Why pay for nothing? An experiment on a conditional subsidy scheme in a threshold public good game

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Abstract

The voluntary provision of public goods can be boosted by subsidies paid to contributors. This paper compares the performance of two types of subsidy schemes in a threshold public game: an unconditional subsidy paid to each contributor proportionally to his contribution; and a conditional subsidy paid to each contributor only if the public good threshold is attained. Our experimental results show that subsidy schemes are not only effective but also efficient to improve the provision of threshold public goods. In addition, introducing a conditional payment improves the efficiency of the mechanism and in some cases improves its effectiveness, despite identical game-theoretic predictions. By drawing an analogy between agri-environmental contracts and subsidy schemes in threshold public goods, these results suggest that the performance of environmental contracts (such as agri-environmental schemes) could be improved in the case of threshold effects of pollution on the environment by introducing a collective conditionality on contract payments.

1 Introduction

This paper investigates the performance of two subsidy schemes designed to improve the production of threshold public goods by voluntary contributions. We carry out a laboratory experiment in order to compare an "unconditional subsidy" paid to public good contributors proportionally to their contribution (unconditional subsidy), with a conditional subsidy which is paid to contributors only if the threshold is reached. Our objective is twofold: (1) to check if a subsidy scheme can increase efficiency compared to a classical voluntary contribution game and (2) to assess whether a conditional subsidy scheme could save public money without jeopardizing public good production, compared to an unconditional subsidy scheme.

In a voluntary contribution game for a linear public good, the Nash equilibrium prediction is zero contribution by all, also known as the strong free riding equilibrium. When a threshold is introduced, i.e. if the public good is produced only when contributions reach a provision point, theoretical predictions change significantly. The provision point mechanism generates a multiplicity of non-cooperative equilibria and participants need to coordinate to select one (Ledyard, 1995). Results presented in Isaac et al. (1989) and confirmed in most experiments show that simply introducing a threshold can raise contributions compared to a standard voluntary contribution mechanism (Suleiman and Rapoport, 1992; Dawes and Orbell, 1986; Rondeau *et al.*, 2005). However, the threshold is not attained in all cases. To mitigate this problem, mechanisms such as money back guarantee[1] (Rapoport and Eshed-Levy, 1989; Cadsby and Maynes, 1999) and rebate rules[2] (Marks and Croson, 1998; Spencer *et al.*, 2009) are investigated in the literature.

The effect of subsidies on the production of public goods without threshold has been largely studied and is a frequent justification for public policy interventions, such as subsidies to individuals to adopt virtuous behavior. Andreoni and Bergstrom (1996) theoretically demonstrate that a tax system used to finance subsidies to contributors allows an increase of the equilibrium supply of a public good. In the Common agricultural policy, which is the first European policy in terms of budget spending, supporting the production of public goods by the agricultural sector is one of the main justifications for the implementation of subsidy schemes targeted at farmers. However, thresholds are often observed in the case of environmental public goods such as biodiversity (Metzger and Décamps, 1997) and water quality (Muradian, 2001) and subsidies may be spent in vain if the provision point is not reached. Given budgetary restrictions, there is a growing interest for subsidy schemes which are triggered only when the environmental benefit is obtained. Surprisingly, subsidy schemes offering a payment to contributors in a threshold public good game have been less investigated in the literature. Our experiment brings a novel contribution in this area of

[1] A money back guarantee is a system that guarantees the reimbursement of contributions to the public good if the threshold is not reached.

[2] Rebate rules are used to compensate subjects for their excess contributions when aggregate contributions are beyond the threshold

research by testing in a laboratory experiment the effectiveness and the efficiency of a conditional subsidy system in comparison to a standard unconditional subsidy scheme.

2 The experiment

2.1 Treatments

We compare three treatments of voluntary contribution to a threshold public good game: (i) a benchmark treatment with no subsidy, often referred to in the literature as the provision point mechanism (PPM), (ii) a treatment with an unconditional subsidy paid to all contributors proportionally to their contribution (US) and(iii) a treatment with a conditional subsidy scheme (CS) paid only if the threshold is reached.

At the beginning of each session, subjects are assigned to a fixed group of N subjects ($N = 4$). In each period, subject i is requested to allocate his endowment (E = 20 tokens) between a private account and a public account common to the N members of the group. The amount placed by subject i in the public account is noted C_i. At the end of each round, tokens placed in the private account have a private return α_i ($\alpha_i = 1 \; \forall \, i \, \in \{1 \ldots N\}$). If the total amount of tokens placed in the public account ($\sum_{i=1}^{N} C_i$) is above the threshold T for the provision of the public good, each subject of the group gets the benefits of the common account $\beta \sum_{i=1}^{N} C_i$ (with $1/N < \beta < 1$). In this experiment, we consider that the public good keeps increasing beyond the provision point which is similar to the public good production function in Isaac et al. (1989).

Therefore in the PPM treatment, subject i's payoff is G_i :

$$G_i(C_i, C_j) = \begin{cases} E - C_i & \text{if } \sum_{i=1}^{N} C_i < T \\ E - C_i + \beta \sum_{i=1}^{N} C_i & \text{if } \sum_{i=1}^{N} C_i \geq T \end{cases}$$

The US is similar to the PPM except that when subjects contribute C_i, they get an individual subsidy that is a proportion γ ($0 < \gamma < 1$ and $\beta + \gamma < 1$) of their individual contribution. In order to ensure that the benefits generated by 1 token placed in the public account are superior to the costs of the subsidy for the regulator if the public good is produced, γ is inferior to $N\beta$.

Therefore in the US treatment, subject i's payoff is:

$$G_i(C_i, C_j) = \begin{cases} E - (1-\gamma)C_i & \text{if } \sum_{i=1}^{N} C_i < T \\ E - (1-\gamma)C_i + \beta \sum_{i=1}^{N} C_i & \text{if } \sum_{i=1}^{N} C_i \geq T \end{cases}$$

Finally, in the CS treatment, the individual subsidy remains proportional to the contribution but is paid only if aggregate contributions reach the threshold:

$$G_i(C_i, C_j) = \begin{cases} E - C_i & \text{if } \sum_{i=1}^{N} C_i < T \\ E - (1-\gamma)C_i + \beta \sum_{i=1}^{4} C_i & \text{if } \sum_{i=1}^{N} C_i \geq T \end{cases}$$

Therefore, if the threshold is not reached the payoff of subject i is the same as in the PPM treatment and if it is reached the payoff of subject i is the same as in the UC treatment:

In the three treatments, the threshold T is set at an intermediate level of 40 tokens which represents 50% of the total endowment of the group since $N = 4$ and $E = 20$. The value of β is set at 0.3, a relatively low level. The subsidy rate γ is set at 0.3. This relatively modest subsidy level is chosen to ensure that allocating money to the public account is not too attractive. These subsidy schemes differ from other mechanisms tested in PPM experiments, although they present similarities. When the threshold is not reached, the US is equivalent to a partial money back guarantee, but in our US treatment, subject's contribution is partially reimbursed even if the threshold is not reached. The US and CS could also be considered as forms of rebate rules, however subjects receive a proportion of their whole contribution to the public good, not only a proportion of their excess contributions beyond the threshold, as in rebates.

2.2 Protocol

This experiment is run in a "between-within" setting in order to determine the effect of each treatment on total contribution and on the production of the public good. For policy relevance, we also investigate the impact of the introduction of a subsidy scheme after a classical provision point mechanism has been in place. The treatment sequences and the number of groups participating in each session are presented in Table 1.

	Sequence 1	Sequence 2	Number of subjects	Number of groups
Session A	PPM	US	40	10
Session B	PPM	CS	40	10
Session C	US	CS	28	7
Session D	CS	US	32	8

Table 1: Treatments tested in each session of the experiment

At the beginning of each session, subjects were randomly affected to a group of 4 subjects, which remained the same during the two sequences of the session. The voluntary contribution game was repeated for 10 periods within each sequence. The experiment was conducted in a complete information setting as defined by Bagnoli and Lipman (1989): the number of participants, the level of the provision point, the vector of endowments, and the vector of valuations for the public good (in our case a common β) are common knowledge. In addition, each subject got a feedback at the end of each period on the aggregate contribution of his group to the public account and on his individual payoff.

Subjects were invited through the recruitment software for experimental economics ORSEE (Greiner, 2004). Experiments were conducted in 2013 at the LEEM (Laboratoire d'Economie Expérimentale de Montpellier). 92% of the subjects were students from the University of Montpellier. 28% had already participated in an economic experiment but we made sure that none had participated in a public good experiment before. The experiment lasted a maximum of 2 hours and the average earning was 16.21 € with a standard deviation of 3.13€. Subjects were given an addition show-up fee of 2€ if they were students in the university site where the experiment was carried out and of 6€ otherwise.

3 Theoretical predictions and conjectures

In the PPM game when $\beta > 1/N$, there is a multiplicity of equilibria: a multiplicity of combination of contributions such as $\sum_{i=1}^{4} C_i = 20$; and a strong free-riding equilibrium in which $C_i = 0, \forall i$. The level of asymmetry between contributions in the group is however bounded with a maximum contribution of $C_i = 12$. For contributions which are only integer numbers, there are 165 equilibria[3] respecting this condition.

Theoretical predictions for the US and the CS treatments are the same as for the PPM treatment if the level of subsidy γ is inferior to $(1-\beta)$, i.e. a multiplicity of equilibria for which $\sum_{i=1}^{4} C_i = 20$ and a strong free riding equilibrium. However the number of equilibria at the threshold is much higher (3551) since the maximum contribution is 17 with the parameters chosen in this experiment.

The equilibria at the threshold level pareto-dominate the strong free riding equilibrium but cannot be Pareto-ranked. When the threshold is reached, we can consider that additional contributions are made in the framework of a classical voluntary contribution mechanism. There is therefore an incentive to "free ride" and to stick to the level of the threshold. The Pareto optimum in all treatments is that all players contribute their full endowment to the public good. Therefore there is still a social dilemma like in classical public good games.

Despite the fact that game theoretic predictions are similar for the three treatments, we make the following conjectures:

Conjecture 1*: Treatments with subsidy (US and CS) lead to a more frequent attainment of the threshold and to higher contributions than the PPM treatment.*

The step return[4] in the PPM treatment equals 1.2, while the step return in the subsidy treatments (US and CS) equals 1.5. Considering that the step return is a good predictor for successful provision in PPM experiments (Croson and Marks, 2000; Cadsby *et al.*, 2007), we expect that this will lead to more frequent successful provision of the public good and to higher contributions.

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[3] For contributions allowing only integer numbers

[4] Step return = $\frac{\text{agregate group payoff from the public good}}{\text{total contribution threshold}}$

***Conjecture 2**: With the conditional subsidy (CS), contributions are not lower and the public good is as frequently produced as with the unconditional subsidy (US)*

In the US treatment, we may expect that unconditional subsidies encourage contributions even under the risk that the threshold is not reached since subjects know that they will get at least the subsidy (partial money back guaranteed or insurance effect). In the CS treatment, the fact that the subsidy is conditional may have two opposed impacts. On the one hand, the conditionality increases the risk of contributing, leading most pessimist or risk averse subjects to limit their contribution. On the other hand, the conditionality increases the incentive to reach the threshold which may lead to higher contributions and to a higher frequency of success. Therefore, we expect a higher variability between groups in the CS treatment. However, we hypothesize that the use of the CS scheme will not reduce contributions significantly compared to the US scheme.

***Conjecture 3**: The subsidy schemes are more efficient than the PPM. Besides, the CS scheme displays greater efficiency than the US scheme.*

We measure efficiency as the sum of players' payoffs minus public spending on subsidies. We assume that expenditures associated with raising public money and distributing it are negligible. We conjecture that the cost of public subsidies is more than compensated by the increase of players' payoffs in the subsidy treatments. Besides, we expect CS to be more efficient than US since public spending occurs only when the public good is produced.

4 Results

4.1 Effectiveness of subsidy schemes

We measure the effectiveness of a mechanism by its capacity to induce the production of the threshold public good. Average group contributions within each session (averaged over the ten periods) and frequency of success of public good production are presented in Table 2. Both the Wilcoxon paired test on average contributions and the Khi2 test on the frequency of success confirm our conjecture 1 that the two subsidy treatments (US and CS) are more effective than the treatment without subsidy (PPM), when they are introduced after a situation without subsidy (session A and session B).[5] The level of effectiveness is not significantly different between CS and US when these treatments are applied to the same group successively (sessions C and D).

[5] Additional experiments are being carried out to confirm that this result is also valid when the subsidy treatments are in sequence 1 and the PPM treatment in sequence 2. The preliminary results seem to confirm our conclusion.

Session	Sequence	Treatment	Number of groups	Average group contribution	Wilcoxon paired test	Success	Khi2 test
A	1	PPM	10	26.0	**	33%	***
	2	US		41.1		69%	
B	1	PPM	10	29.6	***	42%	***
	2	CS		53.7		86%	
C	1	US	7	42.0	NS	63%	NS
	2	CS		47.2		75%	
D	1	CS	8	38.0	NS	59%	NS
	2	US		44.0		67%	

Table 2: Summary of sessions and within-group comparison of treatments using Khi2 and Wilcoxon paired test (***: significant at 1%, NS: not significant)

To provide firmer results, we use a between-analysis by comparing the 1st sequence of each session. A significant Khi2 test shows that the threshold is reached with a greater frequency in the two subsidy treatments than in the PPM treatment. There is no significant difference between CS and US neither on group contribution nor on frequency of successful production of the threshold public good (Table 3 and 4). Thus, conjecture 2 is supported by our data.

Treatment	**Number of groups**	**Frequency of success**	**Frequency of failure**	**Pairwise Khi2 test**	
				PPM	**US**
PPM	20	38%	62%		
US	7	63%	37%	***	
CS	8	59%	41%	***	NS

Table 3: Frequency of success and failure of production of the public good of the different treatments tested (***significant at α=1%, NS: not significant)

Treatment	**Number of groups**	**Average group contribution**	**Mann Whitney U test**	
			PPM	**US**
PPM	20	27.8		
US	7	41.8	NS	
CS	8	38.0	NS	NS

Table 4: Comparison of average group contributions between treatments using the Wilcoxon Mann-Whitney test. (NS: not significant)

Since we have checked that the levels of group contributions and the frequency of success in attaining the threshold is not significantly different in the PPM sequences of sessions A and B, we pool the data of these two sessions and run a panel regression with random effects to compare the level of group contributions when subsidies are introduced in sequence 2 (Table 5).

Group contribution	Coef. (Std. Err.)
Intercept	60.7*** (3.9)
PPM (ref CS)	-24.3*** (2.1)
US (ref CS)	-9.3*** (2.9)
Period (1 to 10)	-1.6*** (0.3)

Nb. of obs. 400, Nb. of groups 20, *** p<0.001

Table 5: Panel regression with random effects on group contribution with data of sessions A and B

This panel regression shows the classical decrease of group contributions over the periods observed in public good experiments and more importantly the positive effect of the conditional subsidy as compared to the unconditional subsidy on group contributions. It therefore seems that the conditional subsidy presents a better effectiveness than the standard subsidy system when introduced after a situation without subsidy. This result confirms the potential interest of this subsidy scheme in public policies.

However, these average results hide heterogeneous patterns of behavior. Figure 1 shows group contributions in sequences 1 of all sessions. We observe different types of group behavior heterogeneity according to treatments. In the PPM, there are quite unstable contributions from one period to the other. In treatments with subsidy (US and CS), there is less time instability but we observe greater inter-group heterogeneity: two types of groups clearly emerge: groups that manage to coordinate over the threshold and groups that do not. In particular, the patterns for the CS scheme show that if a group manages to coordinate in the first period and to reach the provision point, then it manages to stay above the threshold for most of the sequence ((except for end-game effects). However if the group fails to reach the threshold in the first period, its contribution rapidly converges to zero which is the strong free-riding equilibrium. Therefore the CS scheme can display effectiveness provided the success of the first periods.

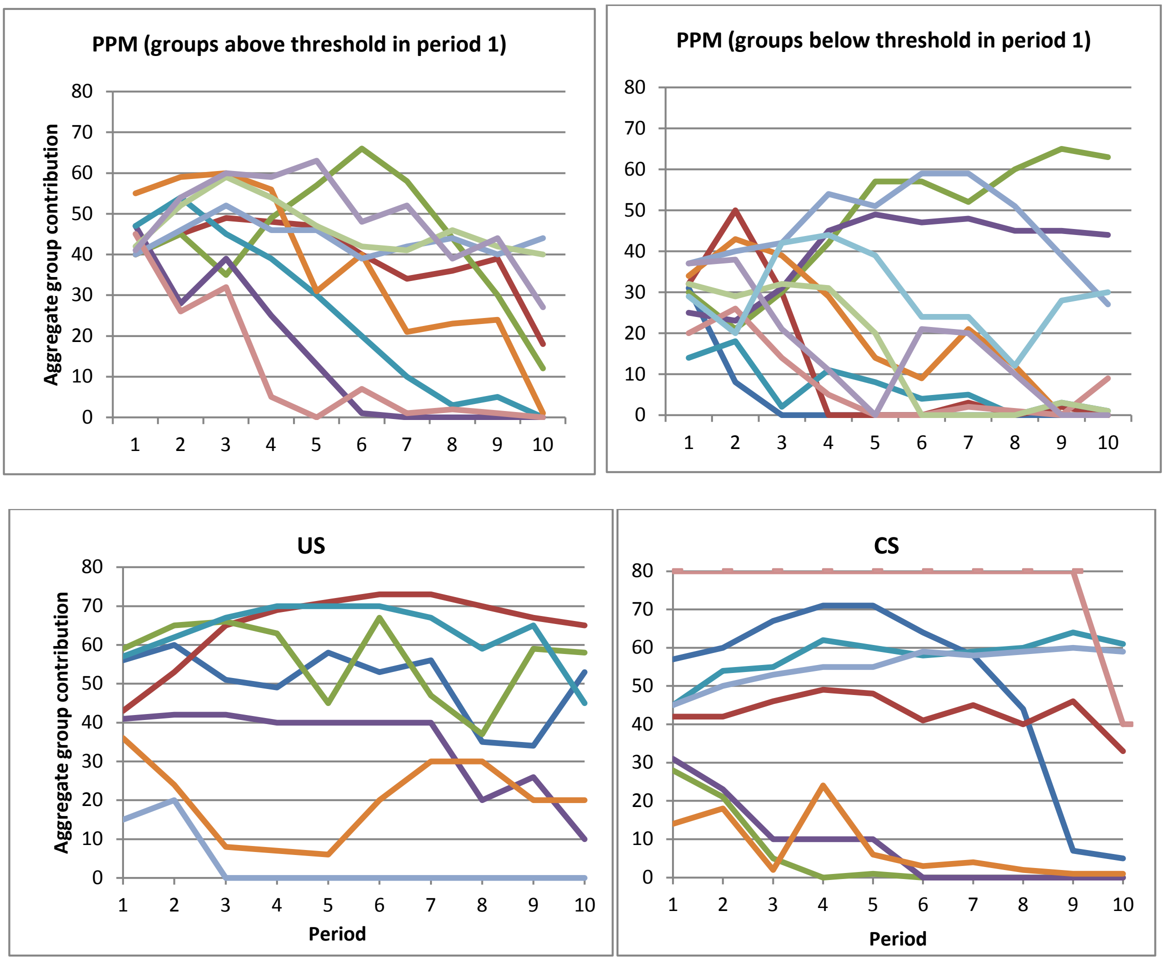

Figure 1: Group contributions in sequence 1 for the three treatments (1 group = 1 data serie). For the PPM treatment, two graphs are represented: 1 for groups that contributed more than 40 tokens in the first period and one for groups that contributed less than 40 tokens in the first period.

4.2 Efficiency of subsidy mechanisms

We compare the efficiency reached under the three treatments using a between analysis (comparison of sequence 1 of all sessions) provided in Table 6. Net social gains are a proxy for efficiency and are measured as the sum of players' payoff minus public spending on subsidies.

			Mann Whitney test	
Treatment	**Number of groups**	**Net social gains**	**PPM**	**US**
PPM	20	74.3		
US	7	81.5	**	
CS	8	83.7	**	NS

Table 6: Comparison of net social gains between treatments using the Wilcoxon Mann-Whitney test. (**significant at α=5%, NS: not significant).

Both subsidy schemes generate net social gain improvements as compared to the classical PPM, which is a significant result in the debate on the usefulness of subsidy schemes. However, we observe no significant difference between the US and the CS scheme.

To investigate further the comparison between the two subsidy treatments and to support conjecture 3, we use a cost efficiency indicator: the average public good produced by groups by period, divided by the average subsidy received. For the CS, this rate amounts mathematically to 4 while this rate can deviate from 4 in the US if subsidies are disbursed without production of public good. Results presented in Table 7 show the greater efficiency of the CS as compared to the US.

Treatment	**Average group public good produced**	**Average group subsidy**	**Efficiency (units of PG/Subsidy)**
US	43.4	12.6	3.5
CS	41.7	10.4	4.0

Table 7: Comparison of subsidy efficiency between US and CS using data of sequence 1 of all sessions.

5 Conclusion

The objective of this paper is to evaluate the potential gains that could be obtained by using a conditional subsidy system to increase the production of a threshold public good. In a laboratory experiment conducted with 140 students, we have compared the effectiveness and efficiency of a standard provision point mechanism and two subsidy schemes: an unconditional subsidy scheme and a conditional subsidy paid if the public good threshold is reached. Results show that both subsidy mechanisms are more effective and more efficient than a PPM without any subsidy. More interestingly, the conditional subsidy performs as well as the unconditional subsidy and even better when subsidy schemes are introduced after a treatment without subsidy. In addition, the efficiency of the conditional subsidy is slightly superior, mainly due to the fact that subsidies are not spent when the public good is not produced, which is politically attractive especially when budget constraints are tight. The results of the conditional subsidy are however quite variable and depend very much on group behavior, especially in the first period of the game. Therefore the use of this type of subsidy requires particular attention in the early phases of implementation. And of course, it is important to understand why some groups manage to cooperate above the threshold, while others fail despite the incentive of a subsidy scheme. Further developments of this research are to analyze individual decisions to understand how individual preferences underpin the performance of the conditional subsidy system. Individual risk aversion and expectations about others' behavior along with other preferences, such as reciprocity, may explain the behavior heterogeneity observed in this experiment.

Agri-environmental payments are widely used in order to encourage farmers to contribute to environmental public goods. Our results provide a strong justification for the use of conditional payments when these public goods present thresholds, such as a minimum area of suitable habitat for the survival of a species or water quality threshold for drinkable water… These conditional payment schemes, that could be for example payments triggered only when a minimum number of ha or of farmers is enrolled, could both prevent worthless public expenditures and improve environmental impact as compared to traditional agri-environmental schemes. Field testing will of course be required to confirm these experimental results.

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