogenous time).
   (b) Alternatively, time of contribution could be measured in "relative" terms, meaning that the subsidy would be a function of the position (order, rank) of contribution. That is, early contributors would get a subsidy different from the subsidy obtained by late contributors. Thus, time affects the subsidy I obtain not only via my own time of contribution, but *also* via everyone else's: $s_i = s(k_i, t_i; \mathbf{k}_{-i}, \mathbf{t}_{-i})$. This setup is the one used in treatments A, B, C and D. They differ in terms of the risk associated to each one of them, as shown in the following table:

		Strategic Risk	
		Zero	Positive
Exogenous Risk	Zero	C(ertain)	A(verage)
	Positive	D(ominant)	B(ase)

Table 1: Factorial design

where the exogenous risk refers to the degree variability of the subsidy function (how heterogeneous are the subsidies received by the members of the group) and the strategic risk refers to probability of coordination failure (as explained in the theory section, if the subsidy is a weakly decreasing function of the position of contribution, then the situation becomes a coordination game with multiple equilibria).

4.2 Selection of payoffs and hypotheses to test

4.2.1 Base treatment

Let us start with the Base treatment. The subsidy function is:

$$s_i^B = s\left(k_i, t_i; \mathbf{k}_{-i}, \mathbf{t}_{-i}\right) = \begin{cases} 90 & \text{if} \quad \text{player } i \text{ is the first person of the group to choose } Y \\ 70 & \text{if} \quad \text{player } i \text{ is the second person of the group to choose } Y \\ 20 & \text{if} \quad \text{player } i \text{ is the third person of the group to choose } Y \\ 0 & \text{if} \quad \text{player } i \text{ is the fourth person of the group to choose } Y \end{cases} \tag{14}$$

It can clearly be seen that the subsidy depends on the *relative* time of contribution[19]. It is also straightforward to see that different members of the group get different subsidies, and hence also different private consumption levels and different payoffs (in other words, exogenous risk is strictly positive: the variance of the distribution is 1325). It is not so simple to see the presence of strategic risk. For that, it is better to see matrix of payoffs of player i:

		$K_{-i} := \sum_{j \neq i} k$			
		300	200	100	0
	Z	100 + 72 = 172	100 +24 = 124	100 + 6 = 106	100 + 0 = 100
	$Y1^o$	90 + 132 = 222	90 + 72 = 162	90 + 24 = 114	90 + 6 = 96
c_i	$Y2^o$	70 + 132 = 202	70 + 72 = 142	70 + 24 = 94	
	$Y3^o$	20 + 132 = 152	20 + 72 = 92		
	$Y4^o$	0 + 132 = 132			
	Average Y	45 + 132 = 177	60 + 72 = 132	80 + 24 = 104	90 +6 = 96

Table 2: Payoff table. Base treatment

In every cell it is indicated the payoff of the (row) player i when her choice is c_i and the other members of the group (gross) contribute K_{-i} pesetas. The first term is the private consumption (the subsidy if Y is chosen) and the second one is the public good consumption. Note that when player i chooses Y her final payoff (and her subsidy) depends on the position of contribution (indicated by 1^o, 2^o, etc. on the row headers). The last line shows the average payoff that player i gets if she chooses Y when the rest of the group (gross) contributes K_{-i} pesetas and all contributors make their contributions at the same moment in time. If player i were risk neutral, hence, she would choose to contribute (Y) if at least 2 other people in her group also contribute (if $K_{-i} \geq 200$): when three (resp. two) other people in her group contribute, then contributing gets her 177 pesetas (resp. 132) while not contributing gets her only 172 pesetas (resp. 124). Otherwise (if $K_{-i} < 200$), she is better off not contributing (either 106>104 or 100>96). That is, player i has an incentive to do as the others in her group do: if they contribute, she is better off contributing as well; if they do not contribute, her optimal choice is not to contribute either. Since this situation is true for all members in the group, the result is a coordination game with two pure strategy equilibria: one in which everyone contributes and another in which nobody contributes. Thus, this is evidence of the presence of strategic risk. Note that the "Full Contribution" equilibrium (FCE) Pareto-dominates the "Zero Contribution" one (ZCE). Furthermore, the numbers in equation 14

[19] In case of a tie in the time of contribution, the computer randomly asigns a position to each participant in the tie (each one has the same probability in each of the possible positions).

were chosen so that the FCE would also risk-dominate the ZCE.[20] Thus, both criteria select the same (good) equilibrium, which means that if this mechanism is actually implemented, the outcome is very likely to be similar to the one associated with the FCE. Finally, it is important to mention that the above analysis also holds if the player is risk averse and her utility function is of the Constant Relative Risk Aversion (CRRA) type, with index of risk aversion r as high as 1 (let us call this type of player a "moderately risk averse person", MRA person).[21]

4.2.2 Dominant treatment

The subsidy function is:

$$s_i^D = s\left(k_i, t_i; \mathbf{k}_{-i}, \mathbf{t}_{-i}\right) = \begin{cases} 100 & \text{if} \quad \text{player } i \text{ is the first person of the group to choose } Y \\ 50 & \text{if} \quad \text{player } i \text{ is the second person of the group to choose } Y \\ 30 & \text{if} \quad \text{player } i \text{ is the third person of the group to choose } Y \\ 0 & \text{if} \quad \text{player } i \text{ is the fourth person of the group to choose } Y \end{cases} \tag{15}$$

As with the Base treatment, the subsidy depends on the *relative* time of contribution[22] and the exogenous risk is strictly positive (the variance of the distribution is also 1325). The matrix of payoffs of player i is now:

		$K_{-i} := \sum_{j \neq i} k$			
		300	200	100	0
	Z	100 + 72 = 172	100 + 30 = 130	100 + 0 = 100	100 + 0 = 100
	Y1^o	100 + 132 = 232	100 + 72 = 172	100 + 30 = 130	100 + 0 = 100
c_i	Y2^o	50 + 132 = 182	50 + 72 = 122	50 + 30 = 30	
	Y3^o	30 + 132 = 162	30 + 72 = 102		
	Y4^o	0 + 132 = 132			
	Average Y	45 + 132 = 177	60 + 72 = 132	75 + 30 = 105	100 + 0 = 100

Table 3: Payoff table. Dominant treatment

A risk neutral player would now realise that choosing Y (i.e., contributing) is a weakly dominant strategy (and strictly dominant as long as someone else in the group contributes). Thus, there is no strategic risk here: the only robust equilibrium is the FCE. And this result also holds for MRA people. So, treatments B and D have the same level of exogenous risk (same variance) but B has a higher (strictly positive) level of strategic risk than D (strategic risk is zero). It is reasonable to assume that coordinating on the good equilibrium (FCE)

[20] Risk dominance is another criterion used to select an equilibrium when a game has multiple ones. It reflects the risk (payoff loss) associated with deviating from an equilibrium: it selects the equilibrium with the largest associated payoff loss.

In the case of treatment B, deviating from the FCE means switching from Y (that yields expected payoff 177) to Z (payoff=172). The associated loss is 177-172=5. On the other hand, deviating from the ZCE means switching from Z (that yields payoff 100) to Z (payoff=96). The associated loss is 100-96=4. Since the loss associated to the FCE is larger than the one associated to the ZCE, then the risk dominance criterion selects the FCE.

[21] According to Holt and Laury (2002), this should encompass about 75% of the population.

[22] In case of a tie in the time of contribution, the computer randomly asigns a position to each participant in the tie (each one has the same probability in each of the possible positions).

is easier in D than in B (less demanding in terms of belief formation). Thus, by comparing treatments B and D we can test the following hypothesis:

Hypothesis 1 ***Effect of strategic risk (ESR)****: Higher strategic risk decreases the number of contributors and lowers net contributions (less of the public good is produced).*

Formally, the hypothesis can be written as

$$K^D > K^B \tag{16}$$
$$G^D > G^B \tag{17}$$

where $K^h := \sum k_i^h$ is the number of contributors in treatment h.

4.2.3 Average treatment

The subsidy function is:

$$s_i^A = s\left(k_i; \mathbf{k}_{-i}\right) = \begin{cases} 90 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do everyone else in her group} \\ 80 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do two other people in her group} \\ 60 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do one other person in her group} \\ 45 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and everyone in her group choose } Z \end{cases} \tag{18}$$

Unlike the Base and Dominant treatments, the subsidy here does not depend on the time of contribution: it only depends on the contribution decisions of the player and of the members of her group. Unlike B, there is no exogenous risk here: at the end of the day, *every* player gets the same payoff: the variance of the distribution is also 0. The matrix of payoffs of player i is now now:

		$K_{-i} := \sum_{j \neq i} k$			
		300	200	100	0
	Z	100 + 72 = 172	100 + 24 = 124	100 + 6 = 106	100 + 0 = 100
c_i	Y	45 + 132 = 177	60 + 72 = 132	80 + 24 = 104	90 + 6 = 96

Table 4: Payoff table. Average treatment

Note that this table consists of the first and last row of the table of payoffs of treatment B (table 2). The analysis is, therefore, identical to the one developed immediately below that table, and so are the results: the game is a coordination game, it is optimal to contribute if at least two other people in the group do so, and the FCE is both the Pareto-dominant and the risk-dominant equilibrium. So, treatments B and A have the same level of strategic risk (in both treatments it is optimal to contribute if at least two other people in the group do so, and not to contribute otherwise) but B has a higher (strictly positive) level of exogenous risk than A (variance in B is 1325 while variance in A is 0). It is reasonable to assume that risk averse people would prefer treatment A over treatment B because expected values are the same but variability is lower in the first treatment. Thus, by comparing treatments A and B we can test the following hypothesis:

Hypothesis 2 ***Effect of exogenous risk (EER)****: Higher exogenous risk decreases the number of contributors and lowers net contributions (less of the public good is produced).*

Formally, the hypothesis can be written as

$$K^A > K^B \tag{19}$$
$$G^A > G^B \tag{20}$$

4.2.4 Certain treatment

The subsidy function is:

$$s_i^C = s\left(k_i; \mathbf{k}_{-i}\right) = \begin{cases} 100 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do everyone else in her group} \\ 75 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do two other people in her group} \\ 60 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and so do one other person in her group} \\ 45 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and everyone in her group choose } Z \end{cases} \tag{21}$$

Just like in A and unlike B and D, the subsidy here does not depend on the time of contribution: it only depends on the contribution decisions of the player and of the members of her group. There is no exogenous risk here either: at the end of the day, *every* player gets the same payoff: the variance of the distribution is also 0. The matrix of payoffs of player i is now now:

$K_{-i} := \sum_{j \neq i} k$

		300	200	100	0
	Z	100 + 72 = 172	100 + 30 = 130	100 + 0 = 100	100 + 0 = 100
c_i	Y	45 + 132 = 177	60 + 72 = 132	75 + 30 = 105	100 + 0 = 100

Table 5: Payoff table. Certain treatment

Note that this table consists of the first and last row of the table of payoffs of treatment D (table 3). The analysis is, therefore, identical to the one developed immediately below that table, and so are the results: the game is a coordination game and contributing is a weakly dominant strategy. So, treatments C and D have the same level of strategic risk (in both treatments contributing is a weakly dominant strategy) but D has a higher (strictly positive) level of exogenous risk than C (variance in D is 1325 while variance in C is 0). It is reasonable to assume that risk averse people would prefer treatment C over treatment D because expected values are the same but variability is lower in the first treatment. Thus, by comparing treatments C and D we can test the following hypothesis:

Hypothesis 3 ***Effect of exogenous risk (EER):*** *Higher exogenous risk decreases the number of contributors and lowers net contributions (less of the public good is produced).*

Formally, the hypothesis can be written as

$$K^C > K^D \tag{22}$$
$$G^C > G^D \tag{23}$$

Also, treatments A and C have the same level of exogenous risk (same variance) but A has a higher (strictly positive) level of strategic risk than C (strategic risk is zero). It is reasonable to assume that coordinating on the good equilibrium (FCE) is easier in C than in A (less demanding in terms of belief formation). Thus, by comparing treatments A and C we can test the following hypothesis:

Hypothesis 4 ***Effect of strategic risk (ESR)****: Higher strategic risk decreases the number of contributors and lowers net contributions (less of the public good is produced).*

Formally, the hypothesis can be written as

$$K^C > K^A \quad (24)$$
$$G^C > G^A \quad (25)$$

4.2.5 Exogenous time treatment

The subsidy function is:

$$s_i^E = s(k_i, t_i) = \begin{cases} 90 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ at } t = 1 \\ 70 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ at } t = 2 \\ 20 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ at } t = 3 \\ 0 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ at } t = 4 \end{cases} \quad (26)$$

Unlike the previous cases, the subsidy here does not depend on the decisions of the other members of the group: it only depends on the contribution decisions of the player. There is positive exogenous risk: the variance of the distribution of subsidies is 1325 (like in B and D)[23] but there is no strategic risk (players' decisions are strategically independent from each other). The Nash equilibrium consists in every member of the group choosing Z (not contributing), which is an inefficient outcome (full contribution Pareto-dominates it). Thus, by comparing treatments B and E we can test the following hypothesis:

Hypothesis 5 ***Absolute v Relative Time (ART)****: Ceteris paribus, mechanisms based on relative time are superior to those based on absolute time. Thus, the number of contributors and the level of aggregate net contributions is higher in the former ones than in the latter ones.*

Formally, the hypothesis can be written as

$$K^B > K^E \quad (27)$$
$$G^B > G^E \quad (28)$$

[23] The variance is computed using the distribution in the equation above. However, when the game is actually played by economic agents, the actual distribution of subsidies could be quite different (and hence present a different variance). However, it seems reasonable to compute the variance of the distribution in the table because the values of the subsidy are the same as in treatment B.

4.2.6 Voluntary Contribution Mechanism (VCM) treatment

Though this mechanism does not involve the use of subsidies, for comparison reasons it might be useful to re-write it as if subsidies were available. Thus, the subsidy function is:

$$s_i^{VCM} = s\left(k_i, a_i\right) = \begin{cases} 90 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and “component } A\text{”} = 90 \\ 70 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and “component } A\text{”} = 70 \\ 20 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and “component } A\text{”} = 20 \\ 0 & \text{if} \quad \text{player } i \text{ chooses } Y \text{ and “component } A\text{”} = 0 \end{cases} \tag{29}$$

where $a_i \in \{0, 20, 70, 90\}$ is the player's choice of "component A" (i.e., of private consumption). Thus, a player's net contribution is $g_i = k_i - a_i$ if $k_i = 100$ and $g_i = 0$ if $k_i = 0$. That is, in order to compare treatment VCM to the other five treatments, it is better to used the table above. However, the game is still a simple VCM game in which the player can choose among 5 different levels of contribution, namely, $g_i \in \{0, 10, 30, 80, 100\}$: $g_i = 0$ if the player chooses Z; $g_i = 10$ if the player chooses Y ($k_i = 1$) and Component A = 90 ($a_i = 90$); etc.

It is easy to see that the subsidy functions shown in equations 26 and 29 are mathematically identical, the only difference being that the variable t_i in equation 26 was relabeled as a_i in equation 29. The economic interpretation also changed: in the first case the explanatory variable was the (absolute) moment in time at which the player chose to contribute; in the second one it is the choice of the player regarding the level of her component A (private consumption). Game theoretically, the change does not alter the properties of the game, which yields the same equilibrium than in the E treatment (nobody contributes, the usual Nash equilibrium in VCM games with linear utility functions). Thus, by comparing treatments E and VCM we can test the following hypothesis:

Hypothesis 6 ***Framing effect/Relevance of time (FERT)****: The E mechanism –based on absolute terms– is not superior nor inferior to the VCM one. Thus, the number of contributors and the level of aggregate net contributions are not significantly different in the former than in the latter.*

Formally, the hypothesis can be written as

$$K^E = K^{VCM} \tag{30}$$

$$G^E = G^{VCM} \tag{31}$$

From the last two hypotheses, we can obtain a third one, namely

Hypothesis 7 ***Superiority of Relative Time Mechanism over VCM (SRTMVCM):*** *Ceteris paribus, mechanisms based on relative time are superior to the standard Voluntary Contribution Mechanism. Thus, the number of contributors and the level of aggregate net contributions are higher in the former ones than in the latter.*

Formally, the hypothesis can be written as

$$K^B > K^{VCM} \tag{32}$$

$$G^B > G^{VCM} \tag{33}$$

Before we move on to the results, an important issue needs to be commented: implicit in the analysis above is the fact that the maximum amount of subsidies that the designer may end up paying is the same in all treatments A, B, C and D: it is equal to $90+70+20+0 = 180$ (in B), $100+50+30+0 = 180$ (in D), and $45+45+45+45 = 180$ (in A and C). Furthermore, since in all 4 cases the prediction of the model is that the FCE will be selected, we can expect that the actual amount paid out in terms of subsidies will be exactly 180 pesetas per group. Thus, we can determine which treatment is better by simply comparing the number of contributors and the level of aggregate net contributions in each one of them. In treatments E and VCM the model predicts the Zero Contribution outcome, and hence the zero subsidy scenario. Valid comparisons between these two treatments can also be made in terms of number of contributors and aggregate net contributions, knowing that total spending on subsidies is the same in both treatments. Finally, the comparison between the first four cases (A, B, C, D) and the last two (E, VCM) is less direct because the subsidies paid out in equilibrium are quite different. The way to overcome this problem is to compute the number of contributors and the aggregage net contributions as proportions/ratios of their first-best counterparts, and make the comparisons based on these so computed variables.

5 Results

A total of 1728 observations were collected in the experiment. There are two variables of interest for our analysis:

1. the number of contributors K, and
2. the aggregate level of net contributions (or, equivalently, the amount of public good provided) $G := \sum_i g_i$

The two of them are related as follows:

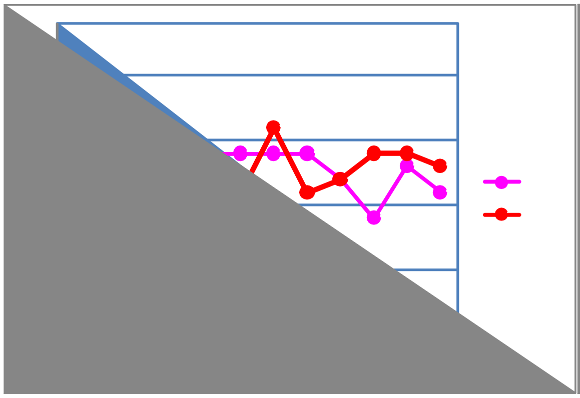
$$G = \sum_i g_i \tag{34}$$

$$\frac{G}{N} = \frac{1}{N}\sum_i g_i \tag{35}$$

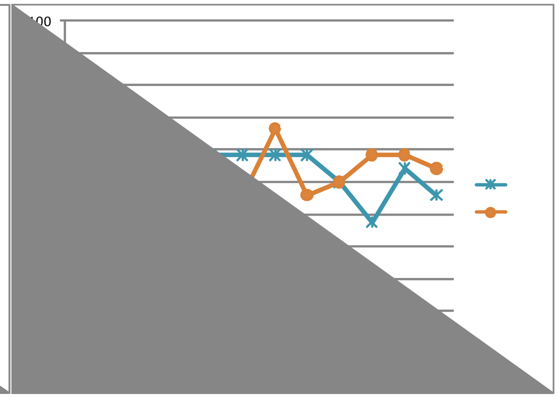
$$\frac{G}{N} = \frac{K}{N} \times \frac{1}{K}\sum_i g_i \tag{36}$$

i.e., the level of net contributions per capita $\frac{G}{N}$ is the product of two factors: the proportion of people in the matching group who contributes $\frac{K}{N}$ and the level of net contributions per contributor $\frac{1}{K}\sum_i g_i$.

5.1 E v VCM



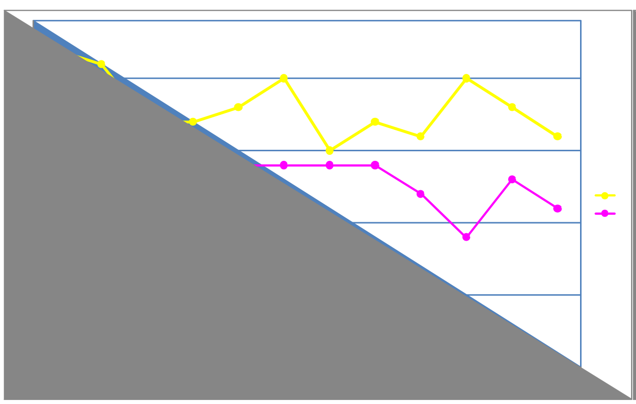
Number of contributors. Session average.



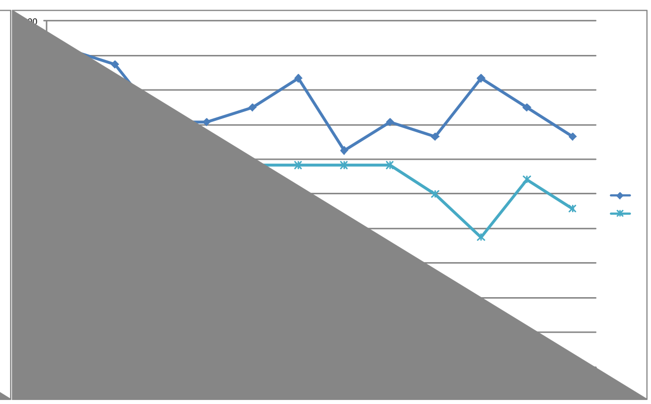
Net contributions per capita. Session average.

It can be seen that E and VCM yield the same results both in terms of number of contributors and of net contributions per capita. Thus, hypothesis 6 is not rejected. As a consequence, we conclude that introducing time per se is not enough to improve over the VCM.

5.2 E v B



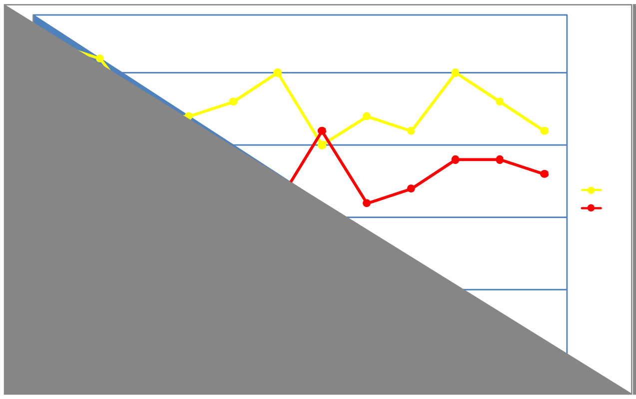
Number of contributors. Session average.



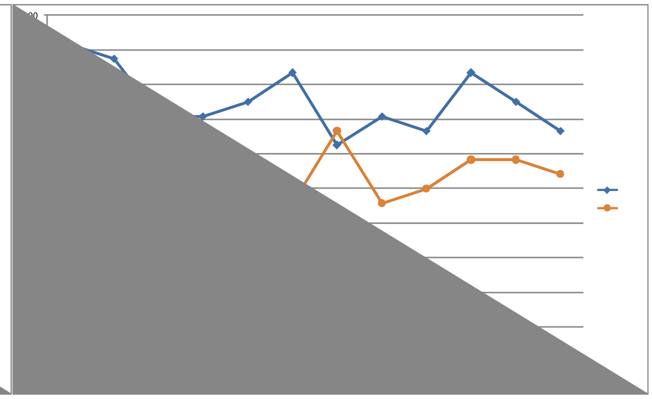
Net contributions per capita. Session average.

It can be seen that the Base treatment leads to both more contributors and more net contributions per capita than the E treatment. Thus, hypothesis 5 is not rejected. Therefore, it can be said that mechanisms based on the relative timing of contributions are superior to those based on the absolute timing of contributions.

5.3 B v VCM



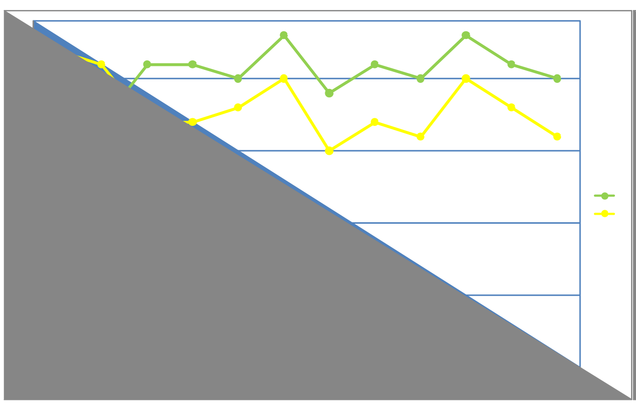
Number of contributors. Session average.



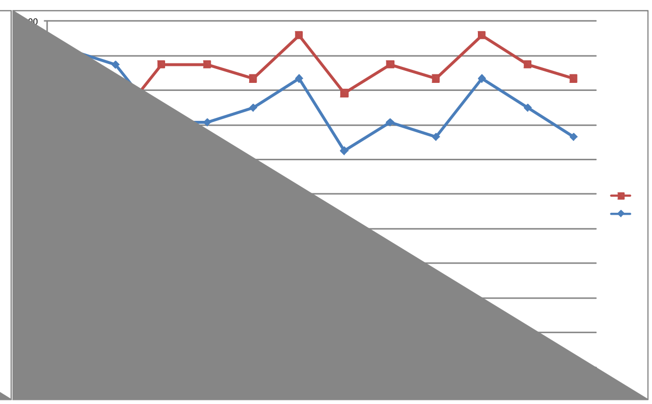
Net contributions per capita. Session average.

From the previous two subsections, it is not surprising to find that the Base treatment is better than the VCM one.

5.4 B v A



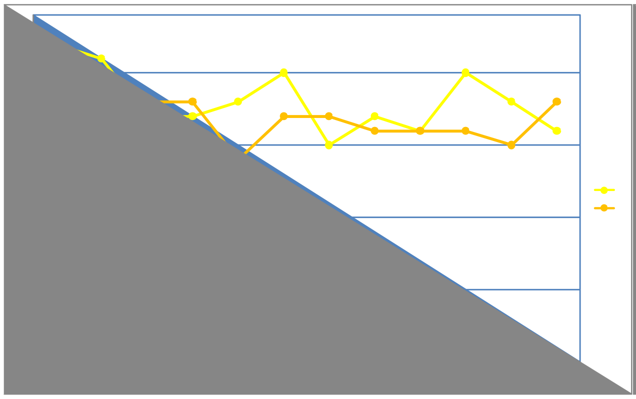
Number of contributors. Session average.



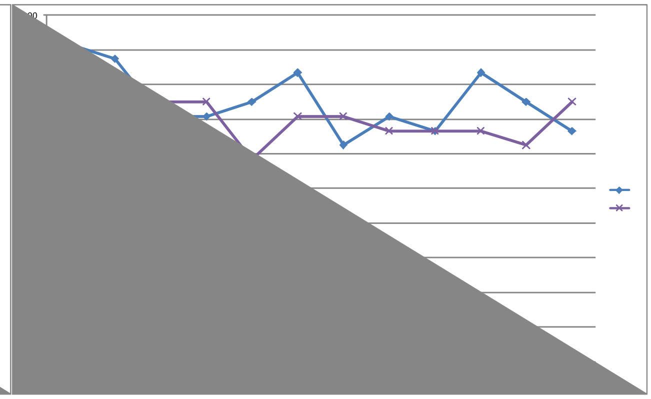
Net contributions per capita. Session average.

After a somewhat erratic beginning of the session, it can be seen that the Average treatment is better than the Base one. That is, hypothesis 2 is not rejected. Thus, we can conclude that reducing the degree of exogenous risk is a good policy. Further, we can also draw another inference: that adding more dimensions to the subjects' decision problem (in particular, adding the time dimension, either in absolut or relative terms) does not necessarily increases (net) contributions.

5.5 B v D



Number of contributors. Session average.

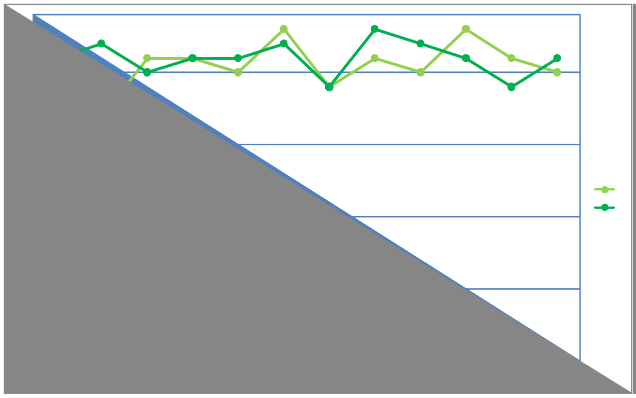


Net contributions per capita. Session average.

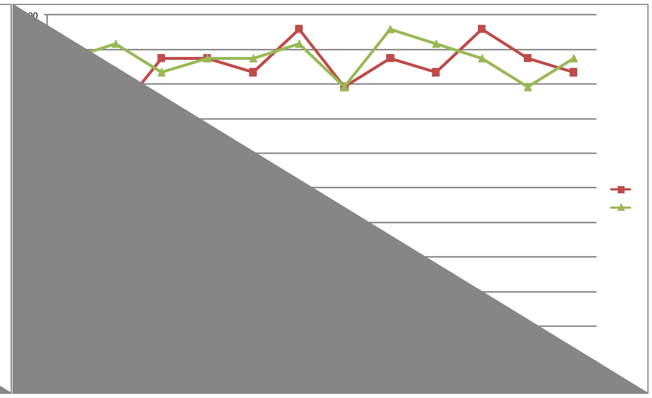
Both the number of contributors and the net contributions per capita of treatment B are not significantly different from their counterparts of treatment D. Thus, hypothesis 1 is rejected. We can then conclude that strategic risk seems not to affect players' choices. This is especially surprising because B is a coordination game (hence risk of coordination failure is quite high) while D has a weakly dominant strategy (contributing), so we do not really know how to explain this result. A possible explanation is related to the idea of complexity, though since both treatments have identical rules and only differ in some numbers in the payoff table, it is difficult to support this idea. Maybe it is related to risk aversion, but even people as risk averse as those with $r = 1$ should contribute all her endowment, and they do not. Finally, it might be the result of some kind of cognitive (or in general, behavioural) constraint. E.g., it might be the case that people do not measure (exogenous) risk by computing the variance of the distribution, but they simply "count" good cases and bad cases (above and below a reference point) and then attach equal probability to each of these cases. Thus, if the reference point is the (focal) point 50, then in treatment B there are two "good" possibilities (70 and 90), while in D there's only "one and a half" (one: 100 and a half: 50). This is in line with the idea of "chance maximisers" in Sánchez Villalba (2008).

5.6 A v C and C v D

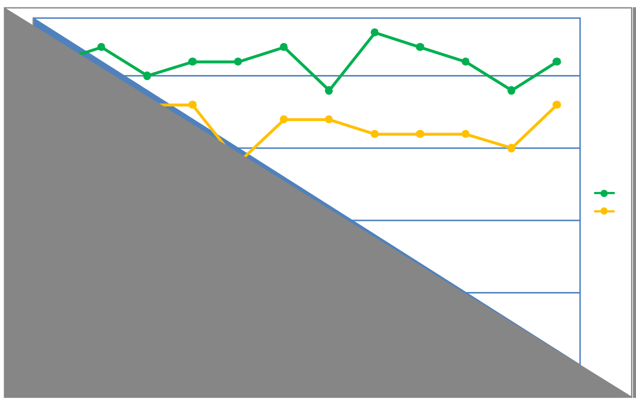
The analysis supports the data gathered above: C (zero exogenous risk, zero strategic risk) dominates D (positive exogenous risk, zero strategic risk) and is not significantly different from A (zero exogenous risk, positive strategic risk) and



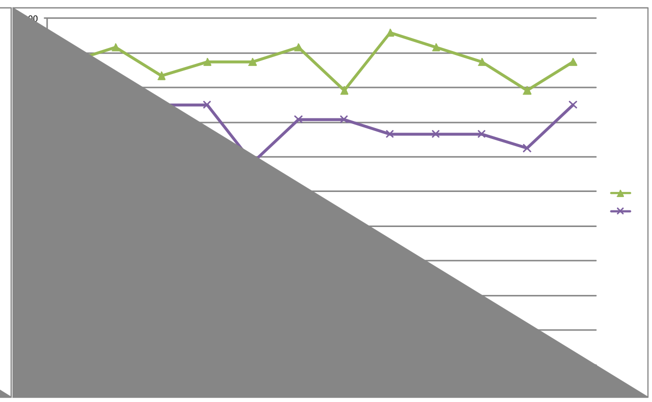
Number of contributors. Session average.



Net contributions per capita. Session average.



Number of contributors. Session average.



Net contributions per capita. Session average.

Thus,

this is further evidence that hypothesis 2 is supported by the data while hypothesis 1 is rejected. It also seems to suggest that the (net) contributions seems to be independent of the strategic risk while it is quite sensitive to changes in the exogenous risk. If one drew "iso-contribution" indifference curves, they would be straigth lines (plotting exogenous risk on the horizontal access and strategic risk on the vertical one.

Summarising the information of this section, one could order treatments in three groups: the best are A and C, that are equally good and whose main feature is that exogenous risk is zero; then second-best are B and D: the presence of exogenous risk implies less contributors/contributions compared to the previous two treatments; finally, the worst of them all, E and VCM: the absence of interrelation between my own subsidies and other people's implies less contributors/contributions compared to the intermediate treatments. Thus, interaction (not just time) is important, and while exogenous risk seems to be very important, strategic risk seems to be totally irrelevant for decisions.

6 Conclusions

The private provision of public goods is one of the fundamental topics of Public Economics and has ample application to many real-world situations. Indeed, the presence of public goods is one of the sources of market failure: when left alone, the private market will provide an inefficiently low level of provision of public goods. Examples of this problem can be found in many scenarios, from the low level of charity giving in a society or of foreign aid among states, to the low effort exerted by workers when paid according to the team output, to the underinvestment in private vigilance in a neighbourhood, to many others.

The underlying problem behind all of this situations is always the same: the clash between social and individual objectives: while the socially optimal action is to contribute, the individually optimal action is to "free-ride". Several studies have considered different alternative methods designed with the objective of eliminating (or at least mitigating) the inefficiency associated with the private provision of public goods. From pricing strategies (Lindahl), to truth-telling mechanisms (Groves-Ledyard), to alternative settings (provision points, money-back guarantees, lotteries *à la* Morgan), to a long list of etceteras.

The mechanism we propose in this paper is based on the same idea than Morgan's (2000) paper, namely, introducing a negative externality among the individuals that (partially) offsets the positive externality present in the voluntary contribution mechanism. Our goal was to contribute to the area of voluntary contribution mechanisms (VCM) by formulating a theoretical model to predict the behaviour of individuals when they have to decide not only if and how much, but also *when* to contribute to the public good provision. We proposed that contributors should get a "discount" or "subsidy" for early contribution and pay the full price otherwise. This could lead to some people –that may had not contributed at the non-discounted price– to contribute early in order to pay less.

Our mechanism is based on voluntary contributions and improves the performance of the best alternative (in terms of number of contributors and aggregate contributions) and yet it is simple (easy to implement and understand), cheap and self-financed (it is *never* needed to pour money into it from other sources). Furthermore, it can even generate an equitable outcome.

The key feature of the mechanism is that it changes the nature of the game: the VCM Prisonners' Dilemma is transformed into a coordination game with two equilibria: one is the "bad" equilibrium in which nobody contributes (as in the VCM case) and the other one is the "good" equilibrium in which everybody contributes. If properly designed, the good equilibrium can then be selected by the two most popular criteria used to select an equilibrium in games with multiple ones, namely, the payoff-dominance criterion and the risk-dominance one.

Since larger discounts were awarded to early contributors than to later ones, then different people would receive different discounts, which in turn raised the issue of the risk associated with the subsidy scheme. This type of risk we labelled "exogenous risk" because it was the direct result of offering different discounts to different people. On the other hand, the existence of multiple equilibria in the coordination game implied that the risk of coordination failure was something to take into account. We called this "endogenous or strategic risk" because it is the result of players' actions. Further, we could crudely rank the degree of strategic risk by "counting" the minimum number of contributors in the economy that are needed to make my contribution a profitable path of action: if contributing is profitable only if everyone else contributes as well, then the risk of coordination failure (hence, the strategic risk) is high, because one deviation is enough to make me change my decision and choose not to contribute instead.

We tested the theoretical predictions of the model using experimental data. We ran 6 treatments (all of them using neutral terminology):

- one standard VCM treatment to be used as benchmark for comparison (treatment *VCM*),

- another one in which discounts were a function of the absolute time of contribution (treatment E),
- four other treatments in which discounts were a function of the relative time of contribution, each one of them presenting a different combination of exogenous and strategic risk levels, namely
  - one in which both types of risk were strictly positive and that was used as the basis for comparison with all other treatments (treatment B or $Base$),
  - one in which the exogenous risk was as in the B treatment and the strategic risk was eliminated (treatment D), meaning that "contribution" became a (weakly) dominant strategy,
  - one in which the strategic risk was as in the B treatment and the exogenous risk was eliminated (treatment A), meaning that every contributor received the same discount,
  - finally, one in which both the exogenous and the strategic risk were eliminated (treatment C), which meant that this treatment was, a priori, the best of them all.

Our hypotheses were such that we could order treatments in terms of their performance (number of contributors and net contributions per capita): we expected C to be better than A and D (lower risk) and B to be worse than A and D (higher risk), but we did not know what to expect from the comparison between A and D. Also, we expected E to be equivalent to the VCM (no externality) and both of them to be worse than B (externality). Our hypotheses can therefore be represented as follows:

$$C \succ best\,\{A, D\} \succcurlyeq worst\,\{A, D\} \succ B \succ E \sim VCM \tag{37}$$

Our empirical results support almost every one of our hypotheses: we obtained the following ordering of the treatments in terms of their performance

$$C \sim A \succ D \sim B \succ E \sim VCM \tag{38}$$

That is, the only two hypotheses that were rejected were that $C \succ A$ and that $D \succ B$. In both cases, the intuition behind the hypothesis was that the strategic risk in the treatment on the left-hand side was lower than in the one on the right-hand side. Empirical evidence seems to reject, therefore, the idea that people care about strategic risk. It is quite a surprising result, and we do not have a definitive explanation for this "anomaly". Our best shot at it is based on the idea that, when making risky decisions, some people seem not to weight their payoffs using the associated probabilities but they simply "count" the number of "good" outcomes (in which the person "wins" and gets extra money) and the number of "bad" outcomes (in which the person "loses" and has to pay/give up some money) and then they simply choose the option with the highest number of "good" outcomes (see, for example, Sánchez Villalba (2009) for a case in which such rule of thumb seems to be followed).

On the other hand, the experimental evidence seems to also categorically determine that $A \succ D$, which is consistent with the results in the previous paragraph and implies that changes in the exogenous risk are more important than changes in the strategic risk.

In summary, we designed a mechanism that is better than the alternative methods suggested in the literature: it produces a larger amount of the public good (which is the efficient action to undertake in this setting) than alternative mechanisms, it is simple to understand by the potential contributors and it is easy and cheap to implement by the fundraiser (with special stress on the fact that it is an entirely self-financed mechanism). Furthermore, in some of their variants (like in treatments A and C) it can be shown to yield an equitable outcome (every person gets the same subsidy). On top of that, our preliminary results suggest that first best provision both in terms of number of contributors and size of contributions may be feasible under some conditions that we are trying to pin down precisely. Also, our preliminary results seem to indicate that the mechanism is robust to the introduction of heterogeneity (say, in terms of income or of the rate of transformation between private and public consumption) and of more general utility functions. All of these topics are part of our research agenda connected to this topic, as well as others including the issues that we could not cover so far like provision points or dynamic games.

We also showed empirical evidence (obtained in 6 experimental sessions) that supports most of our hypotheses. Thus, the combination of a solid theoretical model and the supporting experimental evidence suggest that the mechanism we designed can be successfully implemented as a means to finance public goods through voluntary contributions, yielding results that are both efficient and equitable. And since free-riding is a pervasive problem in our everyday lives –from littering to road congestion to the alleviation of world poverty– this implies that policy suggestions as the one we put forward can have a significant impact on the lives of many people.

A Instructions for treatment B[24]

INSTRUCCIONES

Introducción

Antes de empezar, muchas gracias por participar en este experimento. Es importante que sepas que, aunque forma parte de un proyecto de investigación serio, este experimento NO es un examen. No hay, por lo tanto, respuestas "correctas" ni "incorrectas". Igualmente, en todo momento, se preservará el anonimato de todos los sujetos participantes del mismo.

Cómo funciona el experimento

Primero que nada, te indicaremos las reglas básicas y te daremos las instrucciones necesarias. Luego pasaremos al experimento propiamente dicho, donde se te pedirá que tomes decisiones en una serie de situaciones que te presentaremos. Finalmente se te pagará: una parte fija por haber participado (1,50 €) y una parte variable que dependerá de tu actuación en las situaciones mencionadas anteriormente.

El experimento se compone de 6 secciones:

- Instrucciones
- Mini-test
- Rondas de prueba
- Rondas experimentales
- Cuestionario
- Pago

Las repasaremos en detalle un poco más adelante.

[24] Instructions for the other treatments were similar to these ones, with the logical changes in rules and parameters needed in each case.

Reglas básicas

Para que el experimento funcione necesitamos llevarlo a cabo de acuerdo a unas pocas, pero estrictas, reglas:

- A partir de ahora y hasta el final del experimento, por favor no hables (¡no tardaremos demasiado!) y apaga tu teléfono móvil.

- Si tienes alguna(s) pregunta(s) sobre el experimento o alguna de sus partes, simplemente levanta tu mano y el experimentador se acercará a tu escritorio a responderla(s).

- Por favor no uses el ordenador hasta que se te lo indique.

Las 6 secciones

1 Instrucciones

El experimentador leerá las instrucciones en voz alta. Si necesitas alguna aclaración, éste es el momento para requerirla. Simplemente levanta tu mano y el experimentador responderá a tus preguntas en forma privada. Por favor, no te quedes con ninguna duda sobre el experimento. Es importante que lo entiendas con todo detalle. Formúlanos toda pregunta que te surja en cualquier momento y que no esté claramente desarrollada en este texto.

2 Mini-test

Es para asegurarnos de que entendiste correctamente las instrucciones.

3 Rondas de prueba

El experimento está organizado en una serie de "rondas". En cada ronda interactuarás –mediante el ordenador únicamente– con otros participantes y tomarás decisiones que afectarán el montante que obtendrás al final de la sesión.

Como calentamiento, primero jugarás 2 rondas de prueba. Estas rondas de prueba son idénticas a las rondas experimentales en todos los aspectos, excepto uno: el efecto sobre el dinero que obtendrás. Las rondas de prueba NO afectarán el montante que recibirás al final del experimento. Pero te permiten observar cómo funcionan las cosas y familiarizarte con las pantallas, tablas, botones y comandos del experimento. Las rondas de prueba también te permiten cometer algunos errores sin por ello perder dinero.

4 Las rondas experimentales

Ésta es la parte importante. Lo que hagas durante estas rondas determinará el montante total que obtendrás.

Las siguientes "Preguntas frecuentes" te instruirán sobre la mecánica básica de las rondas.

4.1. ¿De qué se trata todo ésto?

Comencemos por decir que el experimento consistirá en una serie de rondas. En cada una de ellas el ordenador te agrupará con otros 3 participantes, aunque tú nunca sabrás las identidades de dichas personas. Es decir, el experimento es anónimo: tú sabes que compartes grupo con otras 3 personas, pero no sabrás quiénes son dichas 3 personas ni ellas sabrán quién eres tú. El ordenador elegirá aleatoriamente a tus compañeros, todos los cuales son a priori igualmente probables de formar parte de tu grupo. Los otros 3 participantes serán asignados así: A partir de las 24 personas en el laboratorio, el ordenador formará 3 "megagrupos", cada uno compuesto de 8 personas elegidas aleatoriamente por el ordenador (es decir, cada una de las 24 personas en el laboratorio tiene la misma probabilidad de ser asignado a un megagrupo determinado). Tú seras asignado a algunos de los 3 megagrupos, y pertenecerás al mismo durante todo el experimento. En cada ronda, el ordenador repartirá aleatoriamente a los 8 integrantes de cada megagrupo en 2 grupos de 4 personas cada uno. Es decir, cada una de las otras 7 personas de tu megagrupo son a priori igualmente probables de formar parte de tu grupo de 4.

Nota: La composición de tu grupo en una ronda dada no tiene ningún impacto sobre la composición de tu grupo en el futuro: cada posible composición de tu grupo es igualmente probable en cada ronda.

Las rondas experimentales están divididas en 2 grupos: un primer grupo de 12 rondas en el que se aplicarán las reglas especificadas en estas instrucciones, y un segundo grupo de 12 rondas en el que se aplicarán otras reglas –aunque similares a éstas– que te serán indicadas al finalizar las primeras 12 rondas.

4.2. ¿Qué tengo que hacer?

En cada ronda tienes que decidir cómo utilizar tus recursos. Para ello todos recibiréis al comienzo de cada ronda recursos personales iguales a 100 "pesetas".

Hay dos posibles usos para los recursos: la actividad Y y la actividad Z. Puedes elegir la una o la otra haciendo click sobre el botón correspondiente en la pantalla "Tu decisión" (figura 1).

Nota importante: Si eliges la actividad Y, entonces todos tus recursos (las 100 pesetas) son direccionados a la actividad Y. Si eliges la actividad Z, entonces todos tus recursos (las 100 pesetas) son dedicados a la actividad Z.

[Figura 1: Pantalla "Tu decisión"]

4.3. ¿Cómo se determina el resultado que obtengo en cada ronda?

El resultado de la ronda depende de tu decisión respecto al uso de tus recursos (aplicarlos a la actividad Y o a la Z) y de las respectivas decisiones de las otras personas de tu grupo. Nota que al momento de tomar tu decisión NO SABRÁS las decisiones tomadas por las otras personas de tu grupo.

4.4. ¿Pero exactamente cómo se determina mi resultado de la ronda?

Tu resultado total (R) es la suma de dos componentes: (1) el componente "A", que (puede) ser diferente para diferentes personas en el grupo; y (2) el componente "B", que es el mismo para cada uno de los integrantes del grupo. Formalmente,

R = A + B

Tu componente A depende de tu decisión y de las decisiones de los otros integrantes de tu grupo:

1. si dedicas tus 100 pesetas a la actividad Z, entonces A = 100;

2. si dedicas tus 100 pesetas a la actividad Y, entonces

2.1. A = 90 si eres el primero de tu grupo en dedicarlas;

2.2. A = 70 si eres el segundo de tu grupo en dedicarlas;

2.3. A = 20 si eres el tercero de tu grupo en dedicarlas;

2.4. A = 0 si eres el cuarto de tu grupo en dedicarlas.

En caso de empate en el tiempo de dedicación por parte de 2 o más personas, el ordenador decidirá la posición de cada una de ellas, asignando a cada persona empatada la misma probabilidad de obtener cada una de las posiciones posibles.

El componente B depende de lo que haga tu grupo en su conjunto y se obtiene así:

B = 240 – 0,6×$SUMA$

donde SUMA es la suma de los componentes A de todos los individuos de tu grupo (incluido/a tú mismo/a).

Es decir que si en tu grupo tres personas asignan sus recursos a Y y la cuarta asigna sus recursos a Z, entonces SUMA = 90 + 70 +20 + 100 = 280. El componente B es, por lo tanto, B = 240 − 0,6×280 = 240 − −168 = 72$pesetas$.

Otra forma de visualizar el cómputo de tus resultados es mediante una tabla como la siguiente.

$K_{-i} := \sum_{j \neq i} k$

		300	200	100	0
	Z	100 + 72 = 172	100 + 30 = 130	100 + 0 = 100	100 + 0 = 100
	Y1^o	100 + 132 = 232	100 + 72 = 172	100 + 30 = 130	100 + 0 = 100
c_i	Y2^o	50 + 132 = 182	50 + 72 = 122	50 + 30 = 30	
	Y3^o	30 + 132 = 162	30 + 72 = 102		
	Y4^o	0 + 132 = 132			
	Average Y	45 + 132 = 177	60 + 72 = 132	75 + 30 = 105	100 + 0 = 100

Table 6: Payoff table. Dominant treatment

En cada celda se indica el resultado total (R) como la suma del componente A (el primer término) y del componente B (el segundo término). El resultado de cada celda depende de: (1) la acción que tú tomes y en qué posición lo hicieras en caso de elegir Y (indicada en las filas, donde la fila Yn corresponde al caso en el cual eres el n-ésimo integrante de tu grupo en hacer click en Y) y de (2) la suma de los recursos dedicados a la actividad Y por todos los otros individuos de tu grupo (indicado en las columnas).

Nota importante: En la tabla se presentan los recursos dedicados a la actividad Y por parte de todos los otros individuos de tu grupo, es decir, tus recursos no están incluidos. Las celdas con un guión "-" son casos imposibles: por ejemplo la celda correspondiente a la tercera fila, tercera columna es imposible porque según la columna sólo hay dos personas en el grupo que hicieron click en Y (sólo uno de los otros integrantes del grupo dedicó sus 100 pesetas a la actividad Y, y por ello la columna es "100" –el otro que dedicó sus 100 pesetas a Y eres tú) por lo que nunca podrías ser el tercero en hacer click en Y.

Para que tengas claro cómo se calculan los resultados, veamos un par de ejemplos:

1. Si los otros individuos de tu grupo dedican 200 pesetas a la actividad Y (segunda columna) y tú dedicas tus 100 pesetas también a la actividad Y y eres el primero en hacer click (primera fila), entonces A = 90 por ser el primero en hacer click en Y, y B = 72 porque la suma de los componentes A de los integrantes del grupo fue SUMA = 100 + 90 + 70 + 20= 280 (componentes A del que eligió Z, tuyo, y de los que eligieron Y en segundo y tercer lugar, respectivamente), y por tanto B = 240 − 0,6×280 = 240 − −168 = 72.$Turesultadofinalesporlotanto R = A+B = 90+72 = 162, exactamenteloqueseindicaenlacelda(primerafila, segu$

2. Si los otros individuos de tu grupo siguieran dedicando 200 pesetas a la actividad Y (segunda columna), pero ahora tú dedicas tus 100 pesetas a la actividad Z (última fila), entonces A = 100 porque dedicaste tus 100 pesetas a la actividad Z, y B = 24 porque la suma de los componentes A de los integrantes del grupo es SUMA = 2×100 + 90 + 70 = 360$(componentesAdelosqueeligieronZ--entreellost--ydelosqueeligieronYenprimerysegundolugar, respectivam$ $240 - -0,6 \times 360 = 240 - -216 = 24. Turesultadofinalesporlotanto R = A+B = 100+24 = 124, exactamenteloqueseindicaenlacelda(ltimafila, segundacolumna)$.

Nota importante: Tanto las fórmulas como la tabla proveen exactamente la misma información. No hay ninguna ventaja intrínseca en usar una u otra. Simplemente son dos formas de visualizar la misma información.

4.5.Entonces, ¿cuánto dinero obtengo?

Tus resultados son transformados en dinero a una tasa de:

100 “pesetas” = 10 euros

Es decir, si en una ronda obtienes, por ejemplo, 150 pesetas, tu ganancia en dicha ronda es de $150\times10/100 = 15 euros.Lapartevariabledetugananciatotalessimplementeeldineroobtenidoen ALGUNAdelasrondas$

[Figura 2: Pantalla “Calculador de escenarios”]

4.6. ¿Hay algo más que debería saber antes de decidir?

Si necesitas realizar algunos cálculos puedes realizarlos utilizando la pantalla “Calculador de escenarios”, donde puedes ver el efecto de las diferentes acciones tomadas por ti y por los otros integrantes de tu grupo. Esta pantalla te permite asignar posibles acciones a tus compañeros de grupo y elegir tu acción, y ver el resultado de las mismas. Nota que nada de lo que hagas en esta pantalla afecta tu pago. Es una especie de “papel borrador” que puedes utilizar para averiguar cómo cambian tus resultados cuando cambian tus decisiones y/o las de los otros integrantes de tu grupo. Esta pantalla está disponible al comienzo de cada ronda, por lo que puedes utilizarla a lo largo de todo el experimento.

Papel y lápiz/bolígrafo también están disponibles para aquellos que los prefieran: levanta tu mano y el experimentador te los acercará.

Nota importante: Es muy importante remarcar que no existe un botón “Atrás”, por lo que te rogamos que prestes atención a la hora de tomar tus decisiones y que sólo presiones el botón “Continuar a la siguiente pantalla” cuando estés seguro/a de querer pasar a la siguiente pantalla.

4.7. Pues bien, ya he tomado mi decision. ¿Ahora qué?

Después de tomar tu decision, verás la pantalla “Tu resultado”, donde se te indicará la decisión que tomaste, en qué posición hiciste click (en caso de hacer click en Y), el resultado de los componentes A y B, y tu resultado total (la suma de los dos anteriores). Haciendo click sobre el botón “Continuar a la siguiente pantalla” pasarás a la siguiente ronda (si quedara alguna por jugarse).

Figura 3: Pantalla “Tu resultado”

4.8. ¿Y luego?¿Es lo mismo en todas las rondas?

Básicamente, sí. En cada ronda, la estructura es idéntica a la descrita arriba: (1) el ordenador te asignará a un grupo con otros 3 participantes; (2) deberás tomar la decisión de asignar tus recursos entre las dos actividades; y (3) verás tus resultados en la pantalla “Tu resultado”.

Puedes ver tus resultados en rondas anteriores en el área oscura en la pantalla “Tu decisión” (figura 1). Dicha área incluye la información indicada en la pregunta 4.7 correspondiente a todas las rondas pasadas.

Nota importante: Al finalizar cada ronda hacemos “borrón y cuenta nueva”: las personas con las que compartes grupo pueden variar de ronda a ronda y te daremos otras 100 pesetas para que las asignes entre las dos actividades. Sin embargo las REGLAS que determinan quién va a cuál grupo y cómo se calculan los resultados no varían. En una palabra, las rondas son independientes unas de otras: el resultado de una ronda determinada no depende de los resultados de rondas pasadas o futuras. Asimismo, la constitución de un grupo en una ronda determinada no depende de los grupos formados en rondas anteriores o a formarse en rondas futuras.

5 Cuestionario

Te preguntaremos unas pocas preguntas que nos ayudarán a entender mejor los datos recolectados en el experimento. Por favor, contesta a todas ellas.

6 Pago

¡Por fin! Se te pagará privadamente un montante fijo de 1,50 € más la suma del dinero obtenido durante la sesión, como se explicó en la pregunta 4.5.

Y eso es todo. Una vez más, ¡muchas gracias por participar!

MINI TEST

1. ¿Cuántas pesetas obtienes si dedicas tus 100 pesetas a la actividad Y (eres el tercero en hacer click) y los otros individuos de tu grupo dedican (en conjunto) otras 300 pesetas a la actividad Y? ¿y si dedicaras tus 100 pesetas a la actividad Z? . . . .

2. Si dedicaste tus 100 pesetas a la actividad Y y observas que tu resultado de la ronda es 142, ¿cuántas pesetas dedicó el resto de tu grupo a la actividad Y? ¿y a la actividad Z? ¿En qué posición hiciste click? . . . .

3. Si en una ronda compartiste grupo con Abel, Beatriz y Carlos, ¿implica eso que en la siguiente ronda los tres volverán a compartir grupo contigo? ¿Que ninguno compartirá el grupo contigo? ¿Qué algunos lo compartirán y otros no? . . . .

TABLA DE RESULTADOS – PARTE 1 DE 2

Ronda	Resultado
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	