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Interior Collective Optimum in a Voluntary Contribution to a Public-Goods Game: an Experimental Approach[1]

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Abstract

We run a public good experiment with four different treatments. The payoff function is chosen such that the Nash equilibrium (*NE*) and the collective optimum (*CO*) are both in the interior of the strategy space. We try to test the effect of varying the level of the collective optimum, which changes the "*social dilemma*", involved in the decision as to how much to contribute to the public good . Our results show that contributions increase with the level of the *interior CO.* There is overcontribution in comparison to the *NE* and under contribution in comparison to the *CO.* But contributions are as far from the *CO* as the level of this former gets high. An overcontribution index that takes into account the effective contribution relative to both, the *NE* and the *CO,* shows that subjects adopt a constant behavior while passing from one treatment to another: they contribute a constant share of the *CO.*

Résumé

Nous présentons une expérience de contribution à un bien public. La fonction de paiement est choisie telle que l'équilibre de Nash et l'optimum collectif sont intérieurs. Nous testons l'effet de la variation du niveau de l'optimum collectif sur les contributions des agents au bien public. Nous présontons ainsi quatre traitements différents, où chaque traitement est défini par un niveau de l'optimum collectif. Nos résultats montrent que cette contribution augmente avec le niveau de l'optimum collectif intérieur. Il y a une surcontribution par rapport à l'équilibre de Nash et une sous-contribution par rapport à l'optimum. Mais ces contributions sont d'autant plus loins de l'optimum que le niveau de ce dernier augmente. Le Calcul d'un indice de surcontribution qui prend en compte la contribution effective relativement à l'équilibre de Nash et à l'optimum collectif, montre que les sujets adoptent un comportement invariant lors du passage d'un traitement à un autre: ils contribuent une part constante de l'optimum collectif.

Key-words: *Public Goods, Experiments, Interior Solutions, Social Dilemma.*

Mots clés: *Biens Publics, Economie Expérimentale, Solutions Intérieures, Dilemme Social.*

JEL Classification : *C72, C92, H41*

1 Introduction

The problem of how much people contribute to the provision of a public good is a very old one in economics. For the public good to be provided at a socially optimal level cooperation and coordination is necessary. For, those who contribute realize that they have an incentive to deviate, to "free-ride." However, if all the participants reason in this way, the result will be a Nash equilibrium generally well below the socially optimal level of contribution. The tension between the noncooperative and cooperative solutions is often referred to as the "*social dilemma*[2]."

Experimental economics would seem to be the obvious way to examine the behavior of individuals in such situations and many experiments have indeed been run. The general conclusion is that people systematically contribute less than the social optimum but more than the Nash equilibrium. Furthermore, contributions diminish as the situation is repeated. Nevertheless, there is typically persistent overcontribution.

In the basic game of private contribution to a public good, each subject has to split an initial endowment into two parts: the first part represents his private share and the other part represents his contribution to the public good. The payoff of each share depends on and vary with the experimental design, but is generally linear (Andreoni (1995)). This linear case gives rise to a corner solution. In fact, assuming that it is common knowledge that players are rational payoff maximizers, such a function gives a Nash equilibrium (*NE*) at zero and full contribution as social optimum. As it has been mentioned, experimental studies show that there is generally overcontribution (30 to 70% of the initial endowments) in comparison to the *NE*.

Two natural questions arise. Why do people behave differently than the theory might predict? How do the various parameters of the particular situation with which individuals are faced influence the outcome? The answers to these two questions are not unrelated and responses to the second can eliminate possible explanations for the first. This will be the case here.

Indeed, the purpose of this paper is to provide some answers to the second question and, in particular to focus on the effect that varying a particular parameter, the level of the social optimum has on contributions. This parameter has not been singled out for examination in previous work on this subject. A series of experiments were run to examine the effect of variations in the social optimum and some clear results emerged.

Such an approach is in the line of the major literature that has sprung up and which tries to suggest explanations for overcontribution and to test these by varying different parameters.

This literature tries to answer why do we have a difference between the theoretical and the experimental results. To do so, different parameters were experimentally tested in different contexts to see the effect of their variation on individual contributions (for a survey, see Davis and Holt (1993), Ledyard (1995) and Keser (2002)). Among the explanations given to overcontribution, there is altruism (Anderson et al. (1998)), equity (Chan et al. (1997)), reciprocity, kindness and confusion (Andreoni (1995) and Palfrey and Prisbey (1997)), etc...

Another possible explanation is that people simply make errors. however, the basic set-up of most experiments makes this difficult to test. Most experiments have been run in a linear context and in the linear case, given that the *NE* is at zero, and seeing that subjects could not contribute negative amounts

[2]A general definition is given in U. Schulz et al. (1994, Preface) who define the "*social dilemma*" as a situation where there are "...two relevant types of strategies: a cooperative strategy, which gives reasonable payoffs to all players, and an individualistic or defective strategy, which gives defectors a somewhat higher payoff, but essentially lower payoffs to the others, in a way that the total sum of payoffs of the group is reduced."

to the public good, error can only be an overcontribution. To test the error hypothesis experimentally, Keser (1996) made a new experiment. She proposed a new design in which the payoff function is quadratic and the equilibrium is a dominant strategy in the *interior* of the strategy space. With such a design, undercontribution becomes possible and error on average could be expected to be null. The results of Keser's experiment show that in each period, contributions are above the dominant solution. The robustness of overcontribution to the variation of the equilibrium level means the rejection of the error's hypothesis as an explanation of the difference between the experimental and the theoretical results.

Willinger and Ziegelmeyer (2001) run the same experiment than Keser (1996) with the equilibrium level of contribution as a treatment variable. They use the same quadratic payoff function and vary the marginal payoff of the public good such that the dominant strategy takes different interior levels. The experimental results show that subjects' contributions increase with the equilibrium level and that "moving the equilibrium level of contribution closer to the Pareto optimum, leads to a decrease in average overcontribution" except for the very high level of equilibrium[3]. These results confirm the stylized fact of overcontribution in comparison to the theoretical equilibria, but reject some behavioral rules, such as altruism, kindness or reciprocity.

By increasing the marginal payoff of the public good, Willinger and Ziegelmeyer (2001) increase the equilibrium contribution level while the Collective Optimum *(CO)* is constant at the highest level and reduce in this way the "strength" of the "*social dilemma*[4]". But one thing thus remains to be investigated is the effect of varying the *CO* level on contributions, which is the subject of this paper. Answering such a question is interesting for two reasons. The first one is to see whether the social optimum level is a parameter that affects contribution decisions. Second, if the influence of this parameter is confirmed by the experimental data, one has to seek an explanation to how the level of the collective optimum intervenes in the decision process and one has to see whether the variation of the "*social dilemma*" affects contributions in the same way as in Willinger and Ziegelmeyer (2001). Our paper try to answer these questions.

Isaac and Walker (1998), by varying the Nash equilibrium level, also altered the "*social dilemma*," but they do not specify whether the *CO* vary or not in their design. We will proceed differently and focus experimentally on this specific way of modifying the "*social dilemma*". We use a design that gives an interior but almost unchanged level of the Nash equilibrium and an interior *CO*. While the *CO* in Willinger and Ziegelmeyer (2001) does not vary with the equilibrium level, we will take this optimum level as a treatment variable. We will compare four treatments representing a low (L), medium (M), high (H) and very high (VH) level for the *C.O.* The first three levels are in the interior of the strategy space which results directly from our choice of a non-linear payoff function in the public good. The *VH* case, as in Willinger and Ziegelmeyer's design gives a corner *CO*.

As in Willinger and Ziegelmeyer (2001), the passage from one treatment to another involves an increase in the marginal payoff of the public good. But while this reduces the "*social dilemma*" in Willinger and Ziegelmeyer (2001) (that is, the *NE* becomes closer to the *CO*), it has an opposite effect in our design where increasing the marginal payoff leads to an increase of the "*social dilemma*" (the *NE* becomes further from the *CO*). A comparison between our results and Whillinger's ones would be interesting to understand better the effect of the strength of the "*social dilemma*" on contributions.

Our results show that contributions vary with the *CO* level. There is overcontribution in comparison to the *NE*. This overcontribution increases with the *CO* level in absolute value. Nevertheless, average

[3]Using a payoff function that is quadratic in the public good, Isaac and Walker (1998) found significant over-contribution for low, but not for high levels of equililibrium.

[4]The "*social dilemma*", as explained in Willinger and Ziegelmeyer (2001), refers to the difference between the equilibrium contribution level and the social optimum.

contributions remain proportionately as far from the *CO* as the level of the latter gets high. Computing these contributions in relative values by calculating an overcontribution index that takes into account the *NE* and the *CO*, shows that, except in the *VH* treatment, this ratio is constant.

The paper is organized as follows: after presenting in Section two the literature dealing with interior solutions and the theoretical design of our experiment, we introduce the practical procedures of the experiment in Section three. Section four analyses the experimental results and Section five concludes the paper.

2 Theoretical Design

2.1 Interior Solutions in the Literature

An "*interior solution*[5]" to the public goods contribution problem is one in which the players do not contribute all or nothing at the *CO* nor at the *NE*. In other words, they have to contribute a certain amount that is different from zero and less that their initial endowment when they play the *NE* or the *CO* value. This "*interior solution*" can be obtained by defining a non-linear payoff function in the private and/or in the public good. We can either choose a concave function for the private payoff, which gives us a unique dominant strategy equilibrium, or use a concave function for the public payoff. In this case, all the individual Nash equilibria correspond to a unique amount of aggregate contribution and differ in the way this amount is split among the individuals, seeing that the strategy of a given player i depends on the contributions of the other players.

Sefton and Steinberg (1996) compare experimentally these two reward structures with interior solutions and find that "average donations significantly exceed the predicted equilibrium under both treatments, falling roughly midway between the theoretical equilibrium and optimum... Donations are less variable under the dominant strategy equilibrium treatment than under the Nash equilibrium treatment", even if this difference is not significant. A reward structure where both, the private and the public payoff are quadratic could be found in Andreoni (1993).

As in Keser (1996), Van Dijk et al. (1997) test the interior dominant strategy using a quadratic payoff for the private good. The results, similar to those of Keser (1996), confirm the robustness of overcontribution to the variation of the equilibrium level. Willinger and Ziegelmeyer (1999) take the same quadratic function as Keser (1996) with "*interior solution*" and present it into two different contexts to study the difference between contributions in the cases of positive and negative externalities. They show that "subjects contribute more to the public good if they perceive the actions of others as a positive externality rather than a negative externality". A similar experiment was done already by Andreoni (1995), but in the context of a game with "*strangers*" and with a corner solution. Willinger and Ziegelmeyer (1999) replace "*strangers*" by "*partners*" and corner solution by an interior dominant strategy.

In another context, Willinger and Ziegelmeyer (2001) keep the same function used in Keser (1996) and by varying the marginal payoff, they vary the equilibrium of the game. The same idea is experimentally tested by Isaac and Walker (1998). While the latter conclude that there is overcontribution for low levels of the equilibrium and undercontribution for high levels, overcontribution is obtained for all treatments in Willinger and Ziegelmeyer (2001). Isaac and Walker (1998) use several quadratic functions for the public good and a linear function for the private one. They do not specify whether the *CO* is interior or not and focus their analysis on the variation of the symmetric Nash equilibrium. In fact, calculations

[5] For a theoretical analysis of the interior solution, see Anderson et al. (1998)

show that only one of these treatments yields an interior *CO.*

In a context of a common pool resource game, Keser and Gardner (1999) use a concave function that gives an interior solution by introducing a linear payoff for the private good and a concave one for the public good. The results show that players don't play the equilibrium of the game of common resources. They don't try to cooperate for two reasons : the first is that these players don't see clearly at which level cooperation should take place. The second reason is that they don't see any possibility of influencing the behavior of the others by their own behavior. The authors suggest a theory other than the Nash equilibrium to analyze the strategic behavior of experienced subjects in a common pool resource game.

In another context, Andreoni (1993) also uses a design that gives a non-boundary equilibrium. The question as to the effect of varying the *CO* level on contributions is thus still open. To help to answer it, we introduce a new experimental design that is different from all those mentioned above to test the effect of varying the *CO* level on contributions.

2.2 Our Design

Our experiment differs from other experiments that use an interior Nash equilibrium in that they have a corner *CO* which involves full contribution to the public good, while we present an experimental design that gives an interior *CO.* As we have said, we will focus on the effect of varying the level of this optimum on the decision of contributing to the public good. To do so, we choose to use a function that is different from the one used by Keser (1996) and Willinger and Ziegelmeyer (2001). Their function is quadratic in the private payoff and linear in the public one. We choose to use a function that is, as in Keser and Gardner (1999), linear for the private payoff and concave for the public one, but with the particularity that the *CO* is an "*interior solution.*" This function is, for all subject $i = \{1, .., N\}$:

$$Z_i = x_i + \theta(\sum_{i=1}^{N} y_i)^{1/2}$$

where x_i is the private part of subject i and $x_i + y_i = E$, the initial endowment of each subject.

With such a function, there is a very particular design where the *NE* is also an *"interior solution"*. In fact, calculations show that for a group of N subjects, the *CO* is given by the following formula:

$$\overline{Y} = \sum_{i=1}^{N} y_i = N^2 \frac{\theta^2}{4}$$

and the *NE* is equal to:

$$Y^* = Ny^* = \frac{\theta^2}{4}$$

where y^* is the symmetric individual Nash equilibrium.

While the variation of the *CO* is significant (successively almost 1/4, 1/2, 3/4 and 4/4 of the initial endowment), the variation of the *NE* is so insignificant (successively 1/70, 2/70, 3/70 and 5/70 of the initial endowment) that we can consider it as an *interior*, but unchanged equilibrium from one treatment to another. This allows us to isolate the effect of varying the *CO* on contributions from the strategic behavior of subjects that is supposed to lead them to play the *NE.* Thus, any overcontribution could only be due to the variation of the *CO.* Note that when we refer to the *NE*, we mean the symmetric one, where all subjects of the same group give the same amount to the public good ($Y^* = Ny^*$).

The marginal payoff of the private good is equal to one and

$$\frac{\theta}{2(\sum_{i=1}^{N} y_i)^{1/2}}$$

represents the individual marginal payoff of one token allocated to the public good. Increasing θ leads then to an increase in the marginal payoff of the public good. In other words, in our experiment the *marginal per capita return* (*MPCR*)[6] defined as the ratio of benefits to costs for moving a single token from the individual to the group contribution, is equal to the marginal payoff of the public good.

One should notice that an increase in the value of the marginal payoff of the public good has the effect of increasing the values of the *NE* and the *CO*. This could have two contradictory effects: the first one is that a higher marginal payoff makes the public good more interesting in term of returns and leads subjects to increase their contributions both, strategically and through coordination. But on the other hand, increasing the marginal payoff of the public good increases the *CO* level, which means that a greater contribution effort is needed to realize the social optimum. In such a context, playing the *CO* becomes more risky, in the sense that if the other members of the group do not contribute, one will have to share an important part of his or her private payoff with all the members of the group. The experimental results could give us an idea about which of the two effects predominate.

In Willinger (2001), the variation of the marginal payoff of the public good causes a variation in just the *NE* and has no effect on the *CO* which stays at the maximum possible level of contribution. We have four treatments in our experiment. Each treatment have a specific value for θ. By varying this value (and as a consequence the marginal payoff of the public good), we vary the *CO* and the *NE* levels. The following tables summarize for each treatment the different levels of interior solutions for each group of four ($N = 4$) persons (*table 1*) and for one subject in each group (*table 2*):

Value of θ[7]	Treatment	Endowment	Symmetric Nash equilibrium	Collective optimum
4	L	280	4	64
5.66	M	280	8	128
6.93	H	280	12	192
8.94	VH	280	20	280

Table 1: The NE and the CO values for the four treatments for one group.

Value of θ	Treatment	Endowment	Symmetric Nash equilibrium	Collective optimum
4	L	70	1	16
5.66	M	70	2	32
6.93	H	70	3	48
8.94	VH	70	5	70

Table 2: The symmetric NE and the CO values for the four treatments for one subject.

[6] See Isaac et al. (1984).

[7] These are approximative values. The exact values are respectively: 4, 5.6568542, 6.9282032 and 8.9442719. We choose these values such that the *CO* corresponds respectively to 64, 128, 192 and 280.

As we can see, the values of the Nash equilibrium level are very low in comparison to those of the collective optimum and to the initial endowment. Thus, we will be interested here only in the variation of contributions in comparison to the *CO* level, while considering the *NE* almost constant.

3 Practical Procedures

We ran the experiment in November 2001 at the *LeeX* (Laboratori d'Economia Experimental) at the department of economics at "*Universitat Pompeu Fabra*" in Barcelona. The experiment was computerized and we used as software *z-Tree* developed by Fischbacher (1999). The 96 subjects who participated in these experiments have been split into groups of four people ($N = 4$). In each one of the 8 sessions we ran, three randomly formed groups played the same treatment. There is no interaction between groups. Two sessions were devoted to each treatment, producing a total of six independent observations per treatment.

Instructions were distributed in a written form to subjects. The experiment's instructions (see appendix for the instructions relative to the L treatment) were read out loud before the beginning of each session. We made sure that these instructions were well understood. Subjects were asked to rase their hands if they have any questions and answers were given privately by the experimenter.

Subjects were asked in every period to make their contribution. In each period, each subject was endowed with 70 *ECU*[8], to be shared into two parts: one for the private good and one for the public one. Parts allocated to the public good allowed the group to have a certain amount that was presented to subjects in a tabular form[9]. Each group played a session of 25 periods where the total game is a repetition of the one-shot game. The total gain is the sum of the payoff of the 25 periods. During the experiment, communication was not allowed. After the end of the experiment, a questionnaire is distributed to subjects. The gain of each subject was converted at the end of the session from *ECU* into *Pesetas* and people were paid privately in cash.

We test four treatments with four different payoff tables. Each treatment has its own marginal payoff value for the public good . Each session lasts on average one hour.

4 Experimental Results

Our analysis will be based on the aggregate level where we have for each treatment the average contribution on the six groups (Y), the aggregate *NE* (Y^*) and the aggregate *CO*. These results are reported in *figures 1* to *4*. The first thing we observe when analyzing the experimental results is the fact that the average group contribution (Y) decreases over time. In fact, the Very High treatment ($\theta = 8.94$), has 133.33 and 91.5 as values of the first and the last periods (see *figure 1*). In the case of the H and the M treatments, the average group contribution (Y) decreases during the 10 first periods and stays at a steady level during the rest of the periods of the game (see *figures 2* and *3*).In the last treatment *L,* this average group contribution starts at 67.67 and decreases steadily during the 25 periods of the game until finishing at 7.16 (see *figure 4*). The decrease of contributions is however less evident in the *VH* treatment. Generally, if we do not consider the first five periods that could be assimilated to "*learning periods,*" contributions are almost steady over the twenty last periods for the *M*, *H* and *VH* treatments.

[8] Experimental Currency Unit

[9] To simplify the lecture of the payoff tables, two tables were presented to subjects in each treatment. The first gives a detailed idea about the payoff, while the second is a summarized version that considers only the payoff for values that are multiple of 10.

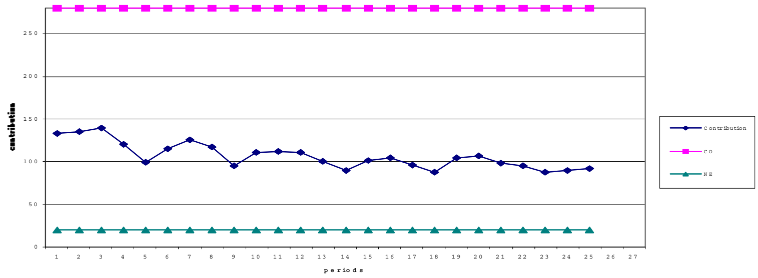

Figure 1: Total Contribution in the VH treatment

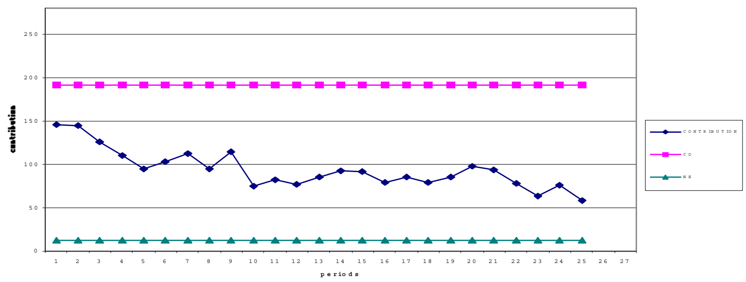

Figure 2: Total Contribution in the H treatment

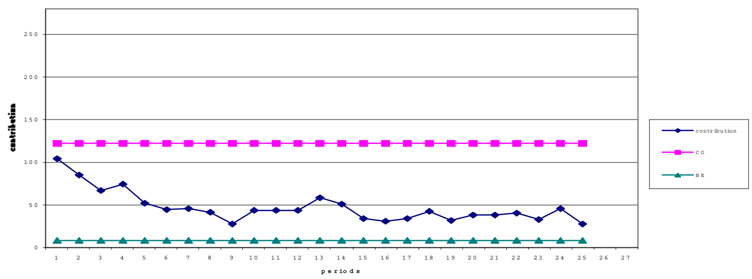

Figure 3: Total Contribution in the M treatment

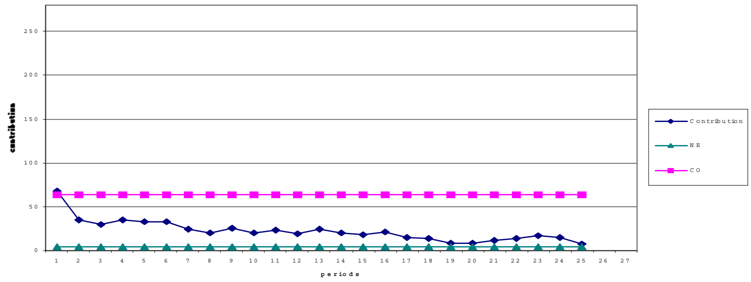

Figure 3: Total Contribution in the L Treatment

These results are summarized in the following table:

Treatment	Y at the first period	Average on 25 periods	Y at the last period	Max	Min
L	67.67	22.41	7.16	67.67	8
M	103.83	47.23	28.16	103.83	27.5
H	145.33	93.87	58	145.33	58
VH	133.33	106.77	91.5	139.67	87.33

Table 3: average group contribution to the public good for the four treatments.

Except in the H treatment, there is no significant "*end effect*" in any of the four treatments. By "*end effect*" we mean a decrease in contributions during the last periods because of the strategic reasoning by backward induction and to the fact that the time at which the game ends is common knowledge: subjects know that there will not be a reaction to their final decision.

Except for the first period of the Low treatment, where average contribution (67.67) was bigger than the CO value (64), for all the other periods of the four treatments contributions are always between the NE level and the CO one. The collective optimum is never reached but in all periods of all treatments there is overcontribution[10]. There is in fact no reasonable behavior that could lead one subject to consider contributing a level that is superior to the CO.

The design of the VH treatment corresponds almost to the case of linear payoff function with corner solutions. The results we obtain confirm those concerning the linear case in the literature (Andreoni (1995)): there is overcontribution. We still have the typical contradiction between the theoretical predictions and the experimental results. When the CO level is reduced, contributions move closer to the theoretical prediction. This confirms our intuition that the level of the CO has a significant effect on subjects' contributions. By decreasing the level of this optimum, contributions vary in the same direction. Average group contribution (Y) is equal to 106.77 for the VH treatment. This value is equal to 93.87 (respectively 47.23 and 22.41) for the H (respectively M and L) treatment. The decrease of the CO level is the consequence of the decrease of the marginal payoff of the public good. The decrease clearly makes contribution to the public good less interesting for subjects, since they expect to receive less from one token allocated to the group.

Let us first compare the different treatments in absolute values of the level of contribution before using as in Willinger and Ziegelmeyer (2001) an "overcontribution index" for this comparison. To do so, let us define the *under-optimum value* as the difference between the CO and average group contribution (Y) and the *overNash value* as the difference between average contribution (Y) and the NE (Y^*). The results show that the *overNash value* is decreasing over time and that the *under-optimum value* is increasing over time in all the treatments. This means that for each treatment, while playing the game, subjects' contributions are closer to the NE and farther from the CO. These values are also increasing with the collective optimum level (see *table 4*). That means that an increase of this level has as effect both, an increase of contributions but also an increase of the gap between contributions and the CO: in terms of absolute values players are more likely to play the collective optimum when its level is low than when it is high. That is contributions are nearer to this optimum as the level of the collective optimum is reduced.

[10] in comparison to the Nash equilibrium.

Treatment	OverNash value	UnderOptimum value
L	18.41	41.59
M	39.23	80.77
H	81.87	98.13
VH	86.77	173.23

Table 4: OverNash and underOptimum values for the four treatments.

Notice that overcontribution is very high in comparison to the level of the *NE*. This is due to the fact that the equilibrium values are very low (almost at zero) in the four treatments in comparison to the initial endowment.

Willinger and Ziegelmeyer (2001) examine the rate of overcontribution with a design where the initial endowment coincides with the collective optimum ($E = CO$) and the *NE* is interior. They define this rate as the difference between the effective (Y) and the equilibrium contribution (Y^*) relative to the range of possible over contribution:

$$\frac{(Y - Y^*)}{(E - Y^*)}$$

They found that this rate decreases when the "*social dilemma,*" representing the difference between the equilibrium contribution level and the social optimum ($CO-NE$) is reduced. Using the same formula to calculate the overcontribution rate, our experiment confirms these results: this rate varies from 33.37% to 6.67% as we pass from the *VH* to the *L* treatment (see *table 5*).

Treatment	Y^*	CO	Y	$(Y - Y^*)/(E - Y^*)$	$(Y - Y^*)/(CO - Y^*)$	Y/E	Y/CO
L	4	64	22.41	6.67%	30.68%	8%	35.02%
M	8	128	47.23	14.42%	32.69%	16.9%	36.9%
H	12	192	93.87	30.55%	45.48%	33.5%	48.89%
VH	20	280	106.77	33.37%	33.37%	38.1%	38.13%

Table 5: the Overcontribution rate and the corrected overcontribution rate for the four treatments

But this way of calculating the overcontribution rate, as in Willinger and Ziegelmeyer (2001), use the initial endowment (E) that is unchanged from a treatment to another and does not take into account the fact that the *CO* is in our design in the interior of the strategy space. Our experiment allows such a thing, given that in our design the *CO* varies and does not coincide with the initial endowment as in Willinger and Ziegelmeyer (2001). To take into account the variation of the *CO* level, we will correct this rate by replacing the initial endowment (E) in the formula of the overcontribution rate by the *CO*. There is no reason, in fact to compare the effective overcontribution to the range of possible overcontribution if the *CO* is interior. We assume logically that subjects have no interest to contribute more than the *CO*, because any results that can be achieved with a level of contribution that is greater than this optimum can be obtained with less individual effort of contribution. Using this corrected overcontribution index, our results show that, except for the *H* treatment where we have the largest rate (45.48%), there is no significant difference between the rates of the three other treatments. This rate is about 30% for the *L*, *M* and *VH* treatment (see *table 5*).

Since the values of the *NE* are very small in comparison to contributions and to the *CO*, we can safely ignore the *NE* and define the corrected overcontribution rate as the percentage of effective contribution in comparison to the *CO*. Using this definition, we can say that subjects in our experiment contribute a value that increases with the *CO* but their contribution represents a constant proportion of the collective optimal contribution. This suggests that subjects adopt the same behavior while passing from a treatment to another.

In terms of "the *social dilemma*", Willinger and Ziegelmeyer (2001) found that reducing this gap as they measure it leads to a decrease in the average contribution rate. Our experiment, using the same average contribution rate confirms these results. But with the corrected rate, variations in "the *social dilemma*" do not affect the overcontribution rate. That is, in our experiment, subjects adapt their contributions such that while the "*social dilemma*" is varying, the average group contribution remains a constant part of the *CO* of the game.

In the *L* treatment (*figure 4*), the average group contribution seems to decrease and to converge steadily to the *NE* value (4). For this treatment, where the *CO* level is very low, subjects seem to converge to the theoretical predicted value. The difference between the theoretical prediction and the experimental results is less evident and such a result is rarely observed generally in the experimental literature relative to public goods. Paradoxically, subjects contribute less and learn to play the *NE* value when the *CO* is low. For this is precisely the case in which the *CO* is easy to reach in the sense that it does not require a large contribution. For high levels of the *CO*, it is in fact risky for one subject to cooperate and to try to reach the social optimum by contributing a large amount to the public good. Taking such a risk can lead one subject to share his or her contribution with other subjects that choose not to contribute, and to lose, in so doing most of his or her private payoff. For the *L* treatment, the "*social dilemma*" is very low and nevertheless, subjects do not play the *CO*. However, for high levels of the *CO*, subjects contribute more than the *CO* value of the *L* treatment.

5 Conclusion

Our experiment shows that the level of the collective optimum is one of the parameters that intervenes in the decision as to how much to contribute and should be taken into account in a public good experiment as have several other parameters that have been experimentally tested before, like the Nash equilibrium level, the number of players constituting the group or the context of the experiment.

When this collective optimum is low, although it is not risky to play the social optimum, subjects learn to play their Nash equilibrium and do not cooperate or try to test strategies others than playing almost the equilibrium of the game. Nevertheless, overcontribution is observed for all treatments. An increase in the collective optimum level leads to the standard remark of the non-correspondence of the experimental results to the theoretical ones, since there is an effective increase in contributions. The latters are further from the Nash equilibrium and from the Collective optimum (in absolute value) as the collective optimum increases. We show in fact that in all treatments, the *overNash* value is decreasing over time, while the *under-optimum* value is increasing over time.

In relative value, we calculate the average overcontribution rate, and as in Willinger and Ziegelmeyer (2001), we find that reducing the "*social dilemma*" leads to a decrease in this average overcontribution rate. This result is not true anymore when we compute a new index taking into account the *CO* in spite of the initial endowment. The part (in percentage) allocated to the public good is almost constant (with the except of the H treatment) in comparison to the CO level. The fact that the corrected index is constant, reflects a stability in the group behavior.

6 Appendix

Instructions to the Experiment:

Welcome,

This is an experiment that allows you to earn money. The instructions are simple and if you follow them carefully and make good decisions, you may earn a considerable amount of money. This money will be paid to you in cash at the end of the experiment.

You will be randomly assigned in the beginning of the experiment to a group of 4 people (you and 3 others). Each group will consist of the same persons for the duration of the session. The session will last for 25 periods. In each period you will be required to make a decision and your total income will depend on these decisions. Your total earning for the session will be the sum of your earnings in all the 25 periods. The specific identities of the other people in your group will not be revealed to you.

You are not allowed to communicate with anyone else in the room during all the session. If you have a question at any time, please raise your hand. One of us will come to your seat, and you can privately ask your question. Any communication will lead to your exclusion from the game without any payment.

At the beginning of each period you will receive a constant income in tokens (the same for all the periods). You will be asked to share this income into two parts: part A and part B.

The tokens you allocate to part A are already for you. The rest of the tokens that you will allocate to the part B will allow you to earn an amount that depends on your contribution, but also on the contributions to the part B of the three other persons of your group. The amount you earn from the sum of your contributions to the part B will be shared equally between the four persons of your group. The earning of all the group from the part B will be calculated as shown in the following payoff table[11] (*table 6*).

Your total payoff will be equal to the tokens you allocate to part A plus your part from the earnings from the sum of the tokens allocated by all the persons of your group to part B.

At the end of each period, you will know the total amount that the group allocates to part B, your personal earnings from the part B and your total profit (from part A and part B).

At the end of the experiment, your total earning from the 25 periods will be given to you privately in cash.

The tokens will be exchanged for money at a rate of :

100 tokens = 17.85714 pesetas.

[11] A summerised version is given in *table 6*.

If the Group invests in B	The group wins	Your part from the gain of the group
1	16	4
10	50.59	12.64
20	71.55	17.88
30	87.63	21.9
40	101.19	25.29
50	113.13	28.28
60	123.93	30.98
70	133.86	33.46
80	143.1	35.77
90	151.78	37.94
100	160	40
110	167.8	41.95
120	175.27	43.81
130	182.42	45.6
140	189.31	47.32
150	195.95	48.98
160	202.38	50.59
170	208.61	52.15
180	214.66	53.66
190	220.54	55.13
200	226.27	56.56
210	231.86	57.96
220	237.31	59.32
230	242.65	60.66
240	247.87	61.96
250	252.98	63.24
260	257.99	64.49
270	262.9	65.72
280	267.73	66.93

Table 6: the payoff table for the group and the share of each player

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