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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 enhanced by subsidies paid to contributors. However, in the case of threshold public goods, subsidies can be wasted if the public good is not ultimately produced. We therefore test the performance of a conditional subsidy paid to each contributor only if the public good threshold is attained by the group, in comparison to the classic subsidy paid to contributors even if the public good is not produced. This system offers the obvious advantage of sparing public money when the public good is not produced but there is the risk that such incentive discourages contributions. Our experimental results show that subsidy schemes improve the provision of threshold public goods and are welfare-improving compared to a no-subsidy situation. Furthermore, the collective conditionality improves the efficiency of the subsidy mechanism and in some cases improves its effectiveness, despite identical game-theoretic predictions. Applying this conclusion to environmental issues, these results suggest that, in the case of threshold pollution, subsidy schemes encouraging polluters to abate could be improved by introducing a collective conditionality.

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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, with a "conditional subsidy" which is paid to contributors only if the threshold is reached by the group. 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, and Rondeau, Poe, and Schulze 2005). However, the threshold is not attained in all cases. Failure to reach the threshold leads to net losses in terms of wasted contributions. To mitigate this problem, mechanisms such as money back guarantee[1] (Rapoport and Eshed-Levy 1989, and Cadsby and Maynes 1999) and rebate rules[2] (Marks and Croson 1998, and 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. Andreoni and Bergstrom (1996) demonstrate in a theoretical paper that a tax system used to finance subsidies to contributors allows an increase of the equilibrium supply of a public good. Subsidy schemes designed to encourage the production of public goods are often mobilized by public policies. For example the Common agricultural policy justifies part of its interventions (Agri-environmental schemes) by the need to subsidize farmers who contribute to the production of environmental services. 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. They offer the obvious advantage of sparing public money when the public good is not produced but there is the risk that such incentive mechanism might be counterproductive by discouraging contributions. Surprisingly, there are few results on this issue in the literature. Our experiment brings a

[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

novel contribution in this area of 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.

The structure of this article is as follows: section 2 describes the treatments and the protocol of the experiment; section 3 gives the theoretical predictions and conjectures; section 4 presents the results of the two subsidy schemes especially in terms of effectiveness and efficiency; and section 5 concludes.

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) whatever the outcome in terms of public good production and (iii) a treatment with a conditional subsidy scheme (CS) paid only if the threshold is reached by the group.

At the beginning of each session, subjects are assigned to a fixed group of N subjects (N = 4). At the beginning of each round, they receive an endowment E. For each round, subject i is requested to allocate this 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 yield 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, the maximum value of γ is $N\beta$.

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:

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

Therefore, if the threshold is not reached, subject i's payoff is the same as in the PPM treatment and if the threshold is reached, subject i's payoff is the same as in the US 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. 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 system, but in our US treatment, subject's contribution is partially reimbursed even if the threshold is 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 whereas in classical rebate rules, contributors get only a proportion of their excess contributions beyond the threshold.

2.2 Protocol

This experiment is run in a "between-within" setting in order to compare the performance of the various treatments when they are applied successively to the same subjects or when they are applied to different subjects. The treatment sequences and the number of groups participating in each session are presented in Table I.

Table I: Treatments tested in each session of the experiment

	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	PPM	40	10
Session D	CS	PPM	40	10
Session E	US	CS	28	7
Session F	CS	US	32	8
Total			**220**	**55**

At the beginning of each session, subjects were randomly assigned 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 N, the level of the provision point T, 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 and 2014 at the LEEM (Laboratoire d'Economie Expérimentale de Montpellier). 92% of the subjects were students from the University of Montpellier. 42% 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 15.9 € with a standard deviation of 3.0 €. Subjects were given an additional show-up fee of 2€ if they were students from 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 $\sum_{i=1}^{4} C_i = 40$; and a strong free-riding equilibrium in which $C_i = 0, \forall i$. For the threshold equilibria, the level of asymmetry among 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 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 $\sum_{i=1}^{4} C_i = 40$ and a strong free riding equilibrium. However the number of equilibria at the threshold is much higher (3551) since the maximum individual contribution rises to 17 tokens, 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[3] 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, and Cadsby et al. 2007), we expect that this will lead to more frequent successful provision of the public good and to higher contributions.

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.

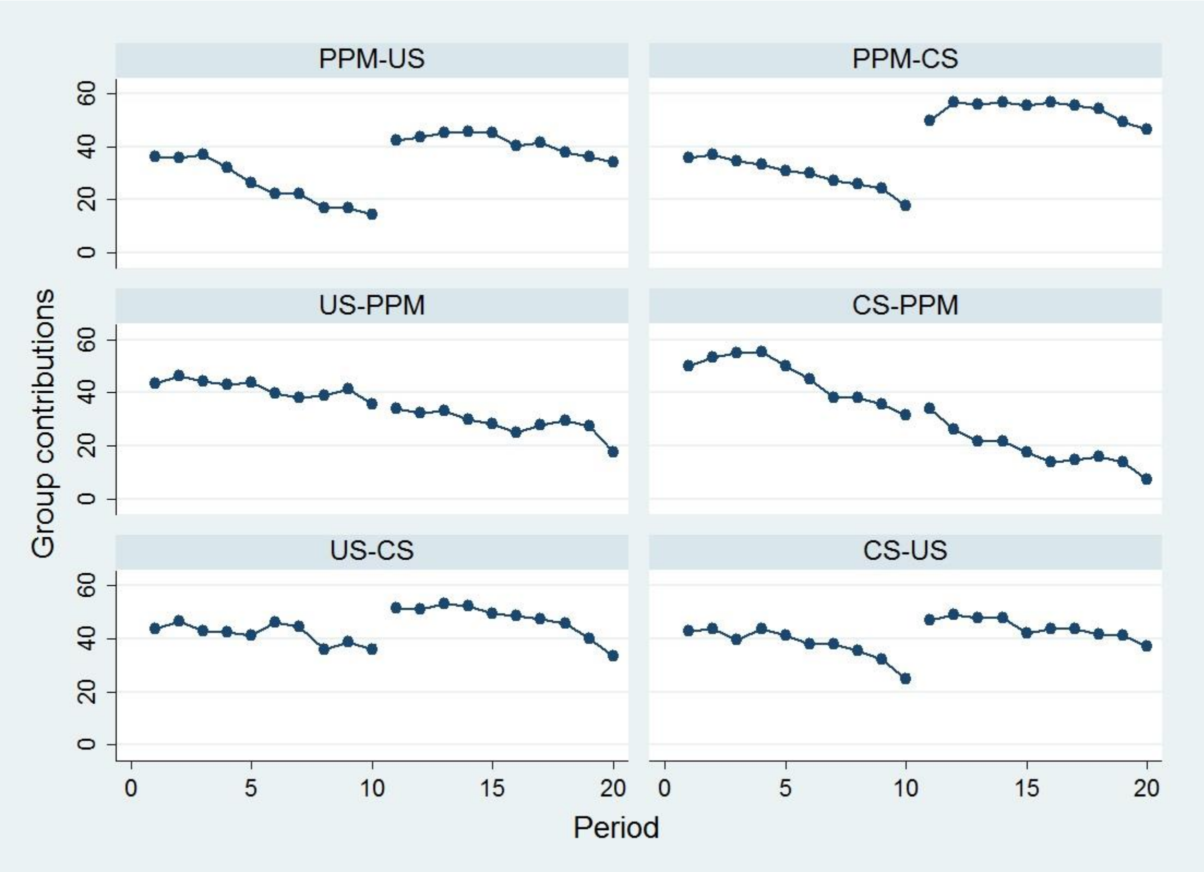
[3] Step return = $\frac{\text{agregate group payoff from the public good}}{\text{total contribution threshold}}$

4 Results

4.1 Effectiveness of subsidy schemes

We first analyze the effectiveness of the various treatments by examining graphically group contributions in the 6 sessions of the experiment (figure 1). As expected, group contributions seem to be higher with subsidy treatments than with the PPM and the level of contribution seem to be quite similar with the two subsidy treatments. We can also observe a decay of contributions over the periods of the experiment, throughout treatments, as generally reported in public good experiments. Finally, subsidy treatments seem to be particularly effective when they are applied in the second sequence of the experiment.

Figure 1: Average group contribution by period in the 6 sessions of the experiment



We subsequently analyze statistically these results. Average group contributions within each session (averaged over the ten periods) and frequency of success of public good production are presented in Table II. Both the Wilcoxon paired test on average contributions and the chi2 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), either when the PPM treatment is applied before or after the subsidy treatments. However, the level of effectiveness is not significantly different between CS and US when these treatments are applied to the same group successively (sessions E and F).

Table II: Summary of sessions and within-group comparison of treatments using chi2 and Wilcoxon paired test (***: significant at 1%, **: significant at 5%, NS: not significant).

Session	Sequence	Treatment	Number of groups	Average group contribution	Wilcoxon paired test	Success	chi2 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	10	41.5	***	62%	**
	2	PPM		28.4		45%	
D	1	CS	10	45.2	***	71%	***
	2	PPM		18.7		28%	
E	1	US	7	42.0	NS	63%	NS
	2	CS		47.2		75%	
F	1	CS	8	38.0	NS	59%	NS
	2	US		44.0		67%	

To provide firmer results, we use a between-analysis by comparing the 1st sequence of each session. The results confirm that group contributions are higher and that the public good is more frequently produced when subsidy schemes are implemented (Table III and IV). There is no significant difference between CS and US neither on group contribution nor on frequency of successful production of the threshold public good. Thus, conjecture 2 is supported by our data.

Table III: Frequency of success of production of the public good in the first sequence of all sessions (***significant at 1%, NS: not significant)

Treatment	**Number of groups**	**Frequency of success**	**Pairwise chi2 test**	
			PPM	**US**
PPM	20	38%		
US	17	62%	***	
CS	18	66%	***	NS

Table IV: Comparison of average group contributions in the first sequence of all sessions using the Wilcoxon Mann-Whitney test. (**significant at 5%, NS: not significant)

Treatment	**Number of groups**	**Average group contribution**	**Mann Whitney U test**	
			PPM	**US**
PPM	20	27.8		
US	17	41.6	**	
CS	18	42.0	**	NS

This result is also confirmed when group contributions are analyzed using a panel regression with random effects[4] (Table V). In addition, the analysis highlights the decrease of contributions over the 10 periods of the first sequence, traditionally observed in repeated public good experiments.

Table V: Panel regression with random effects on group contributions in the first sequence of all sessions (***significant at 1%).

Group contribution	Coef.	(Std. Err.)
Intercept	52.3***	(4.6)
PPM (ref CS)	-14.2***	(6.2)
US (ref CS)	-0.4	(6.5)
Period (1 to 10)	-1.9***	(0.2)
Nb. of observations	550	
Nb. Of groups	55	
Wald chi2	142.39	
Prob chi2	0.00	

In order to investigate further treatment comparison, we analyzed the data of all sessions pooled together. Treatment comparison is possible as treatments are represented in a balanced way in sequences 1 and 2[5].

We carried out a panel regression on all data. We included an additional dummy variable in order to control the potential effect of the sequence on contributions (Table VI).

[4] Random effect regression is used because we want to estimate the effect of time invariant variables such as treatments (PPM and US).
[5] For PPM: 20 groups in sequence 1 and 20 groups in sequence 2; For US: 17 groups in sequence 1 and 18 groups in sequence 2; For CS: 18 groups in sequence 1 and 17 groups in sequence 2.

Table VI: Panel regression with random effects on group contributions with all data pooled (***significant at 1%,**significant at 5%).

Group contribution	Coef.	(Std. Err.)
Intercept	54.7***	(2.7)
PPM (ref CS)	-21.7***	(1.1)
US (ref CS)	-4.1***	(1.2)
Period (1 to 10)	-1.6***	(0.1)
Sequence 2 (ref 1)	1.6**	(0.8)
Nb. of observations	1100	
Nb. Of groups	55	
Wald chi2	593.34	
Prob chi2	0.00	

Contributions are significantly higher in sequence 2 than in sequence 1, as we had observed in figure 1. After having played 10 periods together (with generally a decay of contributions), many subjects take the opportunity of the beginning of a new sequence to try to coordinate above the threshold and have more success than in the first sequence.

Furthermore, this panel regression interestingly reveals a positive effect of the conditional subsidy as compared to the unconditional subsidy scheme on group contributions. It therefore seems that the conditional subsidy leads to significantly higher group contributions (+ 4.1 tokens on average) than the unconditional subsidy system when all data are pooled together. This difference of result, as compared to the previous analysis with only data of the first sequences, probably comes from the increase of observations, that allows us to discriminate smaller differences. This result strongly confirms the potential interest of this subsidy scheme for public policies.

However, these average results hide heterogeneous patterns of behavior. Three types of group emerge, groups that contribute above the threshold for most of the sequence, except at the very end, groups that never reach the threshold and quickly converge to the equilibrium with no contribution and finally groups that start with a contribution above the threshold that rapidly decline. Understanding this heterogeneity will require further investigations on individual behavior.

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 VII. Net "social gains" are a proxy for efficiency and are measured as the sum of players' payoff minus public spending on subsidies.

Table VII: Comparison of net social gains in the first sequence of all sessions using the Mann-Whitney test. (**significant at 5%, NS: not significant).

			Mann Whitney test	
Treatment	**Number of groups**	**Net social gains**	**PPM**	**US**
PPM	20	74.3		
US	17	80.4	**	
CS	18	82.6	**	NS

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, although we could expect a net advantage of the CS scheme over the US scheme, since the subsidy is paid only when the public good is produced, experimental results are less clear-cut. The net social gains generated by CS are not significantly different from those generated by the US treatment. This might be due to the heterogeneity of group contributions. However, when we pool all data together and carry out a panel regression analysis, we can emphasize that net social gains are superior with the CS scheme than with the US scheme (Table VIII). This confirms our third hypothesis of greater efficiency of the conditional subsidy system as compared to the two other systems. As observed in the previous section, net social gains are also superior in sequence 2.

Table VIII: Panel regression with random effects on net social gains with all data pooled together (***significant at 1%,*significant at 10%).

Net social gains	Coef.	(Std. Err.)
Intercept	83.2***	(1.4)
PPM (ref CS)	-8.0***	(1.0)
US (ref CS)	-2.0*	(1.1)
Period (1 to 10)	-0.1	(0.1)
Sequence 2 (ref 1)	4.3***	(0.8)
Nb. of observations	1100	
Nb. Of groups	55	
Wald chi2	99.11	
Prob chi2	0.00	

5 Conclusion

The objective of this paper is to evaluate the performance of a conditional subsidy system to increase the production of a threshold public good. In a laboratory experiment conducted with 220 students, we have compared the effectiveness and efficiency of a standard provision point mechanism (PPM) and two subsidy schemes: an unconditional subsidy and a conditional subsidy paid only if the public good threshold is reached by the group. Results show that both subsidy mechanisms are more effective and more efficient than the standard PPM. More interestingly, the conditional subsidy performs as well as the unconditional subsidy and even better when the whole data is considered (sequence 1 and 2 of the experiment). In addition, the efficiency of the conditional subsidy is 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. Applying this conclusion to environmental issues, these results suggest that, in the case of threshold pollution, subsidy schemes encouraging polluters to abate could be improved by introducing a collective conditionality. This result could have direct applications for the design of agri-environmental schemes.

The results of the conditional subsidy system are however quite variable across groups and depend very much on group behavior. Therefore the use of this type of subsidy requires particular attention. Further investigations are especially necessary 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 the behavior of other members of the group, along with other characteristics of preferences, such as reciprocity, may explain the behavior heterogeneity observed in this experiment.

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