(a) High reference point $x_0 \geq g$

Equilibrium condition at reference point $x_0 = g$,

$$w(1-q)v(-g) = v(c-g). \tag{54}$$

Clearly, $c = 0$ is always an equilibrium and $c = 1$ is also an equilibrium if and only if $g = 1$.

Equilibrium condition at reference point $x_0 = g + c$,

$$v(-c) + w(1-q)\left[v(-g-c) - v(-c)\right] = v(-g) \tag{55}$$

Clearly, $c = 0$ is always an equilibrium and $c = 1$ is also an equilibrium if and only if $g = 1$.

It is also immediate that if v is linear in losses the equilibrium conditions at any reference point $x_0 \geq g$ are the same, so the equilibria are the same too. Proposition 12, next, establishes a number of properties for the symmetric equilibria at these high reference points. We have already observed that $c = 0$ is an equilibrium and $c = 1$ is also an equilibrium if and only if $g = 1$. These equilibria however are not stable in the sense that the best reaction to a small deviation results in a further deviation. Besides, the equilibrium $c = 1$ is not robust in the sense that it is not the limit of any equilibria as g tends to 1 from below, that is, even though it is an equilibrium when $g = 1$, there is no equilibrium close to it when g is slightly smaller than 1.

When the group has two members, $N = 2$, there is a unique interior equilibrium with threshold $c_1 = c_{1+c} = 1 - c_f$. As N increases the maximum interior equilibrium—the most efficient—diminishes while there exists an interior equilibria, in particular,

$$c_{1,N} < 1 - c_f, \;\; N > 2. \tag{56}$$

While if for some N there is no interior equilibrium then there is no interior equilibrium for any larger N either.

Proposition 12. *Suppose the public good is provided as long as all players contribute. Under Prospect Theory with linear value functions in losses, the set of symmetric equilibria for reference point $x_0 \geq g$ includes $c = 0$, and $c = 1$ if and only if $g = 1$, in addition,* *(i) The set of equilibria is the same for any reference point $x_0 \geq g$.*

(ii) For $N = 2$, at $g = 1$ and in the limit as $g \to 1$, the only interior equilibrium is

$$c_1^* = c_{1+c}^* = 1 - c_f. \tag{57}$$

(iii) For $N > 2$, at $g = 1$ and in the limit as $g \to 1$, there is no interior equilibrium greater than or equal to $(1 - c_f)$.

(iv) More generally, for $g = 1$ and in the limit as $g \to 1$, if $c_{1,m}$ is the maximum interior equilibrium for $N = m > 1$, then the maximum interior equilibrium for $N = m + 1$, if it exists, satisfies,

$$c_{1,m+1} < c_{1,m}. \tag{58}$$

(v) For $N > 2$ there can be a continuum of equilibria in $[0, 1 - c_f)$, no interior equilibrium, or any number of them in that interval.

(vi) For $g = 1$ and in the limit as $g \to 1$, if for $N = m > 2$ there is no interior equilibrium, then there is no interior equilibrium for any $N > m$.

Proof. With v linear in losses, and $g = 1$, the equilibrium conditions (54) and (55) become the same,

$$w(1 - c^{N-1}) = 1 - c, \tag{59}$$

which shows (i).

Any $c \in (0, 1)$ satisfies the equilibrium condition (59) if and only if $x = 1 - c \in (0, 1)$ satisfies,

$$w(1 - (1 - x)^{N-1}) = x, \tag{60}$$

that is, if and only if the function f,

$$f(z) = 1 - (1 - z)^{N-1}, \tag{61}$$

is the inverse of w at x, i.e.,

$$f(x) = w^{-1}(x). \tag{62}$$

Note that since w is increasing on $[0,1]$ it has a well defined inverse and it is also increasing and has the same fix point c_f.

For $N=2$, f is the identity, so that (62) becomes, $x=w^{-1}(x)$, that is, $x=w(x)$, whose interior solution is $x=c_f$. Thus, for $N=2$ the only interior solution is $c=1-c_f$, as (ii) states.

Now, for any $z\in(0,1)$, $(1-z)<1$, so that for any $N>2$, $(1-z)^{N-1}<1-z$ and $f(z)=1-(1-z)^{N-1}>z$. So, that $c=1-x\in(0,1)$ can be an equilibrium only if $w^{-1}(x)=f(x)<x$, that is, if $w(x)>x$, which occurs if and only if $x>c_f$, that is, $c<1-c_f$, as stated in (iii).

Note that (iii) and (ii) imply (iv) for the case $m=2$.

To show (iv) for $m>2$, let $c_n\in(0,1)$ be the supremum interior equilibrium for $N=n>3$. Let $x_n=1-c_n$ and $G_N(z)=f_N(z)-w^{-1}(z)$ be the left-hand side minus the right-hand side of the equilibrium condition (62). Let m be an integer such that $n>m>2$. Note that $G_m(1-c_f)=f_m(1-c_f)-c_f>0$. Note also that because f_N, and consequently G_N, are increasing in N for any $x\in(0,1)$, $G_m(x_n)<G_n(x_n)=0$. Then by continuity of $G_m(x)$ in $x\in(0,1)$ it follows that there exists a $x_m\in(1-c_f,x_n)$ such that $G_m(x_m)=0$. Thus $c_m=1-x_m$ is an interior equilibrium for $N=m$, satisfying $c_m<c_n$. This proves (iv).

To show (vi) note that if there is no interior equilibrium for $N=m>2$, then $G_m(x)>0$ for all $x\in(1-c_f,1)$ for we know that $G_m(1-c_f)>0$. Now since G_N is increasing in N, the same inequality holds for any larger $N>m$, and no interior equilibrium exists either.

To show (v), for any given integer $n>2$, take a weighting function such as for $1>p>\underline{p}_n$ is defined by

$$w_n(p):=f_n^{-1}(p)=1-(1-p)^{1/(n-1)} \text{ if } p\in\left[\underline{p}_n,1\right], \tag{63}$$

where $\underline{p}_n>f_n(c_f)$. For $p<\underline{p}_n$ $w_n(p)$ can be defined to have a fix point $p=c_f$ and have all the properties assumed in Prospect Theory. With such a weighting function, it is clear from the equilibrium condition (62) that for $N=n$, the set of equilibria is $\left[\underline{p},1\right]\cup\{0\}$, while for $N>n$ there is no interior equilibrium. Similarly it can be shown that for any subset $S\subset(c_f,1]$ with S being a union of close intervals included in $(c_f,1]$, there is a weighting function satisfying the properties stated in Prospect Theory and with fix point c_f,such that S is the set of equilibria for some $N>2$. $\square$

(b) Low reference point $x_0=0$

Equilibrium condition

$$w(q)v(g) = v(c). \tag{64}$$

Clearly, $c = 0$ is always an equilibrium and $c = 1$ is also an equilibrium if and only if $g = 1$.

Proposition 13. *Suppose the public good is provided as long as all players contribute. Under Prospect Theory with linear value functions in gains, the set of symmetric equilibria for reference point $x_0 = 0$ includes $c = 0$, and $c = 1$ if and only if $g = 1$, in addition,*

(i) For $N = 2$, in the limit as $g \to 1$ the only interior equilibrium is $c_0^* = c_f$.

(ii) For $N > 1$, in the limit as $g \to 1$ there is no additional equilibrium greater than c_f.

(iii) For $N > 2$ there can be a continuum of equilibria on $[0, c_f]$, no interior equilibrium, or any number of them in that interval.

It follows from Propositions 12 and 13 that for $N = 2$ and g close to 1, the most efficient equilibrium involves more contribution for a high reference point $x_0 = 1$ than for a low reference point $x_0 = 0$.

2.5 Intermediate contribution requirements: $1 < k < N$

Finally we address the problem when the number of contributions required for the provision of the public good is greater than 1 and less than N.

Three probabilities are important to determine the symmetric equilibria. Suppose every player $j \neq i$ is following the strategy of contributing whenever her cost is less than a threshold c. As above, let $q(c)$ be the probability that i is decisive for the provision of the public good, i.e., $q(c)$ is the probability that exactly $k-1$ players other than i have a cost less than c. Similarly, let $p(c)$ be the probability that the public good is provided regardless of what i does, i.e., $p(c)$ is the probability that at least k players other than i contribute. Finally let $r(c)$ be the probability that the public good is not provided regardless of i's choice. We have,

$$q(c) = C_{N-1,k-1}c^{k-1}(1-c)^{N-k} \tag{65}$$

$$p(c) = \sum_{j=k}^{N-1} C_{N-1,j} c^j (1-c)^{N-1-j} \tag{66}$$

$$r(c) = 1 - p(c) - q(c) \tag{67}$$

The following facts will be useful.

Lemma 14 *(i) p and $p+q$ are increasing in c.*

(ii) r and $q+r$ are decreasing in c.

(iii) q is increasing in c for $c < \frac{k-1}{N-k}$, and decreasing thereafter. $q(0) = 0$ and $q(1) = 1$.

Under Expected Utility Theory, the symmetric equilibrium condition is,

$$q(c_{eu}) = c_{eu}. \tag{68}$$

From (65) it follows that $c = 0$ is an equilibrium and $c = 1$ is not an equilibrium. Any other equilibrium has to satisfy,

$$C_{N-1,k-1} c^{k-2} (1-c)^{N-k} - 1 = 0 \tag{69}$$

For $k = 2 < N$ the only equilibrium other than 0 is $c_{eu} = 1 - 1/(N-1)^{1/(N-2)}$. Since the left-hand side of (69), $L(c)$, is an increasing affine transformation of $q(c)$ it follows from Lemma 14 that $L(c)$ is increasing in c if $c < (k-2)/(N-2)$ and it is decreasing thereafter. It is then clear that for $2 < k < N$ there are at most two positive equilibria, one of them greater than $(k-2)/(N-2)$ and the other one smaller than $(k-2)/(N-2)$.

It can also be shown that for any $k > 2$ if N is large enough there are two positive equilibria, and that if N is small enough there is no positive equilibrium.

In particular, for $N = 4$ and $N = 5$ there is no positive equilibrium with $N > k > 2$. For $N = 6$ there are positive equilibria only if $k = 2$ and $k = 3$.

Proposition 15 *Suppose the public good is provided as long as all players contribute. Under Prospect Theory with loss aversion but linear value functions in gains and losses, and linear weighting function, the maximum equilibria satisfy*

$$c_c^* < c_{1+c}^* = c_0^* = c_{eu}^* < c_1^*, \tag{70}$$

with weak inequality whenever the maximum is zero.

Proof. (i) It is straightforward that, since with reference point $x_0 = 0$—matrix of gains and losses (**??**)—the prospects at choice (4) involve only gains, and since with reference point $x_0 = 1 + c$—-matrix (**??**)—the prospects at choice (7) involve only losses, there is no role for loss aversion so that with linear value function both in gains and in losses and with linear probability weighting function, the equilibrium conditions for these extreme reference points coincide with the equilibrium condition under Expected Utility Theory (68),

$$q(c) = c, \tag{71}$$

so that $c_0 = c_{1+c} = c_{eu}$.

(ii) We show the first inequality of the proposition. For reference point $x_0 = c$—matrix of gains and losses given by (**??**)—the equilibrium condition making indifferent the prospects at choice (5), becomes

$$w(p + q)v(1 - c) + w(r)v(-c) = w(p)v(1). \tag{72}$$

With linear value function both in gains and in losses and linear probability weighting function, the equilibrium condition (72) becomes,

$$(p + q)(1 - c) - \lambda rc = p, \tag{73}$$

so,

$$q(c) = [1 + (\lambda - 1)r(c)]\, c. \tag{74}$$

Suppose that there exists a solution $c_c \in (0, 1)$ to (74). Then, since for $k > 1$, $r(c_c) > 0$, and by loss aversion $\lambda > 1$,

$$q(c_c) = [1 + (\lambda - 1)r(c_c)]\, c_c > c_c. \tag{75}$$

So that at c_c the left-hand side of the equilibrium condition (71) is greater than the right-hand side $L_0(c_c) > R_0(c_c)$. Since at $c = 1$, for that equilibrium condition the inequality is the opposite, $L_0(1) = 0 < R_0(1) = 1$, and both sides are continuous, it follows that there exists an equilibrium $c_0 > c_c$.

(iii) We finally show the last inequality of the proposition. For reference point $x_0 = 1$—matrix of gains and losses given by (**??**)—the equilibrium condition making indifferent the prospects at choice (6), becomes

$$w(r)v(-1) = w(p)v(c) + w(q + r)v(-1 + c). \tag{76}$$

With linear value function both in gains and in losses and linear probability weighting function, the equilibrium condition (76) becomes,

$$-\lambda r = pc - \lambda(q + r)(1 - c). \tag{77}$$

so,

$$q(c) = c\left[1 - \left(1 - \frac{1}{\lambda}\right)p(c)\right]. \tag{78}$$

Suppose that there exists a solution $c_0 \in (0, 1)$ to (71). Then, since for $k < N$, $p(c_0) > 0$, and by loss aversion $\lambda > 1$,

$$q(c_0) = c_0 > c_0\left[1 - \left(1 - \frac{1}{\lambda}\right)p(c_0)\right]. \tag{79}$$

So that at c_0 the left-hand-side of the equilibrium condition (78) is greater than the right-hand side $L_1(c_0) > R_1(c_0)$. Since at $c = 1$, for that equilibrium condition the inequality is the opposite, $L_1(1) = 0 < R_1(1)$, and both sides are continuous, it follows that there exists an equilibrium $c_1 > c_0$. $\square$

Note that the maximum equilibrium is the most efficient. Note also that if the weighting function is not linear, for sufficient loss aversion then the efficient equilibrium is lowest at reference point $x_0 = c$ and largest at reference point $x_0 = 1$.

It can also be seen that for $k = 2$ and $N > k$ small, given a degree of loss aversion $\lambda \geq 1$, if the probability weighting function is sufficiently regressive, then the equilibrium under Expected Utility Theory is larger than any of the equilibria under Prospect Theory, whatever the reference point.

3 Calibration

In this section we report calibrations for the equilibria under Prospect Theory from the four natural reference points and under Expected Utility Theory. We assume that the value function is linear both in gains and in losses and it has a loss aversion of $\lambda = 2$. For the weighting function we take the functional form proposed by Tversky and Kahneman (1992),

$$w(p) = \frac{p^\delta}{(p^\delta + (1 - p)^\delta)^{1/\delta}}. \tag{80}$$

Using a maximum likelihood estimation procedure Camerer and Ho (1994) estimate $\delta = .56$. Table 1 presents equilibrium probability of contribution for a few small group sizes N and for all possible levels of contribution requirements $k = 1$ through $k = N$. When there are multiple equilibria the *efficient* interior equilibrium is reported. The number of interior equilibria is reported in parentheses when it is greater than 1. Table 1 assumes that the common value of the public good is $g = 1$, the same as the supremum of the distribution of costs of contribution.

For $k = 1$, by Proposition 1 we know that for each reference point x_0, there is a unique equilibrium and it is interior to $(0, 1)$. In Table 1, for $k = 1$,

$$c_{1+c} < c_{eu} < c_0 = c_c < c_1, \tag{81}$$

which is in accordance with Propositions 2 through 10. In accordance to Propositions 2, 3, and 5, $x_0 = 1 + c$ is the reference point resulting in the lowest equilibrium probability of contribution, that is, when both the lack of provision of the public good and the cost of contributing are seen to involve losses. In contrast, in accordance with Propositions 4 through 6, the highest equilibrium contribution results at reference point 1, that is, when on the one hand the lack of the provision of the public good is seen as a loss, and on the other hand, not contributing is seen to involve an individual gain. In accordance to Proposition 7, the equilibrium for the highest reference point is less than the equilibrium under Expected Utility Theory, since for $N \leq 4$ the latter is greater than the fix point of the probability weighting function. The equilibrium under all the other reference points is greater than under Expected Utility Theory, as predicted by Propositions 8 through 10.

In sharp contrast with the results for $k = 1$, and in line with Proposition 15, for $k > 1$ Table 1 shows that the lowest efficient equilibrium probability occurs for reference point $x_0 = c$, that is when obtaining the public good is taken as a gain and contributing involves an individual loss; meanwhile the highest efficient equilibrium contribution results for a reference point $x_0 = 1$, that is, the reverse perspective. For $k = N$, Table 1 also exemplifies other results obtained in Propositions 11–13: for $k = N$, $c_1 = c_{1+c}$; for $N = 2$, $c_0 = c_f = .312$ the fix point of the weighting function, while $c_1 = c_{1+c} = 1 - c_0$. Finally note that as pointed out after Proposition 15, because the weighting function is quite regressive, for (small) $N > k = 2$ the equilibrium probability of contribution is greater under Expected Utility Theory than under any reference point in Prospect Theory.

Table 1: Framing Effects on the Equilibrium Probability of Contribution.

N	k	$x_0 = 0$	$x_0 = c$	$x_0 = 1$	$x_0 = 1 + c$	$\max \Delta$	$\max \Delta$ %	**EUT**
2	1	.573	.573	.609	.427	.182	43	.500
2	2	.312	.171	.688	.688	.517	303	$[0, 1]$
3	1	.485	.485	.511	.356	.155	44	.382
3	2	.204	.150	.370	.290	.220	147	.500
3	3	0	0	.417(2)	.417(2)	.417	∞	0
4	1	.428	.428	.449	.316	.133	.42	.318
4	2	.190	.152	.323	.242	.171	113	.423
4	3	.057(2)	0	.301	.253	.301	∞	0
4	4	0	0	0	0	0		0

Public good value $g = 1$. Loss aversion $\lambda = 2$.
Weighting function parameter $\delta = .56$.
Number of interior equilibria in parentheses.

The fifth and sixth columns of Table 1 report the maximum framing effect on equilibrium probability of contributions in levels and in percentage, respectively. Table 1 shows that the effects of framing are substantial. For $k = 1$ and $N = 1$, the framing effect from a reference point of $x_0 = 1 + c$ to a reference point $x_0 = 1$ is an increase of .182 of probability of contribution, that is, a 43% increase. For $N = 3$, the increase in probability of contribution is .155, a 44% increase. For $N = 4$, the increase is .133, a 42% increase. The effect increases both in levels and in percentages as k increases, while it decreases slightly in levels as N increases..

In Table 2, it is assumed that $g = .95$. Qualitatively the Table is similar to Table 1, with slightly smaller probabilities of contribution.

As a robustness test, we have computed the equilibria for other estimates of the probability weighting function, obtaining similar results. Table 3 reports the framing effects on equilibrium probability of contribution ($\max \Delta$) and their percentages ($\max \Delta\%$) for three estimates of the parameter δ in the probability weighting function (80): $\delta = .56$ estimated by Camerer and Ho (1994), $delta = .61$ estimated by Tversky and Kahneman (1992), and $\delta = .71$ estimated by Wu and Gonzalez (1996).

Table 2: Framing Effects on the Equilibrium Probability of Contribution.

N	k	$x_0 = 0$	$x_0 = c$	$x_0 = 1$	$x_0 = 1 + c$	$\max \Delta$	$\max \Delta$ %	**EUT**
2	1	.553	.553	.589	.412	.177	43	.487
2	2	.285	.153	.629	.629	.476	312	0
3	1	.470	.470	.496	.345	.151	44	.373
3	2	.192	.140	.353	.278	.212	152	.474
3	3	0	0	.336(2)	.336(2)	.336	∞	0
4	1	.416	.416	.437	.306	.131	43	.311
4	2	.180	.143	.309	.233	.166	117	.407
4	3	0	0	.279	.236	.279	∞	0
4	4	0	0	0	0	0		0

Public good value $g = .95$. Loss aversion $\lambda = 2$.
Weighting function parameter $\delta = .56$.
Number of interior equilibria in parentheses.

4 Experimental design

In what follows, we describe the features of the experiment in detail.

4.1 Subjects

The experiment was conducted in 4 subsequent sessions in December, 2005. A total of 96 students (24 per session) were recruited among the undergraduate student population of the Universidad de Alicante -mainly, undergraduate students from the Economics Department with no (or very little) prior exposure to game theory. The sessions lasted approximately 60' each.

4.2 Treatments

The 4 experimental sessions were run in a computer lab.[4] Instructions were provided by a self-paced, interactive computer program that introduced and described the experiment. Subjects were also provided with a written

[4]The experiment was programmed and conducted with the software z-Tree (Fischbacher [4]).

Table 3: Robustness of Framing Effects.

N	k	$\delta = .56$		$\delta = .61$		$\delta = .71$	
		$\max \Delta$	$\max \Delta\%$	$\max \Delta$	$\max \Delta\%$	$\max \Delta$	$\max \Delta\%$
2	1	.182	43	.158	35	.124	26
2	2	.517	303	.517	358	.529	633
3	1	.155	44	.134	36	.106	28
3	2	.220	147	.226	141	.254	145
3	3	.417	∞	0		0	
4	1	.133	.42	.115	36	.092	28
4	2	.171	113	.175	104	.189	92
4	3	.301	∞	.270	∞	0	
4	4	0		0	0		

Public good value $g = 1$. Loss aversion $\lambda = 2$.

copy of the experimental instructions, identical to what they were reading on the screen.

In each session, subjects played two a total of 48 rounds of two treatments each. As explained in Section x, a treatment is uniquely defined by a reference point. Within the 4 possible alternatives, we decided to focus on two cases only, T_c and T_g, where T_x is the contribution game in which the reference point is equal to x. Let design D_1 (D_2) be the design in which treatment T_c (T_g) is played first (see Figure 7).

	D_1		D_2	
Rounds	S_1	S_2	S_3	S_4
1-24	T_c	T_c	T_g	T_g
25-48	T_g	T_g	T_c	T_c

Fig. 7. Experimental Sessions

In each session, the 24 subjects were divided into 2 *cohorts* of 12, with subjects from different cohorts never interacting with each other throughout the session. We shall therefore read our experimental data under the assumption that the history of each individual cohort (4 for each design, D_1 and D_2) corresponds to an independent observation of our experimental environment. Within each round $t = 1, ..., 48$, in each cohort, 4 groups of 3 subjects were randomly determined. The value of the prize g was fixed to 50 ptas. at all times. Consistently with our theoretical framework, the cost for contributing was, for all subjects and rounds, an independent draw $c_i \sim U[0, \bar{c}]$, with $\bar{c} = 55$ ptas. (?).Let *period* $\tau_i = \{3(i-1) < t \leq 3(i)\}, i = 1, ..., 8$, be the subsequence of the $i-$th 3 rounds of each treatment. Within each period t_i, subjects experienced each and every possible $k \in \{1, 2, 3\}$, with the order being randomly determined within each τ_i. We did so to keep under control the time distance between two rounds characterized by the same value of k. After being told the current level of k and c_i, for that each subject had to

1. Choose whether to contribute or not forfor that round;
2. Elicit their belief on the number of contributors in their group (excluding herself). Every correct guess would be paid 10 ptas. at the end of that round.[5]

[5] We borrow this design feature from Nyarko and Schotter (2003).

After each round each agent was informed of the contribution decision of the other group members (i.e. the outcome for that round), together with her payoff (on both dimensions: belief and contribution game) and the average payoff of her group members (only as for the contribution decision was concerned). The same information was also given in the form of a *History table*, so that subjects could easily review the results of all the rounds that had been played so far.

At the beginning of each treatment, subjects received 1.000 ptas. (1 euro is approx. 166 ptas.) as initial endowment. A particular care was devoted in explaining the two different treatments (i.e. the two frames). As for T_c, subjects would gain $g = 50$ ptas. if the number of contributors in their group would reach the target k (with c_i being subtracted from their initial endowment; in T_g subjects would loose g from their initial endowment if the numbers of contributors would not reach target, gaining c_i in case of non contribution. Subjects received, on average, 15 euros for a 45' session.[6] Instructions were read aloud and we let subjects ask about any doubt they may had. At the end of the sessions, subjects were asked to answer a detailed questionnaire on their socio-demographic characteristics, together with standard questions to estimate their pro-social behavior.[7]

5 Results

In what follows, we shall report our experimental results in detail. In Section 5.1 we present some descriptive statistics; while in Section 5.2 we estimate some (panel) logit regressions which take more carefully into account the impact of all our experimental conditions on outcome and behavior distributions. In reading the experimental evidence, our first concern will be to test the theoretical conjectures of Section 2, which have been calibrated, by analogy with our experimental conditions, in Table 3. Let p_x^k denoting the equilibrium probability under Prospect Theory when $N = 3$, the reference point is x and the contribution threshold is equal to k (with p_{eu}^k denoting the corresponding BNE probability). Our theoretical model provides us with the following testable hypotheses:

[6]The complete set of instructions, translated into English, can be found in the Appendix.

[7]A copy of the Questionnaire can be found in the Appendix.

1. $H_0 : p^1_g = p^1_c$ ($H_1 : p^1_g > p^1_c$). When $k = 1$, the estimated values for p^1_g and p^1_c are .496 and .47 respectively. In this case, it is difficult to provide a robust alternative hypothesis, since these values are relatively close to each other. Notice that, in this case, $p^1_{eu} = .373$.

2. $H_0 : p^2_g = p^2_c$ ($H_1 : p^2_g > p^2_c$). When $k = 2$, the estimated values for p^2_g and p^2_c are .496 and .47 respectively (with $p^2_{eu} = .474$). In this case, it is difficult to provide a robust alternative hypothesis, since all these values are relatively close to each other.

3. $H_0 : p^3_g = p^3_c$ ($H_1 : p^3_g > p^3_c = p^3_{eu} = 0$). When $k = 3$, the estimated values for p^3_g and p^3_c (p^3_{eu}) are .332 and 0 respectively. That is, in this case, Prospect Theory and BNE yield the same prediction when $x_0 = c$.

5.1 Descriptive statistics

Figure 8 reports the relative frequency of contributors across treatments.

Fig. 8. Frequency of contributors across treatments

As Figure 8 shows, contributing patterns differ between the two designs. Precisely, average frequency of contribution is higher (lower) in T_c than in T_g when k is low (high), while for the intermediate level of $k = 2$ both designs yields basically the same frequency of contribution (.43 and .44 respectively). In Figure 9 we refine this evidence, by disaggregating contribution frequencies for treatment, contribution thresholds k and cost levels, c_i.

Fig. 9. Frequency of contributors and individual cost levels

Each diagram in Figure 9 reports in two overlapping histograms reporting, for each cost interval, absolute frequency of observations and absolute frequency of contributors.[8] Not surprisingly, average frequency of contributors is decreasing in the cost level, although this effect is more pronounced in T_{c_i}.

[8]Since, by analogy with the theoretical model of Section 2, $c_i \sim U[0, 1.1]$, we have a differenct number of observation for each cost interval. This is the reason why the histogram of observations for class interval is not uniform.

How do these contribution patterns affect the probability of achieving (or loosing) the public good g? In Figure 10 we plot the average frequency with which the public good is achieved (not lost) across time in the six experimental conditions.

Fig. 10. Public good provision/non deterioration over time

As Figure 10 shows, this relative frequency basically stay constant over time (with the sole exception of T_g when $k = 2$). We do not generally observe "endgame effects", that is, a sharp decline in contributions close to τ_8, with exception of T_g when $k = 3$. Again, the probability of successful provision/not deterioration is decreasing in k, and is basically zero in D_1 when $k = 3$.[9]

We now turn our attention to the extent to which contributing is *individually rational*, that is, it corresponds to a best-reply to the current strategic situation. We can look at this question from two complementary viewpoints: an *ex-ante* or an *ex-post* perspective, that is, consistency of contribution decision with the elicitated belief of Stage 2 (and consistency of beliefs with actual behavior), or consistency of contribution decision with the with the *actual* opponents' behavior,respectively.

As for the former, Figure 11 looks at *a)* the extent to which elicitated beliefs in Stage 2 depend on k and *b)* the extent to which they match actual behavior in Stage 1.

Fig. 11. Elicitated beliefs in Stage 2

Each row of Figure 11*a) (b)* corresponds to a particular level of k (s_{-i}), each column to any particular (point) belief. of Figure 11 corresponds to a particular k (observed strategy profile s_{-i}). First notice that 1 is the modal belief when $k = 1$ and $k = 2$, where when $k = 3$ beliefs are more dispersed and peak at 2. This is in clear contrast with our theoretical prediction with

[9] Basically, Figure 10 also describes the evolution of *efficient* outcomes over time. In our context, ex-ante (ex-post) efficiency is measured by the efficiency of each individual action (outcome). Precisely, contributing is always ex-ante efficient because $c_i < 3g - \text{Exp}[\sum_{j \neq i} c_j] = 150 - 55 = 95$. As for ex-post efficiency, the event that, for some particular group and period, $\sum_j c_j > 150$ only occurs 5 times out of the total of the 1536 observations.

VNM preferences, as the unique BNE should imply beliefs concentrated at 0. This has clear consequences when we look at consistency between elicitated beliefs and actual behavior in Figure 11*b)*, where the cell of the main diagonal corresponds to those situations in which beliefs turn out to be correct. In this respect, we notice that for any given opponents' contribution level s_{-i} modal (point) belief is always 1. This, in turn, implies that subject tend to (under) overestimate opponents' behavior when contribution is high (low).

Do elicitated belief change over time? In Figure 12 we look at the evolution of subjects belief along the experimental timeline.

Fig. 12. Belief dynamics

As Figure 12 shows, the two experimental treatments exhibit two rather different dynamic patterns: while in T_g average beliefs increase with k and stays basically constant over time, in T_c beliefs are less dispersed over k, with a much more complex dynamic evolution. In particular, average beliefs drop dramatically both in the case of $k = 3$ and $k = 1$.

By analogy with Figure 12, in Figure 13 we look at the evolution of best-reply over time, both taking into account the ex-ante and the ex-post interpretation.

Fig. 13. Best-reply dynamics

Each histogram of Figure 13 counts the number of times in which, in each experimental period, each subject played a best response either to *a)* her elicitated beliefs or to *b)* the current opponents' strategy profile. As Figure 13 shows, subjects' average frequency of best-responses is higher when actual behavior is observed. In other words, subjects seem to realize that the mode of the probability distribution that define their belief is not a sufficient statistics to determine optimal behavior. Also notice that, with the sole exception of T_g when $k = 2$, learning effects seem negligible, as average frequency of best-replies stays basically constant over time.

5.2 Panel regressions

To fully exploit the panel structure of our dataset, in this Section we shall run some regressions in which individual heterogeneity is controlled for.

As for our hypothesis testing, we begin by looking at the following simple regression:

$$C_{i\tau}^{kT} = \beta_0^k + \beta_1^k (T_g = 1) + \epsilon_i + \varepsilon_{i\tau}^{kT}, \tag{82}$$

where $C_{i\tau}^{kT}$ is 1 (0) is subject i has (not) contributed in treatment condition (k, T_x) and Period τ, $\epsilon_i \backsim N(0, \sigma_i^2)$ describes the unobserved time-invariant heterogeneity which characterizes subject i and $\varepsilon_{i\tau}^{kT}$ is an idiosyncratic error term (we further assume $\epsilon_i \perp \varepsilon_{i\tau}^{kT}$). In other words, β_0^k $(\beta_0^k + \beta_1^k)$ gives panel estimates of p_c^k (p_g^k), to be used in testing the theoretical conjectures of Section 3. Let $\hat{\beta}_l^k$ denote the corresponding estimate by regression (82). As for $k = 1$, we have $\hat{\beta}_0^1 = .34$ and $\hat{\beta}_1^1 = -.07$ (S.E. .021 and .022 respectively). This confirms the results of Table 8: when $k = 1$ subjects contribute significantly more in T_g than in T_c. Also notice that we cannot reject the hypothesis $p_c^1 = p_{eu}^2 = .373$. As for $k = 2$, we have $\hat{\beta}_0^2 = .42$ and $\hat{\beta}_1^2 = -.01$ (S.E. .022 and .025 respectively). This, again confirms the results of Table 8: when $k = 2$, treatment effects are not significant. By the same token, also in this case we can accept the null hypothesis $p_c^2 = p_{eu}^2$. Finally, when $k = 3$, we have $\hat{\beta}_0^3 = .31$ and $\hat{\beta}_1^3 = .21$ (S.E. .024 and .023 respectively). Consistently with our theoretical conjecture, when $k = 3$, we have more contribution in T_g than in T_c. On the other hand, in both cases, actual contribution is much higher than our "calibrated" forecasts, as derived by Table 3.

We now look further into the relation between contribution and cost levels by estimating, for each of the six treatment conditions the following static panel logit regression:

$$\Pr(C_{ikt} = 1) = \beta_0^{kT} + \beta_1^{kT} c_i + \beta_2^{kT} c_i^2 + \beta_3^{kT} c_i^3 + \epsilon_i + \varepsilon_{it}^{kT}. \tag{83}$$

In other words, for each treatment conditions, we estimate the probability of contributing as a polynomial function of the individual cost level, c_i.

Fig. 14. Estimated switching functions

Figure 14 plots the estimated logit functions, together with the theoretical BNE threshold functions, (2). Since regressions (83) also includes the constant, β_0, we basically estimate a logit function in which the constant proxies the average "utility" associated to the action of contributing, independently on the outcome, that is, the average level of μ_i in equation (3). By the same token, estimated thresholds $c_i^*(k)$ correspond to the estimated logit functions when $c_i = .5$, highlighted by the dotted line in all diagrams of Figure 14, have to be interpreted as the estimated cost thresholds (3) in the theoretical framework of Section 2.1.[10] The estimated thresholds of Figure 14 follow the same ranking of the descriptive statistics of Figure 8: the switching cost is higher (lower) in D_1 than in D_2 when k is low (high), where, for the intermediate level of $k = 2$, the two switching costs are basically identical.

Fig. 15. Panel logit estimations

Equation (83) only considers the relation between contribution decisions and cost level. In Figure 15 we estimate a richer model which includes, together with all explanatory variables in (83) *all* our experimental conditions, as follows:

- **belief** is subject's elicitated belief in Stage 2;
- **forecast_1** is the difference between elicitated belief and actual behavior one period behind;
- **outcome_1** is equal to 1 (0) if, one period behind the public good was (not) produced/not deteriorated;
- **seq** is equal to 1 (2) if the observation is taken from a treatment played first (second) in the sequence;
- τ is the time pointer (see Section 4);
- **TR** is equal to 0 (1) in T_c (T_g).

First notice that, as already know from previous analysis, our treatment dummy act in different directions depending on the level of k, shifting average effort up in (down) in T_g when k is high (low). As for the effect of

[10]In this respect, the estimated constants in all six regressions of Figure 10 are always positive and significant at any conceivable confidence level.

beliefs on contributions, again, we see a different pattern depending on the level of k : contribution moves with beliefs only when k is high. In this sense, together with the fact that subjects tend to overestimate the contribution of others -see Figure 11) implies a gradual reduction in free-riding behavior as k increases. Finally order effects seem to matter, as average effort is lower in treatments played last in the sequence. By contrast, learning effect within a treatment seem negligible, as τ is never significant.

To summarize: even after controlling for all our experimental conditions, the basic message we get from Section 5.1 remains. Prevention is better than cure when k is high (i.e. when is relatively difficult for the public good to be achieved/not deteriorated). When public good provision is relatively easier the opposite holds.

6 Conclusion

Inspired by the seminal works of Kahnemann and Tversky (dated more than 30 years from now), economists have learned that *frames matter* since they affect the way in which people understand problems and plan to solve them. In our paper, we study frame effects in the classic problem of public good provision, a problem which have important policy implications. To this aim, we applied Prospect Theory to get different equilibrium distributions in the four possible different problems. Our basic theoretical conjecture would call for$a$) different contribution probabilities in the two frames tested in the lab with b) more contribution in T_g (basically, because of loss aversion). In this respect, our experimental evidence backs definitely up the first working hypothesis; as for the second, this is only true when k, the threshold below which public good is not provided/not maintained, is high. When k is low, good old VNM theory seem to predict reasonably well. Another interesting feature of our experimental data is that subjects generally contribute more than expected. This evidence is consistent with Andreoni's model of altruism. An interesting spin-off for this paper would be to generalize Prospect Theory to some classic interdependent utility specification.

References

[1] Andreoni, J. and J. Miller (2002): "Giving According to GARP: An Experimental Test of the Consistency of Preferences for Altruism," *Econometrica* 70(2), 737-753.

[2] Camerer, C. (2003), *Behavioral Game Theory*, Princeton NJ, Princeton University Press.

[3] Camerer, Colin F. and Teck-Hua Ho, "Violations of the Betweenness Axiom and Nonlinearity in Probability," *Journal of Risk and Uncertainty*, 8 (1994), 167-196.

[4] Fischbacher, Urs (1999), *z-Tree. Toolbox for Ready-made Economic Experiments*, IEW Working paper 21, University of Zurich.

[5] Kahneman, Daniel and Amos Tversky, "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, 47 (1979), 263-291.

[6] Ledyard, J. (1995): "Public Goods: A Survey of Experimental Research." In John H. Kagel and Alvin E. Roth, eds., *Handbook of Experimental Economics*. Princeton, NJ: Princeton University Press.

[7] J. Ledyard. Public goods: A survey of experimental research. In J. Kagel and A. Roth, editors, *Handbook of Experimental Game Theory*. Princeton University Press, Princeton, 1995.

[8] Mas-Colell, A., M. Whinston and J. Green (1995): *Microeconomic Theory*, Oxford University Press.

[9] Nyarco and Schotter (???), AER.

[10] Olson, M. (1971): *The Logic of Collective Action*, Harvard University Press, Cambridge Massachusetts.

[11] Palfrey, T. and H. Rosenthal (1991): "Testing Game-Theoretical Models of Free-Riding: New Evidence on Probability Bias and Learning." In *Laboratory Research in Political Economy* (Thomas R. Palfrey, ed.), University of Michigan Press.

[12] Prelec, Drazen "The probability weighting function," *Econometrica*, 66 (1998), 497-527.

[13] Tversky, Amos and Daniel Kahneman, "Advances in Prospect Theory: Cumulative Representation of Uncertainty," *Journal of Risk and Uncertainty*, 5 (1992), 297-323.

[14] Wu, George and Richard Gonzalez, "Curvature of the Probability Weighting Function," *Management Science*, 42 (1996), 1676-1690.