

A game of common-pool resource management: Effects of communication, risky environment and worldviews

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Abstract

The ‘tragedy of the commons’ has been investigated for several decades. At its centre is the question whether a common resource will collapse under over-exploitation. The isolated analysis of one resource has many conceptual benefits, yet in reality resources and welfare are intertwined. In this paper, we investigate a situation where a resource which is exploited for profit has the additional feature of protecting against risk. Our main question is whether participants in an experimental game will prioritize such additional feature over maximizing profit and, if so, to what extent. Therefore, we designed a forest-harvesting game: Participants can harvest trees to generate income, and at the same time the forest serves as a protection against floods. Communication has been shown to play a vital role in managing commons. Our second aim is to test the importance of communication when the resource functions as a device of protecting against external risk. Lastly, we introduce a new perspective to the tragedy of the commons literature. Specifically, we investigate how the anthropologically motivated theory of risk perception (often called Cultural Theory) correlates with behaviour in our economic game. We believe that there is much potential in combining insights from these separate disciplines.

Keywords: tragedy of the commons, social dilemma, cooperation, behavioural experiment, cultural theory

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23 1. Introduction

24

25 The sustainable use of common resources is one of the major challenges humanity has to face
26 this century. Such resources include global climate, clean air, civil security, social security, the
27 internet, and all living resources with shared ownership, such as stocks of fish and game. In
28 many situations, common resources can be accessed by individuals without or with low
29 restrictions. Therefore, they are threatened by over-exploitation. In the worst case, this may lead
30 to the collapse of the entire resource, to a “tragedy of the commons”. This term was coined by
31 the influential work by Garret Hardin (Hardin 1968), where it is argued that such a tragedy is
32 inevitable in many cases. Indeed a simplified game-theoretic model of such a situation, the
33 public goods game (PGG), permits only selfish exploitation as equilibrium. Why then can we
34 observe that many real commons can be managed consistently and without collapsing for a
35 significant amount of time?

36 In the extended research on this topic, two classes of explanations arose. The first
37 explains the gap between theory and observation by questioning the classical assumption of
38 purely self-interested agents (*homo oeconomicus*). Instead of maximizing their expected
39 utilities, individuals are suspected to have different goals. Prominent examples are risk
40 preferences (Kahneman and Tversky 1979, Raub and Snijders 1997, Gintis 2000, Holt and
41 Laury 2002, Hilbe et al. 2013), pro-social preferences (Fehr and Schmidt 1999, Fehr and
42 Fischbacher 2002, Bénabou and Tirole 2006) or essentially different rationalities (Douglas and
43 Wildavsky 1983, Thompson et al. 1990). In the second class of explanations, it is argued that
44 realistic common goods situations often exhibit additional features or restrictions which are
45 essential for maintaining cooperation. This means that even self-interested agents can cooperate
46 if there are suitable mechanisms which ensure that cooperation pays off in the long run.
47 Specifically, behaviour in a particular PGG may have impact on repeated interactions with the
48 same social partners, or affect one’s reputation (e.g., Axelrod and Hamilton 1981, Nowak and

49 Sigmund 1998, Leimar and Hammerstein 2001, Panchanathan and Boyd 2004, Berger 2011).
50 Monitoring and sanctioning systems can provide incentives to support or enforce cooperative
51 behaviour (Fehr and Gächter 2002, Hauert et al. 2007, Maier-Rigaud et al. 2010, Rustagi et al.
52 2010, Sigmund et al. 2010, Zhang et al. 2014, Chen et al. 2015). In this case, models have
53 shown that even self-interested agents should behave cooperatively under many circumstances,
54 because it is in their own long-term interest. It is likely that both classes of explanations are
55 relevant to understand the many examples of non-collapsing common goods situations in the
56 real world.

57 Our main goal is to shed light on mechanisms that govern human-environment
58 interactions. In the traditional tragedy of the commons, the tragedy consists of society losing
59 one particular resource due to over-exploitation. However, in many typical environmental
60 issues, this is not the main problem. Instead, it is the consequences on the environment: We
61 may be less worried about the profits of the forest industry than about the extended effects of
62 deforestation on the rest of the world. Surprisingly, literature on economic experiments is
63 largely focused on direct effects of a single resource. We designed an experimental game in
64 order to see how awareness of such additional effects affects sustainable management of a
65 resource. In the long run, we aim to build upon the present work to enrich the concept of present
66 economic experiments in a way that goes beyond overly simplistic decisions. In an attempt to
67 ensure tractability and an incremental accumulation of insights, this work shall serve as the first
68 step in that direction. Therefore, the multiplicity of decisions is still rather limited compared to
69 realistic scenarios. Specifically, we added exactly one additional layer of complexity beyond
70 the well-studied common-pool resource game: The resource gathered for profit has the
71 additional feature of protecting against external risk so that its depletion increases that risk.

72 Our first and main research question is whether participants will prioritize such a second
73 feature over maximizing profit and, if so, to what extent. To embody such a situation, we use
74 the context of a forest-harvesting game: participants can harvest trees from a stylized forest to

75 generate income. Additionally, the forest serves as a protection against floods (e.g., EEA 2015).
76 However, we chose values such that the damage from floods is relatively low. Thus, the game-
77 theoretic structure of a social dilemma is not resolved, in particular, the addition of flood risk
78 does not change the Nash equilibrium of the game (see Appendix A3). According to
79 Kahnemann and Tversky's (1979) prospect theory, some individuals are likely to weight losses
80 stronger than gains (loss aversion). We therefore expect that the risk of floods will make
81 participants more careful and hence more efficient in managing the resource.

82 Communication has been identified as a major driving force to resolving the tragedy of
83 the commons (Cardenas et al. 2004). Thus, our second hypothesis concerns the role of
84 communication in our setting. Apart from hoping to provide a replication of the cooperation-
85 enhancing effect of communication, we want to identify whether the effect of our first
86 hypothesis holds with and/or without the possibility of communication.

87 In addition, we introduce a different angle to the subject using the theory of *plural*
88 *rationality* (also called cultural theory; see, e.g., Thompson et al. 1990, Linnerooth-Bayer et al.
89 2003, Verweij and Thompson 2006)⁴, which postulates that stakeholder discourses (or voices)
90 are plural but limited in number. The discourses stem from different social contexts, which, in
91 turn, are shaped by the ways in which people organize, perceive and justify their social relations.
92 The theory argues that there are four ways of organizing (thus the limited number of
93 discourses): *hierarchy*, *individualism*, *egalitarianism* and *fatalism*. Individual tendencies to
94 accord with these four ways we shall call *worldviews*. It is very likely that such worldviews
95 affect behaviour in social dilemma games. However, due to lack of overlap between the
96 respective disciplines, little is known about such a possible connection. As a first step into
97 filling this gap, we used a questionnaire on the worldviews of participants and correlated it with

⁴ Originally developed by Mary Douglas (1978) as a "heuristic device" or "analytical scheme", it is a cultural theory – a theory of cultural bias, to be precise – but it all too easily gives the mistaken impression that it is culture that is doing the explaining. "Plural rationality" avoids that; it also helps position this theory in relation to those – rational choice and post-structuralism – that it challenges.

98 their behaviour in the game. Since this is – to our best knowledge – the first study connecting
99 these scientific areas, it is difficult to give specific hypothesis on the direction of correlations.
100 Further work must address this question more specifically in order to disentangle correlation
101 and causation of worldviews and pro-social behaviour.

2. Material and methods

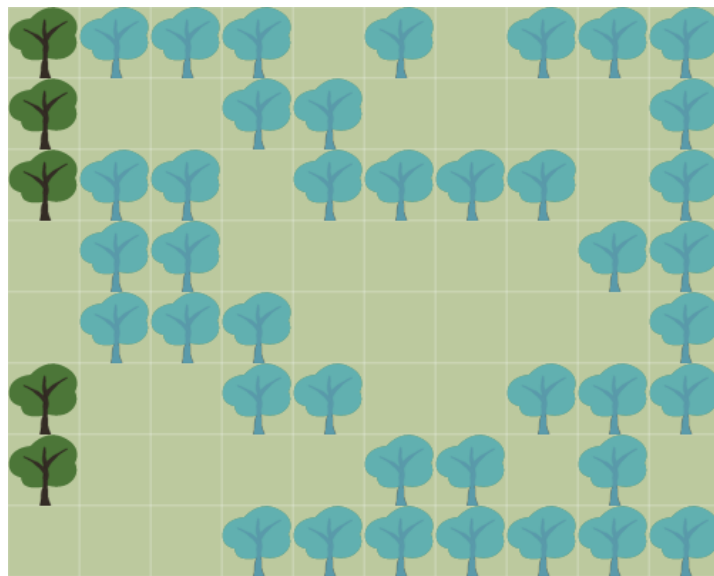
2.1. The participants

We conducted computerized experiments with 320 students, tested in fall 2015 and spring 2016. Students were recruited via the online recruitment system ORSEE (Greiner 2004) and represented a broad range of disciplines. They were composed of 48.7% females. Upon arrival participants were randomly seated in front of computers separated by opaque partitions. Participants were informed via written instructions (see Appendix A1) about the game rules and were informed that their decisions would be made anonymous to the other participants and the experimenters. They were forbidden to communicate except via computers. To allow for in-game identification while ensuring anonymity with regard to their real identity, participants were given pseudonyms (in each of the groups of five we used the names Helike, Ferin, Ananke, Metis and Kalisto, which are names of moons of the solar system, cf. Bednarik et al. 2014). Sessions lasted approximately 70 minutes and participants earned $\text{€}17.12 \pm \text{€}4.96$. After the game, participants filled out a questionnaire indicating their worldviews on various topics (see Appendix A4. For the questionnaire analysis, only part A of the questionnaire was used.).

2.2. Game rules and treatments

In fall 2015, we conducted eight groups for each of the five treatments (described below) with five participants in each group. In spring 2016, we conducted eight groups for each of three treatments, one of which was the same as in 2015. Thus, we have in total seven treatments, each with eight groups except one treatment with 16 groups. The reason is that the initial five treatments all included the option to communicate via chat-box, which we controlled for in the second cohort of experiments. We shall first explain the detailed rules of the simplest treatment and later the additional rules of the subsequent treatments:

127 Time was allocated for the participants to read the written instructions and to ask
128 questions, after which the experimenter started the game. Each round of the game consisted of
129 two phases: i) the operations phase and ii) the results phase. The participants were informed
130 about the total length of the game, which was 20 rounds. In the operations phase, participants
131 could harvest trees from a forest that was represented by an 8x10 matrix (Figure 1), where each
132 cell or patch contained one tree. Initially, all patches were filled by trees. For each harvested
133 tree, the participants received €0.10. Apart from the show-up fee (€5), this was the only source
134 of the participants' income. In the operations phase, participants could continuously harvest
135 trees for one minute. In the results phase, which also lasted one minute, participants had the
136 opportunity to check their own and other players' earnings, and prepare their strategy for the
137 next round. At the beginning of each new round, a specified proportion of the forest regrew.
138 For each existing tree, one additional tree regrew, up to a maximum of 80 trees. Additionally,
139 5 trees grew each round independently of existing trees unless the maximum of 80 trees was
140 reached already.



141 **Figure 1.** The forest game. In each group, five players may click on a tree to harvest it and
142 receive profit points. In treatments with rainfall, trees serve an additional function: to protect from
143 floods. If the rainfall intensity exceeds the size of the forest, players will be subject to flood damage,
144 reducing their payoffs. In the example shown above, the rainfall is fully absorbed by the sufficiently
145 large forest and no damage occurs.
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149 In five treatments, participants were permitted to communicate throughout the entire
150 experiment via chat-box, using their pseudonyms. During each round, a certain (fixed or
151 random as explained below) amount of precipitation occurred. The uncut forest served as flood
152 protection. If the precipitation exceeded the capacity of the uncut trees to absorb the water, a
153 flood occurred and reduced participants' payoffs. The treatment without the possibility of
154 floods was labelled NOFLO. The other treatments with chat-box followed a 2×2 design.
155 Rainfall could happen REGularly or IRRegularly and the resulting flood losses could be
156 distributed EQUally or Unequally (hence these treatments were labelled REGEQ, REGUN,
157 IRREQ and IRRUN). In all treatments except NOFLO, rainfall occurred at the end of each
158 operations phase. The rainfall intensity was either 25 for REG treatments or a random number
159 between 0-50 for IRR treatments (the sequence of the numbers was pre-generated with the
160 condition that the mean was exactly 25). The uncut forest had the capability of absorbing runoff
161 from the rain: Each tree reduced the potential flooding intensity by one point. If the resulting
162 intensity was reduced to 0 or below, no flood occurred. Otherwise, the resulting flood inflicted
163 damage which was deducted from players' payoffs. The total flood damage was estimated as
164 the difference between the rainfall intensity (0-50) minus the number of uncut trees. The flood
165 damage was distributed to the players (reducing their payoffs) either equally (in EQ treatments)
166 or unequally (in UN treatments). In the latter case, one player bore 50% of the flood damage,
167 one player 25%, one player 15%, one player 10% and one player 0%. This damage distribution
168 was different in each round (randomly, but modified to ensure the same sums of weights over
169 all rounds for all players). Regardless of whether the distribution of damage was equal or
170 unequal the flood damage did not outweigh individual profits from harvesting trees. Even if the
171 forest was at its minimal water carrying capacity, each harvested tree gave one point to the
172 harvester while it caused only between 0 and 0.5 points (on average: 0.2 points) damage.

173 In addition to these five treatments, we ran the treatments NOFLO and REGEQ without
174 the chat-box, which we shall refer to as NOFLO-NC and REGEQ-NC. In the second cohort we

175 also ran another 8 groups with the REGEQ treatment. In summary, we had 7 treatments, with
176 8 groups of 5 players in each treatment, except for REGEQ, where we had 16 groups. Thus, we
177 had $(7+1) \times 8 = 64$ groups, meaning that a total of 320 participants were tested.

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179 **2.3. Statistical analysis**

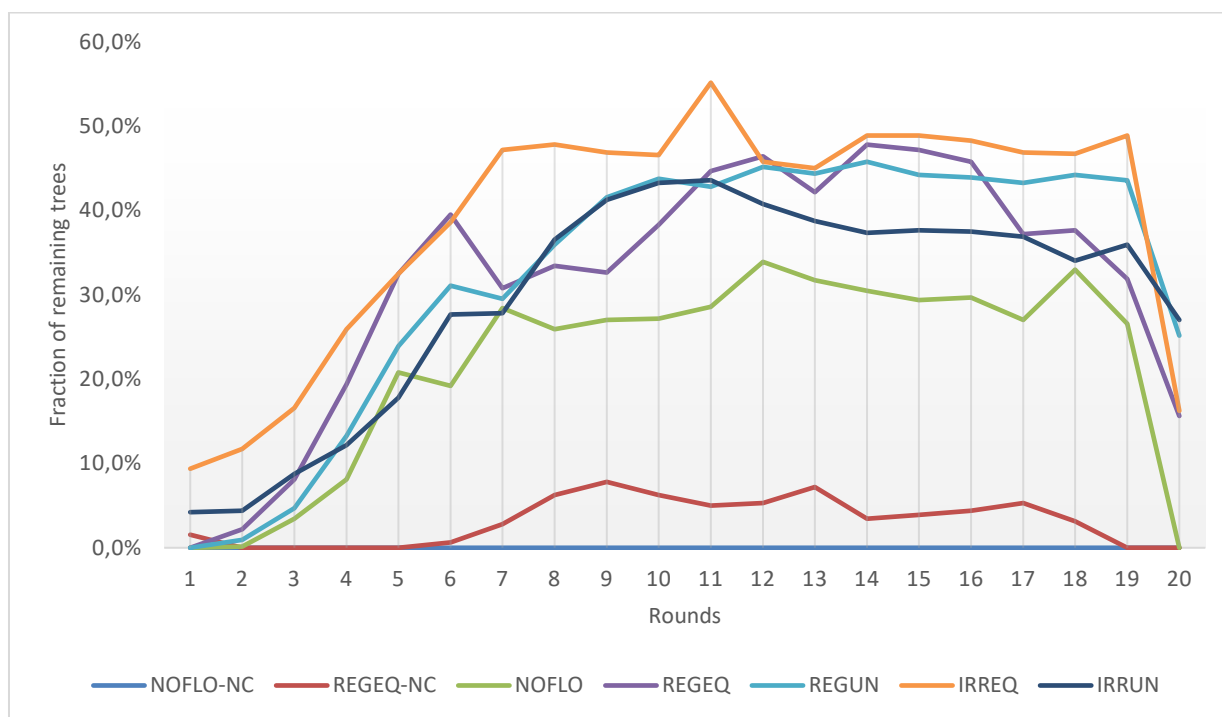
180 Except where specifically indicated, we used group averages as our statistical units since the
181 behaviour of individual participants within each group was interdependent. For statistical
182 analysis R 3.2.1 (R Core Team 2013) was used. Probabilities are reported as two tailed at a 5%-
183 significance level.

184

185

186 **3. Results**

187 **3.1. Flood risk reduces over-harvesting**



188 **Figure 2.** Average fraction of remaining trees per round for each of the seven treatments (abbreviations
 189 see in methods section 2.2). Clearly, treatments without the possibility of chat communication perform
 190 poorly. Further, the groups’ ability to maintain a larger number of trees is also affected by the possibility
 191 of floods.
 192

193

194 Average forest condition (% of uncut trees) is higher in the flood treatments than in the no flood
 195 treatment (27.47 ± 15.12 vs. 10.77 ± 14.23 , Wilcoxon rank-sum test: $W = 171$, $p < 0.001$, see Fig.
 196 2), which suggests that the risk of floods mitigates the social dilemma of forest management.
 197 However, the resulting increase in efficiency was not sufficient to compensate for occasional
 198 losses from floods. Hence, the final payoffs were not significantly different in treatments with
 199 and without floods. Interestingly, however, individual payoffs were significantly negatively
 200 correlated with individual harvest rate (the percentage each individual harvested from each
 201 round’s initial forest condition, averaged over all 20 rounds, Pearson’s $r = 0.179$, $df = 318$, $p =$
 202 0.0013). This can be interpreted as evidence for “nice guys finish first”, because high individual
 203 harvest rates often imply an early deforestation. After that, a collective agreement to abstain

204 from harvesting in order to regrow the forest is difficult. As a result, individual earnings of all
205 group members can be reduced.

206 **3.2. Uncertainty impacts behaviour**

207 Contrary to the differences to the NOFLO-treatment, all treatments with floods showed similar
208 behaviour when averaged over the entire game duration. However, on a closer look there exist
209 clear differences in behaviour of groups in treatments with irregular rainfall compared to the
210 rest. In the first round, nearly all (57 of 64) groups deforested the entire area. Of the seven
211 groups that did not deforest the entire area, five belonged to the irregular treatments (IRREQ or
212 IRRUN). This is especially remarkable because in the first round, players had little time to
213 gather experience about the game or to communicate. Evidence for risk-averse behaviour is
214 found when looking at the optimal harvesting rate. The maximum regeneration in all treatments
215 was 42 trees per round which could be achieved by leaving 38 trees and harvesting the rest.
216 Groups in the irregular treatment tended to leave more trees than 38 significantly more often
217 than other groups (36.56 ± 26.57 vs. 15.83 ± 15.58 , Wilcoxon rank-sum test: $W = 281.5$, $p =$
218 0.0132). Because rainfall was unpredictable in these treatments (IRREQ and IRRUN), it is
219 likely that these groups tried to build up a buffer to prevent flood damage.

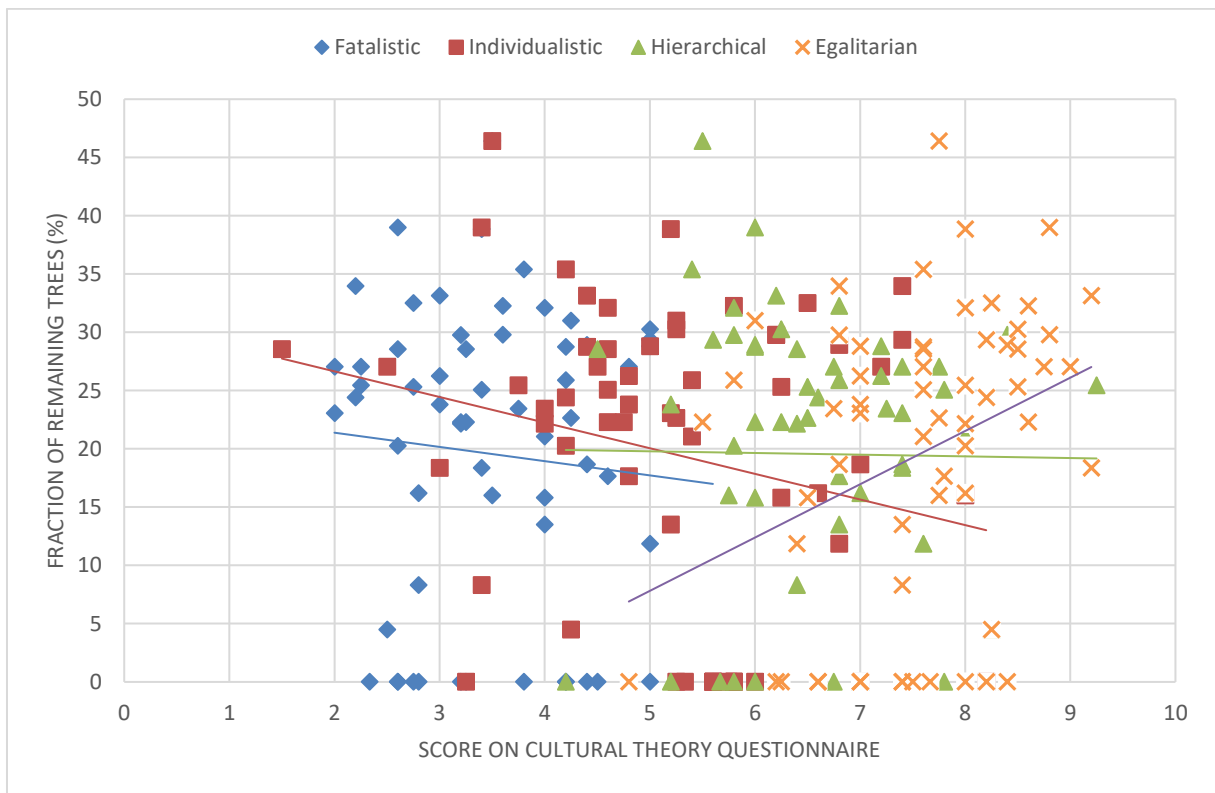
220 **3.3. No cooperation without communication**

221 As expected, communication appears to play a vital role in managing common goods: Average
222 forest condition is higher in the chat treatments than in the no chat treatments (30.53 ± 12.01 vs.
223 1.57 ± 4.38 , Wilcoxon rank-sum test: $W = 29$, $p < 0.000001$, cf. Fig. 2). Further, among those
224 treatments with chat, we find a tendency that longer chat communication correlates with higher
225 levels of cooperation, i.e., lower levels of over-harvesting (Pearson's $r = 0.258$, $t = 1.6456$, df
226 $= 38$, $p = 0.108$).

227

228 **3.4. Worldviews matter**

229 As mentioned in the section 1, we made a first step for building a bridge to the
230 sociologically/anthropologically driven theory of plural rationalities, which states that social
231 interactions depend on four distinct worldviews: *hierarchy*, *individualism*, *egalitarianism* and
232 *fatalism*. We applied a post-game questionnaire to elicit worldviews of the players, and
233 compared the four worldviews with the group outcomes. The questionnaire allowed us to score
234 participants on each of the worldviews on a scale 1-10. Linking group averages of the individual
235 scores with average group forest condition resulted in the correlations show in Figure 3.
236 Egalitarian affinities improve a group’s ability to preserve the forest (positive correlation),
237 whereas individualistic and fatalistic affinities have a slightly opposite effect (negative
238 correlations). This finding is in line with the theory’s predictions, because preserving
239 environment and sharing resources equally are assumed to be predominantly egalitarian traits.



240
241 **Figure 3.** Group averages of worldview scores plotted against group averages of remaining trees. Each
242 circle represents a group’s average score on one of the four worldviews plotted against the same
243 group’s average number of remaining trees.

244 **4. Discussion**

245 The conducted experiments show the influence of shared benefits, communication, and
246 individual worldviews on the outcome of a common-pool resource management game. The
247 addition of group-level benefits for reducing the harvest rate improves the group outcomes in
248 terms of the forest sustainability in all treatments with and without communication. One
249 explanation for this result is based on risk aversion (Kahneman and Tversky 1979). The flood
250 damage affects everyone (although not always to the same extent, depending on the treatment)
251 which means that individual over-harvesting does not only destroy the potential long-term
252 benefits, but also leads to direct costs in terms of flood damage. Although the addition of flood
253 risk does not change the dominant individual strategy leading to overharvesting, by reframing
254 the context, it may trigger different heuristics for making harvesting decisions (Shaffer et al.
255 2011). The potential of flood losses, by adding an external source of uncertainty (besides
256 uncertainty related to decisions of other players), increases cognitive processing required to
257 assess the decision with a best individual outcome. In such situations, players may rely more
258 on simple heuristics (Todd and Gigerenzer 2000) – in this case lowering the harvest. It has been
259 demonstrated that such simple heuristics can perform better than decisions guided by optimal
260 outcomes, in highly uncertain situations (Pflug et al. 2012). In future studies we will try to
261 assess to what extent participants are aware of the game-theoretic individual optimum decisions
262 and if additional risk induces a deviation from this decision or, alternatively, if they switch to a
263 different decision mode using one of simple heuristics.

264 The results linking individual cultural theory-based characteristics with the behaviour
265 in the common-pool resource experiments show that egalitarian worldviews are correlated with
266 more sustainable strategies. This demonstrates a potential for cultural theory to add another
267 classification to the repertoire of other-regarding preferences (e.g., Fehr & Schmidt, 1999) that
268 may explain and enrich our understanding of how different combinations of player types may
269 lead to more sustainable behaviour. A number of studies investigating cultural effects on the

270 behaviour of participants in experimental economics games have revealed interesting patterns
271 (Prediger et al. 2011, Ghate et al. 2013). Cultural theory seeks to explain cultural differences
272 by addressing four “ways of life” that are present within any specific culture (as addressed by
273 anthropological and psychological literature). The results we obtained are consistent with the
274 understanding of the key instruments used by different solidarities: individualists relying on
275 incentives, hierarchists relying on rules and egalitarians relying on norms. In the absence of
276 incentives and rules in the game design, egalitarians are more likely to overcome the social
277 dilemma and achieve more sustainable outcomes. At the same time, a well-functioning group
278 which results in good forest management could make participants respond stronger to
279 egalitarian values. Further research is needed to investigate the causal interactions between
280 participants’ behaviour and worldviews.

281 Finally, it is important to emphasize the dynamic form of resource representation in the
282 experiments. Although it is now common to investigate the common-pool resource situation
283 with the static resource model (as in public goods games), such a representation misses the
284 critical component of the resource dynamics. The participants’ harvesting decisions affect the
285 resource state that may lead to a case-specific trajectory, adding the history dimension that may
286 in turn induce path-dependency. Effectively, participants’ decisions depend not only on
287 decisions of others from previous rounds but also on the state of the resource itself. This
288 additional complexity can increase the difficulty of identifying the players’ strategies; however,
289 the findings better represent actual decision-making in common-pool resource situations.

290

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295

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