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Cooperation is unaffected by the threat of severe adverse events in public goods games

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ABSTRACT

In the context of a one-shot public goods game with a large group size and a low marginal per capita return, we study if and how cooperation is affected by the presence of environmental risk – defined as an exogenous stochastic process that generates a severe adverse event with a very small probability – and by the correlation of such risk among the group members. More specifically, we run an online experiment to investigate the effect of a risk that is independent across group members, a risk that is positively correlated among group members, and a risk that is negatively correlated among group members on cooperation. We find that neither the presence nor the correlation of risk significantly affects individual contributions.

1. Introduction

Cooperation, especially among strangers, is a recurring phenomenon in human societies that 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) (Chaudhuri, 2011; Ledyard, 1995; Zelmer, 2003). Indeed, the PGG adequately captures the tension between self-interest, ultimately leading to free-riding, and the common good, which pushes towards maximizing group payoff in a social context, i.e., not only in dyadic interactions (like in a Prisoner's Dilemma) but in sizable groups.

While most of the existing studies on the PGG have focused on deterministic (i.e., risk-free) situations, actual decisions about how much to contribute to public goods are made in situations entailing some form of environmental risk. We define environmental risk as an exogenous stochastic process that generates adverse events that negatively affect individuals' payoff. Since environmental risk has accompanied a vast part of human history (e.g., climate change, production shocks, technological change, floods, earthquakes), assessing if and to what extent it affects cooperative behavior seems both a natural and relevant matter, especially given the importance of cooperation for humankind's success and development.

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 low and, in addition, there is a small probability that an adverse event will occur, which has a severe negative impact on individuals' payoff and is independent of individuals' behavior. The reason for focusing on this case is twofold. First, this is a widespread situation for social dilemmas involving cooperation. Second, it is the simplest and most basic setting for studying the role of environmental risk. One may want to consider cases where the risk depends on the individuals' behavior (e.g., the public good is a defense against the adverse event) or the 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 could consider a situation in which the individual return to cooperation is substantial (e.g., the public good is very local or the group is small). Apart from possibly being 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.

Empirical research has demonstrated that environmental risk can somewhat influence cooperation in the linear PGG (e.g., Fischbacher, Schudy, & Teyssier, 2014; Gangadharan & Nemes, 2009; Levati, Morone, & Fiore, 2009). However, only a few papers in this area of

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research have examined the role of risk correlation across individuals (i.e., Corazzini & Sugden, 2011; Théroude & Zylbersztejn, 2020; Vesely & Wengström, 2017; Zhang, 2019). They report mixed results and there is surely ample scope for further investigations. Moreover, none of these papers focuses on small-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 PGG 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.

To assess how cooperation reacts to the introduction of each one of the aforementioned types of risk, we run an incentivized online experiment with four between-subject treatments: (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 risk-involving 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 substantial and constant across treatments.[2]

Differently from other papers investigating the effect of shared versus idiosyncratic risks (e.g., Corazzini & Sugden, 2011; Zhang, 2019), our one-shot experimental design allows us to minimize 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, it would be difficult to conduct this experiment in a laboratory environment, 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. Like most other papers, we study whether risk affects behavior in the absence of payoff-driven concerns because payoffs are equivalent in expectation across all treatments.[3]

To anticipate our results, we find that contributions do not vary significantly across treatments. This means that neither the presence nor the correlation – whether zero, positive, or negative – of risk affects cooperation. These findings support standard choice models that rely on expected utility theory with other-regarding preferences, excluding specific effects of small probabilities or risk correlations. Therefore, our results are in line with the findings of Théroude and Zylbersztejn (2020) and extend them to a negatively correlated risk and a small 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 the procedures. In Section 4, we present the empirical analyses. Section 5 discusses the results and offers concluding remarks.

2. Related literature

This paper is generally related to the experimental economics literature that studies the effects of uncertainty on the provision of public goods. Scholars have used many different ways to introduce uncertainty into 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 sum of the contributions exceeds a target level with a variant of the PGG known as the threshold – or step-level – PGG (e.g., Gueth, Levati, & Soraperra, 2015; Sonnemans, Schram, & Offerman, 1998).[4]

In some experimental studies, uncertainty is introduced in the PGG via a lottery-style MPCR. Levati et al. (2009) were the first to combine risk preferences with voluntary contributions in this setting. They show that introducing a stochastic MPCR, which could be either high or low for all group members, decreases contributions with respect to a situation with a deterministic marginal benefit and that risk aversion has a strong negative effect on the willingness to contribute. In a follow-up paper, Levati and Morone (2013) find that the previous result cannot be generalized to the case where the minimum value of the stochastic MPCR still allows for efficiency gains, even when probabilities are unknown. Also, Artinger, Fleischhut, Levati, and Stevens (2012) and Cherry, Howe, and Murphy (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). Remarkably, very differently from our design, in these papers the payoff of the public good is the only at risk, so the private account represents a safe investment.

Only a few recent papers in this branch of literature vary, as we do, the level at which the environmental risk arises, i.e., whether at the individual or at the group level (Théroude & Zylbersztejn, 2020; Vesely & Wengström, 2017). Despite the fact that we do not have stochastic MPCRs, our work closely relates to these papers precisely because of the risk correlation's treatments. Table 1 provides a summary of the differences in terms of parameters, treatments, and results in these studies, as well as in Zhang (2019) and Corazzini and Sugden (2011), who also manipulate risk correlations but pick as a negative event the risk of losing each period's payoff. These studies share some characteristics (which are not reported in the table for brevity) that, instead, deviate from our design: they all employ laboratory experiments with students and have small group sizes—groups are made up of 3 or 4 members. In Zhang (2019)'s repeated PGG, the probability of experiencing the adverse event – namely, the loss of the entire 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

[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 returns.

[2] This prediction holds true for settings in which there are no future consequences for one's actions, such as, for instance, in one-shot interactions as we consider here. However, contributing can maximize an individual's payoff if the PGG is repeated, especially when punishment is possible.

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

[4] When failure to reach the target involves a chance of loosing funds, the game is also known as the "collective-risk social dilemma" (e.g., Brown & Kroll, 2017; Dannenberg, Löschel, Paolacci, Reif, & Tavoni, 2015; Milinski, Röhl, & Marotzke, 2011; Milinski, Sommerfeld, Krambeck, Reed, & Marotzke, 2008; Tavoni, Dannenberg, Kallis, & Löschel, 2011). This game has been extensively used to model environmental dilemmas related to the fight against climate change. The general result of this branch of literature is that groups cooperate more (less) when they perceive a catastrophic event as likely (unlikely) to occur.

Table 1
Summary of experimental designs and results employed to manipulate the role of risk correlations.

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	Heterogeneous Risk no effect. Homogeneous Risk positive effect only in early rounds.
Z (2019)	Repeated (20 periods)	Independent Risk, Common Risk	0.4	–	Payoff of the period	Positively related to risk level & negatively to payoffs	Common Risk positive effect compared to Independent Risk.
VW (2017)	Repeated (20 periods)	No Risk, Independent Risk, Correlated Risk	0.5	0, 2	–	0.75	Independent Risk and Correlated Risk positive effect compared to No Risk. Independent Risk strongest effect.
CS (2011)	Repeated (25 periods)	Common Fate, Independent Fate, Rival Fate	0.5	–	Payoff of the period	0.67	Common Fate positive effect compared to Independent Fate and Rival Fate.

Notes: TZ (2020) is Théroude and Zylbersztejn (2020), Z (2019) is Zhang (2019), VW (2017) is Vesely and Wengström (2017), CS (2011) is Corazzini and Sugden (2011). α is the MPCR in the non-risky conditions in TZ (2020) and VW (2017), and always in Z (2019) and CS (2011). 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.

of risk at the group level than at the individual one. Corazzini and Sugden (2011), similarly, design a negative event consisting in the loss of the period's payoff; however, with a fixed probability of 67%. They find that contributions are higher when the risk is positively correlated among group members, while they are almost the same in the independent fate and the rival fate treatments—a treatment where there is only one "winner" out of the group and everyone else loses out their payoff. This condition involves asymmetric outcomes, as in our *Negatively Correlated Risk treatment*, but in our case, there is only one "loser" out of the group. Differently, Théroude and Zylbersztejn (2020) keep the risk, which is embodied in the stochasticity of the MPCR, to be wholly exogenous and compare 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) compare 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 a 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%.

Finally, the design choice of having groups of 40 members relates our work 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 the group size positively affects cooperative behavior (e.g., Barcelo & Capraro, 2015; Diederich, Goeschl, & Waichman, 2016; Isaac & Walker, 1988; Isaac, Walker, & Williams, 1994; Nosenzo, Quercia, & Sefton, 2015). Although we do not manipulate the 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 in 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 correlations of the 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 is realized 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.[5] To ensure that the risk-involving treatments are equivalent to the standard PGG (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.[6]

Furthermore, to avoid negative payoffs in case of adverse event, participants' contributions in all treatments are restricted to integer numbers between 0 and 20 Points, i.e., $c_i \in \{0, 1, 2, \dots, 20\}$.

It is worth mentioning that the risk of an exogenous adverse event does not change the incentive structure of the PGG. Given that all treatments apply to a one-shot setting, 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.

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

[6] 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 in the initial endowment is very unlikely to change behavior across treatments.

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, the risk might not play an influential role (for instance, null effects are found in Björk, Kocher, Martinsson, & Nam Khanh, 2016). It is not easy to advance specific hypotheses in this regard. *A priori*, it is unclear whether inducing different correlations of the environmental risk, 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 test the following two null hypotheses:

Hypothesis 1. No difference exists in contribution levels between the Control treatment and any of the risk-involving treatments.

Hypothesis 2. No difference exists in contribution levels between any pair of risk-involving treatments.

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, Schonger, & Wickens, 2016) and conducted online between the end of January and the beginning of March 2022. The participants were recruited through Prolific (Palan & 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).[7] Before starting the experiment, subjects had to answer some control questions testing their comprehension of the decision task. The experiment did not start until the 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 their 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, Engelmann, Koch, & Normann, 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.[8]

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).[9] 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, Huffman, Schupp, Falk, Sunde et al. (2011). Positive reciprocity, altruism and trust were elicited with questions from the Global Preference Survey (Falk, Becker, Dohmen, Enke, Huffman 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 assume 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.[10] 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 min 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,[11] 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 works and, at the same time, exclude economically irrelevant effects.

Table 2 reports summary statistics of demographic characteristics and individual preferences of our sample, divided by treatment. Overall, the average 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, the risk tolerance (on a 0–10 scale)

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[7] 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.

[8] 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, Gneezy, & Rasocha, 2021). We preferred asking first about choices because these are our most important data.

[9] The post-experimental questionnaire (reproduced in the Appendix) did not include questions on the participants' demographic characteristics – namely, age, gender, and student status – as this information can be retrieved from Prolific. The questionnaire also elicited loss aversion using the lottery choice task proposed by Gächter, Johnson, and Herrmann (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.

[10] 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).

[11] 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, Gächter, and Molleman (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

is, on average, slightly above 5 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.[12]

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, we briefly report on the elicited first-order beliefs.

4.1. Descriptive and non-parametric analyses

Fig. 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 (Catola, D'Alessandro, Guarnieri, & Pizziol, 2021; Isler, Gächter, Maule, & Starmer, 2021; van den Berg, Dewitte, Aertgeerts, & Wenseleers, 2020): 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).

The second fact documented through Fig. 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 0.525) or when implementing pairwise comparisons between treatments (Wilcoxon rank-sum tests, all p-values > 0.165). The lack of treatment effects is further confirmed by looking at the distribution of contributions across treatments, which is displayed in Fig. 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 do not reject the null hypothesis of equal distributions across treatments (all p-values > 0.055).

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 & Blanchard-Fields, 2014). A higher willingness to take risks – 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 presence of environmental risk – taking the form of an exogenous stochastic process that generates a severe adverse event with a very small probability – does not significantly affect contribution decisions.*

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

Given these null results, we deem it important to discuss the statistical power related to our sample size. We substantially improved the statistical power of our analyses with respect to the previous literature. For instance, Théroude and Zylbersztejn (2020) also report a null result, but with a sample size of around 70 subjects per treatment. With an *ex ante* Cohen's d equal to 0.275, we would have been able to detect statistically significant differences in contributions between treatments if and only if these differences had been at least equal to 1.78 Points. Clearly, the observed effect sizes are much smaller. Hence, we can confidently conclude that our experimental treatments have no economically meaningful impact on the contribution decisions.

[12] 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 do 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 when applying the Bonferroni correction for multiple testing. All p-values in the paper are two-tailed.

[13] The effect of different risk correlations 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.

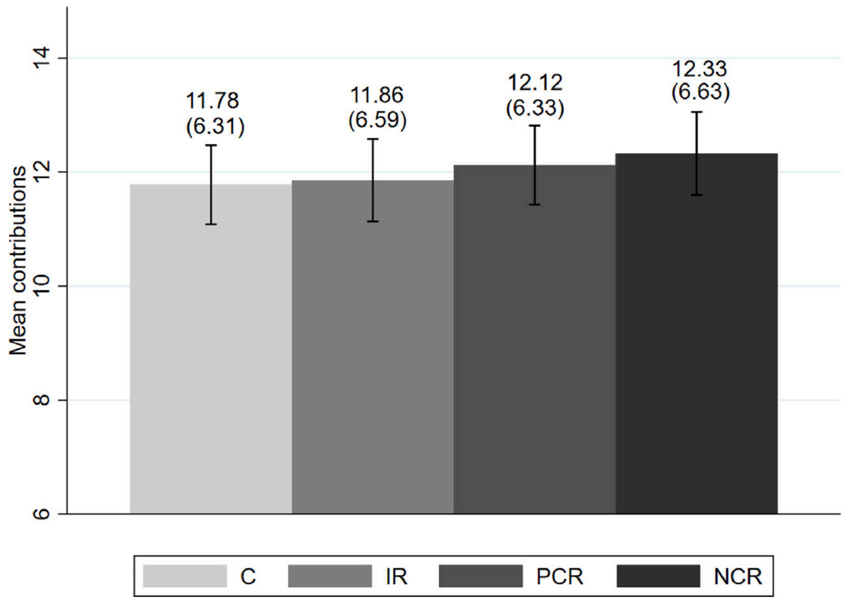
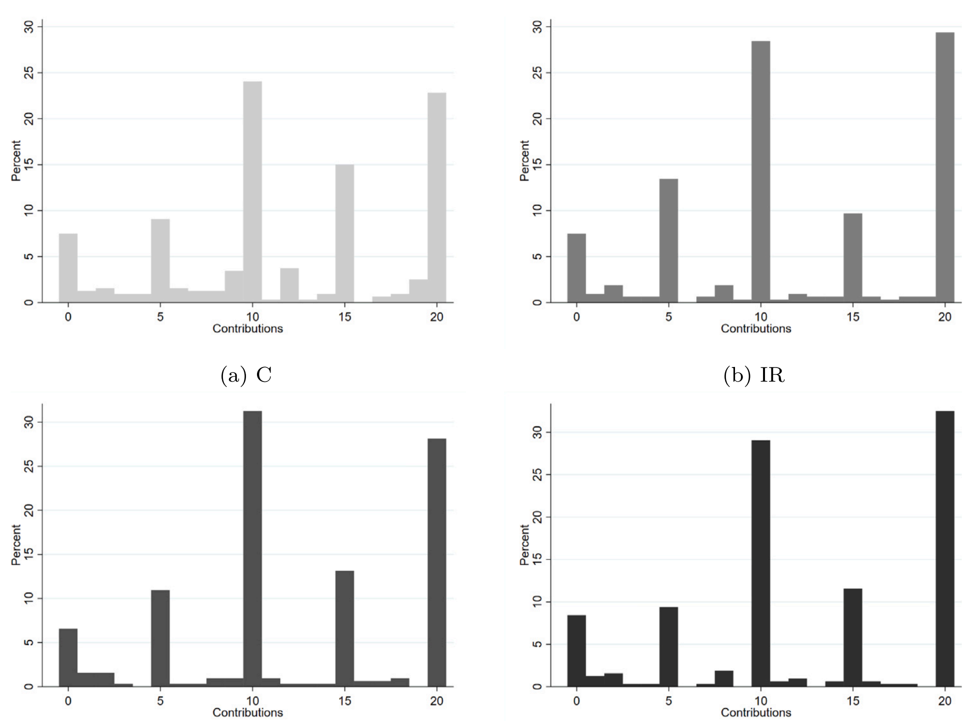


Fig. 1. Mean contributions by treatment. Standard deviations in parentheses. Confidence intervals at the 95% level.



(a) C (b) IR

(c) PCR (d) NCR

Fig. 2. Distributions of contribution choices by treatment.

4.3. Beliefs

Fig. 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 (Pearson's correlation coefficients are equal to 0.485, 0.581, 0.531, and 0.521 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, Dimant, Gächter, & Nosenzo, 2022). Alternatively, it could reflect the so-called *false consensus effect* (Ross, Greene, & House, 1977), suggesting that participants who are more prone to contribute have more optimistic beliefs about others' behavior.

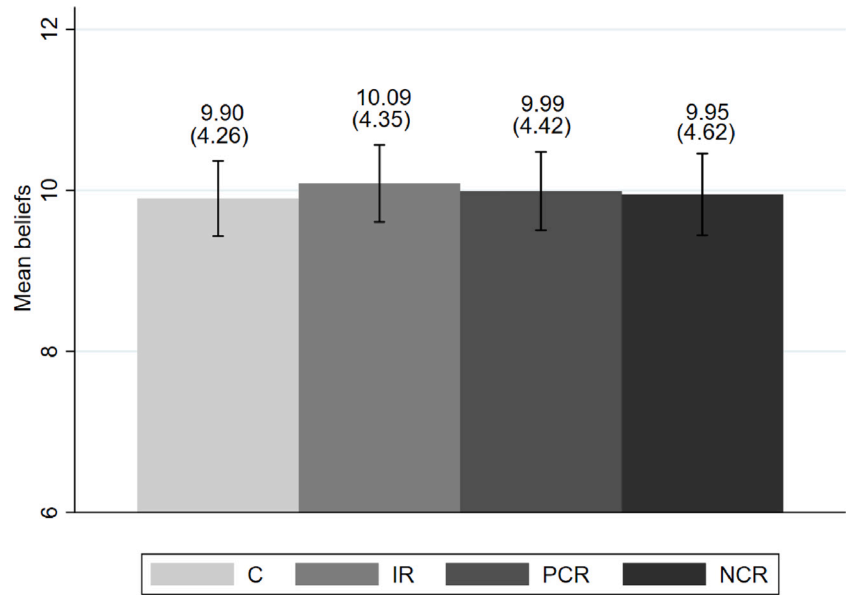


Fig. 3. Mean beliefs by treatment. Standard deviations in parentheses. Confidence intervals at the 95% level.

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	0.845
IR vs. NCR	0.417	0.752
PCR vs. NCR	0.612	0.612
Observations	1280	1280
Pseudo R^2	0.000	0.022

Notes: Robust standard errors are reported in parentheses.
* Significance at the 5% level.
** Significance at the 1% level.
*** Significance at the 0.1% level.

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., Bilancini, Boncinelli, & Celadin, 2022; Catola et al., 2021), while the opposite is found for laboratory experiments (e.g., Fehr, Hoff, & Kshetramade, 2008; Kocher, Martinsson, Matzat, & Wollbrant, 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 correlation of the environmental risk – i.e., whether it is independent, positively, or negatively correlated across individuals – does not significantly 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 crucially depends on the expected value of the negative shock and on the individuals' risk attitude. 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, the fact that individuals do not follow the expected utility theory (see, e.g., Starmer, 2000) might not show up in our data, provided that risk attitudes are not too far from risk neutrality, as it seems to be the case with our experimental subjects.

Furthermore, one may consider the role of other-regarding preferences, such as altruism (Anderson, Goeree, & Holt, 1998; Andreoni & Miller, 2002) or inequity aversion (Bolton & Ockenfels, 2000; Fehr & Schmidt, 1999; 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 highlight that our experimental data improve, in terms of statistical power, upon previous work. Hence, the lack of treatment effects suggests that the correlation of the environmental risk 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 be explored 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 type 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, Gächter, & Fehr, 2001) to check whether there are differences in the behavior of such player types that do not mirror the average behavior.

CRediT authorship contribution statement

Ennio Bilancini: Conceptualization, Funding acquisition, Supervision, Writing – original draft, Methodology. **Leonardo Boncinelli:** Conceptualization, Funding acquisition, Supervision, Writing – original draft, Methodology. **Chiara Nardi:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Resources, Project administration. **Veronica Pizziol:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing, Resources, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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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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