Cooperation is unaffected by the threat of severe adverse events in Public Goods Games

Ennio Bilancini[a], Leonardo Boncinelli[b], Chiara Nardi[a], Veronica Pizziol[*,a]

[a]IMT School for Advanced Studies Lucca, Italy
[b]Department of Economics and Management, University of Florence, Italy

Abstract

We study how cooperation in one-shot Public Goods Games with large group sizes is affected by the presence of a slight chance of severe adverse events. We find that cooperation is substantial, notwithstanding a low marginal return of contributions. The cooperation level is comparable to what is found in similar settings for small-sized groups. Furthermore, we find no appreciable effect of the threat of severe adverse events, whether their realization is independent across individuals, perfectly positively or negatively correlated. We conclude that cooperation in the Public Goods Game is unlikely to be affected by rare adverse events, independently of how risk is correlated across individuals.

JEL classification: $C90$; $D81$; $H41$.
Keywords: public goods game; online experiment; social dilemma; cooperation; risk; adverse events.

*Corresponding author. Address: IMT School for Advanced Studies, Piazza S. Francesco, 19, 55100 Lucca, Italy. E-mail addresses: *ennio.bilancini@imtlucca.it* (E. Bilancini), *leonardo.boncinelli@unifi.it* (L. Boncinelli), *chiara.nardi@imtlucca.it* (C. Nardi), *veronica.pizziol@imtlucca.it* (V. Pizziol).

1 Introduction

Cooperation, especially among strangers, is a recurring phenomenon in human societies which is not easy to explain (Nowak, 2006). Understanding its determinants and the extent to which it occurs has produced a large body of experimental evidence relying on the Public Goods Game (PGG) (Ledyard, 1995; Zelmer, 2003; Chaudhuri, 2011). Indeed, the PGG adequately captures the tension between self-interest, ultimately leading to free-riding, and the common good, which pushes towards maximising group payoff in a social context, i.e., not just between two persons (like in a Prisoner's Dilemma) but in a larger group.

While most of the existing studies on the PGG have focused on deterministic situations, actual decisions about how much to contribute to public goods are made in situations entailing some form of environmental risk. By the term "environmental risk", we intend the existence of an exogenous stochastic process that can generate adverse events that negatively affect individuals' payoff. Environmental risk has accompanied a vast part of human history (e.g., climate change, production shocks, technological change, floods, earthquakes). So, understanding if and to what extent environmental risk may affect cooperative behaviors seems both a natural and relevant matter, given the importance of cooperation for humankind's success.

In this paper, we try to understand the role played by a specific form of environmental risk in an experimental setting. In particular, we consider the case where the individual marginal return to cooperation is small and, in addition, there is a low probability that an adverse event will occur, which has a considerable negative impact on individuals' payoff independently of individuals' behavior. We focus on this case because, on the one hand, this is a widespread situation for social dilemmas involving cooperation and, on the other hand, it is the simplest and most basic setting for studying the role of environmental risk. One may want to consider cases where risk depends on individuals' behavior (e.g., the public good is a defense against the adverse event) or where adverse events are very likely (e.g., the gains from the public good are structurally very volatile). However, both these characteristics could have additional effects besides those of the kind of environmental risks we study here, presumably blurring the interpretation of results. Also, one may want to consider the situation where individual return to cooperation is substantial (e.g., the public good is very local or the group is small). Still, besides being possibly less relevant for actual social dilemmas, this case would lead to a relatively too small expected negative payoff generated by the small-chance adverse event, potentially diluting effects.

There is reliable evidence showing that environmental risk can affect cooperation in the linear PGG (e.g., Levati et al., 2009; Gangadharan and Nemes, 2009; Fischbacher et al., 2014). However, only few papers in this line of research have compared the role of risk correlation across individuals (i.e., Vesely and Wengström, 2017; Zhang, 2019; Théroude and Zylbersztejn, 2020), finding mixed results and leaving the scope for further investigations. Moreover, none of these papers focuses on low probability events. This feature may be relevant to understanding the evolution of cooperative behaviors in areas with a threat of natural disasters, social emergencies and targeted sacrifices. In particular, one may wonder whether cooperation might be more likely when a village is subject to the risk of floods, random kidnapping by bandits, or necessary sacrifice by one of its members.

In our experimental setting, we consider a one-shot linear Public Goods Game with groups of 40 members. We introduce stochastic adverse events that induce three different risk correlations across individuals: independent risk (each individual has a 2.5% probability of experiencing the adverse event), perfectly positively correlated risk (there is a 2.5% probability that all group members experience the adverse event), and perfectly negatively correlated risk (1 member out of 40 is randomly selected and experiences the adverse event for sure). This latter type of risk has led us to work with relatively large groups, allowing adverse events to occur with low probability. To the best of our knowledge, no experimental study has explored this setting.

More specifically, we run an incentivized online experiment with between-subject conditions: i) a negative event independently affecting a different number of group members, depending on a random draw at the individual level (*Independent Risk treatment*); ii) a negative event that strikes either all or nobody in the group, which depends on the realization of a random draw happening at the group level (*Positively Correlated Risk treatment*); iii) a negative event that hits only one member with certainty, depending on a random draw at the group level (*Negatively Correlated Risk treatment*).[1] We compare these

[1] Freundt and Lange (2021) introduce the concept of a negatively correlated risk in the PGG but, very differently from our design, apply it to the riskiness of internal and external

conditions to a *Control treatment* with deterministic payoffs in the absence of environmental risks. While it is always socially optimal to contribute, the incentive to free-ride is significant and constant across all conditions.

Differently from other papers investigating the effect of shared versus idiosyncratic risks (e.g., Zhang, 2019), our one-shot experimental design permits us to sterilize the impact of potential confounding factors, such as self-insurance or risk-sharing considerations, as well as learning effects. Given our focus on large groups, our experiment would be hard to implement in a laboratory setting, which is the main reason why we opted for an online setting. In turn, an online setting makes it hard to run repeated games due to asynchronicity and frequent drop-outs. This would especially hold for our case, where the group is quite large and learning effects require a high number of repetitions due to small probabilities. Likewise most other papers, we also study these differences in the absence of payoff-driven concerns because payoffs are equivalent in expectation across all conditions.[2]

We establish that there is no appreciable difference in cooperation levels across the four conditions. So, the presence of a slight chance of severe adverse events does not affect cooperation, and risk correlation across individuals—positive or negative—does not appear to play any role. These findings support the generalizability of previous results based on the deterministic PGG workhorse. Likewise, they also support standard choice models that rely on expected utility theory with other-regarding preferences, excluding specific effects of low probabilities or risk correlations. Therefore, we are in line with Théroude and Zylbersztejn (2020)'s findings and extend them to a negatively correlated risk and a low probability of substantial losses.

The remainder of the paper is organized as follows. In the next section, we review the relevant literature. In Section 3, we describe the experimental design, the hypotheses, and procedures. In Section 4, we present the empirical analyses. Section 5 discusses the results and offers concluding remarks.

returns.

[2]This is a standard approach used in other social dilemmas as well (e.g., Xiao and Kunreuther, 2016).

2 Related literature

The present paper is generally connected to the experimental economic literature that studies the effects of uncertainty on the provision of public goods. Scholars have been employing many different ways to introduce uncertainty in the PGG. For instance, Dickinson (1998) does so through the possibility of *ex post* exclusion from the public good's benefits. Others induce uncertainty by allowing for the production (or enhancement) of the joint investment's benefits only if the total amount of contributions overcomes a target level with a variant of the PGG known as the threshold or step-level PGG (e.g., Sonnemans et al., 1998; Gueth et al., 2015).[3]

Some other studies induce uncertainty in the PGG by seeding risk via a lottery-style MPCR. Levati et al. (2009) is the first study to combine risk preferences with voluntary contributions in this setting. They show that introducing risk on the MPCR, which is randomly selected for all group members, decreases contributions and that risk-aversion has a strong negative effect on them. Levati and Morone (2013) find that this result cannot be extended to the case where the minimum value of the stochastic MPCR still allows for efficiency gains, even when probabilities are unknown. Also Artinger et al. (2012) and Cherry et al. (2015) study cooperation in a linear PGG with risky MPCRs, finding that cooperation in the risky settings compared to deterministic ones is lower (Artinger et al., 2012; Cherry et al., 2015) or comparable when the negative event's probability is very low (Artinger et al., 2012). Very differently from our design, however, in these papers, the payoff of the public good is the only at risk, so the private account represents a safe investment.

Lastly, within this same branch of literature, only a few recent papers vary, as we do, the level at which the environmental risk arises, i.e., whether at the individual or the group level, namely, Vesely and Wengström (2017); Théroude and Zylbersztejn (2020). Despite we do not have stochastic MPCRs, our work closely relates to Vesely and Wengström (2017); Théroude and Zylbersztejn (2020) precisely because of the risk correlation's treatments. Table 1 provides

[3] When failure to reach the target entails a chance to lose funds, the game is known under the name of "collective-risk social dilemma" (e.g., Milinski et al., 2008, 2011; Tavoni et al., 2011; Dannenberg et al., 2015; Brown and Kroll, 2017). This framework has been extensively used to model environmental dilemmas related to the fight against climate change. A typical finding of this branch of literature is that groups fail to cooperate when they perceive a low probability for a catastrophic event to occur, while the perception of a likely catastrophe fosters cooperation.

a summary of the differences in terms of parameters, treatments, and results in these studies, as well as in Zhang (2019), who also manipulates risk correlations but picks as negative event the risk of losing each period's payoff. These three studies share some characteristics (which are not put in the table) that, instead, deviate from our design: they all employ lab experiments with students, and have public good groups made up of 4 members. In Zhang (2019)'s repeated PGG, the probability of experiencing the adverse event—that is, the loss of all the payoff in a period—is negatively related to the payoffs from the game in that period. What is found is that cooperation is higher in the presence of risk at the group level than at the individual one. Differently, Théroude and Zylbersztejn (2020) keep the risk, which is embodied in the stochasticity of the MPCR, to be wholly exogenous and compares the risky treatments also to a control treatment with deterministic payoffs. No statistically significant and systematic effect of risk on the patterns of cooperation is found across all conditions, neither in the one-shot nor in the repeated version of the game. Likewise, Vesely and Wengström (2017) compares these same three conditions in a setting of risky MPCRs, where only a repeated version of the game is present. They instead find that risk stimulates cooperation, with an higher effect when risk is at the individual rather than at the group level. Overall, these results provide mixed evidence and leave space for further investigation on the role of risk correlation across individuals. Also, these papers never focus on a very low probability of the adverse event, as we do by keeping it constant to a value as low as 2.5%.

Paper	Type of Interaction	Treatments	α no risk	α low, α high	Loss	Probability	Results
TZ (2020)	One-shot, Repeated (10 periods)	Baseline, Heterogeneous Risk, Homogeneous Risk	0.4	0.3, 0.5	-	0.5	HetR no effect. HomR +ve effect only in early rounds.
Z (2019)	Repeated (20 periods)	Independent Risk, Common Risk	0.4	-	Payoff of the period	+vely related to risk level & -vely to payoffs	COM +ve effect compared to IND.
VW (2017)	Repeated (20 periods)	No Risk, Independent Risk, Correlated Risk	0.5	0, 2	-	0.75	IR and CR +ve effect compared to NoRisk. IR strongest effect.

Table 1: Summary of experimental designs and results employed to manipulate the role of risk correlations. TZ (2020) is Théroude and Zylbersztejn (2020), Z (2019) is Zhang (2019), VW (2017) is Vesely and Wengström (2017). α is the MPCR in the non-risky conditions in TZ (2020) and VW (2017), and always in Z (2019). *α low, α high* are the two MPCRs in the risky conditions in TZ (2020) and VW (2017). *Loss* is the loss type in Z (2019). *Probability* indicates the probability of the negative event.

Since we have groups of 40 members, our work also relates to the literature on PGGs with big group sizes. Contrary to the intuition that cooperation should be more attainable in smaller groups, some studies find that larger groups cooperate moderately or significantly more than smaller ones, concluding that group size positively affects cooperative behavior (Isaac and Walker, 1988; Isaac et al., 1994; Nosenzo et al., 2015; Barcelo and Capraro, 2015; Diederich et al., 2016). Although we do not manipulate group size, we bring new evidence on PGGs characterized by a low MPCR and a high number of members, enhancing the connection to real-world scenarios where public goods naturally provide small marginal returns in big communities.

3 The experiment

3.1 The public goods game and treatments

The main task of our experiment is a linear PGG. Participants are randomly matched in large groups of $N = 40$ and interact only once. Each individual $i \in N$ receives an endowment e_i which he can either keep for himself (private account) or contribute to a public good. Any contribution to the public good is multiplied by 2 and divided equally among the members of the group, implying that the MPCR is 0.05.

To investigate whether and to what extent different types of environmental risk influence cooperation, contribution decisions in the PGG are collected under four treatments.

(i) In the *Control* treatment (C) participants play the standard deterministic (i.e., risk-free) PGG.

(ii) In the *Independent Risk* treatment (IR) participants face the risk of being hit by an exogenous adverse event. The adverse event—which takes the form of a lump-sum loss λ—happens with probability p. In each group, the participants' chances of being hit by the adverse event are independent, meaning that none, some, or all group members can be hit.

(iii) In the *Positively Correlated Risk* treatment (PCR) participants face the same probability p of being hit by the adverse event (loss λ) as in IR. However, contrary to IR, the participants' chances of being hit by the adverse event are positively correlated, meaning that none or all group members can be hit.

(iv) In the *Negatively Correlated Risk* treatment (NCR) participants face, once again, the same probability p of being hit by the adverse event (loss λ). Their chances of being hit by the adverse event are now negatively correlated, meaning that only one randomly selected group member can be hit.

In the risk-involving treatments (IR, PCR, and NCR), the adverse event realizes after the game choices are made. The probability of the adverse event, p, is the same across all three treatments and it is set to be equal to $1/N$ (i.e., 1/40 or 2.5%). When a participant is hit by the negative event, a loss λ of 40 Points is deducted from his earnings.[4] To ensure that the risk-involving treatments are equivalent to the standard public goods game (treatment C) in terms of expected payoffs, we set the endowment in IR, PCR and NCR equal to 60 Points and the endowment in C to 59 Points.[5]

Furthermore, to avoid negative payoffs in case of adverse event, participants' contributions in all treatments are restricted to integer numbers between

[4]The exchange rate between Points and Pounds is set at 10 Points = £0.20 for all participants.

[5]The difference in endowments between the risk-involving treatments and the risk-free treatment is equal to the expected loss (i.e., 1 Point). Such a small difference is very unlikely to produce endowment effects.

0 and 20 Points, i.e., $c_i \in \{0, 1, 2, \ldots, 20\}$.

It is worth mentioning that the risk of an exogenous adverse event does not change the incentive structure of the PGG. In all treatments, a rational and selfish participant has an incentive to be a free-rider and to contribute nothing ($c_i = 0$), whereas a full contribution ($c_i = 20$) represents the social optimum.

3.2 The role of uncertainty

Following the so-called *perceived target of the threat* principle outlined by Weisel and Zultan (2016), one could expect that when individuals perceive their group to be under threat, they tend to act for the group's good and contribute more. In contrast, they tend to act more selfishly and withhold their contributions when they perceive the threat to be personally upon themselves. However, in a context where uncertainties cannot be reduced by cooperation, risk might not play an influential role (for instance, null effects are found in Björk et al., 2016). It is not easy to advance specific hypotheses in this regard. *A priori*, it is unclear whether inducing different types of environmental risks, affecting the whole community, part of it, or only one member, can overcome or boost the free-riding problem and to what extent. We believe that the first step is to document if and to what extent cooperative behavior is affected.

For the above reasons, we just test the following two null hypotheses:

Hypothesis 1: *No difference exists in contribution levels between the control and any of the risky experimental conditions.*

Hypothesis 2: *No difference exists in contribution levels between any pair of risky experimental conditions.*

The answers to these hypotheses are given in Subsection 4.2 (Result 1 and Result 2, respectively) by testing the significance of the different conditions in Tobit regressions run on the experimental data collected.

3.3 Procedures

The experiment—preregistered (AsPredicted number: #85704) and approved by the Joint Ethical Committee of Scuola Normale Superiore and Scuola Superiore Sant'Anna (Italy)—was programmed in oTree (Chen et al., 2016) and conducted online between the end of January and the beginning of March 2022. The participants were recruited through Prolific (Palan and Schitter, 2018) among the US adult population. Upon entering the study, they were asked to provide informed consent and to read the instructions (reproduced in the Appendix).[6] Before starting the experiment, subjects had to answer some control questions testing their comprehension of the decision task. The experiment did not start until participants had answered all the questions correctly. We can, therefore, safely assume that they understood the game.

After making their game choices, and before receiving any feedback, participants had to report their (first-order) beliefs about others' contributions. Beliefs were elicited by asking each participant to guess the average contribution of the group members. We gave participants a financial incentive to report beliefs accurately. We paid them 10 Points if they estimated the actual contribution of others correctly (+/−0.5 Points) and nothing otherwise. Incentives in the belief task were kept small relative to incentives in the PGG to avoid hedging (Blanco et al., 2010). When participants made their game decisions, they were unaware of the subsequent belief elicitation task. This avoids any influence of beliefs on game decisions.[7]

Upon completion of the belief elicitation task, participants filled out a post-experimental questionnaire asking them about their risk tolerance and their general preferences (positive reciprocity, altruism and trust).[8] The risk tolerance was measured with a non-incentivized question from the German Socio-Economic Panel asking participants to rate their willingness to take risks in general on an 11-point scale ranging from 0 (not at all willing to take risks) to 10 (very willing to take risks). The behavioral validity of this survey risk measure has been confirmed by Dohmen et al. (2011). Positive reciprocity, altruism and trust were elicited with questions from the Global Preference Survey (Falk et al., 2018). More specifically, they were respectively measured by asking participants to self-assess their willingness i) to return a favor, ii) to give to good causes without expecting anything in return, and iii) to as-

[6]The instructions contained a simple attention check to ensure that participants were reading them carefully. As stated in the preregistration, only subjects who did not fail the attention check were allowed to participate in the experiment.

[7]Notwithstanding the extensive body of literature devoted to the question of how beliefs should be elicited (before or after choices), this is not a settled issue (Charness et al., 2021). We preferred asking first about choices because these are our most important data.

[8]The post-experimental questionnaire (reproduced in the Appendix) did not include questions on the participants' demographic characteristics—namely, age, gender, and student status—as these information can be retrieved from Prolific. The questionnaire also elicited loss aversion using the lottery choice task proposed by Gächter et al. (2021). Yet, given the pitfalls of this task in settings (like ours) in which the stakes can no longer be considered small, in the remainder of the paper we overlook such measure.

sume that people have only the best intentions. The three answers had to be provided on a scale from 0 to 10, where a higher rating indicated a higher willingness to act in the described way.

The post-experimental questionnaire also included two mathematical questions testing the participants' literacy about probability. These questions were intended to measure both a basic knowledge of probabilities and the so-called 'conjunction fallacy', which occurs when it is assumed that the conjunction of two events is more—rather than less—likely to occur than one of the events alone.[9] A math score was then constructed as the sum of correct answers, ranging from 0 to 2.

We used a between-subjects design, i.e., each subject was exposed to only one of the four treatments. Averaging over all treatments, mean earnings amounted to £2.18 (inclusive of a £0.75 fixed participation fee) and participants took about 10 minutes to complete the experiment. The incentives in the experiment were thus substantial and perfectly resembled the hourly compensation usually provided in lab experiments (namely, £13).

3.4 Participants

Overall, 1280 subjects participated in the experiment, i.e., 320 participants (8 groups) per treatment. The sample size was determined using an *a-priori* power analysis for a t-test with a mean contribution in the control treatment equal to 14,[10] a power of 0.80, an alpha of 0.05, and an alleged effect size of 0.275. We aimed at having an effect size between 0.2 and 0.3 because we wanted to improve on the previous related work significantly (d=0.5 in Théroude and Zylbersztejn, 2020), while at the same time excluding economically irrelevant effects.

Table 2 reports summary statistics of demographic characteristics and individual preferences of our sample, divided by treatment. Overall, the average

[9]The questions read: "Two fair six-sided dice are rolled. What is the probability that their sum is exactly equal to 2? a) 1/3, b) 1/6, c) 1/18, d) 1/36" and "Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations. Which of the following statements is more probable? a) Linda is a bank teller, b) Linda is a bank teller and is active in the feminist movement". The latter question is due to Kahneman and Tversky (1982).

[10]This is a conservative expectation: in an online, standard PGG experiment conducted on MTurk, with a group size of 4 and a MPCR of 0.4, Arechar et al. (2018) reported an average contribution of 15 out of 20.

Table 2: Means (and standard deviations) of participants' characteristics and preferences.

	C	IR	PCR	NCR
Age	28.00	29.31	29.40	29.33
	(10.13)	(11.35	(11.49)	(12.39)
Female	0.62	0.63	0.63	0.63
	(0.48)	(0.48)	(0.48)	(0.48)
Student	0.29	0.28	0.24	0.28
	(0.45)	(0.45)	(0.43)	(0.45)
Experienced	0.30	0.31	0.32	0.31
	(0.46)	(0.46)	(0.47)	(0.46)
Risk tolerance	5.05	5.06	5.50	5.42
	(2.22)	(2.38)	(2.30)	(2.17)
Positive reciprocity	8.71	8.86	8.76	8.83
	(1.32)	(1.25)	(1.30)	(1.27)
Altruism	7.59	7.63	7.64	7.72
	(2.03)	(1.99)	(1.96)	(2.02)
Trust	5.22	5.09	5.25	5.31
	(2.34)	(2.48)	(2.26)	(2.38)
Math score	1.52	1.43	1.47	1.49
	(0.58)	(0.60)	(0.59)	(0.56)
Observations	320	320	320	320

age is around 29 and about two-thirds of the participants are female. Approximately thirty percent of the participants are students and about the same percentage are experienced Prolific users (i.e., have completed at least 150 studies). Based on the participants' responses to the SOEP question, our sample is, on average, risk neutral in all treatments. Finally, our sample is well balanced in terms of general preferences (positive reciprocity, altruism, and trust) and probability literacy, which is measured by the math score.[11]

4 Results

In this section, we present our results. We first display some descriptive and non-parametric analyses. We then investigate the presence of treatment effects by making use of regressions, which allow us to control for heterogeneity in participants' demographic characteristics and individual preferences. Finally,

[11] According to a series of χ^2 tests, we find no differences in gender, student status and experience in using Prolific across treatments (p-values equal 0.996, 0.528, and 0.964, respectively). Similarly, a series of Kruskal-Wallis tests does not reveal any differences in age, positive reciprocity, altruism, trust, and math score (p-values equal 0.689, 0.376, 0.824, 0.864 and 0.306, respectively). Although the risk tolerance seems to vary across treatments (Kruskal-Wallis test, p-value = 0.025), this variation becomes statistically insignificant applying the Bonferroni correction for multiple testing.

we briefly report on the elicited first-order beliefs.

4.1 Descriptive and non-parametric analyses

Figure 1 depicts, separately for each treatment, the mean contributions to the public good. Its visual inspection reveals two noteworthy features. First, the Control treatment replicates the most recent findings in online, one-shot PGGs (van den Berg et al., 2020; Catola et al., 2021; Isler et al., 2021): the mean contributions are equal to 11.78, or, alternatively, 59% of the points available for the allocation decision. Remarkably, contributions in the C treatment are substantial, even though—compared to the previous studies—we implement a larger group size ($N = 40$) and a much smaller marginal per capita return ($MPCR = 0.05$).

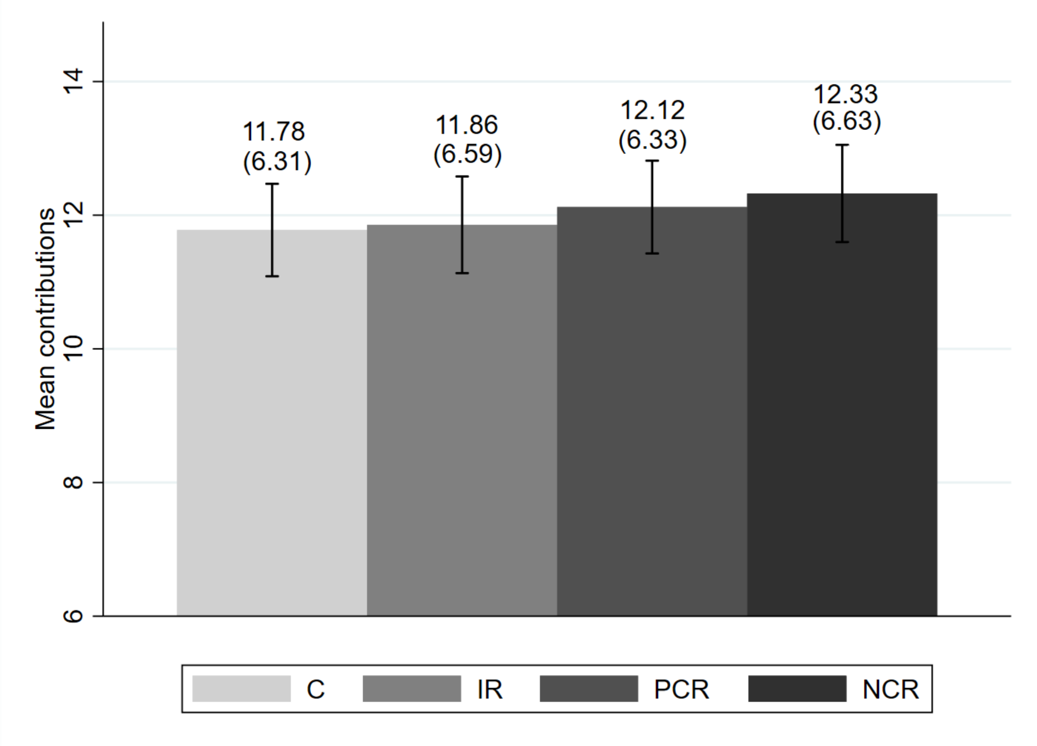
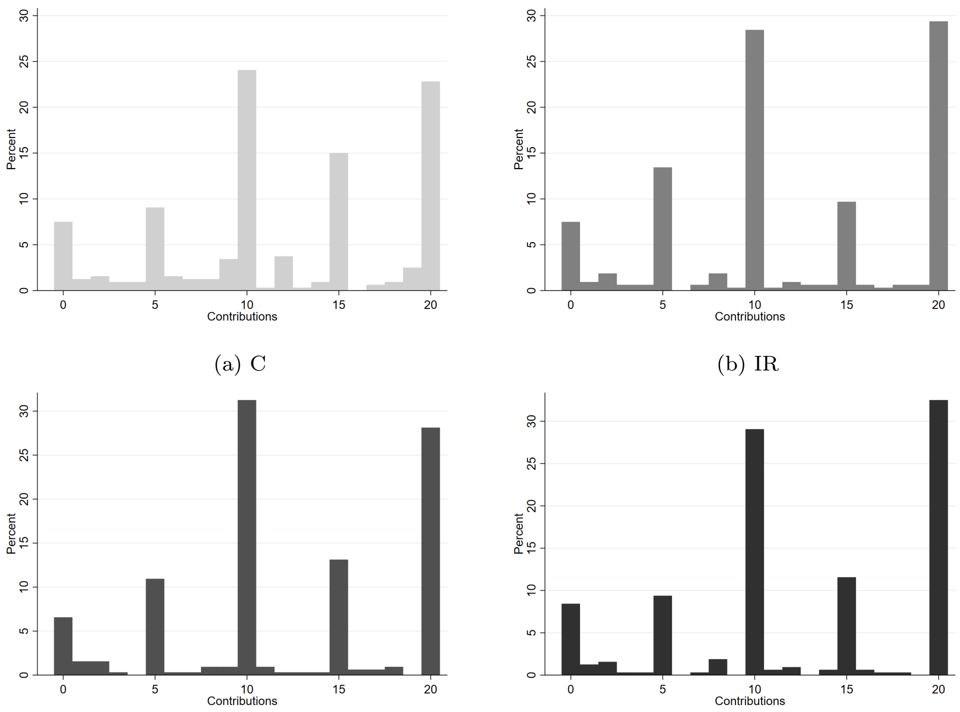


Figure 1: Mean contributions by treatment. Standard deviations in parentheses. Confidence intervals at the 95% level.

The second fact documented through Figure 1 is that the mean contributions in the risk-involving treatments are slightly higher than in C, especially in the PCR and NCR treatments. Yet, the differences are not statistically significant, either when simultaneously comparing all treatments (Kruskal-Wallis test, p-value equal 0.5254) or when implementing pairwise comparisons between treatments (Wilcoxon rank-sum tests, all p-values > 0.1653).[12] The lack of treatment effects is further confirmed by looking at the distribution of contributions across treatments, which is displayed in Figure 2. The figure shows that the game-theoretic prediction of universal free riding, based on general opportunism, is clearly rejected in all treatments: the proportions of free-riders are stable across treatments and are as low as 7.5% in C and IR, 6.5% in PCR and 8.5% in NCR. Moreover, the contributions are bimodal (at 10 and 20 Points) in all treatments, with a higher proportion of people contributing 10 or 20 in the risk-involving treatments than in the Control. Although there seems to be some variation in the fraction of half and full contributors between the risk-free and the risk-involving treatments, a series of Epps-Singleton tests does not reject the null hypothesis of equal distributions across treatments (all p-values > 0.0545).



(a) C (b) IR

(c) PCR (d) NCR

Figure 2: Distributions of contribution choices by treatment.

[12]All p-values in the paper are two-tailed.

4.2 Treatment effects on contributions

Table 3 shows the results of Tobit models aimed at examining the contribution choices in the PGG, which are bounded between 0 and 20. The coefficients of the treatment dummies—"IR", "PCR" and "NCR"—in column (1) are positive and insignificant, confirming that the contributions in the risk-involving treatments do not statistically differ from those in the Control treatment (the reference category). The coefficients of the treatment dummies are also similar (i.e., not statistically different) in magnitude (see the post-estimation equality of coefficient tests reported at the bottom of the table). This holds true even if we add controls for participants' demographics and preferences as well as for the time spent on the decision page (see column (2)).[13] Among the added control variables, "Age", "Risk tolerance", "Positive reciprocity", "Altruism", and "Trust" have a positive and significant impact on contributions. More specifically, contributions are found to increase with age. This evidence is consistent with psychological research reporting that older adults value contributions to the public good more than younger ones (Freund and Blanchard-Fields, 2014). A higher willingness to take risk—as measured by the SOEP question—is associated with a higher propensity to contribute (which is not surprising since the participants receive a lower payoff if their group members do not contribute anything) and participants with a higher positive reciprocity disposition are more inclined to contribute. Finally, as one would intuitively expect, more altruistic participants and those who exhibit higher levels of trust in others tend to contribute more.

In conclusion, we state the following two results:

Result 1: *Keeping the expected payoff constant for given contribution levels, the mere addition of environmental risk—taking the form of an exogenous low chance of a substantial negative shock—does not produce appreciable changes in contribution decisions.*

Result 2: *Different risk correlations (zero, positive, negative) of the environmental shock do not appreciably affect contribution decisions.*

[13]The effect of different types of environmental risks on contributions remains null even if double-hurdle regressions, which allow to separately consider the decision to contribute (extensive margin) and the decision of how much to contribute (intensive margin), are used. Results are available upon request.

Table 3: Tobit regressions examining the contribution choices in the PGG.

	(1)	(2)
IR	0.475	0.282
	(0.769)	(0.718)
PCR	0.732	0.137
	(0.752)	(0.713)
NCR	1.138	0.525
	(0.786)	(0.740)
Age		0.096***
		(0.029)
Female		-1.133
		(0.661)
Student		-0.890
		(0.579)
Experienced		-0.832
		(0.650)
Risk tolerance		0.847***
		(0.134)
Positive reciprocity		0.602*
		(0.236)
Altruism		0.498**
		(0.161)
Trust		0.295*
		(0.125)
Math score		-0.070
		(0.470)
Log(Time)		-0.302
		(0.514)
Constant	12.694***	-2.667
	(0.523)	(2.732)
Tests of coefficients (p-values)		
IR vs. PCR	0.744	0.8448
IR vs. NCR	0.417	0.7523
PCR vs. NCR	0.612	0.6118
Observations	1280	1280
Pseudo R^2	0.000	0.022

Notes: Robust standard errors are reported in parentheses. ***, **, and * denote significance at the 0.1%, 1%, and 5% level, respectively.

Given these null results, we think that it is crucial to devote particular attention to discussing the statistical power related to our sample size. With a Cohen's d being equal to 0.275, we would have been able to detect a small effect size. This, in turn, corresponds to a 1.78 Point difference in the mean contribution values between treatments, given that the standard deviation over the whole sample is about 6.46. We substantially improve the statistical power of our analyses if compared to Théroude and Zylbersztejn (2020), where a null result is also found but with a sample size of around 70 subjects per treatment, which attains the reference power of 0.8 (and the significance level of 0.05) with a Cohen's d of 0.5, thus detecting just effects of medium size. Detecting a small effect size is an improvement because it excludes any economically meaningful effect of our experimental conditions on the contribution variable.

4.3 Beliefs

Figure 3 plots the mean values of elicited first-order expectations about others' behavior, divided by treatment. Participants expect the group members to contribute, on average, about half of the available points and this is stable across treatments.

The participants' beliefs are strongly and positively correlated with their own behavior in the PGG (the Pearson's correlation coefficients are equal to 0.4854, 0.5814, 0.5311, and 0.5206 in C, IR, PCR, and NCR, respectively; all coefficients are statistically significant at the 0.1% level). This finding can be interpreted as a signal of compliance with social norms. Indeed, in many contexts, social norms can help explain why individuals behave prosocially at a cost for themselves (e.g., Bicchieri et al., 2022). Alternatively, it could reflect the so-called *false consensus effect* (Ross et al., 1977), suggesting that participants who are more prone to contribute have more optimistic beliefs about others' behavior.

As for the accuracy of beliefs, we find that only a small fraction of subjects—i.e., less than 10%—perfectly predicts the actual average contribution of the group members (±0.5). The mean difference between beliefs and others' actual contributions is always negative and ranges from -1.77 (SD = 4.45) in IR to -2.37 (SD = 4.78) in NCR. Hence, participants underestimate the degree of others' prosocial behavior in all treatments. This is in line with recent findings for linear PGG games played online (e.g., Catola et al., 2021; Bilancini

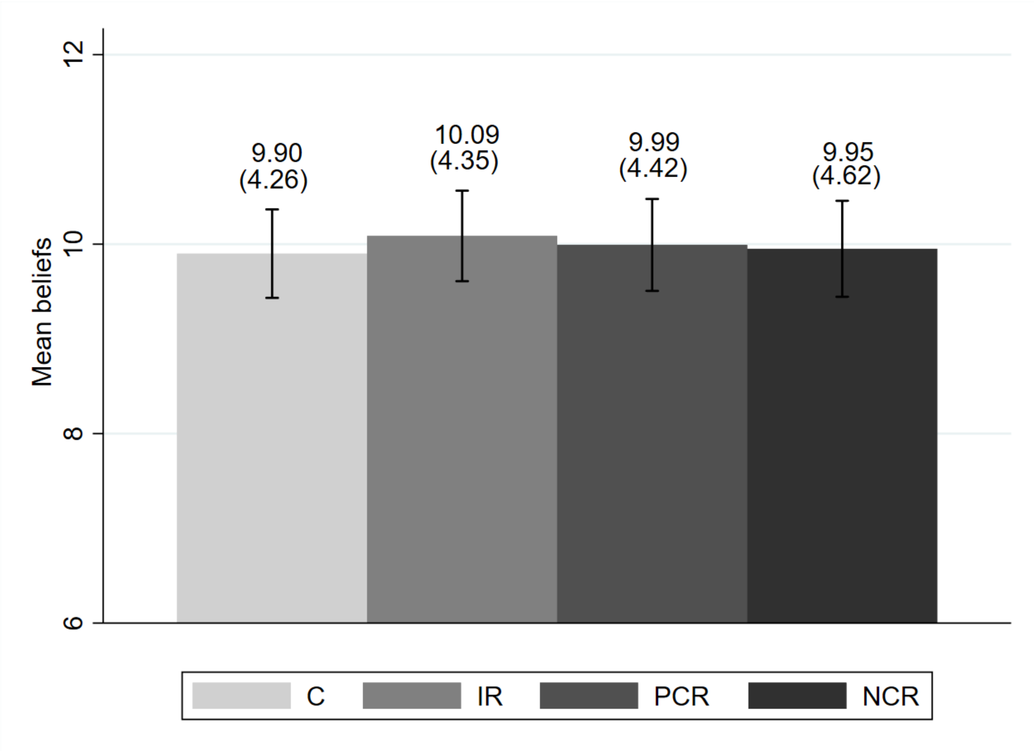


Figure 3: Mean beliefs by treatment. Standard deviations in parentheses. Confidence intervals at the 95% level.

et al., 2022), while for laboratory experiments it has been often found the opposite (e.g., Fehr et al., 2008; Kocher et al., 2015). It is not straightforward to rationalize such mixed evidence.

5 Discussion and conclusions

A large body of experimental evidence reports that people typically cooperate in the PGG, even in one-shot anonymous interactions. Most studies focus on the case with no environmental risk. In this paper, we add to the literature by documenting that this tendency is fundamentally preserved in the presence of a low probability of an adverse event having a considerable negative impact on individuals' payoff independently of individuals' behavior. More specifically, we document that cooperation levels are considerable (about 60% of resources available for contribution) even though the marginal return of contributing is as little as 0.05 and, interestingly, these cooperative levels are in line with what is found in other online one-shot PGGs employing small group sizes with much larger individual returns.

Most importantly, from our experimental findings we can conclude that the mere addition of environmental risk does not change cooperative behaviors with respect to deterministic scenarios. Additionally, we find that the nature of environmental risk—i.e., whether it is independent, positively or negatively correlated across individuals—does not appreciably affect cooperation levels.

Our results can be considered in the light of decision theories in uncertain environments. For instance, following Tversky and Kahneman (1992) and Prelec (1998), one could expect that people tend to overweight low probabilities when dealing with described probabilities in scenarios entailing some risk, like ours. However, the actual effect on the behavior of such over-weighting depends crucially on the expected value of the negative shock and individuals' risk attitudes. In our experimental setting, expected payoffs conditional on group members' contributions are identical across all treatments. Moreover, there is only a 2.5% chance that the final payoff is reduced by about 2/3 of the initial endowment. So, under the assumption of risk-neutrality, the expected value of the negative shock is little and should not affect behavior even if over-weighting is strong. Our results are consistent with this prediction. In general, although individuals might not follow the expected utility theory (see, e.g., Starmer, 2000), it needs not to show up in our data, provided that risk attitudes are not too far from risk neutrality, as seems to be the case with our experimental subjects.

Furthermore, one may consider the role of other-regarding preferences, such as altruism (Anderson et al., 1998; Andreoni and Miller, 2002) or inequity aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Fischbacher et al., 2014). In principle, one might expect that such other-regarding preferences affect behavior depending on the presence of risk and the type of risk correlation since the realization of the adverse event will not affect group members in the same way. However, given the additive nature of the stochastic component in our setting and its small expected value in absolute terms, the expected welfare changes in a large group are quite diluted. So, even substantial altruism or strong inequity aversion are not expected to affect behavior across treatments, in line with what we observe.

We stress that our experimental data improve, in terms of statistical power and detectable effect size, upon previous work (Théroude and Zylbersztejn, 2020). Hence, the lack of treatment effects suggests that the nature of environmental risk—i.e., whether it is independent, positively, or negatively correlated across individuals—is not a primary source of behavioral effects, at least as a single source of variation as we tested in our experiment. It remains to explore whether this neutrality survives in different settings with an endogenous risk, endogenous group membership, and size, or adverse event mitigation.

Indeed, in our study, we focus on a kind of environmental risk where contributing to the public good does not affect the probability of the adverse event or the size of its effects upon realization. Thus, we leave out the relation between investments in the PGG and the negative environmental shock. A different research line can investigate this aspect, along the lines of Dickinson (1998). Also, it seems interesting to inquire about the reactions to the realization of a disaster by looking at the *ex-post*, rather than *ex-ante*, cooperative behavior. Further research could also investigate the role of conditional cooperators (Fischbacher et al., 2001) to check whether there are differences in the behavior of such players type that do not mirror the average behavior.

Declaration of competing interest

The authors declare that there are no conflicts of interest.

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Appendix: Experimental instructions, belief elicitation and questionnaire

Instructions

Group formation and exchange rate

In this study, you will be placed in a group of 40 people. The group will be randomly formed. Nobody will ever learn the identity of the other members of the group. In this study all amounts will be expressed in Points rather than pounds. The exchange rate is 10 Points = £0.20.

Decisions

You (as well as the other members of your group) will be endowed with 60 Points. You have to decide how many of the Points that you have you want to contribute to a project that yields Points for you as well as for the other group members. More specifically, the sum of contributions that you and your group members make to the project is multiplied by 2 (return from the contribution in the public project), and then divided by 40 (number of members in the group). Your contribution can be any integer number between 0 and 20 Points (i.e., 0, 1, ..., 20). The Points that you do not contribute you keep (they are your own and yield income just for you).

Your earnings

Your earnings are calculated as the sum of:

a) "Points from the project" = sum of contributions to the project made by you and your group members, multiplied by (2/40 =) 0.05;
b) "Points that you keep" = 60 minus your contribution to the project.

The calculation of the other group members' earnings will be completely similar.

[*Participants in the Independent Risk treatment read:*

Risk of negative event on each member of the group

There is the risk that 40 Points are deducted from the earnings calculated above. To determine whether to deduct the 40 Points, the computer will randomly select an integer number between 1 and 40 (i.e., 1, 2, ..., 40). If the selected number is equal to 1, the 40 Points will be deducted from the earnings; if the selected number is between 2 and 40, the earnings will remain unchanged. The computer will select a number for EACH member of the group. Consequently, the 40 Points will be deducted from the earnings of none, some, or all members of the group.]

[*Participants in the Positively Correlated Risk treatment read:*

Risk of negative event on all members of the group

There is the risk that 40 Points are deducted from the earnings calculated above. To determine whether to deduct the 40 Points, the computer will randomly select an integer number between 1 and 40 (i.e., 1, 2, ...,40). If the selected number is equal to 1, the 40 Points will be deducted from the earnings; if the selected number is between 2 and 40, the earnings will remain unchanged. The computer will select a number for ALL members of the group. Consequently, the 40 Points will be deducted from the earnings of none or all members of the group.]

[*Participants in the Negatively Correlated Risk treatment read:*

Risk of negative event on one member of the group

There is the risk that 40 Points are deducted from the earnings calculated above. The 40 Points will be deducted from the earnings of ONE member of the group. This member will be randomly selected by the computer from the 40 people in the group.]

Belief elicitation task

(We now ask you to guess the average contribution of your group members. You can earn an extra amount of money depending on how close your estimate is to the actual average contribution of the other group members. If your estimate is exactly right or not more than 0.5 Points away from the actual average contribution, you will earn 10 Points. Otherwise, you will earn 0 Points.)

In your opinion, what is the average contribution of your group members? You can insert any number (with two digits) between 0 and 20. . . .

Post-experiment questionnaire

(We kindly ask you to answer a short questionnaire. Your responses are completely confidential and are not incentivized.)

1. Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please indicate your answer on a scale from 0 to 10, where 0 means "unwilling to take risks" and 10 means "fully prepared to take risks".

2. How well do the following statements describe you as a person? Please indicate your answer on a scale from 0 to 10, where 0 means "does not describe me at al" and a 10 means "describes me perfectly".
   - When someone does me a favor I am willing to return it.
   - I assume that people have only the best intentions.

3. How willing are you to give to good causes without expecting anything in return? Please indicate your answer on a scale from 0 to 10, where 0 means "completely unwilling to do so" and 10 means "very willing to do so".

4. We now ask you to make 6 different decisions. Each decision implies a choice between two options:
   - Option A gives you a 50% chance to win £6 and a 50% chance to lose an amount x, and
   - Option B gives you nothing with certainty.

   Please make your 6 decisions, choosing each time your preferred option.

	Option A	**Option B**	**Decision**
1	50% chance to win £6, 50% chance to lose £2	£0 for sure	A ○ ○ B
2	50% chance to win £6, 50% chance to lose £3	£0 for sure	A ○ ○ B
3	50% chance to win £6, 50% chance to lose £4	£0 for sure	A ○ ○ B
4	50% chance to win £6, 50% chance to lose £5	£0 for sure	A ○ ○ B
5	50% chance to win £6, 50% chance to lose £6	£0 for sure	A ○ ○ B
6	50% chance to win £6, 50% chance to lose £7	£0 for sure	A ○ ○ B

5. Two fair six-sided dice are rolled. What is the probability that their sum is exactly equal to 2?
   - 1/3
   - 1/6
   - 1/18
   - 1/36

6. Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations. Which of the following statements is more probable?
   - Linda is a bank teller.
   - Linda is a bank teller and is active in the feminist movement.

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