Voluntary contributions with imperfect information: An experimental study

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Abstract

We use a two-person linear voluntary contribution mechanism with stochastic marginal benefits from the public good to examine the effect of imperfect information on contributions levels. To assess prior risk attitudes, individual valuations of several risky prospects are elicited via a second-price auction. We find that limited information about the productivity of the public good lowers significantly initial contributions in comparison to a setting with perfect information, whereas different information conditions do not result in qualitatively different contribution patterns. Moreover, our results show clear evidence of risk aversion, and of a negative relationship between the latter and willingness to cooperate.

Keywords: Public goods experiments, Vickrey auctions, Imperfect information, Risk attitudes

JEL classification: C72; C92; D80; H41

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1. Introduction

Body of literature on linear public goods games has accumulated in the last twenty years. A reason for this enduring interest is that, though such games are usually parameterized to create a social dilemma (Dawes, 1980) so that free-riding is a dominant strategy, a large percentage of participants in public goods experiments are found to voluntarily cooperate. In repeated settings, however, contributions decline over time and reach their minimum when the interaction terminates (see Ledyard, 1995 for a review). These findings have stimulated a massive amount of research aimed at explaining the observed behavior and ascertaining features of the institution or environment that may influence it. In this paper, we focus on two related such features: the information conveyed to the agents and their risk attitudes.

Most previous experimental studies have been performed in an extremely rich informational environment in which the public good's productivity was commonly known. Yet, in real life, one hardly knows in advance the marginal benefit she can derive from a public good she is asked to finance, but has at best some expectations about its productivity. Most public goods are normally supplied after contributions are made, and thus initial contributors do not know how much the good is worth *a priori*. The question can therefore be raised as to whether or not the voluntary cooperation typically observed in linear contribution mechanisms would endure in a world of imperfect information about the public good's productivity.

The experiment reported here is designed to address this question. A linear voluntary contribution mechanism is tested under two informational environments. Under *perfect information* (henceforth, *PI*-treatment), the marginal productivity of the public good takes only one value, which is known to all. This condition is similar to those used in previous studies. Under *imperfect information* (henceforth, *II*-treatment), the marginal productivity of the public good can assume one of two (equiprobable) values, and each subject just knows these values and their probability distribution.

By implementing two information conditions our paper is connected to a (small) strand of experimental literature that considers the effect of *incomplete* information on contributions. In an asymmetric step level public goods experiment, van Dijk and Grodzka (1992) find no difference in contribution levels between subjects who only know their own endowment and subjects who also know the endowments of the others. In a similar vein, van Dijk et al. (1999) find that the overall (group) averages in their complete and partial information condition are very similar. Marks and Croson (1999) analyze a point provision game where subjects have incomplete information about the evaluation of others, and report no significant difference in the level of group contributions depending on information conditions.[1] All these experiments assume private information. In this paper, we move a step further and suppose that one does not even know her own marginal benefit from the public good, but she is just informed that it can take one of two values with the same probability.

The stochastic productivity adds an element of risk to the standard public goods setting, thereby allowing us to explore whether and to what extent the presence of risk affects the usually observed behavioral patterns. To make our two treatments comparable, the parameters are chosen such that the Nash equilibrium and the efficient outcome are corner solutions, opposite to each other, both when the information is perfect and when it is imperfect and

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[1] On theoretical grounds, it is worth mentioning the studies by Gradstein et al. (1994) and Menezes et al. (2001). Gradstein et al. investigate the robustness of the neutrality theorem (Warr, 1983) when an individual does not know the others' income, and find that attaining neutrality is more difficult with incomplete information. Menezes et al. confirm the superiority of subscription games (Admati and Perry, 1991) over contribution games in the presence of incomplete information about the others' valuation of the public good.

participants are risk-neutral. Thus, under risk-neutrality, imperfect information about the public good's marginal benefit should not alter behavior as compared to a perfect information environment.

However, Bagnoli and Lipman (1989, p. 585) suggest that a severe lack of information as in our experimental treatment may lower individuals' willingness to contribute.[2] Furthermore, Ledyard (1995, p. 143) lists risk aversion among the systematic variables which may shape contributions level, although he acknowledges that its effect has not been tested yet. To the best of our knowledge, the relation between risk attitudes and willingness to contribute has remained mainly unexplored, although there is some literature that comes close to the issue. For instance, in a non-linear public goods game involving risk about one's own and/or another person's marginal benefit from the public good, Brennan et al. (forthcoming) find that contributions to the public good are, on average, decreasing in own risk.

Due to the crucial role of risk preferences in our setup, we deem necessary to measure individual risk attitudes (and compare the latter to contribution behavior). To this aim, we elicit individual valuations of ten risky prospects using an incentive-compatible second-price auction prior to the public goods game. Valuations are defined as reservation prices that a person is willing to pay to buy the prospect. To maintain the same risk preferences in both the auction and the following public goods game, the lotteries' payoffs are chosen so as to span the payoffs' range of the respective public goods treatment.

In the following Section 2 the experimental procedures and the different treatments are described in detail. The results of the experiment are reported in Section 3. Section 4 concludes.

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[2] Note that, actually, Bagnoli and Lipman have in mind a voluntary contribution mechanism for the provision of threshold, rather than linear, public goods.

2. The experiment

The computerized experiment was performed at the laboratory of the Max Planck Institute in Jena (Germany). The experiment was programmed using the z-Tree software (Fischbacher, 1999). Participants were undergraduate students from different disciplines at the University of Jena.

In total, two experimental sessions were run, each involving 32 participants, and implementing one of the two treatments (between-subjects design). Each session consisted of two different experiments. Individual risk preferences were assessed in the first experiment. A linear voluntary contribution mechanism was played repeatedly in the second experiment under either perfect information or imperfect information. The instructions distributed at the beginning informed participants that they would take part in two separate experiments, and explained the rules of the first experiment only. Written instructions on the second experiment were distributed at the end of the first one (a translation of the German instructions for the two experiments can be found in the Appendix). In both experiments amounts were denoted by ECU (Experimental Currency Unit), where 10 ECU = €1. The average payoff, earned in about 1½ hour, was €11.7 (including a show-up fee of €2.50).[3]

2.1. Risk elicitation experiment

In the first experiment, individual risk attitudes are elicited via an incentive-compatible second-price auction (Vickrey, 1961).[4] Each participant is required to submit the maximum integer amount she is willing to pay to acquire a lottery

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[3] In order to avoid portfolio-diversification effects (see Markowitz, 1952), participants in each session/treatment were paid according to one choice only.

[4] The second price auction is a market institution which should induce subjects to reveal their true values (for examples of its application see Shogren et al., 1994; Di Mauro and Maffioletti, 2004). Other approaches to determine individual risk attitudes are the random price mechanism (Becker et al., 1964), the binary lottery technique (Smith, 1961; Roth and Malouf, 1979), and the paired lottery-choice tasks (Holt and Laury, 2002).

yielding a payoff of L or H $(0 < L < H)$ with probabilities θ and $1-\theta$, respectively. Each player must decide on 10 lotteries, being aware that each lottery is granted to the highest bidder at a price equal to the second highest bid. Table 1 lists the set of implemented lotteries separately for each treatment. To simplify the task and avoid miscalculation of the variance, the probabilities attached to the two possible payoffs are presented not only numerically but also graphically via pie charts of the type reported in Fig. 1.

Table 1 and Fig. 1 about here

The low (high) payoff L (H) attainable in each lottery-set is chosen so as to equalize the minimum (maximum) payoff achievable in the subsequent public goods game. In this way, risk preferences refer always to the same (expected) wealth. This is important as risk attitudes may vary with wealth (cf., Rabin and Thaler, 2001).

For each auction, participants receive an endowment of 100 ECU. Yet, due to some expected values exceeding 100 (see Table 1), participants are informed that bids can be as high as 300, and thus paid out of own pocket. No feedback about the ten lotteries is provided until the end of the whole experimental session. Only at the end, each subject is informed, for each lottery, of its actual outcome, its highest bid, its second highest bid, and whether she wins that lottery or not. If one of the lotteries is randomly chosen for payment, that lottery is played out for real, and payments are contingent on the lottery's outcome.

2.2. The public goods experiment

In the second experiment, we investigate the impact of imperfect information on contributions. To this aim, we rely on the standard linear public goods game as introduced by Isaac et al. (1984).

Groups of size two interact for 10 periods in a partners design (i.e., pair composition never changes). In any one period, each participant is endowed with 100 ECU and must privately decide how much to contribute to a public good, keeping the remaining ECU for herself. Let c_i denote individual *i*'s contribution to the public good (with $c_i = \{1, 2, 3, ..., 100\}$, $i = 1, 2$), and let $C = c_1 + c_2$ be the total amount of public good provided. The monetary payoff of each i is given by

$$U_i(c_i, C) = 100 - c_i + \tilde{\alpha}C,$$

where $\tilde{\alpha}$ is *i*'s marginal benefit from the public good.

In the *PI*-treatment, subjects are told that $\tilde{\alpha}$ is fixed at 0.75; we use this treatment as control. In the *II*-treatment, subjects are informed that $\tilde{\alpha}$ can be either $\underline{a} = 0.4$ or $\bar{a} = 1.1$, with probability ½ each. To avoid confounding effects due to asymmetric marginal productivities, the value of $\tilde{\alpha}$ is simultaneously determined for both members of a pair, and subjects know this. Regardless of the treatment, at the end of each period, participants get feedback on their partner's contribution and their private payoff. In the *II*-treatment, everyone is also informed about the randomly chosen marginal productivity in her own pair.

Given our parameter values, a *risk-neutral* player should contribute zero in both treatments if she is strictly self-interested, whereas she should always fully contribute if she is efficiency-oriented (i.e., wants to maximize the sum of U_1 and U_2). However, in the *II*-treatment, deviations from risk neutrality may eliminate the social dilemma. If, for instance, the expected value of $\tilde{\alpha}$ is not greater than 0.5, a risk-averse player should contribute zero both if she is interested only in her own monetary payoff and if she cares for efficiency. Similarly, if the expected value of $\tilde{\alpha}$ is not smaller than 1, a risk-lover player should contribute her whole endowment if she is either strictly self-interested or efficiency-minded. It becomes therefore necessary to find out when behavior is due to the elimination of the dilemma. Accordingly, we compute the thresholds beyond which risk aversion or risk loving rules out the dilemma.

Let us assume that a risk-averse agent is indifferent between a sure payoff of 0.5 and a risky prospect yielding 0.4 or 1.1 with probability ½ each. Let us further impose that the agent has a Constant Absolute Risk Aversion (CARA) utility function. Then, denoting the absolute risk aversion coefficient by r, $(1/2)e^{-0.4r} + (1/2)e^{-1.1r} = e^{-0.5r}$ must hold, which entails $r = \underline{r} = 6.85$. A parallel reasoning for a risk-lover agent yields $r = \overline{r} = -6.85$. This means that, in our stochastic public goods game, a risk-(loving) averse actor with an r-coefficient (greater) smaller than (–)6.85 will prefer a risky $\tilde{\alpha}$ (i.e., 0.4 or 1.1 with probability ½ each) to an $\tilde{\alpha}$ equal to (1) 0.5, thereby confronting the dilemma.

Some recent studies suggest that a plausible explanation for the observed contribution behavior in social dilemma situations is the existence of conditional cooperators, i.e., individuals who are more cooperative the more others are (expected to be).[5] Several experiments reveal that conditional cooperation is important (see, e.g., Keser and van Winden, 2000; Brandts and Schram, 2001; Fischbacher et al., 2001; Levati and Neugebauer, 2004). All these experiments have been performed under perfect information conditions. Here, we want to examine whether imperfect information about the public good's productivity affects beliefs and/or the relationship usually detected between beliefs and actions.[6] Accordingly, in each period of both treatments, we ask subjects to predict how many ECU their partner will contribute in the current period. To

[5] As Fischbacher et al. (2001) suggest, conditional cooperation can be considered as a motivation in its own or result from fairness preferences like reciprocity or inequity aversion (see, e.g., Sugden, 1984; Fehr and Schmidt, 1999; Bolton and Ockenfels 2000).

[6] Former experimental studies measuring the correlation between beliefs and contributions include González et al. (2005), Neugebauer et al. (2005), and Fischbacher and Gächter (2006).

encourage subjects to report truthful beliefs, we paid an additional bonus of €15 to the participant with the most accurate predictions in each session.[7]

3. Results

We start our analysis by classifying subjects according to their risk attitudes, based on their bids in the second-price auctions. We then proceed to examine cooperation levels in the two public goods treatments so as to investigate whether and how they are affected by the different information conditions. Finally, we examine the relationship between individuals' contribution behavior and risk attitudes.

3.1. Risk attitudes

To assess risk attitudes we calculate each subject's local absolute risk aversion coefficient, as originally proposed by Pratt (1964). The advantage of this method is that it does not rely on a specific functional form for the utility function.

Define $\pi(x, \tilde{z})$ to be the risk premium a decision maker is willing to pay out of her nonstochastic wealth x to avoid a risky prospect $\tilde{z}$. Formally, the decision maker is indifferent between $\tilde{z}$ and $E(\tilde{z}) - \pi(x, \tilde{z})$, i.e., receiving $\pi(x, \tilde{z})$ less than the expected value of the lottery. If her utility function is u, we can write $u(x + E(\tilde{z}) - \pi(x, \tilde{z})) = E\{u(x + \tilde{z})\}$. Pratt (1964) shows that expanding u around x on both sides of the latter expression and equalizing the two expansions yields $\rho(x) = \dfrac{\pi(x, \tilde{z}) - o(\sigma_z^2)}{0.5\sigma_z^2}$, where σ_z^2 is the variance of the risky prospect, and, in expansions, $o(\ )$ means "terms of smaller order than".

[7] Previous research in experimental economics has shown that the mere act of eliciting beliefs about the others' actions can affect behavior in finitely repeated public goods games (see, e.g., Croson, 2000; Gächter and Renner, 2006). As we elicit beliefs in both our treatments, this caveat applies to both of them, thereby leaving unaffected their comparison.

We use the ratio above to measure a subject's attitudes to risk. Omitting $o\left(\sigma_z^2\right)$, we can easily estimate the variance σ_z^2 of each lottery and the risk premium $\pi(x,\tilde{z})$. In particular, for each lottery $\tilde{z}$ and each subject, $\pi(x,\tilde{z})$ is calculated as the difference between the expected value of $\tilde{z}$ and the subject's elicited willingness to pay for $\tilde{z}$. A coefficient ρ equal to 0 indicates risk neutrality, whereas a coefficient greater (smaller) than zero corresponds to risk aversion (proneness). Table 2 lists the average (over the 10 lotteries) risk aversion coefficient ρ of each individual subject, separately for each session/treatment.[8]

<u>Table 2 about here</u>

Thirty (twenty-nine) out of thirty-two participants in the *II*- (*PI*-)treatment are classified as risk-averse; the remaining 2 (3) participants are risk-lover. In sum, the following result corroborates earlier experimental evidence (see, e.g., Holt and Laury, 2002; Dohmen et al., 2005).

Result 1 *In both sessions/treatments, more than 90% of subjects are risk-averse.*

Our next step is to investigate whether, in the *II*-treatment, risk-aversion triggers expectations of a marginal productivity not greater than 0.5. Such expectations would rule out the dilemma, turning free-riding into the socially optimal result. To verify whether this is the case, we estimate the risk preferences of the participants in *II* using certainty equivalent data. Differently from the Arrow-Pratt measure, computing certainty equivalents requires assuming a specific functional form for the subject's utility. Moreover, as subjects' responses are typically affected by errors (cf., Hey and Orme, 1994), the specification of the functional form needs to be stochastic. Accordingly, we suppose that subjects have a CARA utility function to which we add a normally

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[8] Averaging the 10 individual ρ-coefficients is justified by the very small variance of individual ρ across lotteries.

distributed (with mean 0 and variance 1) error term. To derive the estimates of the absolute risk aversion coefficient *r*, we use maximum likelihood methods.[9]

Table 3 about here

Table 3 reports the estimations of each individual *r*-parameter. Except for 6 subjects who are infinitely risk-averse, the remaining 26 participants in the *II*-treatment exhibit a risk aversion coefficient smaller than $\underline{r} = 6.85$ (the threshold identified in section 2.2).[10] We can therefore convincingly state:

Result 2 *In the II-treatment, more than 80% of the subjects prefer a risky* $\tilde{\alpha}$ *(yielding either 0.4 or 1.1 with the same probability) to an* $\tilde{\alpha}$ *equal to 0.5 so that they face the standard conflict between their own personal interest and the collective interest of the group.*

3.2. Contribution behavior

The experimental results under the two public goods treatments are summarized in Fig. 2 and Table 4. The difference in contribution decisions between treatments is remarkable: as compared to a situation with perfect information, the presence of imperfect information about the public good's productivity lowers significantly average contributions. Two-sided Wilcoxon rank-sum tests (based on averages over players for each pair as independent unit of observation) confirm that the difference between treatments is highly significant in each of the first nine periods ($p < 0.001$ in periods 1 to 9; $p = 0.92$ in period 10; N= 16) as well as averaging over all periods ($p = 0.001$; N= 16).

[9] See Hey and Orme (1994), Morone and Schmidt (2003), and Hey et al. (2006) for details about this estimation technique.

[10] Note that the estimations in Table 3 mirror qualitatively those for the *II*-treatment in Table 2. The subjects with infinite risk aversion in Table 3 show a higher Arrow-Pratt coefficient than the others. Moreover, although in Table 2 participants 11 and 16 are classified as risk-lovers, their ρ-value is very close to zero; these two subjects exhibit the smallest *r*-coefficient in Table 3. The differences between estimations may be due to the data interpolation, which is linear in case of Arrow-Pratt and polynomial in case of maximum likelihood.

Fig. 2 and Table 4 about here

There is also more full free-riding (contributions of zero) in the *II*-treatment than in the *PI*-treatment (overall, 25.31% vs. 9.06%). The difference in proportions of free-riding between the treatments is significant at the 1% level (t -test of proportions;[11] $N = 320$, $t = 5.58$).[12] This evidence gives our first result concerning contribution behavior.

Result 3 *Imperfect information decreases significantly average private contributions.*

Fig. 2 indicates that, although participants in *II* start out with significantly lower contributions than participants in *PI*, average contributions stay roughly constant from the first until the last but one period in both treatments. To check the latter, we performed, separately for each treatment, a generalized linear mixed regression (based on a quasi-Poisson distribution to model over-dispersion) with individual contribution decisions as dependent variable and periods 1 to 9 as independent variable. The model has random effects at two levels: the 16 independent matching groups, and the 288 individual subjects.[13] The regression results corroborate the stability of contributions from the first to the ninth period in both treatments: slope coefficients equal –0.112 ($p = 0.98$) in *PI*, and 0.001 ($p = 0.23$) in *II*.[14] Furthermore, the slopes are not significantly different from each other. This confirms that the lower overall contributions in

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[11] See Andreoni (1988, p. 297) for details about the *t*-test.

[12] We wondered if the decrease in contribution level between treatments could be explained wholly by the increase in free-riders (i.e., more people free-ride in *II*, but the contributions of those who contribute is unaffected). To answer this question, we removed the contributions of zero from our sample. Even so, the average contribution in the *PI*-treatment is higher than that in the *II*-treatment (*PI*: 85.86 ECU, *II*: 54.56 ECU).

[13] The estimation method accounts for first-order autocorrelation in the within-(matching) group residuals.

[14] This is at odds with the usual picture of a declining trend (Ledyard, 1995), and may depend on our experimental design: interacting finitely often with always the same partner may facilitate conditionally cooperative behavior (more on this below).

the treatment with imperfect information are due to a shift in the level of contributions (i.e., a lower intercept in the regression), but not to a different time trend. The qualitatively similar behavioral patterns of the two treatments are substantiated by a significant end game effect (Andreoni, 1988) in both of them. Wilcoxon signed-rank tests (one-tailed) comparing averages in the first nine periods and in the last period show that subjects contribute significantly more in the first nine periods ($p = 0.008$ for both treatments; N = 16). These observations lead us to our next result.

Result 4 *The time trend of average contributions is not significantly different between treatments.*

Since contribution patters are qualitatively similar over periods, to shed light on what triggers the significantly quantitative difference between treatments we analyze behavior in the first-period (where all individual responses are independent). We find that, whatever the information condition, first-period individual contributions and first-period individual beliefs are highly significantly correlated: Spearman rank correlation coefficients are 0.83 in *PI*, and 0.80 in *II* ($p < 0.001$ in each treatment; $N = 32$). Thus, irrespective of the information being perfect or imperfect, players' contributions almost perfectly match their beliefs in period 1.

As first-period contributions are significantly lower when information is imperfect, we also detect a statistically significant difference in first-period beliefs between treatments ($p = 0.004$; one-tailed Wilcoxon rank-sum test; $N = 32$). It is worth mentioning that no participant is expected to free-ride under perfect information, whereas 6 subjects hold free-riding expectations under imperfect information. These results seem to indicate that imperfect information lessens agents' willingness to cooperate at the outset of the interaction because it strongly affects initial beliefs: when confronted with a risky situation, most participants decrease their expectations about the contribution of their co-player. On the other hand, psychologists observe that people have a tendency to believe that others behave similarly to themselves (the so-called "false consensus effect"; cf., Kelley and Stahelski, 1970). If this were the case, expectations of less cooperation may be triggered by one's own predisposition to cooperate less. While our experiment is not designed to provide insights into the determinants of beliefs, it clearly shows that a risky payoff (with stochastic marginal benefits from the public good) has a negative impact on willingness to cooperate, and that first-period decisions are decisive for future average contribution levels.[15] We will provide a plausible justification for the significant difference in initial behavior between treatments in the next section. For the moment, we sum up the evidence on first-period behavior as follows.

Result 5 *First-period beliefs are significantly smaller when information is imperfect rather than perfect. Whatever the information condition, actual and expected contributions in period 1 are highly and positively correlated.*

Does the relationship between own and expected contributions, detected in the first period, persist over the remaining repetitions of each session/treatment? Before answering such a question, we note that, in all periods following the first, beliefs may become endogenous in the sense of being influenced by the other's observed contributions (see González et al., 2005, and Fischbacher and Gächter, 2006, for a thorough discussion of this issue). To check whether this holds true in our experiment, we performed a correlation analysis between beliefs in period t about the partner's contribution in t and the actual contribution of the partner in period $t-1$. The analysis yields significantly positive Spearman's coefficients

[15] The importance of first-period contributions to the whole game has been noticed also by Keser and van Winden (2000), who compared partners and strangers conditions.

in both treatments (0.92 in *PI*, 0.98 in *II*; $p < 0.001$; $N = 16$). Thus, participants in our experiment anchor their beliefs about the other's contribution to what the other did in the previous period. This is consistent with the work of, e.g., Neugebauer et al. (2005) who observe expectations to depend significantly on the partners' one-period lagged contributions.

Turning to the relationship between beliefs and own contributions, to shed light on it we ran a generalized linear mixed regression with random effects for matching groups and individuals. The dependent variable is individual i's contribution decision (c_i). Independent variables are i's expectations about her partner's contribution in the current period (Exp_i), *Period* (which takes value 1 to 10), and a treatment dummy variable (*Info*) that equals 0 for *PI* and 1 for the *II*.[16] The specification of the model includes the interaction of Exp_i and *Period* with *Info*. Table 5 describes the results of the regression.

Table 5 about here

Expected contributions have a significantly positive effect on own contributions, and this does not depend on information conditions (the coefficient of $Info \times Exp_i$ is not significant). Since beliefs and observed contributions of the partner are highly significantly correlated, this is qualitatively equivalent to assert that behavior in whatever treatment depends on the other's behavior in the previous period. This result is in line with earlier studies (see, e.g., Croson, 2000, 2002; Neugebauer et al., 2005; Gächter and Renner, 2006), and provides evidence for conditionally cooperative behavior in both treatments. The coefficient of *Info* is negative and significant, i.e. (as

[16] We excluded from the regression the amount most recently contributed by i's partner because of its correlation with the variable Exp_i. Thus, although the other's one-period lagged contribution is significantly correlated to c_i, if Exp_i is included in the regression it becomes insignificant (see Neugebauer et al., 2005 for a similar finding). Note also that the regressor *Period* includes here the tenth and final period of interaction, which was left out from the regression testing the stability of contributions over the first nine periods.

already summarized by Result 3) participants in *II* contribute less than participants in *PI*. Finally, the coefficient of *Period* is significantly negative, meaning that the inclusion of the final period (where contributions decline significantly) gives rise to a negative time trend. However, this effect is less pronounced for the *II*-treatment. This is indicated by the significantly negative coefficient of the variable *Period* and the significantly positive coefficient of $Info \times Period$: the total influence of *Period* in *II* is still negative, but its size is (in absolute terms) smaller than the influence in *PI*. Our next result sums up the most interesting evidence from the regression analysis.

Result 6 *The relationship between contributions and beliefs is unaffected by treatment: regardless of the information being perfect or imperfect, higher contributions are positively correlated with higher beliefs.*

To recapitulate the main findings of this subsection, whether information is perfect or not has no impact on people's behavior *during* the game; yet, since imperfect information leads subjects to contribute significantly less *at the outset* of the game, our two treatments differ significantly in contribution rates. Individuals' attitudes towards risk may hold the clue to the causes of this difference. Thus, the final step in our analysis is to look at how risk preferences affect people's contribution decisions.

3.3. Relationship between risk attitudes and contribution behavior

Section 3.1's analysis has shown that almost all our participants are risk-averse, and that the risk aversion coefficient of most of those who subsequently face a stochastic public goods game does not exceed the threshold leading to the elimination of the social dilemma. The negative effects of imperfect information on voluntary contributions cannot therefore be attributable to the absence of the standard conflict between one's own and the group's interests. Even though the degree of risk aversion is not so extreme to rule out the dilemma, it may well influence decisions when one's own payoff is risky.

To investigate how risk attitudes relate to contributions and whether imperfect information affects such relationship, Table 6 reports the results of two OLS regressions: the dependent variable is each individual's average contribution over all 10 periods in one model, and each individual's contribution in period 1 in the other model. Independent variables are individual Pratt's risk aversion coefficients ρ (as reported in Table 2), the treatment dummy *Info* (being 0 in *PI* and 1 in *II*), and the interaction between them.

Table 6 about here

We find clear evidence for a significantly negative relationship between contributions and degree of risk aversion in both models: the more risk-averse a subject is, the less her average and first-period contributions. While this does not depend on the information being perfect or imperfect in case of average contributions (the coefficient of *Pratt's* $\rho \times$ *Info* is not significant in model 1), the degree of risk aversion lowers significantly first-period contribution when information is imperfect rather than perfect (in model 2, the coefficient of the interaction effect between *Pratt's* ρ and *Info* is negative and significant at the 1%-level). This implies that the degree of risk aversion leads individuals to start out with significantly lower contributions when their own payoff is risky than when no risk for oneself is involved. Finally, (in line with previous results) the dummy *Info* is always negative and significant. These findings lead us to our last result.[17]

[17] Given that contributions are strongly positively related to beliefs – both in period 1 (see Result 5) and overall periods (see Result 6) – the findings of Table 6 do not qualitatively change using expected instead of actual contributions as response variable. As emphasized earlier, our experimental design abstains from disentangling whether risk aversion affects first beliefs and then contributions or vice versa (i.e., first own predisposition to cooperate and then, due to the "false consensus effect", beliefs).

Result 7 *The degree of risk aversion is negatively and significantly correlated with willingness to contribute. Higher risk aversion induces subjects to reduce significantly initial contributions in case of imperfect information.*

4. Conclusions

In this paper we have provided experimental evidence on two main issues: the impact of imperfect information on voluntary contribution behavior in linear public goods games, and the relationship between risk attitudes and willingness to cooperate. To the best of our knowledge, we are the first to investigate these issues, and hence to combine two hitherto unrelated strands of experimental work (namely, the one on risk preferences and the one on voluntary contributions).

Our results indicate that, compared to a setting with perfect information, imperfect information about the public good's productivity decreases significantly cooperation, with average contributions dropping down from 78% to 41%. The basis for this noticeable difference is created in the first period: a risky payoff has a negative impact on contributions at the start of the game, and first-period contribution levels appear to be decisive for future contribution decisions (see Keser and van Winden, 2000 for an analogous result in a linear public goods experiment comparing strangers and partners conditions).

The explanation we provide for the significant behavioral difference detected in the first period relies on people's aversion to risk. We find that the more risk-averse a subject is, the less she contributes, and such negative relationship is particularly pronounced in the first period of the imperfect information treatment. These results are akin to those of Brennan et al. (forthcoming) who, studying the relation between other-regarding concerns and attitudes towards private and collective risk, find less cooperation when one's own payoff is risky than when it is certain.

After the first period, however, the same qualitative behavior is observed in both treatments with conditional cooperation being the more likely explanation for contributions in each of them: whatever the information conditions, own contributions are highly positively correlated with elicited expectations about the partner's current contributions. Thus, while on the one side our study confirms the findings of previous experiments establishing the importance of conditionally cooperative behavior (see, e.g., Fischbacher et al., 2001; González et al., 2005; Fischbacher and Gächter, 2006), on the other side it provides first evidence of a significant negative effect of imperfect information and risk attitudes on initial contributions. This result undermines the often claimed efficacy of the linear voluntary contribution mechanism in one-shot games or at the outset of finitely repeated games, and suggests that it should be in the interest of politicians and firms involved in privately financed public projects that individuals have a good knowledge about their marginal benefits.

Appendix. Experimental instructions

This appendix reports the instructions (originally in German) we used for the *II*-treatment. The instructions for the *PI*-treatment were adapted accordingly.

A.1. General instructions (distributed at the beginning of the experiment)

Thank you very much for being here. You receive €2.50 for having shown up on time. Today you will participate in two different experiments. The instructions for the first experiment follow on this page. The instructions for the second experiment will be distributed to you at the end of the first experiment.

Please read the instructions – which are identical for all participants – carefully. If you have any questions or concerns, please raise your hand. We will answer your questions individually. It is strictly forbidden to communicate with other participants during the experiment.

During both experiments, the unit of experimental money will be the ECU (Experimental Currency Unit), where 100 ECU = €10.

At the end of today's session, i.e., after the second experiment, one of the two experiments will be randomly selected, where both experiments are equally likely. One of your choices in the selected experiment will be randomly picked up, where all choices are equally likely. Your experimental payoff corresponding to the selected choice will be calculated, converted to euros, and paid out to you.

Instructions for the second-price auction experiment

In the first experiment you will face 10 different lotteries, each of which pays to you either 40 ECU or 220 ECU. At the beginning of each lottery, each participant receives 100 ECU. In the following, we shall refer to this amount as "your endowment".

Your task (as well as the task of each other participant) is to report the highest price for which you would be willing to buy <u>each</u> lottery. In other words, you have to state a **maximum buying price for each lottery**. Your choice must be an integer number (i.e., 0, 1, 2, …).

For buying a lottery you can use part or all of your endowment. If you think that this is not enough, you can use your show-up fee, and even your own money. If you use your own money, you may make a loss (how this happens will be explained later). You will be then required to pay from your own pocket.

Once you and all participants have stated a price, all prices will be set up in a rising order, and the participant with the highest price will buy the lottery at the second highest price. If two (or more) people state the same highest price, one of them is chosen at random and (s)he must pay his/her own price.

EXAMPLE: Suppose that there are six participants, and that their buying prices for the lottery are: 10, 15, 14, 15, 16, 20, 21. The computer will put the prices in an increasing order: 21, 20, 16, 15, 15, 14, 10. The participant whose price is 21 buys the lottery, but pays the second highest price, i.e., 20 ECU.

It is important that you state your true maximum buying price. Assume, for instance, that you are willing to pay 20 ECU, but you state only 18. If another participant reports 19, (s)he will buy the lottery. As a consequence, you will lose the lottery although you would have been happy to pay 20 ECU for it. Assume now that you state 22 (rather than 20) and this results to be the highest price. Assume also that the second highest price is 21. As a result, you will buy the lottery by paying 21 ECU, which is more than what you were willing to pay.

For each lottery, your payoff depends on whether or not you buy the lottery.

- If you state the highest price, you acquire the right to play the lottery. Your payoff will then be:

  Your payoff = Your endowment – Second highest price + Lottery prize

  Notice that if the second highest price is higher than your endowment, you will make a loss that you must cover with your own money.

▪ If you do not state the highest price, you keep your endowment.

Please remain quiet until the experiment starts and switch off your mobile phone. If you have any questions, please raise your hand now.

A.2. Instructions for the public goods experiment (distributed at the end of the auction experiment)

Please take your time to read the instructions for the second experiment at your own pace. If you have any questions while reading them, please raise your hand and one of the experimenters will come to your place.

This experiment consists of 10 separate periods, in which you will interact with another participant. The two of you form a pair that will remain THE SAME in all periods. The identity of the participant you are matched with will not be revealed to you at any time.

At the beginning of each period, each participant receives an endowment of 100 ECU. In any period, each of the members of a pair has to fulfill two tasks.

Task 1

Your first task is to decide **how much of your endowment you want to contribute to a project**. Your contribution decision must be not smaller than 0 ECU and not greater than 100 ECU. Furthermore, it must be an integer number. Whatever you do not contribute, you keep for yourself ("ECU you keep").

In every period, your earnings consist of two parts:

(1) the "ECU you keep": [100 − your contribution] ECU;

(2) the "income from the project".

The "income from the project" is determined by adding up the contributions of the two members of a pair and multiplying the resulting sum by a number that we call α. That is:

Income from the project = [Your contribution + Your partner's contribution] × α

The multiplier α can be either 0.4 or 1.1, where both values are equally likely. You have to decide about your contribution *without* knowing the value of α.

The income from the project is determined in the same way for the two members of a pair; this means that both receive the same income from the project, regardless of the size of their individual contributions.

EXAMPLE: If the sum of the contributions of the two members is 60 ECU, each member receives an income from the project of either $(0.4 \times 60) = 24$ ECU or $(1.1 \times 60) = 66$ ECU.

At the end of each period, after all participants have taken their decisions, the computer will randomly determine *for each pair* whether the multiplier is 0.4 or 1.1, and you will be informed about the contribution of your partner and your corresponding period-earnings.

Task 2

In every period, besides deciding about how much you want to contribute to the project, you have to predict **how many ECU the other member of your pair will contribute to the project**. At the end of the experiment, the participant with the most accurate predictions will receive an additional bonus of €15. The closer your predictions are to the true contribution of the other participant you interact with, the higher are your chances of receiving the bonus.

Before the experiment starts, you will have to answer some control questions to verify your understanding of the rules of the experiment.

Please remain seated quietly until the experiment starts. If you have any questions please raise your hand.

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Table 1
Experimental lotteries

PI-treatment $L = 75$ $H = 175$			*II*-treatment $L = 40$ $H = 220$		
θ	EV	σ^2	θ	EV	σ^2
0.8	95	1600	0.55	121	8019
0.5	125	2500	0.7	94	6804
0.55	120	2475	0.55	121	8019
0.6	115	2400	0.6	112	7776
0.65	110	2275	0.65	103	7371
0.7	105	2100	0.7	94	6804
0.75	100	1875	0.75	85	6075
0.8	95	1600	0.8	76	5184
0.85	90	1275	0.85	67	4131
0.9	85	900	0.9	58	2916

Note: EV and σ^2 denote, respectively, expected value and variance. θ is the probability of the low outcome *L*.

Table 2

Each subject's estimated risk aversion coefficient ρ, separately for each session/treatment (estimations based on Arrow-Pratt measure)

Subject	*PI*-treatment	*II*-treatment
1	0.05374	0.024794
2	0.013798	0.022371
3	-0.03722	0.009355
4	0.056991	0.018648
5	0.049926	0.019404
6	0.004285	0.007009
7	0.058137	0.013203
8	0.057398	0.02102
9	0.072226	0.019465
10	-0.00089	0.019797
11	0.054624	-0.00375
12	0.065534	0.015921
13	0.058404	0.013967
14	-0.00332	0.017409
15	0.027587	0.016175
16	0.08148	-0.00473
17	0.035295	0.018167
18	0.106933	0.014546
19	0.067537	0.019789
20	0.016573	0.018339
21	0.039817	0.015914
22	0.037899	0.01538
23	0.055478	0.016503
24	0.034149	0.01465
25	0.107659	0.02216
26	0.116374	0.016575
27	0.084904	0.016099
28	0.108301	0.016188
29	0.033994	0.009188
30	0.055616	0.01756
31	0.106745	0.015838
32	0.029146	0.021701

Table 3
Each subject's estimated risk aversion coefficient *r* in the *II*-treatment (estimations via maximum likelihood)

Subject	*r*	Subject	*r*
1	0.074	17	0.142
2	∞	18	0.143
3	0.020	19	0.337
4	3.305	20	0.041
5	∞	21	0.596
6	0.027	22	0.285
7	0.082	23	0.273
8	0.054	24	0.172
9	0.095	25	0.149
10	2.473	26	∞
11	0.011	27	0.744
12	0.205	28	∞
13	0.108	29	0.041
14	0.203	30	∞
15	0.943	31	0.820
16	0.010	32	∞

Table 4
Summary statistics on contributions in the two treatments

	Mean	Median	Std Dev	% of $c_i = 0$	% of $c_i = 100$
PI-treatment	78.08	100	35.33	9.06	65.94
II-treatment	40.75	40	35.3	25.31	12.81

Table 5
Generalized linear mixed-effects regression on individual contribution decisions

Independent variable	Coefficient	Std. Error	t-value	*p*-value
Constant	21.505	3.620	5.941	0.000
Exp_i	0.882	0.035	25.098	0.000
Info	-16.876	4.519	-3.734	0.001
Period	-2.689	0.377	-7.134	0.000
$Info \times Exp_i$	0.026	0.048	0.532	0.595
$Info \times Period$	2.557	0.533	4.800	0.000
Observations	640			
AIC	5572.8			

Table 6
Contributions as a function of risk attitudes (OLS regression)

	Dependent variable: contributions					
	Model 1: Average			Model 2: Period 1		
	Estimate	Std. Error	*p*-value	Estimate	Std. Error	*p*-value
Constant	98.12	8.15	0.000	92.50	9.30	0.000
Pratt's ρ	-388.80	130.06	0.004	-427.80	148.40	0.005
Info	-34.53	14.73	0.022	-19.40	16.80	0.007
Pratt's $\rho \times$ *Info*	-1076.83	740.9	0.151	-1800.6	845.60	0.037
Observations	32			32		
Adjusted R2	0.403			0.329		

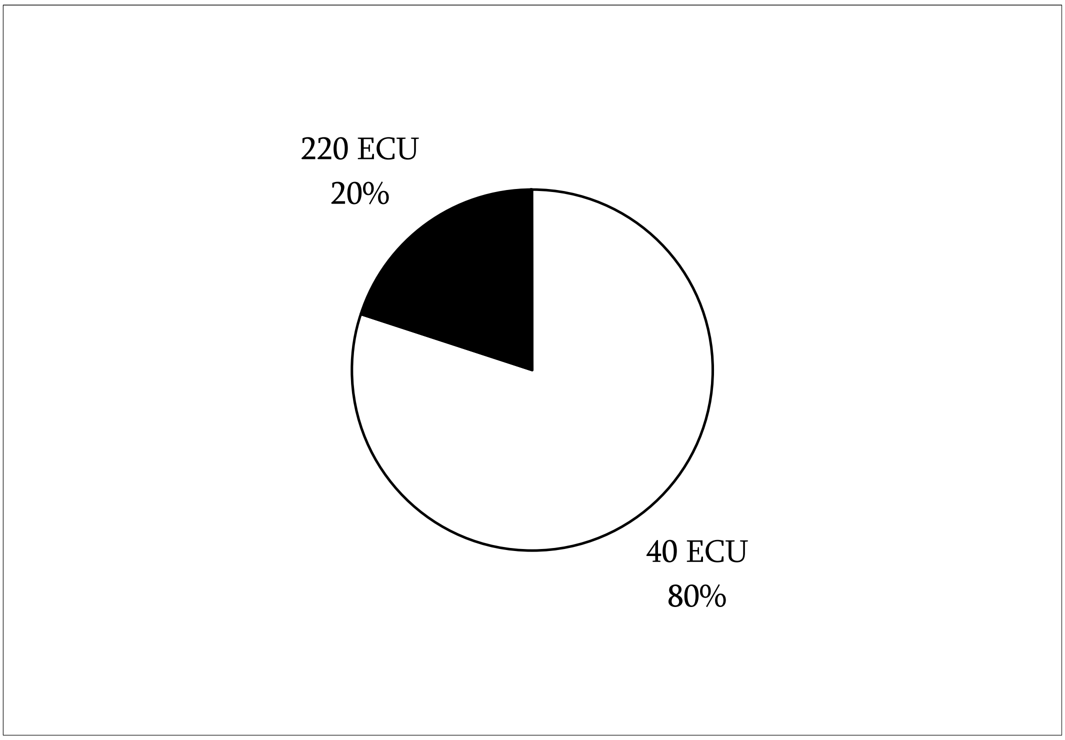

Fig. 1. Presentation of the lotteries.

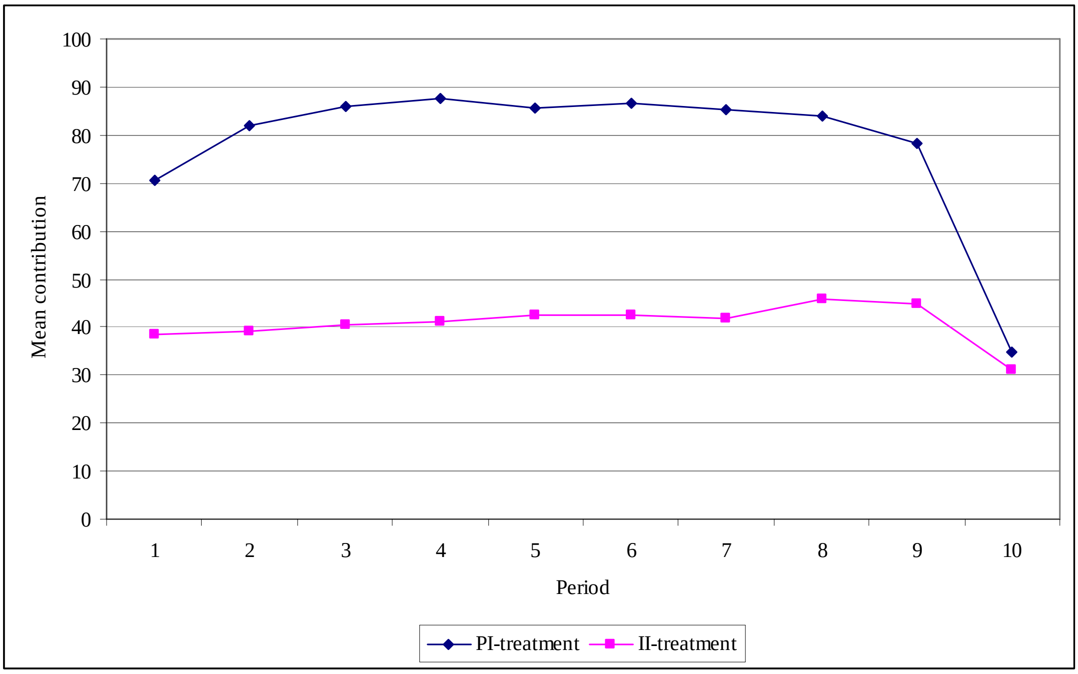

Fig. 2. Average contributions in each period, separately for the *PI*- and the *II*-treatment.