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Working Paper

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Working Paper, No. 2017:3

Provided in Cooperation with:

Department of Economics, School of Economics and Management, Lund University

Suggested Citation: Vesely, Stepan; Wengström, Erik (2017) : Risk and Cooperation: Experimental Evidence from Stochastic Public Good Games, Working Paper, No. 2017:3, Lund University, School of Economics and Management, Department of Economics, Lund

This Version is available at:

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Department of Economics
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Risk and Cooperation: Experimental Evidence from Stochastic Public Good Games

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March 2017



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Stepan Vesely and Erik Wengström*

March 2, 2017

Abstract: Outcomes in social dilemmas often have a stochastic component. We report experimental findings from public good games with both correlated and independent risk across players. We find that the presence of both types of risk prevents the decay of cooperation typically observed in the standard deterministic public good game. The results further suggest that it is greater relative importance of social norms or warm glow giving, rather than risk sharing opportunities that foster cooperation in our stochastic public good game.

JEL Codes: H41, D03, D80

Key Words: risk pooling, risk sharing, social norms, linear public goods game, cooperation decay, stable cooperation

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1. Introduction

Strategic decision making is found in an array of situations, including pricing and investment decisions of firms, public good provision, research & development. Social scientists have investigated the above situations extensively, but mainly in frameworks where payoffs are assumed to be known with certainty or to represent expected payoffs or utilities. Much less is known about strategic decision making under risk.¹ Yet, from the literature on individual decision making, it is clear that behavior under risk is multifaceted and complex and does not always follow standard models of choice such as expected utility theory (see e.g. Starmer 2000). Therefore, we need to ask to what extent is it possible to generalize findings from deterministic strategic situations to settings which are stochastic.

A first step towards addressing this question is to compare behavior in deterministic and stochastic frameworks with equivalent expected payoffs (e.g. Bereby-Meyer & Roth, 2006; Xiao & Kunreuther, 2016). This is the approach we take in the current study. We examine how the presence of risk affects behavior in linear public goods game (PGG). This is a canonical social dilemma, and one of the most studied games in experimental economics in general (Ledyard, 1995; Zelmer, 2003; Chaudhuri, 2011). In many real-world applications of the dilemma, it is natural to think that risk is a highly relevant issue. However, we are aware of almost no previous research comparing behavior in stochastic and deterministic PGGs.

There are several theoretical mechanisms that may influence cooperation when risks are introduced to the PGG. These mechanisms depend on the specifics of the stochastic process. For example, if payoffs from both the public and the private

¹ We refer to risk as exogenous random events (or moves by nature) that generate stochastic payoffs. This type of risk is distinct from strategic uncertainty—originating from the simultaneous actions of others—which has received considerable attention (both theoretically e.g. Harsanyi & Selten, 1988 and empirically e.g. Heineman et al., 2009).

projects are affected by risks that are independent across players, subjects have additional incentives to cooperate since it enables them to share risk. Informal risk sharing has previously been documented in the field (Fafchamps & Lund, 2003 and De Weerd & Dercon, 2006) and in controlled experiments (Barr & Genicot, 2008; Charness & Genicot, 2009; Attanasio et al., 2012 and Suleiman et al., 2015). Suleiman et al. (2015), for example, let participants decide whether to play a risky gamble separately from other participants or whether to pool their gamble with others' gambles. Participants engaged in more risk sharing when facing greater risk. This supports the idea that people can understand how a risk sharing institution can be used. Risk-sharing has also been put forth as conducive for cooperation and the development of trust in a historical perspective.² However, to the best of our knowledge, there exists no previous empirical evidence on risk sharing as a promoter of cooperation in social dilemmas.

If risks among players are instead correlated, the incentives for risk sharing become weaker. However, the introduction of risk may have other effects. For example, it may alter the relative attractiveness of giving to the public good compared to keeping money for oneself. If monetary payoffs are subject to risk, and thus made less important, other non-pecuniary concerns may receive a higher weight. Issues such as warm-glow effects of giving, social-image concerns or social norms compliance may play a bigger role and thus spur higher levels of cooperation.

To investigate the effects of risk in social dilemmas, we conduct a PGG experiment in which the payoffs of both the group project and individual project are stochastic. A stochastic setup such as this seems applicable in many situations. Consider for example two attorneys who, on the one hand, can set up an independent practice each (i.e., invest effort in a "private project") that may or

² Durante (2010) reports that people in regions characterized by higher climate variability in pre-historic times display higher levels of trust.

may not turn out to be successful. Alternatively, they can form a partnership in which they will share profit equally (i.e., invest effort in a “group project”). If they form a partnership, the lawyers’ risks of losing a case and not earning commission money can be either independent if they work independently on unrelated smaller cases (which will make risk sharing possible), or correlated if they work together on one large case (which will preclude risk sharing).³

We run one treatment in which payoffs are determined by independent random draws for each subject (*Independent risk treatment*). We also run one treatment in which payoffs are determined by one random draw common to all participants (*Correlated risk treatment*). This setting captures the traditional PGG in the presence of an exogenous random event determining the success for all players. We compare behavior in these two treatments to a standard deterministic PGG with equivalent expected payoffs (*No risk treatment*).

We find that introducing mean-preserving risk facilitates cooperation. In line with the risk-sharing hypothesis, cooperation is higher with independent risk. Initial cooperation levels are similar across all treatments, but we find no evidence for the typical decay in contributions in the Independent risk treatment. In the Correlated risk treatment, there is a weak decay towards the end, but cooperation remains higher than in the No risk treatment throughout the experiment. While risk sharing can explain the high level of cooperation in the Independent risk treatment, it cannot account for the increase in cooperation observed in the Correlated risk treatment. We believe that the higher cooperation rates in the stochastic treatments are driven by social concerns receiving more attention under risk relative to the weight placed on own earnings under risk. Yet, in the paper we discuss and elaborate on several other potential explanations of this finding.

³ Note that the basic features of a social dilemma are present in this situation. First, there are efficiency gains from partnering up, for instance in the form of a shared office, car and office personnel or in the form of exchanging advice. Second, free-riding opportunities stem from the fact that even if one of the lawyers works poorly, he/she will nevertheless share the profit generated by the other partner.

The prior studies most closely related to ours are Gangadharan & Nemes (2009), Artinger et al. (2012) and Cherry et al. (2015). They also investigate cooperation in linear PGG with stochastic payoffs. In Artinger et al. (2012) and Cherry et al. (2015) they use treatments in which the payoff of the group project is influenced by risk, but the payoff of the private project is not. These games are thus fundamentally different from our games in which risk is affecting group project and private project investments equally. In contrast to our setup, the asymmetry in risk between the two accounts will motivate people to freeride. Indeed, the authors find that cooperation levels in risky PGGs compared to deterministic PGGs are lower (Artinger et al., Cherry et al.) or similar (when the probability of a bad event is very low, Artinger et al.).

Similarly, Gangadharan & Nemes (2009) employ linear PGGs in which the payoffs of either the private or the group project are stochastic, but never the payoffs of both private and group project at the same time (as in our study). As can be expected, participants tend to invest less to a risky group project when their private project is safe, and they, vice versa, invest more to a safe group project when their private project is risky.

Related findings from a dictator game experiment are reported by Brock et al. (2013). When only the recipient's payoff is stochastic, dictators share less than in the standard deterministic game. When, on the other hand, both players' outcomes are stochastic, dictators share about as much as in the standard game. These results underscore that it matters whether the presence of risk affects all investment opportunities equally (as in our study) or just some of them, as in previous studies on public goods provision under risk.

Finally, Dannenberg et al. (2015) compare behavior in deterministic threshold public goods games and in public goods games with uncertain and risky

thresholds. Cooperation is negatively affected by the presence of risk and uncertainty in thresholds.⁴

We contribute to the literature by studying cooperation with novel stochastic structures that we believe are relevant in many real-world situations. The stochastic structures also introduce incentives for risk sharing, which to the best of our knowledge has not been studied in relation to social dilemmas before. Our findings point out that risk can serve as an important facilitator of cooperation.

The paper is organized as follows. In Section 2, we outline the experimental design and state our research hypotheses. The results are presented in Section 3 and Section 4 contains a concluding discussion.

2. Experimental design and hypotheses

To test the effect of risk in social dilemmas, we implement an experimental design with three variations of the PGG. The three treatments – No risk, Independent risk and Correlated risk – are implemented in a between-subjects design. In each treatment, participants play a PGG. Across treatments, the games only differ by the presence and type of stochastic risk – this is the treatment manipulation. In the next subsections, we start by outlining features common to all treatments. We move on to describe the specifics of the treatments and our research hypotheses. Thereafter, we provide information about recruitment, subjects and payments. We conclude this section by describing a set of additional measures collected after the PGG which are used as control variables in the statistical analysis of Section 3.

⁴ Our study is also related to Bereby-Meyer & Roth (2006), Gong et al. (2009), Kunreuther et al. (2009) and Xiao & Kunreuther (2016) who investigate behavior in stochastic versions of the prisoner's dilemma game (PD). Bereby-Meyer & Roth (2006) show that learning is slower when payoffs have a stochastic component, leading to more cooperation in one-shot PD but to less cooperation in iterated PD. Kunreuther et al. (2009) find that risk hurts cooperation between individuals in iterated PD. Using similar setups as Kunreuther et al. (2009), Gong et al. (2009) and Xiao & Kunreuther (2016) study group decision making and punishment, respectively. Gong et al. (2009) find that in the stochastic version of the PD, groups cooperate more than individuals do. Xiao & Kunreuther (2016) report that stochastic payoffs have little effect on cooperation or can hurt cooperation in iterated PD with a legitimate punishment institution (which only allows punishment of a non-cooperator by a cooperator).

Basics of the experimental design

Across all treatments, participants form groups of four that remain together throughout the experiment (partners matching). Participants do not know the identity of the group members they are matched with and all decisions participants make are anonymous (single-blind design).

Participants play 10 periods of the PGG, followed by a surprise restart game (another 10-period PGG). Game parameters remain unchanged after restart and participants are not rematched after restart.

In each round, each participant is endowed with 20 tokens and he/she has to decide how to distribute the tokens between a Group project and an Individual project (see below for treatment-specific details). In expectation, the payoffs are the same in all treatments.

Participants are paid for one round in the pre-restart game and for one round in the restart game randomly selected at the conclusion of the experiment (as in Charness & Genicot, 2009 and Cherry et al., 2015, this prevents income smoothing over rounds). The exchange rate is 10 points = 2 EUR. Participants had to correctly answer a set of control questions checking their understanding of the experimental instructions before proceeding to play the games. We now move on to the specifics of the individual treatments.

Treatments

We conduct the following three treatments in a between-subjects design. Table 1 summarizes the main features of the treatments.

No risk treatment. The first treatment is a standard voluntary contribution linear PGG with a marginal per capita return (MPCR) of 0.5. 1 token invested in the Individual project yields 1 tokens to the investor and 0 tokens to the other three group members. 1 token invested in the Group project yields 0.5 tokens to all four

group members (i.e. 2 tokens shared equally among the four group members). After each round, participants learn their earnings from each project in that round, and total group investment in each project in that round.

Table 1. Description of the payoffs (in points) in the treatments

Treatment	Returns to a 1 token investment in		Random draws
	Individual project	Group project (shared equally by all group members)	
No Risk	1	2	None
Independent Risk	0 with p=0.75 4 with p=0.25	0 with p=0.75 8 with p=0.25	One independent draw for each subject (determining the success for both the individual and group project)
Correlated Risk	0 with p=0.75 4 with p=0.25	0 with p=0.75 8 with p=0.25	One common draw for all (determining success for both the individual and group project for all subjects)

Independent risk treatment. In every round, the payoff of investments to the Individual and Group projects is determined for each player separately by a player-specific independent random event.⁵ New random events are drawn every round. That is, there are precisely four independent random events per group and round.

The random even is “good” with .25 probability and “bad” with .75 probability. Whether a random event is good or bad is determined by a computer random number generator after all decisions are made in a given round.

In case of a good event, the payoffs are as follows: 1 token invested in the Individual project yields 4 tokens to the investor and 0 tokens to the other three

⁵ There are *not* separate random events for the Individual project investment and for the Group project investment, however. For a given player, a single random event jointly determines the payoffs of both project investments.

group members. 1 token invested in the Group project yields 2 tokens to all four group members (i.e. 8 tokens shared equally among the four group members).

In case of a bad event, the payoffs are as follows: 1 token invested in the Individual project yields 0 points to all four group members. 1 token invested in the Group project yields 0 points to all four group members. Hence, in expectation $MPCR = 0.5$ as in the No risk treatment.

Because random events determining the payoffs are not correlated in the group, risk sharing is possible. If, for example, all participants each allocate 15 tokens to the Group project and 5 tokens to their Individual project, and if three participants are faced with a bad event, while the last group member encounters a good event, the first three participants still earn 30 points each (all coming from the last group member's investment to the Group project) and the last group member earns 50 points (30 points from his Group project investment and 20 points from his Individual project investment).

After each round, participants learn their earnings from each project in that round, total group investment in each project in that round, "their" random event, and the number of good random events in their group in that round.

Correlated risk treatment. Payoffs are the same as in the Independent risk treatment, but the payoffs of investments to the Individual and Group projects are determined for all group members jointly by a single random event common to the whole group.⁶ A new random event is drawn every round. I.e., there is precisely one random event per group and round. Because risk is perfectly correlated in the group (as all group members are affected by the same random event), risk sharing is not possible.

⁶ Again, there are *not* separate random events for the Individual project investment and for the Group project investment. A single random event jointly determines the payoffs of both project investments.

After each round, participants learn their earnings from each project in that round, total group investment in each project in that round, and their group's random event in that round.

Research hypotheses

If subjects have egoistic preferences, always contributing zero is a dominant strategy equilibrium in all treatments. In the last period, subjects should contribute zero and by the standard backward induction argument they should contribute zero also in the preceding periods. However, from the literature it is well established that people do (at least initially) contribute positive amounts to the public good. Given this, we hypothesize that our treatment variations will result in different contributions levels.

First, we recognize that the independent stochastic shocks in the Independent risk treatment will generate risk-pooling opportunities for the subjects while this not the case in the Correlated risk treatment. Specifically, for risk averse subjects, the positive externalities of investments to the group project are larger in the Independent risk than in the Correlated risk treatments. In addition to the positive externality in terms of expected payoffs (which is constant across treatments), the returns from the others' investments in the group project are less spread out and less correlated with the returns from the individual project in the Independent risk treatment. That is, risk averse subjects in the Independent risk treatment can pool risks by investing in the group project.⁷

The above reasoning leads us to formulate the following hypothesis.

⁷ There is a number of factors that may influence people's willingness to share risk with others. For example: the amount of risk (Kunreuther et al., 2009; Artinger et al., 2012; Suleiman et al., 2015), exogenous vs. endogenous group formation and group size (Chaudhuri et al., 2010), pre-existing social ties (Foster & Rosenzweig, 2001; Attanasio et al., 2012), availability of punishment (Xiao & Kunreuther, 2016), commitment constraints (Foster & Rosenzweig, 2001; Barr & Genicot, 2008; Cherry et al., 2015; Janssens & Kramer, 2016) and image concerns (Barr & Genicot, 2008). All such factors are kept constant in our experiment.

Risk sharing hypothesis: Contributions will be higher in the Independent risk treatment compared to the Correlated risk treatment, since in the former subjects can use the group project investments to share risks.

We now turn to our second hypothesis comparing the Correlated risk treatment with the No risk treatment. The private and the group project are affected by a single stochastic shock common to all subjects in the Correlated risk treatment. Hence, the risk sharing argument outlined above does not apply. To illustrate a mechanism that may generate treatment differences between the Correlated risk treatment and the No risk treatment, we assume that subjects derive utility from material payoffs and from making choices according to the social norm governing the situation. Such norm based social motivations have recently been argued to explain behavior in many economic experiments (see e.g. Krupka and Weber 2013), and Kimbrough & Vostroknutov (2016) argue that differences in norm sensitivity explain individual heterogeneity in public good contributions. To fix ideas, consider a modified version of the framework used in Kimbrough & Vostroknutov (2016) and assume that the expected utility of subject i is given by:

$$EU(g_i, G_{-i}) = E[u(\pi(g_i, G_{-i}))] - v(|g_i - \eta_i|) \quad (1)$$

where u denotes the utility from the material payoffs $\pi(g_i, G_{-i})$, given subject i 's contribution g_i and the contributions of the other group members G_{-i} . Moreover, η_i denotes the socially most appropriate contribution level (i.e. the social norm) and the function v gives the disutility of deviating from the norm.

One crucial issue is whether social norms and the disutility of norm deviations are affected by introducing symmetric risk to both the private and public

projects.⁸ Note that in Equation (1) we have assumed that the norm component is independent of the outcomes of the random draws determining the material payoffs.⁹ If we also assume that the social norm η_i is constant across treatments, introducing risk can make investments in the group project more attractive. When the materials payoffs are risky, the marginal utility of investing in the private project falls, while the marginal utility from the norm component is not affected. Hence, the attractiveness of investing in the group project increases. Put differently, since risk decreases the value of keeping money in the private project, complying with the social norm becomes relatively cheaper. Consequently, we should expect higher cooperation levels when payoffs are risky, even when risks are correlated across subjects. We summarize this argument in the following hypothesis:¹⁰

Social norms hypothesis: Contributions will be higher in the Correlated risk treatment compared to the No risk treatment.

We acknowledge that other factors can also be relevant when comparing behavior in the risk and no-risk treatments and Section 4 contains a discussion of other potential mechanisms. In particular, we recognize that the social norms part of the utility function could also be viewed as a warm-glow utility (Andreoni, 1990) or driven by self- or social image concerns (e.g. Bodner & Prelec, 2003;

⁸ There is a large literature on fairness concerns under risk and uncertainty (see e.g. Sen, 1973; Cappelen et al., 2013; Cettolin & Riedl, 2016). We are, however, aware of only a few studies that introduce risk symmetrically into both (all) available investment options. One example is Brock et al. (2013) who study giving in dictator games when the outcomes for both the dictator and the receiver are affected by a random event. They find that dictator giving under such symmetric risk is not significantly different from giving in the standard deterministic dictator game. But their stochastic setup is fundamentally different from ours, in particular because dictators in their study transfer probabilities of winning a high prize, rather than tokens that have an exogenously given probability of being turned into money (a design similar to Brock et al. was employed by Krawczyk & Le Lec, 2010). Existing literature thus does not give us clear guidance with regards to how symmetric risk affects normative perceptions.

⁹ This assumption is consistent with the view that norms prescribe actions rather than outcomes (e.g., Elster, 1989; Krupka & Weber, 2013).

¹⁰ In Appendix A, we spell out the argument behind the hypothesis more in detail using the specific configurations of our treatments.

Andreoni & Bernheim, 2009). We do not make any attempts to distinguish between these, but merely assume that such concerns are less affected by the introduction of risk than the monetary incentives are. As described below, we conduct a social norms elicitation, which suggests that there are no differences in norms across treatments, which is compatible with the idea that the social concerns are less affected by risk than material concerns.

Participants and sessions

A total of 160 participants (90 women, 70 men), recruited from a subject pool maintained by the Vienna Center for Experimental Economics (VCEE), took part in the study across 7 sessions, each of which lasted about 2 h.

We conducted 2 sessions in No risk, 2 sessions in Correlated risk, and 3 sessions in Independent risk, for a total of 11 independent groups in No risk, 12 independent groups in Correlated risk, and 17 independent groups in Independent risk (44, 48, and 68 participants, respectively).

Participants were recruited using the ORSEE software (Greiner, 2015). The experiment was computerized using z-Tree (Fischbacher, 2007) and conducted in VCEE's lab in March and April 2016. A portion of the instructions was presented in paper form.¹¹ Participants earned 37.6 EUR on average (SD = 13.9 EUR) during the experiment, including a 5 EUR show-up fee.

Participants came from various majors (29.4% of participants studied Economics or Business administration, 16.9% Social science, 15.6% Science, 12.5% Humanities, 10.0% Engineering, 15.6% other). Mean age = 25.7 years (SD = 5.1 years).¹²

¹¹ Printed and computerized instructions are available in Online Appendix A.

¹² As a check that randomization into treatments was successful, we separately regressed participants' gender, age, major, reported yearly income, CRT score (Frederick, 2005), and preferred gamble (Eckel & Grossman, 2002) on treatment dummies. None of the regression models turned out to be significant (all p -values > .28). This suggests randomization into treatments was indeed successful.

Additional measures

In addition to the PGG, we also collected a range of other measures.

Confusion test. To rule out that treatment effects are driven by differences in confusion between treatments, we measured participants' game form understanding after the PGG. We used a six-item incentivized test adapted from Fosgaard et al. (2014, 2015). The first three items ask about how many tokens will a person contribute to the Group project, if she wants to maximize her own earnings in the current round of a PGG, provided that the other group members will contribute on average 0, 10, or 20 tokens, respectively, in that round. The next three items ask about how many tokens will a person contribute to the Group project, if she wants to maximize her group's earnings in the current round of a PGG, provided that the other group members will contribute on average 0, 10, or 20 tokens, respectively, in that round. The correct answer for the first three items is 0 tokens in each case, and the correct answer for the last three items is 20 tokens. Participants receive 3 points (0.6 EUR) per correct answer. Summing each participant's incorrect answers gives us his/her Confusion score.¹³

Social norms. To measure potential treatment differences in social norms, we elicited social appropriateness ratings of five possible contributions to the Group project (20, 15, 10, 5 and 0 tokens). Ratings were measured on a 4-point scale (1 = very socially inappropriate, 2 = somewhat socially inappropriate, 3 = somewhat socially appropriate, 4 = very socially appropriate). This test was administered directly after the confusion test. Ratings were incentivized using the protocol introduced in Krupka & Weber (2013). Specifically, before submitting their ratings, participants learned that at the end of the experiment, the experimenters will randomly select one of the possible investment choices being rated. For the selected investment choice, it will be determined which rating was selected by the

¹³ In the first of our 7 sessions, the Confusion test has not been administered.

most people in the session. If a given participant's rating of the randomly selected investment choice will be the same as the most frequent rating of that choice in the session, the participant will earn 20 points (equivalent to 4 EUR).

The core assumption of the Social norms hypothesis is that the social norm component of participants' utility function is less affected by risk than the utility of the monetary payments. We can get some indication of this assumption being justified by testing for differences in perceived social norms across treatments. Large differences in the appropriateness ratings across treatments would clearly cast doubt on the assumption.

Social norms certainty. Along with the normative ratings, we elicited incentivized estimates of how sure participants were that the appropriateness ratings they have submitted will match the respective most frequent appropriateness ratings in their session. Participants stated their certainty on a scale ranging from 25% certain to 100% certain. We used a quadratic scoring rule to incentivize the certainty estimates.¹⁴

Risk preferences. Both of our hypotheses assume that subjects are risk averse. Moreover, it seems plausible that treatment differences are larger for risk averse subjects. Therefore, we measured participants' risk preferences after the norms elicitation. We used an extended version of the procedure of Eckel & Grossman (2002). Participants had to choose one of eight available gambles. Choosing a low-numbered gamble (e.g. gamble 2, which is a prospect of getting either 210 points, or 300 points with equal probability) indicate greater risk aversion than choosing a high-numbered gamble (e.g. gamble 6, which is a prospect of getting either 110 points, or 500 points with equal probability).¹⁵ Higher Risk score thus indicates greater risk loving. The exchange rate for this task was 10 points = 1

¹⁴ The incentivization procedure is described in the printed instructions (Parts 3-4) available in Online Appendix A.

¹⁵ All eight gambles can be found in the instructions available in Online Appendix A.

EUR. The probability that a given participant will be paid for his/her choice in this task was set to .10, of which participants were informed beforehand.

First-order beliefs. After the first round of both 10-round blocks, we elicited incentivized, as well as non-incentivized beliefs concerning others' contributions. We do not report results from this exercise here, as we wanted to focus on behavior beyond the first round in the analyses, and we do not have belief data for the later rounds.¹⁶

Post-experimental questionnaire. After being informed about their total earnings, participants filled in a brief nine-item questionnaire, including questions about age, gender, study major, and yearly income. The complete questionnaire can be found in the instructions available in Online Appendix A.

Cognitive reflection test (CRT). Finally, participants provided answers to a slightly modified and extended CRT (Frederick, 2005), a five-item instrument measuring cognitive ability.¹⁷ As cognitive ability has been shown to be linked to cooperation (Jones, 2008) and noisy decision making (Anderson et al., 2016) we control for the CRT score to make sure that treatment differences are not driven by differences in cognitive ability across treatments.

3. Results

We present our results in two steps. First, we visually inspect cooperation levels across treatments and perform non-parametric tests. Second, we present regressions estimates.

¹⁶ Several previous studies have linked beliefs to cooperation in (deterministic) social dilemmas (e.g. Dufwenberg et al., 2011; Fosgaard et al., 2014).

¹⁷ The five CRT items we use appear as part of the instructions in Online Appendix A.

Descriptive analysis

Figure 1 provides a first glimpse at our data. In the No risk treatment, the typical pattern of decreasing contributions is apparent over the two 10-period games. We also see the characteristic restart effect after a new 10-period game is announced in round 11 (cf. Andreoni, 1988; Croson, 1996).

While contributions start at about the same level across treatments, we observe practically no cooperation decay in the stochastic games (Correlated risk, Independent risk) as in the deterministic game, and as a result also no restart effect in round 11. The contributions in the No risk treatment display the typical decrease over time.

Mann-Whitney rank-sum tests reveal that contributions (averaged over all rounds and over players within an independent group of four) are lower in No risk than in both Independent risk ($p < .01$) and Correlated risk ($p = .051$), while contributions are statistically indistinguishable when comparing Correlated risk and Independent risk ($p = .811$).¹⁸

As Figure 1 suggests, treatment differences are stronger towards the end of each iterated game. This impression is confirmed by Mann-Whitney tests (based on independent group averages) applied to contributions in the first and last round of each 10-period game, i.e., to rounds 1 and 11, and to rounds 10 and 20. There are no differences in first-round contributions between No risk and Independent risk ($p = .915$), between No risk and Correlated risk ($p = .621$), or between Correlated risk and Independent risk ($p = .381$). Similarly, there are no differences in 11th-round contributions between No risk and Independent risk ($p = .547$), between No risk and Correlated risk ($p = .379$), or between Correlated risk and Independent risk ($p = .586$).

¹⁸ All reported tests are two-tailed.

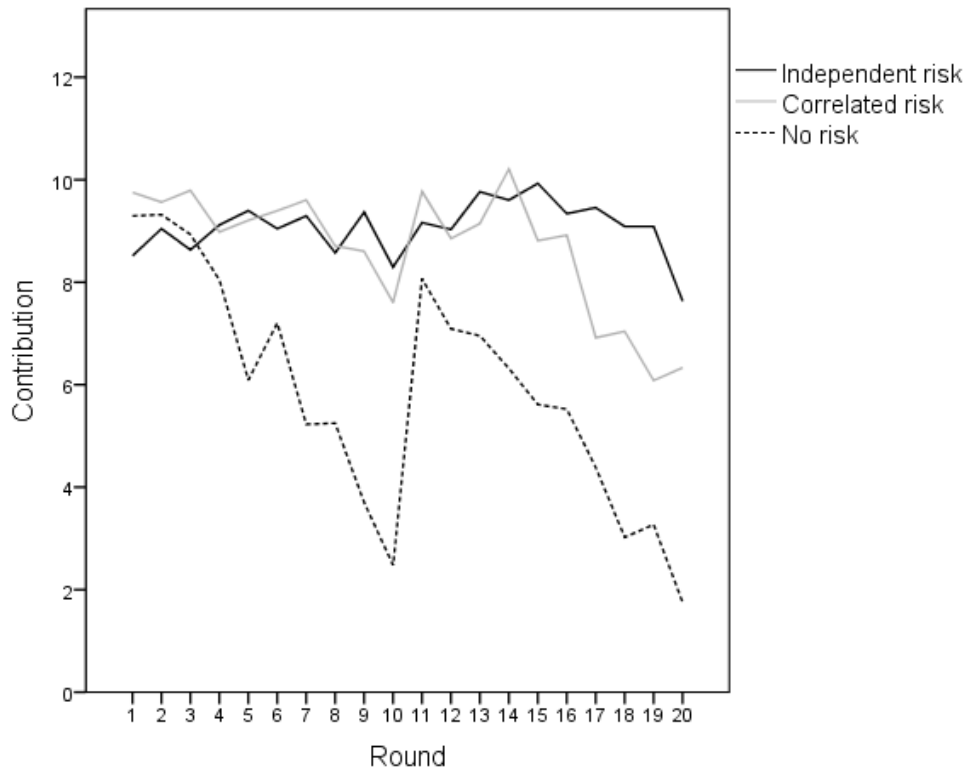


FIGURE 1. AVERAGE CONTRIBUTIONS TO THE PUBLIC GOOD

On the other hand, contributions in the 10th and 20th round are lower in No risk than in both Independent risk (10th round: $p < .001$, 20th round: $p < .001$) and Correlated risk (10th round: $p < .01$, 20th round: $p < .01$). Contributions are similar in Correlated risk and Independent risk in both the 10th round ($p = .913$) and in the 20th round ($p = .347$).

To summarize, non-parametric tests reveal treatment differences between the stochastic games on the one side and the standard deterministic game on the other side. These differences appear, in particular, towards the end of each iterated game. Behavior is rather similar in the stochastic games, whether risk sharing is feasible (Independent risk) or not (Correlated risk). These results are consistent with our Social norms hypothesis, and not consistent with our Risk sharing hypothesis.

In addition, we test for differences in confusion, norm ratings and norm ratings certainty across the three treatments and find almost no differences. We perform 33 pairwise tests in total, only two of which turn out to be statistically significant at the 5% level (see Online Appendix B).¹⁹ These findings suggest, first, that the different cooperation rates between the stochastic treatments and the No risk treatment are not driven by differences in game form understanding (since confusion rates do not differ across treatments, all $p > .56$). Second, the fact that the social norms ratings are unaffected by risk suggests that subjects' normative perceptions do not change abruptly when risk is introduced (there is only one statistically significant difference in norm ratings in 20 tests; furthermore this is a difference between normative perceptions in the two stochastic treatments). It thus seems likely that the utility of norm-compliance is not sharply affected by risk, which is in line with the assumption of the Social norms hypothesis.

Regression analysis

In Table 1 we present estimates from linear random effects models with contribution to the public good as the dependent variable. Models 1 and 2 are estimated on the entire data set. Models 3-5 are estimated separately on data from each individual treatment.

All models use individual-level random effects and period fixed effects and in Models 1 and 2, standard errors are clustered at the group level.²⁰ Models 1 and 2 include Treatment dummies ("No risk" is the baseline category). In addition, we control for Age, Gender, CRT score, Confusion score, and Risk preferences in Models 2-5.

¹⁹ Game misperception seems to be substantial in all treatments. According to our confusion measure, only 36.4-38.7% of participants across the three treatments understood the game perfectly. It is likely that the test overestimates game confusion to some extent, as it is necessary to understand both the game *and* the test questions in order to pass the test (cf. Fosgaard et al., 2015 who show that the wording of the test questions matters).

²⁰ Due to the low number of clusters, standard errors are not clustered in Models 3-5.

Models 1 and 2 corroborate the main results from the non-parametric tests reported in the previous section. Contributions are higher in both risk treatments than in the standard deterministic game. This gives support to the Social norms hypothesis in favor of the Risk sharing hypothesis. Still, it should be noted that the effect appears to be somewhat stronger in the Independent risk treatment.

TABLE 1 – REGRESSION ANALYSIS OF CONTRIBUTIONS

	Model 1	Model 2	Model 3 – Independent risk	Model 4 – Correlated risk	Model 5 – No risk
Independent	3.191*** [1.099]	3.716*** [1.184]			
Correlated	2.787** [1.260]	3.181** [1.237]			
Age		0.00594 [0.0738]	-0.0134 [0.168]	-0.0239 [0.119]	-0.0248 [0.160]
Female		1.058* [0.627]	1.977 [1.566]	-1.051 [1.644]	2.190* [1.256]
Confusion Score		0.264 [0.209]	0.356 [0.405]	0.104 [0.437]	0.158 [0.368]
Risk preference		0.317* [0.170]	0.0746 [0.297]	0.330 [0.322]	0.406 [0.329]
CRT score		0.656*** [0.251]	0.678 [0.576]	0.951* [0.540]	0.319 [0.431]
Constant	3.433*** [0.834]	-1.659 [2.377]	3.546 [5.072]	3.501 [4.136]	-2.138 [4.577]
Period fixed effects	x	x	x	x	x
Observations	3,200	2,720	880	960	880
Number of Subject	160	136	44	48	44
N_clust	40	34			

Notes: Linear random effects panel regressions. Independent and Correlated are treatment dummies. Confusion score denotes the number of incorrect answers to the ex post confusion test (range 0-6). Risk preference indicates which gamble the subject chose in the risk task with higher values indicating less risk aversion (range 1-8). CRT score describes the number of correct answers to the five-item cognitive reflection test (range 0-5). In Model 1 and 2 standard errors are clustered at the group level. * $p < .05$, ** $p < .01$, *** $p < .001$.

As Model 2 shows, age and confusion are not related to contributions, but the other controls are: women, participants with higher CRT score, as well as more risk seeking participants contribute more to the public good.²¹

Importantly, notice that treatment dummies are relatively unaffected by the inclusion of controls (compare the coefficients in Models 1 and 2). Thus, the control variables do not seem to account in any major way for the differences between the stochastic treatments and the deterministic treatment.

We now move to Models 3-5 estimated separately on data from individual treatments. These models show that overall, the effects are not precisely measured and participants' characteristics have a fairly consistent effect on behavior across treatments, the only exception being participants' gender.

4. Concluding discussion

We found that people cooperate more in social dilemmas in the presence of risk than in its absence. At the beginning of a repeated interaction, people behave very similarly in the stochastic and deterministic public goods games. Cooperation level, however, remains stable in the stochastic games, while it gradually declines in the deterministic game (as e.g. in Andreoni, 1988; Croson, 1996; Neugebauer et al., 2009; Fischbacher & Gächter, 2010).

We find that differences between stochastic and deterministic games are not caused exclusively by risk sharing: Cooperation is higher both in the treatment with independent risks and in the treatment with perfectly correlated risks, compared to the No risk baseline. At the same time, cooperation is similar when

²¹ For related results see the following: age (Gangadharan & Nemes, 2009; Thöni et.al, 2012; Kettner & Waichman, 2016), gender (Zelmer, 2003; Charness & Genicot, 2009; Gangadharan & Nemes, 2009; Balliet et al., 2011; Charness & Gneezy, 2012; Thöni et.al, 2012), cognitive ability (Frederick, 2005; Jones, 2008), confusion (Krawczyk & Le Lec, 2010; Fosgaard et al., 2014, 2015), and risk preferences (Charness & Genicot, 2009; Charness & Villeval, 2009; Gangadharan & Nemes, 2009; Krawczyk & Le Lec, 2010; Kocher et al., 2015; Janssens & Kramer, 2016).

comparing the two risky treatments. These observations are not consistent with the Risk sharing hypothesis.

One possible explanation is that the higher cooperation rates under risk are caused by an increased relative attractiveness of following the social norm (the Social norms hypothesis). As we move from the No risk treatment to the two risky treatments, monetary payoffs become stochastic and consequently less attractive to risk averse subjects. Complying with social norms may thus become more important relative to own earnings. As a result, the amount of norm-driven contributions to the group project increases in the stochastic games.

Yet, we acknowledge that there can be other mechanisms at play. First, as noted earlier, the normative component of the utility function can be interpreted in other ways as well, e.g. as warm-glow or as a self-signaling motive (Andreoni, 1990; Bodner & Prelec, 2003). We can to some extent rule out social image concerns in our setup, since participants' decisions were anonymous – although it has been shown that participants in lab experiments can react to even very subtle social cues (Haley & Fessler, 2005).

Second, people may in fact consider risk pooling opportunities in both stochastic treatments. Thus, they can mistakenly think there is an opportunity to pool risk even when – in the Correlated risk setting – there is not. However, we cannot ascertain to what extent subjects understand or misperceive the risk pooling opportunities. Measuring participants' understanding of risk pooling opportunities in future studies will enable testing this conjecture.

It could also be that learning is slower in stochastic environments, which was suggested by Bereby-Meyer & Roth (2006). Yet, our post-experiment confusion test did not reveal any differences in game form understanding. So at least subjects were equally likely to understand that free riding was a dominant strategy across treatments.

Finally, stochastic payoffs might also reduce the impact of strategic uncertainty, making subjects more cooperative. In the deterministic game, the presence of strategic uncertainty makes free-riding look attractive because it is a “safe” option. One could envision that if the focus shifts from strategic uncertainty to exogenous risk, and since there is no difference in exogenous risk between cooperation and defection in the stochastic games, freeriding will appear less attractive in the stochastic than in the deterministic PGGs.

The presence of risk prevents cooperation decay, but it does not shift initial cooperation level upwards. It would thus be also interesting to see whether the presence of risk could support persistently higher levels of cooperation when initial cooperation is first driven up by a one-off intervention, such as group discussion or a normative message, see e.g. Ostrom et al. (1992), Krupka & Weber (2009).

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Appendix A: Theoretical Motivation of the Social Norm Hypothesis

Let the stochastic monetary payoffs of subject i be denoted by $\tilde{\pi}_i(g_i, G_{-i})$ where $g_i \in (0, 20)$ is i 's investment in the group project and G_{-i} is the group project investments of the other group members. We consider a version of the framework used by Kessler & Leider (2012) and Kimbrough & Vostroknutov (2016), and let expected utility be given by:

$$EU(g_i, G_{-i}) = E[u(\tilde{\pi}_i(g_i, G_{-i}))] - v(|g_i - \eta_i|), \quad (\text{A.1})$$

where u is an increasing strictly concave function representing the utility from the material payoffs and η_i denotes the socially most appropriate contribution level (i.e. the social norm) and the function v gives the disutility of deviating from the norm.

Consider any two contribution levels g_i^H and g_i^L , with $g_i^H > g_i^L$. The Social Norms Hypothesis states that the high contribution g_i^H should be more attractive relative to the low contribution g_i^L in the Correlated risk (CR) treatment than in the No risk (NR) treatment. Put differently, the difference in utility between choosing g_i^H and g_i^L should be larger in the CR treatment than in the NR Treatment.²² We hence have the following condition:

$$\begin{aligned} & E \left[u \left(\tilde{\pi}_i^{CR}(g_i^H, G_{-i}) \right) \right] - v(g_i^H) - E \left[u \left(\tilde{\pi}_i^{CR}(g_i^L, G_{-i}) \right) \right] + v(g_i^L) \\ & > \\ & u \left(\pi_i^{NR}(g_i^H, G_{-i}) \right) - v(g_i^H) - u \left(\pi_i^{NR}(g_i^L, G_{-i}) \right) + v(g_i^L) \end{aligned}$$

²² Note for example that this rules out that g_i^H is preferred to g_i^L in NR while g_i^L is preferred to g_i^H in CR.

Where $\tilde{\pi}_i^{CR}$ denotes the stochastic monetary payoffs of the CR treatment and π_i^{NR} the deterministic payoffs of the NR treatment. Since the norm components $v(\cdot)$ are identical across treatments, they cancel out, and we can simplify the expression to

$$\begin{aligned} E \left[u \left(\tilde{\pi}_i^{CR}(g_i^H, G_{-i}) \right) \right] - E \left[u \left(\tilde{\pi}_i^{CR}(g_i^L, G_{-i}) \right) \right] \\ > \\ u \left(\pi_i^{NR}(g_i^H, G_{-i}) \right) - u \left(\pi_i^{NR}(g_i^L, G_{-i}) \right) \end{aligned}$$

In the CR treatment, the material payoffs $\tilde{\pi}_i^{CR}$ are 0 with probability $\frac{3}{4}$ and $4\pi_i^{NR}$ with probability $\frac{1}{4}$. For ease of exposition, we denote the material payoffs of g_i^L and g_i^H in the NR treatment by π^L respectively π^H . We then have

$$\begin{aligned} \frac{3}{4} u(0) + \frac{1}{4} u(4\pi^H) - \frac{3}{4} u(0) - \frac{1}{4} u(4\pi^L) \\ > \\ u(\pi^H) - u(\pi^L) \end{aligned}$$

or

$$\begin{aligned} u(\pi^L) - u(\pi^H) \\ > \\ \frac{1}{4} (u(4\pi^L) - u(4\pi^H)) \end{aligned} \tag{1}$$

This holds by strict concavity of u . To see why, we can obtain the following two inequalities by invoking the definition of strict concavity:

$$u(\pi^L) > \frac{3\pi^L}{4\pi^L - \pi^H} u(\pi^H) + \frac{\pi^L - \pi^H}{4\pi^L - \pi^H} u(4\pi^L) \quad (2)$$

$$u(4\pi^H) > \frac{4\pi^L - 4\pi^H}{4\pi^L - \pi^H} u(\pi^H) + \frac{3\pi^H}{4\pi^L - \pi^H} u(4\pi^L) \quad (3)$$

Payoffs are ranked $\pi^H < \pi^L < 4\pi^H < 4\pi^L$ and the inequalities simply state that the utility of π^L and $4\pi^H$ must be higher than the corresponding linear combinations of π^H and $4\pi^L$. Multiplying (3) with $\frac{1}{4}$ and adding it with (2) gives (1). That is, we have shown that as long as u is concave the high contribution will be more attractive in the CR treatment than in the NR treatment.