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Voluntary contributions to reduce expected public losses

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Abstract: In this experimental study, we ask subjects to allocate tokens between a private investment and a public investment. The latter investment reduces, for all anonymous members of the group, the probability of a loss. Expected loss without public investment is constant across treatments in which the probability of loss and initial wealth vary. In some of these treatments, the participants play under incomplete information (ambiguity). Under the assumption of risk neutrality, the observed behavior allows us to reject, in all treatments, the Nash equilibrium prediction of zero contribution to the public investment. Non-parametric statistical analyses suggest only insignificant difference between treatments in the level and variation of voluntary contributions to the public investment. Parametric regressions, using panel data methods applied to either latent or count variables, shed light on the determinants of the participants' probability of playing the Nash strategy, of their intensity of preference for cooperation, and of their level of voluntary contributions.

Keywords: Voluntary contributions, public losses, risk, ambiguity, experimental data.

JEL codes : H49, D81, C23, C92

1. Introduction

Environmental disasters occur at a startling frequency: one need only think of the number of tornadoes and forest fires in the United States, or of floods in Germany and France during the last couple of years. The mad cow and the foot and mouth deceases are other examples of disasters affecting a great number of people in many European countries. For a given country, in a given year, the probability of such a disaster to occur is far from negligible. The financial losses associated with a disaster could often be reduced by a collective effort. It is, thus, important to know, how much of their personal wealth or effort individuals would voluntarily invest into a collective attempt to reduce the expectation of such losses. Are there circumstances in which people are more willing to contribute than in others? How can we ascertain, for example, whether the residents of a city will be prepared to invest in underground electrical cables to reduce the probability of loss associated with an ice storm as, happened in Québec and New England in 1998/99? Will people voluntarily support a policy of a large campaign of animal vaccination in Europe?

These are the kind of questions that we want to address in our experimental study of a stylized situation, where voluntary contributions to a public investment may reduce the risk of a big loss affecting everybody. The situation is similar to the one of a public good to be financed by voluntary contributions, traditionally examined in the *voluntary contributions mechanism* framework (e.g., Davis and Holt 1993). In our experiment, contributions to the public investment do not yield direct benefits, but rather reduce an expected loss. A typical outcome, reproduced in many experiments on repeated public goods games where contributions to the public investment yield a sure benefit, is to observe substantial expenditures on public goods that clearly exceed the contribution predicted by the Nash equilibrium. We also observe a significant decrease in the contribution to the public good when the final repetition approaches.[1] Several explanations have been advanced to explain these results as *altruistic behavior* (Andreoni 1990, Goeree, Holt and Laury 2002), or by a *warm glow of giving* (Andreoni 1995). Another perspective comes from Sudgen (1984), who postulates behavior that is conditional, or reciprocal. Keser (1999) shows that subjects recognize and signal their interest in cooperation using reciprocity as an instrument.

[1] See the recent reviews of the literature on this subject by Keser (2002) and Holt and Laury (forthcoming).

In most public goods experiments, production of the public good is deterministic and continuously depends on the total contribution of the participants. Some authors have relaxed the continuity assumption of the public good production and introduced into their experimental studies a lower bound (a provision point), which represents the minimum contribution required for production of the public good (see Isaac, Schmidtz and Walker 1988, for example). In these experiments a coordination problem may arise due to the existence of multiple Nash equilibria, implying that a player faces strategic risk with respect to the others' behavior. Dickinson (1998) introduced risk into the production of the public good, suggesting that it may not be produced even when there are positive contributions from the participants. This is the case, for example, for professional sports teams when each member's probability of earning more income increases with the level of effort. Dickinson's results show that the introduction of risk in the production of the public good has no significant effect on the mean contribution level relative to the baseline case of a deterministic production of a public good. Dickinson's example of environmental activists whose efforts reduce the probability of some species becoming extinct is a good illustration of the risk situation we examine in this paper. In our experiment, however, contribution to the public investment reduces the risk of a loss rather than increasing the chance of a gain as in Dickinson's experiment. Kahneman and Tversky (1979) and Loomes and Sudgen (1986) suggest that in risky situations behavior may differ depending on whether losses or gains are at stake[2].

We examine various treatments in our experiments. In some of the treatments, participants play under the condition of pure *risk*, i.e. with the full knowledge of the probability of a loss with and without any voluntary public investment. In other treatments, participants know the amount of the potential loss but have no information about the probability of the loss and its potential reduction through contribution. We refer to this situation as one of *ambiguity*. In all of our treatments, if no contribution to the public account is made, the expected losses are the same.

One of our aims is to examine whether, similar to voluntary contributions to public goods, subjects make voluntary contributions to reduce the probability of substantial losses, and whether the dynamics are similar. We are interested in how behavior varies with the probability of loss, whether

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[2] In riskless public good experiments, a number of studies have found significant differences in the level of cooperation with framing decisions as gains or losses. Andreoni (1995), for example, found that contributions are greater when decisions are framed as gains. Brown and Stewart (1999) examined the influence of initial wealth on the degree of cooperation in a public bad experiment. They observed no significant difference in the situation where, given low initial wealth, net losses were at stake compared to the situation where, given high initial wealth, net gains were at stake.

uncertainty matters, if contributions vary with the size of the original wealth, and whether collective contributions increase or decrease after a loss has been experienced.

In the following section we describe the design of our experimental study. In Sections 3 and 4 we use nonparametric and parametric techniques, respectively, to analyze the data from our experiments. Section 5 concludes the article.

2. Experimental Design

2.1 The Game

Let each of n players be endowed with e tokens to allocate between two alternatives, a private investment X, and a public investment Y. Let $x_i, x_i \in \{0,1,\ldots,e\}$, be the number of tokens that player i invests in X and let $y_i, y_i \in \{0,1,\ldots,e\}$, be the number of tokens that he invests in Y. All tokens must be allocated, i.e., $x_i + y_i = e$.

Each token invested by player i in X yields him a private return of r *Experimental Money Units* (*EMUs*), where $r > 0$. Each token invested in Y reduces the probability of a loss. This loss, if it occurs, affects all n players and amounts to C EMUs to each player. The following equation defines the probability, p, that the loss occurs, depending on the group's investment in Y:

$$p = p^* - \left(\sum_{i=1}^{n} y_i\right) a / ne, \qquad (1)$$

where p^* is the probability of the loss if no collective effort is made, that is, if nobody invests in Y, and a ($a > 0$) is a constant. The second term of equation (1) shows how the probability of loss declines with the group's contribution to the public investment Y. At the limit, if $\sum y_i = ne$, then $p = p^* - a$. Thus, the constant a determines by how much the probability of the loss decreases if all players allocate their entire endowment to Y.

Assuming risk neutrality of all players allows us to consider for each player i (i = 1,…, n) the following expected individual payoff, Π_i, of this game:

$$\Pi_i = rx_i - \left[p^* - \left(y_i + \sum_{j \neq i} y_j \right) a / ne \right] C . \quad (2)$$

Under the assumption of risk neutrality, the typical public good conditions are satisfied if the following two parameters conditions are satisfied at the same time:

- If $r > \frac{Ca}{ne}$, the return of a token allocated to the private investment *X* exceeds the expected loss reduction associated with placing the same token into the public investment *Y*. This implies that the dominant strategy for each individual is to invest nothing in *Y*. In other words, economic theory predicts free-riding behavior for all players.

- If $\frac{Ca}{e} > r$, the collective return of each token invested in *Y* is greater than the individual return of the same token invested in *X*. The collective optimum is thus realized if all players invest all of their tokens in *Y*.

2.2 The treatments

We consider five different treatments, in all of which we keep the expected loss in the absence of investment in *Y* constant. More specifically, with initial probabilities, $p*$, set equal to either 20% or 40%, and the corresponding losses, *C*, at 1000 or 500 EMUs, respectively, the expected loss without investment in *Y* equals 200 EMUs in each treatment. Furthermore, for each token invested in *Y*, we assume that the reduction in the expected loss is the same in all cases. With $n = 3$ and $e = 10$ in all treatments, the parameter a is adjusted to ensure that this condition is maintained. Specifically, $a = 0.15$ when $p^* = 20\%$ and $C = 1000$, and $a = 0.30$ when $p^* = 40\%$ and $C = 500$. The reduction in expected loss per token thus is $\frac{aC}{ne} = \frac{150}{30} = 5$ in all treatments. The private return, *r*, of a token invested in *X* is equal to 10 EMUs in all cases. Therefore, the expected marginal rate of substitution of the private investment for the public investment, under the assumption of risk neutrality, is held constant at ½ across all treatments.[3] The participants begin the experiment with an initial wealth (account balance), W, equal to 7,500 EMUs or 15,000 EMUs. In some of the treatments, the participants play under conditions of *ambiguity*, that is, knowing neither the probability of loss if no tokens are invested in Y nor of the level of risk reduction associated with each invested token. They are, however, informed of the size of the potential loss. In the treatments with *risk*, the players have completed information of the size of the potential loss, the probability of loss if no tokens are invested in Y, and of the level of risk reduction associated with each invested token. Table 1 gives an overview of the treatment design.

Table 1

Presentation of the treatments

Treatment	Initial probability p*	Loss C	Initial endowment W	Ambiguity
R20.7500	20%	1000	7,500	No
A20.7500	20%	1000	7,500	Yes
R40.7500	40%	500	7,500	No
R40.15000	40%	500	15,000	No
A40.15000	40%	500	15,000	Yes

Note: The treatments are identified by the letters R and A, designating experiments conducted under risk and under ambiguity, respectively. These letters are followed by the probability of loss and the initial wealth in EMUs.

For each treatment, we have eight independent groups of three participants. The game is repeated over 100 periods with the (anonymous) membership of the group unchanged over time.

In the risk treatments, assuming risk neutrality, the unique subgame perfect equilibrium is obtained by backward induction: it consists of making no investments in Y. The social optimum is to invest everything in Y. In the treatments with ambiguity we have multiple Bayesian equilibria. Among those, we select the subgame perfect equilibrium of the respective risk treatment as a unique benchmark solution for the game with ambiguity.

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[3] This marginal rate of substitution for a riskless public good situation, was described by Ledyard (1995). Isaac, Walker, and Thomas (1984) called it the marginal per capita return (MPCR). In our model, the expected marginal rate of substitution of the private investment for the public investment is : $\dfrac{\partial \Pi_i / \partial y_i}{\partial \Pi_i / \partial x_i} = \dfrac{(aC / ne)}{r}$.

The experiments were conducted in the experimental economics laboratory LUB-C3E at CIRANO. The participants were drawn from several Montreal universities, with the bulk of students from business administration and economics. The instructions in French (an English translation is available in the Appendix B) were distributed and read aloud to the participants. A questionnaire was used to ensure that the rules were understood before the sessions began. The participants received an average of 21Canadian dollars for about one hour of effort.

2.3 Objectives

Among our broader goals in this study is to ascertain whether, under the various treatments, participants make voluntary contributions to reduce the risk of substantial losses at a level similar to the one in public goods situations where each contribution yields a visible return (33 percent following Ledyard 1995). Do contributions show similar dynamics leading to a decline of the overall contribution level over time? Do we observe reciprocity that shows in the orientation of one's contribution level at the others' contribution in the previous period?

Beyond these questions focusing on the comparison with the standard public good situation, we want to examine how individuals behave subsequent to a loss. Is a greater collective effort observed? The event of a loss occurring provides the occasion for a reassessment of the participant’s strategy, and one would expect a natural disaster to galvanize efforts geared at prevention. This corresponds to the availability hypothesis that a recent loss is more available in memory (Tversky and Kahneman 1973) and thus temporarily increases the subjective probability of a current loss. However, individuals may have the opposite reaction, supposing that such an event is not likely to recur soon. This obviously implies an erroneous belief in conditional probabilities, a form of *gambler's fallacy* as in Camerer and Kunreuther (1989a).

Furthermore, based on the comparison of the various treatments, we attempt to answer the following three questions:

(Q1) *Do people respond differently to ambiguity than to risk?* Comparison of the results of experiments R20.7500 and A20.7500, and those of R40.15000 and A40.15000, will reveal whether or not participants respond with less collective effort (or less reciprocity toward others’ efforts) to ambiguity than to risk? In Cohen, Jaffray and Said (1987), this is referred to being pessimistic or averse to ambiguity. Camerer and Kunreuther (1989a)

observe that, in an experimental insurance market, prices are not affected by ambiguity about the probability of a loss.

(Q2) *Is people's behavior affected by whether they face a small or a large probability of a loss?* Comparison of the R20.7500 and R40.7500 treatments will illustrate the role played by the different probabilities of a loss. Kahneman and Tversky (1979) observe that individuals overestimate small probabilities in lotteries. Other authors (see Camerer and Kunreuther 1989b) find that small probabilities are ignored. An objection could be made that 20% is not a small probability although, compared to 40%, it is relatively small. To generate several losses with extremely small probabilities in the laboratory we would need to have our participants play a very large number (thousands) of periods. This would impose logistic problems and, in particular, participants would likely become bored or tired of the game.

(Q3) *Does initial wealth affect people's behavior when a subject's account balance might become negative?* Comparison of R40.7500 and R40.15000 will reveal the role played by different initial wealth. Brown and Stewart (1999) observed no significant wealth effect (see also Footnote 2). It should be noted that for the treatments in which the initial wealth is 7500 EMUs, the mathematical expectation is of a negative concluding wealth after 100 periods when no tokens are invested in *Y*. The real loss was ex-ante not obvious to the participants. They were informed that their account balance would be converted to Canadian dollars at a rate of 25 cents per 100 EMUs, but they were not told that they were guaranteed a minimum payment of $10 per participant. It is difficult to have participants experience real loss in an experiment, as was emphasized by Cohen, Jaffray and Said (1987).

3. Experimental Results

Table 2 summarizes some descriptive results on the voluntary contributions observed in our experiments. Obviously, the dominant strategy under risk neutrality of zero contribution to *Y* does not explain the participants’ behavior on the aggregate. At the same time, the observed average contributions in all five treatments are far below the efficient level of the full contribution of all 10 tokens. The average contributions in the various treatments, divided by the group optimal level of full contribution, yield efficiency levels varying between 22% and 32%. These are below the average efficiency level of 33% reported by Ledyard (1995).

Table 2

Statistics on voluntary contributions (by treatment)

Treatment	Mean	Median	Mean standard deviation in groups	Mean 1st period	Median 1st period	Mean Period 1-50	Mean period 50-100
R20-7500	3.25	3	2.11	5.25	5	3.23	3.27
A20-7500	2.22	2	1.90	4.29	5	2.38	2.05
R40-7500	2.57	2	2.47	4.17	4	2.82	2.32
R40-15000	3.02	3	2.61	3.92	5	3.29	2.75
A40-15000	2.88	3	2.63	4.13	4.5	3.19	2.57

Pairwise comparisons of the treatments yield no significant differences in the contribution levels. In no case does the Wilcoxon-Mann-Withney (WMW) U-test based on the contribution levels (average or median) of the independent groups allow us to reject the null hypothesis (10% significance level, two-sided testing). Thus, neither ambiguity (Q1), nor the different probabilities of a loss (Q2), nor the different levels of initial wealth (Q3) have a significant impact. Note that the ratio of expected individual return of public investment and the return of private investment, is held constant across treatments.[4]

When we consider the average standard deviation of contributions in the groups, we observe significant influence neither of ambiguity (Q1), nor of the probability of a loss (Q2), nor of wealth (Q3) (WMW U-tests based on the standard deviations of the independent groups, 10% significance level, two-sided testing). We observe, however, a significant joint wealth-probability of loss effect on the standard deviation. The standard deviations in the treatments R40.15000 and A40.15000 are larger than those in R20.7500 (WMW U-test, 5% significance level) and A20.7500 (WMW U-test, 5% significance level). In other words, the larger the initial wealth and the probability of a loss, the higher is the standard deviation.

[4] Isaac, Walker and Thomas (1984), for example, have found an important impact of this variable (the marginal per capita return) on observed contribution levels. This does not apply here.

Contributions to *Y* during the first period are of interest, because at that point the participants can only speculate on the behavior of the other group members. Furthermore, the first-period contribution frequently determines the long-run contribution level in a group (Keser and van Winden 2000, Fehr and Gächter 2000). In keeping with these previous results on riskless public goods, when we pool our data of all five treatments, the Spearman's rank correlation coefficient shows a significantly positive correlation of 0.307 between the first-period contribution and the average contribution over all following periods in the group (5% significance level, one-sided). Thus, and given that the overall contribution levels do not significantly differ, it is not surprising that WMW U-tests reveal that the individual first-period contributions do not differ significantly across treatments. According to Ostrom (2000), subjects contribute between 40 and 60 percent of their endowments in the typical public goods experiments in a one shot-game as well as in the first round of finitely repeated games. As can be seen in Table 2, our results fall in the lower part of this range.

The contribution level to the public investment shows a tendency to decline over time. Comparing the mean voluntary contributions in the first fifty periods with those in the last fifty, we observe in each treatment a decline, except for treatment R20-7500 (see Table 2). The decrease is not statistically significant when considering each treatment individually. However, the sign test indicates that this decrease is statistically significant if we pool the observations of all treatments (two-sided sign test, 5% significance level): 27 of 40 groups exhibit a decline.

Figure 1 presents the distribution of individual contributions of all subjects in all treatments and all periods. Obviously, there is a single mode at a contribution of zero token. Contributions of 6 or more tokens occur only rarely. This is in contrast to many public good experiments where a bimodial distribution is observed, with modes at zero contribution and contribution of the entire token endowment.

Table 3 looks at free-riding and endgame behavior by treatments using definitions from Keser and van Winden (2000): a participant who always plays the Nash strategy, i.e., never invests in *Y*, is considered a strong free rider (only one participant in our study fell into that category). A weak free rider is a participant who plays the Nash strategy during at least 50 percent, but less than 100 percent of all periods. We use a corresponding definition for weak and strong cooperators (requiring the allocation of all 10 tokens to *Y*), but not a single weak or strong cooperator can be identified in our experiments. A participant is demonstrating an endgame behavior if he plays the Nash strategy during the last period(s) after having contributed positive amounts during at least 50 percent of the previous periods. Column 1 in Table 3 presents the number of groups (out of 8 groups in each treatment) with at least one weak free rider. We observe that overall 23 of the 40 groups have at least one weak free rider. We conclude that weak free riding arises, but is not statistically significant (one-sided binomial test, 5% significance level). Considering the number of groups with at least one end-game player presented in Column 2 of Table 3, we reject a significant prevalence of endgame behavior (two-sided binomial test, 5% level) given that only 27 of 40 groups have at least one end-game player. For those who showed an end-game behavior, we note that the longest end game duration is 20 periods while 80% of the end games last 4 periods or less.

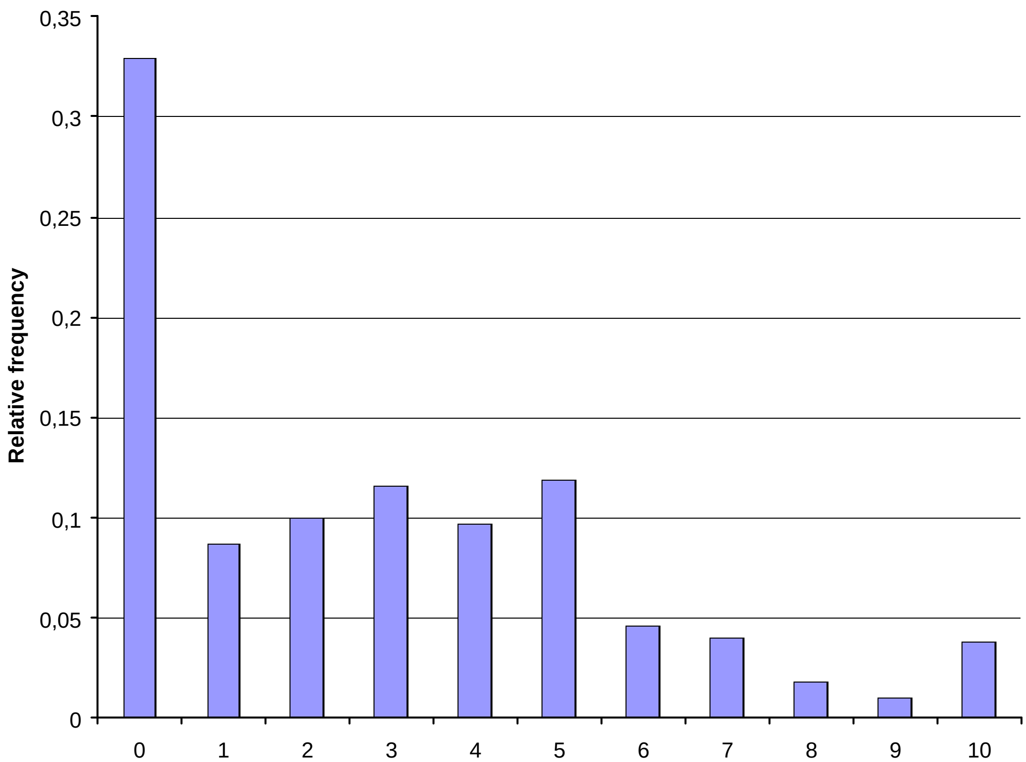

Figure 1: Distribution of contributions to *Y* (all treatments)

Table 3
Free-riding and end-game behavior

Treatment	(1) # groups with at least one weak free rider	(2) # groups with at least one end-game player
R20-7500	3	6
A20-7500	6	6
R40-7500	4	5
R40-15000	5	4
A40-15000	5	6
All	23 of 40	27 of 40

We know from previous public goods experiments (in particular, Keser 2000) that a subject orientates his or her contribution at the others' average contribution observed in the previous period. In Keser and van Winden (2000) such reciprocity is defined in a qualitative way: *if a subject changes his contribution from one period to the next, he adjusts it towards the previous group average. In other words, he increases his contribution if it was below the group average in the previous period and decreases it if it was above.* Given this definition of reciprocity, we observe in our experiments that in each individual group, subjects, if they change their contributions, react in the majority of cases in a reciprocal way. Thus, applying the binomial test, we may conclude that subjects significantly tend to change their contributions in a reciprocal way (1% significance level, one-sided test, overall and for each treatment). If we analyze reciprocity separately in the case of no loss in the previous period and the case of a loss in the previous period, we observe that in the case of no loss, again all 40 groups react in the majority of cases in the predicted way. However, in the case of a loss, only 28 of the 40 groups react in the majority of cases in the predicted way. Thus, immediately after a loss, reciprocity is failing significance at the 5 percent level (one-sided binomial test).

Thus, let us further examine the behavior after a loss, ignoring reciprocity. When we compare the number of cases that an individual increased his contribution after a loss to the number of cases that an individual decreased his contribution after a loss, we observe that in 23 of the 40 groups the majority of individuals increased their contributions while in 13 of the groups the majority of individuals decreased their contributions. We may conclude that over all treatments there is a tendency to increase rather than decrease one's contribution in the periods after a loss has occurred. This would support the hypothesis that a recent loss is more available in memory than the gambler's fallacy hypothesis. However, this tendency is not statistically significant if we require significance at the 5 percent level (one-sided binomial test).

What explains the observed decrease in the contribution level over time? The end-game behavior alone can probably not account for the observed decline from the first set of 50 periods to the second set of 50 periods. Over all treatments there are 31 groups where we observe more often that a subject's individual contribution was below rather than above the others' contribution in the previous period, while we observe only 8 groups where the opposite was true. We have seen before that in case that a subject changes his contribution he tends to increase it in the case that his own contribution was below the average and to decrease it in the case that his own contribution was above the average. We have ignored so far the number of cases that a subject has not changed his contribution from one period to the next. While in the case that a subject's contribution was below the others' contribution in the previous period we observe that in 54 percent of the cases the subject did not change his contribution, we observe only 39 percent of unchanged contributions in the case that a subject's contribution was above the average. Thus, the decrease becomes more important than the increase. This can explain the overall decrease.

4. Regressions

In our experiments, interdependence between the members of a group is a key feature. But, since the groups are assembled randomly, and since their membership is anonymous, voluntary contributions to the public investment, *Y*, by other members of a given group in the previous period explicitly account for the interaction between group members. To explain individual data, in Section 4.1, we condition our regressions on this variable to resolve the identification problem associated with this reflection problem or endogenous interactions (see Manski 1993**,** 2000).

Our experimental data set consists of pooled time-series and cross-section data. Each participant is required to play 100 times. The individual effect in panel regressions can be interpreted as an idiosyncratic measure of attitude toward risk of the participants (see Hoffman, Libecap and Shachat 1998). Controlling for attitude toward risk is important since the subgame perfect equilibria considered for the risk treatments-also a benchmark solution for the game with uncertainty-assumes risk neutrality of the participants.

To complete the econometric analysis, in Section 4.2, we analyze group data regressions.

4.1 Individual data

We consider three econometric models. The *first model* relates to the *Nash equilibrium*, that predicts zero contribution to the public investment Y under the risk neutrality assumption. We use a probit model with random effects to explain the determinants of participants playing this strategy.

Let the latent variable N_{it}^{*} measure individual *i*'s propensity to play the Nash strategy in period t, explained by a vector of observable variables z_{it}, the corresponding parameter vector d, a random individual component h_i, and a random variable e_{it}:

$$N_{it}^{*} = z_{it} d + e_{it} + h_i, \quad i = 1, \ldots, n, \quad t = 1, \ldots, T. \tag{3}$$

The two random elements are independent and distributed normally with mean zero.

The latent variable N_{it}^{*} is unobservable, but we do observe individual i playing the Nash strategy in period *t* if he does not contribute any tokens to *Y*. Thus, we use the auxiliary variable N_{it}

$$N_{it} = \begin{cases} 1, & \text{if } N_{it}^{*} > 0, \\ 0, & \text{otherwise.} \end{cases} \tag{4}$$

with $N_{it} = 1$ if the individual plays Nash and 0 otherwise. Greene (1995) derived the corresponding likelihood function for this model.

Our *second model* examines the determinants of *intensity of preference for cooperation*, J_{it}^{*}, of participant i at period t, that is, how much people are motivated to cooperate in order to reduce expected public losses. This unobservable latent variable is explained by a vector of exogenous variables x_{it}, the corresponding parameter vector b, a random individual component h_i, and a random variable e_{it}:

$$J_{it}^{*} = x_{it} b + h_i + e_{it}, \quad i = 1, \ldots, n, \quad t = 1, \ldots, T, \tag{5}$$

where, $e_{it} \sim N(0,1)$ and $h_i \sim N(0, s^2)$.

To estimate this model, we use an ordered probit with random effects. We consider the number of tokens invested in Y to be an ordinal measure of the intensity of preference for cooperation of the participants. We must, however, specify how the number of tokens invested by individual i at period t is related to the intensity of preference for cooperation. Let the observed counterpart, J_{it}, of the latent variable, be defined as:

$$J_{it} = \begin{cases} 0, & \text{if} \quad J_{it}^{*} \le m_0, \\ 1, & \text{if} \quad m_0 < J_{it}^{*} \le m_1, \\ 2, & \text{if} \quad m_1 < J_{it}^{*}. \end{cases} \tag{6}$$

We arbitrarily define $J_{it} = 0$ as the *uncooperative* behavior of participant i in period t who invests between zero and two tokens. Following definition (6) this implies that the intensity of preference for cooperation is less than a threshold parameter m_0 to be estimated. Similarly, we define $J_{it} = 2$ as the *very cooperative* behavior of participant i in period t who invests eight tokens or more. This implies that the intensity of preference for cooperation is greater than a threshold parameter m_1 to be estimated. In between these two cases, we define $J_{it} = 1$ as the *cooperative* behavior of participant i in period t who invests between three and seven tokens. This implies that the intensity of preference for cooperation is between the threshold parameters m_0 and m_1.[5] Greene (1995), among others, presents the likelihood function for this model.

The *third econometric model* explains the *level of voluntary contributions*, taking into account that it is a non-negative integer with the value zero often observed. We consider tokens invested in Y as count data. Unlike in the previous models, the explained variable (the number of tokens invested in *Y)* is not latent. We now assume that participants decide exactly how much they want to invest in *Y*, and then seek to understand the determinants of these voluntary contributions. Thus, we use the negative binomial model with random effects in this econometric analysis. Explicitly, we assume that the distribution of the probability that a number y_{it} of tokens invested by individual i during period t is a Poisson distribution with mean $l_{it} = \exp(x_{it} b + m_i)$. The random term m_i distributed as

[5] Note that for identification purpose, when there is a constant in the regression equation of J_{it}^{*}, we set $m_0 = 0$.

Gamma with parameters (d_i, d_i) produces the negative binomial model with a parameter that varies between individuals and over time (as in the linear composite-error model with a single element). To facilitate integration of the nuisance variable and obtain the marginal probability, we examine the ratio $d_i/(1+d_i)$, which is distributed as a Beta random variable with parameters (a,b). In short, the random effect is added to the negative binomial model by assuming that the overdispersion parameter is randomly distributed across individuals. The contribution of individual *i* to the likelihood in this model is[6]:

$$p(y_{i1},\dots y_{iT}) = \frac{\Gamma(a+b)\Gamma\left(a+\sum_{t=1}^{T} l_{it}\right)\Gamma\left(b+\sum_{t=1}^{T} y_{it}\right)}{\Gamma(a)\Gamma(b)\Gamma\left(a+b+\sum_{t=1}^{T} l_{it}+\sum_{t=1}^{T} y_{it}\right)}\prod_{t=1}^{T}\frac{\Gamma(l_{it}+y_{it})}{\Gamma(l_{it})y_{it}!}, \tag{7}$$

where $\Gamma(\cdot)$ is the Gamma function.

The standard assumption in such models (of count data) is that the probability of high counts gradually diminishes, becoming infinitesimal. Our data are arbitrarily truncated at ten, the maximum number of tokens that can be invested in *Y*. In the context of panel data this truncation issue is complex, and is simply ignored in this paper. Notice that when we aggregate our data across all treatments, the observed frequency of ten tokens invested in *Y* is 3.77%, and the frequency of zero token is 32.92%. Full discussion of this model can be found in Cameron and Trivedi (1998).[7]

In Table 4 we present the explanatory variables used in the econometric analysis, the symbol for the variable, and a short description of its construction. *SEXM* is a dummy variable for gender, followed by *D1PERD* and *DL5PERD*, dummy variables to account for first and last period effects. *LYOTHER* records the other group members' contribution to *Y* in the preceding period. A positive estimated coefficient of this variable in the cooperation and in the contribution model and a negative estimated coefficient in the Nash model will suggest that participants tend to reciprocate to some extent the contribution of the others. Thus, *LYOTHER* is our reciprocity variable. Other authors,

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[6] See Hausman, Hall and Griliches (1984).

such as Dickinson (1998), use the difference between individual *i*'s contribution and the mean of the other group members' contribution to account for reciprocity. One difficulty with that approach in a parametric framework is the endogenous nature of a deviation variable.[8] It includes the lagged dependent variable and may thus be correlated in a panel model due to the presence of an individual effect. This situation becomes even more complicated in the case of the nonlinear models we use.[9] The coefficient of the cross-effect variable *LYOTHSEX* will measure differences in reciprocity between men and women. The variable *LLOSS* will permit to assess the participants' reaction to the occurrence of a loss in the previous period.

The other variables in Table 4 are associated with wealth. *LWEALTH* is the net balance at the end of the preceding period. This balance fluctuates and is generally positive, but it is important to bear in mind that it can be negative, and did indeed fall below zero in two treatments with an initial endowment of 7500 EMUs.[10] That is why we constructed the variables *LWNEG, LWPOS and LWPOS+*, representing negative and positive segments of *LWEALTH.*

An important consideration raised by Kahneman and Tversky (1979) is that wealth effects on decisions under risk are nonlinear. In other words, utility functions are concave for gains (implying risk aversion) and convex for losses (implying risk seeking), where gains and losses are defined with respect to a reference point, e.g. *LWEALTH.* To account for such nonlinearities in our regressions, we use a piece-wise linear form, as in Lévy-Garboua and Montmarquette (1998). The wealth variable is decomposed in positive and negative segments, where the length of these segments is dictated by the need for sufficient observations in each segment. To illustrate, *LWPOS+* is constructed as the interaction between the variable *LWEALTH* and a dummy variable d**,** where $d = 1$ if $qs < LWEALTH$, with s the standard error of *LWEALTH* and q a positive parameter; $d = 0$ otherwise. We see that the effect of the variable *LWEALTH,* when it assumes values in the interval under consideration, is equal to the sum of estimated coefficients of the variables *LWEALTH* and *LWPOS+*.

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[7] An alternative model to explain the probability of not contributing to Y and the level voluntary contributions is a panel generalized Tobit. However, this model supposes a continuous dependent variable, which is clearly not the case in our experimental data.

[8] We use a qualitative deviation measure in our nonparametric analysis of the data.

[9] Dickinson (1998) estimated unanticipated positive coefficients for the deviation variable.

[10] These treatments are A20.7500 and R40.7500.

Table 4

Explanatory variables of the econometric models

Symbol	Definition
SEXM	1 if the player is male; 0 otherwise.
D1PERD	1 in period one of the game; 0 otherwise.
DLA5PERD	1 in the last 5 periods of the game; 0 otherwise.
LYOTHER	Number of tokens invested in Y by the other group members in the preceding period.
LYOTHSEX	Crossed-effect between SEXM and LYOTHER.
LLOSS	1 if a loss occurred in the preceding period; 0 otherwise.
LWEALTH	The player's account balance at the end of the preceding period.
LWNEG	The negative value of LWEALTH; 0 otherwise.
LWPOS	The positive value of LWEALTH; 0 otherwise.
LWPOS+	The positive value of LWEALTH if greater than a specified value; 0 otherwise.

4.1.1 Estimates with Pooled Treatments

The nonparametric analysis suggests that there is no significant difference between the treatments at the level of the voluntary contributions. A simple confirmation of this result by parametric analysis can be obtained by combining all the data and differentiating between the treatments by use of dummy variables in the regressions. This aggregation relies on two assumptions: i) that the slopes of the explanatory variables do not vary significantly between treatments, and ii) that we can ignore the issue of variations in (unobserved) heterogeneity across treatments. Under these assumptions, to be relaxed later, we have the opportunity to examine the influence of certain variables on the probability of playing the Nash strategy, on the intensity of preference for cooperation, and on the level of voluntary contributions. Table 5 presents the regression results for the three models. For simplicity we restrict the wealth nonlinearity effect to two linear segments of loss and gain.

Assuming risk neutrality, the first set of results reports the determinants of the probability of participants playing the Nash strategy. If participants are risk averse, we can speculate that they are less likely to play Nash by seeking a form of collective insurance against expected losses. Thus, the regressions are not an unequivocal test of the Nash equilibrium. They present, nevertheless, the determinants of zero contribution to *Y* that we will simply associate with the Nash strategy. Note that the random effect probit model is confirmed by the statistically significant r coefficients. As discussed earlier, heterogenous risk attitutes may represent an important part of those individual effects.

We observe *a first period effect*, signaling a potential interest to cooperate, that decreases the probability of the Nash strategy being played and a last periods effect, an end game effect, that increases this probability. There is a gender effect with the male participants being more likely to play Nash than the female participants. In the event of a loss occurring, the probability of playing Nash increases in the following period. This suggests a ¨gambler's fallacy¨ effect in the participants' behavior. As usual in public goods experiments, we observe a reciprocity effect: the greater the voluntary contribution of other group members to *Y*, the less the participant will be inclined to play the Nash strategy during the following period. This reciprocity effect is less important for men than for women. For the wealth variables, an increase in the positive balance, *LWPOS*, reduces the probability of adopting a Nash strategy, while a more negative balance, *LWNEG*, increases it. This result is in some respect consistent with Kahneman and Tversky's (1979) prospect theory, according to which people tend to be risk-seeking when they face a potential loss and risk-averse when they face a potential gain. In our experiment, if we ignore the *strategic risk* of the players' interaction and consider the *risk of a loss* only, being risk-averse to loss implies being less likely to play Nash, and being risk-seeking implies being more likely to play Nash.[11] The coefficients of the treatment dummies are evaluated relative to the R20.7500 treatment (the omitted treatment). *Ceteris paribus*, the probability of playing the Nash strategy is higher in R40.7500 and and in particular in R40.15000 than in the reference treatment. Thus, both a higher probability of loss and a higher initial wealth in the risk treatment increase the probability of playing Nash. In the ambiguity treatment with the same probability of loss and the same initial wealth as in the reference treatment, we observe a small but statistically insignificant increase in the probability of playing Nash. The increase is substantial, however, in the ambiguity treatment with a higher probability of loss and a higher initial wealth.

For the intensity of preference for cooperation and for the level of voluntary contributions model, we expect the signs of the estimated coefficients for several variables (including the dummies for

[11] We are aware of the fact that in our game situation there exist other risks than the risk of loss. For example, if we consider the strategic risk of a player's contribution to *Y*, not knowing the contribution of others, a player who is more 'risk-averse' to the behavior of others should be more likely to play Nash while the 'risk-seeking' player should be less likely to play Nash.

the different treatments) to be opposite to their counterparts in the Nash model. Variables that have the effect of increasing (decreasing) the probability of the Nash strategy, should reduce (increase) the intensity of preference for cooperation and the level of voluntary contributions.[12] This is what we observe in our regressions with few exceptions only. For example, in the intensity of preference for cooperation model, the coefficient of the variable *SEXM* is not significant. It is significant, and negative for the level of voluntary contributions model. This implies that men contribute less than women to *Y*, but that the difference in the number of tokens contributed to *Y* falls within the categories we established for the intensity of preference for cooperation latent variable. Also, *LYOTHSEX*, statistically insignificant in the Nash equation, is positive and statistically significant in the intensity of preference for cooperation and in the level of voluntary contributions model. Thus, men react more than women to the contribution of others.

For the models explaining the intensity of preference for cooperation and the level of voluntary contributions, we find estimates of the relevant parameters *s* , a, b that indicate the pertinence of the random effects specification.

The coefficients of the dummy treatment variables are statistically significant (reference treatment is R20.7500). Moreover, there are clear differences between the estimated coefficients of some of the dummies. These results appear to contradict those of the nonparametric analysis. This contradiction may be more apparent than real, however. One indication of this can be found in the results for the level of voluntary contributions model, which, being the only model without latent variables, lends itself to nonparametric comparison of the means. For this model, in comparison with the omitted reference treatment,R20.7500, the coefficients of the other dummy variables are negative and statistically significant, indicating lower contributions, which is consistent with the results presented in Table 2. It is likely that to obtain significant differences the nonparametric tests require greater differentials than those based on the parametric estimates, since they are based on very few observations. Though the means of the voluntary contributions may be deemed nearly equal across treatments, the process by which they are generated might very well differ. To examine this issue, we now relax the assumption of equal slopes for the explanatory variables across treatments.

[12] However, this does not have to be exactly symmetric as the latent Nash variable translates empirically into a binary decision while the observed matching parts for the latent intensity of preference for cooperation variable are categorized and the level of voluntary contributions is an observed variable.

Table 5
Panel estimates for the Nash equilibrium, the intensity of preference for cooperation, and the level of voluntary contributions (Pooled treatments)

	Nash equilibrium	Intensity of preference for cooperation	Level of voluntary contribution
Constant	**-0.841****	**-0.670****	**2.699****
	(0.076)	(0.098)	(0.031)
D1PERD	**-0.899****	**1.411****	**0.659****
	(0.151)	(0.217)	(0.063)
DLA5PERD	**0.268****	**-0.087**	**-0.092****
	(0.042)	(0.062)	(0.023)
SEXM	**0.541****	**0.104**	**-1.076****
	(0.054)	(0.067)	(0.02)
LYOTHER	**-0.051****	**0.038****	**0.028****
	(0.004)	(0.005)	(0.001)
LYOTHSEX	**0.015****	**0.016****	**0.009****
	(0.005)	(0.006)	(0.002)
LLOSS	**0.333****	**-0.076****	**-0.098****
	(0.024)	(0.029)	(0.012)
LWNEG	**-0.118****	**0.070****	**0.118****
	(0.014)	(0.016)	(0.007)
LWPOS	**-0.073****	**0.078****	**0.032****
	(0.003)	(0.005)	(0.002)
A20.7500	**0.034**	**-0.975****	**-1.064****
	(0.067)	(0.091)	(0.027)
R40.7500	**0.699****	**-0.592****	**-1.855****
	(0.07)	(0.09)	(0.028)
R40.15000	**1.177****	**-1.573****	**-2.262****
	(0.077)	(0.092)	(0.027)
A40.15000	**0.906****	**-1.603****	**-1.977****
	(0.072)	(0.092)	(0.027)
r	**0.405****		
	(0.015)		
m_1		**3.256****	
		(0.01)	
s		**1.284****	
		(0.031)	
a			**1.849****
			(0.339)
b			**1.552****
			(0.195)
Log-L	**-5483.86**	**-8527.42**	**-23685.30**

Number in parentheses are estimated standard errors
** Significant at 1% level

4.1.2 Results by Treatment and Comparisons of Treatments

In the Appendix A, we present for each treatment the estimates of the determinants of the probability of playing the Nash strategy, the intensity of preference for cooperation and the level of voluntary contributions. Relative to Table 5, we retain more complex nonlinear relationships (when justified by the value of the likelihood function) for the wealth variable.[13] We observe that the probability of zero contribution to Y is not overwhelmingly supporting the Nash equilibrium prediction derived under the assumption of risk neutrality. It could, however, be compatible with equilibrium predictions under the assumption of risk aversion. This result is in keeping with what is found in risk-free public goods experiments. In contrast to what is found in risk-free public goods experiments, the first-period effect, *D1PERD*, is never significant for treatments in which the probability of loss is 40%. The endgame effect, *DLAS5PERD*, which is nearly always observed in public goods experiments without risk, is present in our study in all treatments involving ambiguity, but only occasionally in the risk treatments. Reciprocity, *LYOTHER*, is less apparent in situations of ambiguity. The fact that a loss has occurred, *LLOSS*, always increases the probability of playing the Nash strategy. Together with the fact that the realization of a loss never affects the intensity of preference for cooperation, and sometimes reduces voluntary contributions this provides evidence that the changes in the level of voluntary contributions occur within the categories that we established to distinguish between uncooperative (0–2), cooperative (3–7), and very cooperative (8–10).

Our experiments allow us to introduce a wealth effect with losses and gains (see Table 4 for the definition of the relevant variables). We allow for the possibility that wealth has nonlinear effects on our dependent variables. First, notice that the nonlinear specification of wealth effects is always statistically significant for treatments with a 20% probability of loss. Furthermore, this nonlinearity is almost always rejected in the case of treatments with a 40% probability of loss and an initial wealth of 15000 EMUs[14]. The question arises whether this is attributable to the fact that, with a 40% probability of loss, a good deal of noise is introduced into the evolution of the experiment, creating an incentive for the participant to avoid modifying their behavior. Moreover, it

[13] Discussion of the detailed results by treatment is tedious and are omitted in this version of the paper.

[14] Because of multicollinearity, some of the coefficients of these variables are not significant taken individually. They are nonetheless retained in the tables because of the results of a likelihood ratio test indicating specification error when they are removed.

appears that the amount of the initial endowment also plays a role. We observe that in the treatments with the higher initial endowment, 15,000 EMUs, wealth effects across the three models are similar, even when nonlinear effects are retained. When the endowment is only 7500 EMUs there is so little evidence of a pattern that the results need to be analyzed on a case-by-case basis. It seems reasonable to speculate that greater initial wealth also ensures stability in the wealth effect. Note that negative wealth has been experienced by some participants in two treatments yielding statistically significant but different effects: negative wealth decreases the probability of Nash and increases the level of voluntary contributions in treatment A20-7500 but it goes in the opposite direction in treatment R40-7500.

What about the effects of the participants' gender on their behavior? Generally, the dummy variable *SEXM* is more significant than the interaction variable, *LYOTHSEX*. The results for the *SEXM* variable imply that women are more cooperative and contribute more to *Y*. At the same time, men's reaction to the contribution of others is greater than women's, a phenomenon that is observed for all treatments in which this interaction variable is significant.

Finally, analysis of the marginal effects and the simulations to account for the relative importance of the explanatory variables (detailed results available upon request) suggests that in many cases effects related to the period, gender, and wealth dominate those related to the occurrence of a loss and reciprocity.

4.2 Estimates for Group Data

Table 6 presents the results of a parametric analysis of group data. The goal of these linear panel estimates, with fixed or random effects on both the groups and the periods, is to establish whether the number of women in a group, *NWOMEN*, exercises an impact on the average level of the group's contribution to *Y*, and to test the impact of the number of losses during the preceding five periods *NLOSS5P*. Our results reveal that, though positive, the number of women in a group does not significantly impact the group's mean contribution. As to the occurrence of losses during the five preceding periods, we find that in three of five treatments this variable has a significantly negative impact on the groups' mean contribution during subsequent periods. This is in keeping with the¨gambler's fallacy¨ hypothesis.

Table 6
Voluntary contributions of the groups
(Linear Two-way random-effects model by groups and periods)[a]

	R20.7500		A20.7500		R40.7500		R40.15000		A40.15000	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
NWOMEN	-	-	0.1059	0.0958	0.3017	0.2604	0.3967	0.4507	0.2726	0.2685
			(0.643)	(0.637)	(0.541)	(0.513)	(0.853)	(0.846)	(0.311)	(0.306)
NLOSS5P	-0.1859**	-	0.04466	-	-0.1555**	-	0.03199	-	-0.1216**	-
	(0.0742)	-	(0.0334)	-	(0.0417)	-	(0.822)	-	(0.0475)	-
DLOSS	-	-0.4880**	-	-0.0514	-	-0.3739**	-	0.1739**	-	-0.3246**
	-	(0.134)	-	(0.0612)	-	(0.0754)	-	(0.074)	-	(0.0844)
Constant	3.336**	3.451**	2.111**	2.172**	2.463**	2.760**	2.478**	2.732**	2.816**	3.042**
	(0.0559)	(0.0705)	(0.645)	(0.640)	(0.747)	(0.713)	(1.21)	(1.20)	(0.435)	(0.435)
Ps.R2 or R2	0.689	0.689	0.00471	0.0000	0.0521	0.0824	0.0165	0.0269	0.0405	0.0575

[a] Except for R20.7500 where a fixed effect model was used.
** Significant at the 1% level

With the specification (2) of Table 6, we further explore the "gambler's fallacy" hypothesis with the *DLOSS* variable. This variable is a discounted occurrence of previous losses at each period t, computed for each group. Specifically, assume that by time t, three losses have occurred for a given group: one at $t-1$, and the two others at $t-3$ and $t-10$, respectively. *DLOSS* is the discounted sum of ones weighted by the time appearance of the loss relative to t: 1 for the loss at $t-1$, 1/3 for the loss at $t-3$ etc. Thus, a high value of *DLOSS* implies a bundle of recent losses. With the exception of treatment A20.7500, the significant negative coefficients shown in Table 6 for that variable confirm the "gambler's fallacy" hypothesis at the group level.

5. Conclusion

In this study we have examined behavior relating to voluntary contributions to reduce expected losses associated, for example, with the occurrence of natural disasters or major industrial accidents. It is recognized in the literature (see Kunreuther 1997 and Petak 1998) that the consequences of a natural disaster change a private prevention problem to a collective loss problem. Except for a lower efficiency level, and an unimodal distribution of contributions to the public investments, the results we generate are reasonably consistent with classical studies on voluntary contributions to public goods. The Nash equilibrium, under the assumption of risk neutrality, cannot be construed as representative of typical behavior.[15] Both in the risk treatments and the ambiguity treatments, a higher probability of loss and higher initial wealth increase the probability of playing Nash. Reciprocity is an important concept to explain individual's behavior. The occurrence of a loss increases the probability of playing the Nash strategy at the individual level and decreases the voluntary contributions of the group (the gambler's fallacy), making the prospect of mobilizing the population after a natural disaster more difficult.

Regression results suggest some differences in behavior across treatments. A first period effect, signaling a willingness to cooperate, is present in most treatments but not when the probability of loss is 40%. An endgame effect is particularly important in treatments involving ambiguity, but reciprocity is less apparent in those situations. The participants' investments to reduce the expected public losses depend more on their wealth in the presence of a lower probability of a loss and when the initial wealth is smaller. Finally, the observed effects of wealth losses and gains are not always quantitatively or qualitatively similar across the treatments and perhaps more complex than Kahneman and Tversky's (1979) prospect theory suggests.

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[15] If participants tend to be risk-averse, a possibility indirectly controlled with our panel parametric analysis of the data, the evaluation of the Nash equilibrium prediction is problematic.

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Appendix A
Panel estimates for the Nash equilibrium, the intensity of preference for cooperation, and the level of voluntary contributions.
(By treatment)

R20-7500

	Nash equilibrim	Intensity of preference for cooperation	Level of voluntary contribution
CONSTANT	**-1.173****	**-0.692****	**2.92****
	(0.229)	(0.176)	(0.21)
D1PERD	**-1.863***	**1.611****	**1.08****
	(0.775)	(0.223)	(0.129)
DLA5PERD	**0.462***	**-0.006**	**0.02**
	(0.217)	(0.179)	(0.066)
SEXM	**-0.246**	**1.269****	**-0.90****
	(0.253)	(0.146)	(0.201)
LYOTHER	**-0.093****	**0.103****	**0.07****
	(0.016)	(0.013)	(0.007)
LYOTHSEX	**-0.019**	**-0.043***	**0.00**
	(0.024)	(0.017)	(0.008)
LLOSS	**0.555****	**-0.033**	**-0.06**
	(0.073)	(0.1)	(0.042)
LWEALTH	**0.230****	**-0.106***	**-0.06****
	(0.079)	(0.042)	(0.014)
LWPOS+	**-0.092***	**0.066****	**0.04****
	(0.037)	(0.024)	(0.008)
r	**0.357****		
	(0.068)		
m_1		**2.441****	
		(0.027)	
s		**0.854****	
		(0.044)	
a			**10.04**
			(5.689)
b			**1.93**
			(1.083)
Log-L	**-862.04**	**-1392.00**	**-4565.25**

A20-7500

	Nash Equilibrium	Intensity of preference for cooperation	Level of voluntary contribution
CONSTANT	**0.325**	**0.339**	**3.232****
	(0.318)	(0.262)	(1.146)
D1PERD	**-0.144**	**2.100****	**0.567***
	(0.32)	(0.618)	(0.277)
DLA5PERD	**0.175**	**-0.355***	**-0.132***
	(0.106)	(0.161)	(0.059)
SEXM	**0.442**	**-1.450****	**-2.929***
	(0.328)	(0.297)	(1.14)
LYOTHER	**0.014**	**-0.120**	**-0.030**
	(0.033)	(0.069)	(0.021)
LYOTHSEX	**-0.029**	**0.170***	**0.028**
	(0.035)	(0.072)	(0.022)
LLOSS	**0.382****	**0.066**	**0.024**
	(0.069)	(0.1596)	(0.058)
LWNEG	**0.787****	**-0.659***	**-0.496****
	(0.089)	(0.313)	(0.058)
LWEALTH	**-0.249****	**0.133****	**0.124****
	(0.019)	(0.039)	(0.01)
LWPOS+	**0.048****	**-0.050**	**-0.043****
	(0.017)	(0.027)	(0.008)
r	**0.417****		
	(0.03)		
m_1		**3.898****	
		(0.044)	
s		**1.574****	
		(0.09)	
a			**2.021**
			(1.731)
b			**0.992***
			(0.489)
Log-L	**-1102.33**	**-1387.15**	**4223.96**

R40-7500

	Nash Equilibrium	Intensity of preference for cooperation	Level of voluntary contribution
CONSTANT	**-0.745****	**-0.156**	**0.527****
	(0.125)	(0.157)	(0.045)
D1PERD	**-2.271**	**1.532**	**0.590**
	(1.851)	(0.913)	(0.31)
DLA5PERD	**0.045**	**0.209**	**0.060**
	(0.145)	(0.168)	(0.101)
SEXM	**0.984****	**-0.340**	**-0.820****
	(0.154)	(0.179)	(0.052)
LYOTHER	**-0.031****	**-0.003**	**0.005**
	(0.007)	(0.01)	(0.003)
LYOTHSEX	**-0.052****	**0.089****	**0.061****
	(0.01)	(0.019)	(0.006)
LLOSS	**0.321****	**-0.108**	**-0..159****
	(0.058)	(0.919)	(0.035)
LWNEG	**-0.121****		**0.175****
	(0.028)		(0.024)
LWEALTH	**-0.069****	**0.067****	**0.051****
	(0.016)	(0.009)	(0.009)
LWPOS+	**-0.014**		**0.007**
	(0.017)		(0.01)
r	**0.440****		
	(0..038)		
m_1		**2.780****	
		(0.027)	
s		**1.267****	
		(0.093)	
a			**2.076**
			(1.302)
b			**2.576****
			(0.482)
Log-L	**-1106.31**	**-1860.57**	**-4650.69**

R40-15000

	Nash equilibrium	Intensity of preference for cooperation	Level of voluntary contribution
CONSTANT	**0.546****	**-1.573****	**0.566****
	(0.135)	(0.187)	(0.073)
D1PERD	**-0.601**	**0.509**	**0.400**
	(0.346)	(0.578)	(0.306)
DLA5PERD	**0.028**	**0.146**	**-0.114**
	(0.149)	(0.152)	(0.074)
SEXM	**0.275***	**-0.364**	**-0.695****
	(0.131)	(0.21)	(0.068)
LYOTHER	**-0.055****	**0.051****	**0.028****
	(0.014)	(0.019)	(0.008)
LYOTHSEX	**0.031***	**-0.036**	**-0.009**
	(0.015)	(0.021)	(0.008)
LLOSS	**0.268****	**-0.157***	**-0.104***
	(0.054)	(0.078)	(0.039)
LWEALTH	**-0.082****	**0.077****	**-0.009**
	(0.009)	(0.009)	(0.007)
LWPOS+			**0.021****
			(0.004)
r	**0.426****		
	(0.031)		
m_1		**2.758****	
		(0.022)	
s		**1.366****	
		(0.079)	
a			**2.108**
			(1.096)
B			**3.223****
			(0.809)
Log-L	**-1182.69**	**-1903.10**	**-5005.18**

A40-15000

	Nash equilibrium	Intensity of preference for cooperation	Level of voluntary contribution
CONSTANT	**-0.657***	**-1.754****	**1.225****
	(0.291)	(0.225)	(0.091)
D1PERD	**-0.645**	**0.972**	**0.455**
	(0.612)	(0.606)	(0.352)
DLA5PERD	**0.636****	**-0.568****	**-0.563****
	(0.127)	(0.149)	(0.096)
SEXM	**1.300****	**-0.131**	**-1.472****
	(0.357)	(0.222)	(0.075)
LYOTHER	**-0.042**	**0.046**	**0.025****
	(0.024)	(0.039)	(0.006)
LYOTHSEX	**0.023**	**-0.012**	**-0.010**
	(0.027)	(0.041)	(0.008)
LLOSS	**0.331****	**0.035**	**-0.105****
	(0.106)	(0.047)	(0.029)
LWEALTH	**-0.086****	**0.098****	**0.026****
	(0.01)	(0.011)	(0.004)
LWPOS+			
r	**0.479****		
	(0.047)		
m_1		**3.122****	
		(0.022)	
s		**1.118****	
		(0.11)	
A			**3.399**
			(2.433)
B			**4.839**
			(3.231)
Log-L	**-1124.38**	**-1840.26**	**-5010.43**

Number in parentheses are estimated standard errors
** Significant at the 1 % level
* Significant at the 5 % level

APPENDIX B
INSTRUCTIONS FOR R75-7500 AND A20-7500

INSTRUCTIONS (R20-7500)

You are participating in an experiment in which you are asked to make decisions. During this experiment you can win money. The amount you win depends on your decisions and those of the other participants.

Participants make their decisions individually in front of their computers. Communication between participants is forbidden, and you are asked to refrain from noisy reactions while the experiment is in progress.

During the experiment:

- You and two other anonymous participants constitute a group of three.
- The experiment consists of 100 repetitions, called periods.
- You remain with the same group for the 100 periods.

Each **period is independent** and you must make your decisions on the basis of the following considerations:

- During each period you will receive 10 tokens that may be invested in two alternatives, X and Y. You may invest all of your 10 tokens in X, all in Y, or distribute them between X and Y without, however, fractioning them.
- The yield to X is private, depending only on the number of tokens you invest in X. Each token invested in X yields 10 experimental money units (EMU).
- The yield to Y is collective. Each token invested in Y diminishes the probability of a 1000 EMU loss being sustained by all members of the group. The probability of the loss when the group invests nothing in Y is equal to 20%. Each token invested in Y by you or any other member of the group reduces the probability of this loss by 0.5%. If all members of the group invest their 10 tokens in Y, the probability of loss falls from 20% to 5%. The following table yields the probability of loss for each number of tokens the group invests in Y.

Number of tokens in Y	**Probability of loss**	**Number of tokens in Y**	**Probability of loss**
0	20.00%	16	12.00%
1	19.50%	17	11.50%
2	19.00%	18	11.00%
3	18.50%	19	10.50%
4	18.00%	20	10.00%
5	17.50%	21	9.50%
6	17.00%	22	9.00%
7	16.50%	23	8.50%
8	16.00%	24	8.00%
9	15.50%	25	7.50%
10	15.00%	26	7.00%
11	14.50%	27	6.50%
12	14.00%	28	6.00%

13	13.50%	29	5.50%
14	13.00%	30	5.00%
15	12.50%		

In the decision window displayed on your computer, enter the (whole) number of tokens you are investing in X and Y. If you are investing no tokens in either X or Y, type zero (0). The sum of the tokens invested in X and Y must equal 10. Your decision is confirmed when you click on the "submit" button.

At the end of each period, a random draw that factors in the number of tokens invested in Y by the group establishes whether or not a loss of 1000 EMU has been sustained. Your gains for the period are determined by your return on X minus the loss of 1000 EMU, if it occurs.

Your Gains

At the beginning of the experiment, you will be issued 7500 EMU in your account. At the end of each period, this account is updated with the profits or losses realized during the period. At the end of the experiment, the value of your account will be converted into Canadian dollars at a conversion rate of 25 cents per 100 EMU. You will be paid individually.

Available Information

At the beginning of each period (except the first) you will be informed of the outcome of the preceding period, i.e. your investment in X and Y, your group's total investment in Y, the probability of loss, whether or not a loss was realized, the yield to your investment in X, your net profits for the period, and the balance in your account. A historical summary, in table form, with the results of the first period in the first line followed by the results of the subsequent periods, can be accessed by clicking on the magnifying glass.

Additional Information

Before beginning the experiment, we will ask you several questions to gauge your understanding of the rules. Before continuing, all participants must correctly answer all the questions. Next, we will request that you supply us with information concerning your age, sex, level and field of study, and university or school currently attended.

INSTRUCTIONS (A20-7500)

You are participating in an experiment in which you are asked to make decisions. During this experiment you can win money. The amount you win depends on your decisions and those of the other participants.

Participants make their decisions individually in front of their computers. Communication between participants is forbidden, and you are asked to refrain from noisy reactions while the experiment is in progress.

During the experiment:

- You and two other anonymous participants constitute a group of three.
- The experiment consists of 100 repetitions, called periods.
- You remain with the same group for the 100 periods.

Each **period is independent** and you must make your decisions on the basis of the following considerations:

- During each period you will receive 10 tokens that may be invested in two alternatives, X and Y. You may invest all of your 10 tokens in X, all in Y, or distribute them between X and Y without, however, fractioning them.
- The yield to X is private, depending only on the number of tokens you invest in X. Each token invested in X yields 10 experimental money units (EMU).
- The yield to Y is collective. Each token invested in Y diminishes the probability of a 1000 EMU loss being sustained by all members of the group. In other words, the more the group invests in Y, the less likely it is that a loss will be incurred.

In the decision window displayed on your computer, enter the (whole) number of tokens you are investing in X and Y. If you are investing no tokens in either X or Y, type zero (0). The sum of the tokens invested in X and Y must equal 10. Your decision is confirmed when you click on the "submit" button.

At the end of each period, a random draw that factors in the number of tokens invested in Y by the group establishes whether or not a loss of 1000 EMU has been sustained. Your gains for the period are determined by your return on X minus the loss of 1000 EMU, if it occurs.

Your Gains

At the beginning of the experiment, you will be issued 7500 EMU in your account. At the end of each period, this account is updated with the profits or losses realized during the period. At the end of the experiment, the value of your account will be converted into Canadian dollars at a conversion rate of 25 cents per 100 EMU. You will be paid individually.

Available Information

At the beginning of each period (except the first) you will be informed of the outcome of the preceding period, i.e. your investment in X and Y, your group's total investment in Y, whether or not a loss was realized, the yield to your investment in X, your net profits for the period, and the balance in your account. A historical summary, in table form, with the results of the first period in the first line followed by the results of the subsequent periods, can be accessed by clicking on the magnifying glass.

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