Appendix 6. Intuition underlying our hypotheses and proofs.

We rely on methods from repeated game theory and focus on the conditions under which different equilibrium outcomes can be sustained in the different treatments, i.e. we look at which resource stock sizes the group could possibly sustain for the entire game. Please see Lindahl et al. (2012, 2014) for a more detailed description of the game situation.

The subjects of our experiment play a dynamic CPR game with an indefinite time horizon (Carmichael 2005), i.e. they know that the game will end at some point but not exactly when. At each stage (round) of the game, each subject (player) *i* in the group has, however, an individual perception about the likelihood whether or not the game will last another round (we can also call it a discount factor), which we denote δ_i (Fudenberg and Tirole 1998). These subjective probabilities will be crucial, which will become clearer as we go on.

Assume the following strategy for each player $i \in \{1, \dots, n\}$, where *n* is the total number of players in the group: a) In the first round, take $(50 - x)/n$ units of the resource stock (to reach a stock size of x) and then, from the second round and onwards, take $(H_x)/n$ units[1,2], where H_x denotes the sustainable yield to keep stock size x. b) If in some round *t* someone in the group deviates from this strategy (i.e. the new stock size is not x), then deplete the resource stock in the next round, $t+1$, i.e. claim (harvest) the entire resource stock. The maximum possible amount to claim is the current resource stock size (see Instructions in Appendix 1 for equation of individual payment calculation in case of depletion). Hence, for the deviating player in round *t*, the optimal deviation is to claim the entire resource stock (x_t) in period *t*. Equation (A6.1) gives the payment (payoff) P_{DC} of a player *i* who deviates when all other players in the group play according to the strategy described above (i.e. cooperate), h_{jt} represents the claimed harvest of player *j* (who plays according to the strategy), where $j \neq i$.

$$P_{DC} = \frac{x_t^2}{x_t + \sum_{j \in n, j \neq i} h_{jt}} \quad \text{(A6.1)}$$

If all players deplete the resource in the same round, the associated payoff for each player is x_t/n. Let δ_i denote the expected discounted value of one unit harvested capturing the subjective discount factor of player *i* that the game will continue for one more round (in round *t*). Equation (A6.2) shows the total payoff, for player *i* who follows the strategy for the entire game, given that all other players do so as well. The first term refers to the payoff, $P(n, \delta_i)$, in the first round (round 0) and the second term to the sum of the continuation payoffs in all subsequent rounds.

$$P(n, \delta_i) = \frac{50 - x}{n} + \sum_{t=1}^{\infty} \delta_i^t \frac{H_x}{n} \quad \text{(A6.2)}$$

The regeneration rate H_x (i.e. the sustainable yield to keep stock size x) is, however, in the risk treatments not known with certainty for stock sizes $x \in \{10, 11, 12, \dots 19\}$. We refer to the

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[1] Note that we focus only on strategies supporting equal sharing equilibrium outcomes (if an equilibrium is sustained, it is based on equal shares of the resource stock size) because this is actually consistent with what we observed in the experiment. Whereas some of these equal sharing groups shared the harvest equally in each round, others used a rotating scheme to share the harvest equally over time.

[2] Note that in the risk treatments, for the range of resource stock sizes where the regeneration rates differ ($x \in \{10, 11, 12, \dots 19\}$) the actual scenario played (scenario A (no threshold) or scenario B (threshold)) will be revealed after the first round because the regeneration rates differ.

probability of a threshold (scenario B) as $\Pr(T)$ and to the probability of no threshold (scenario A) as $1-\Pr(T)$. Further, we denote regeneration rate when there is a threshold as H_x^T and when there is no threshold as H_x^{NT}. Equation (A6.2) can then be rewritten:

$$P(n,\delta_i)=\frac{50-x}{n}+\sum_{t=1}^{\infty}\delta_i^t\,EU\left(\frac{\Pr(T)H_x^T+(1-\Pr(T))H_x^{NT}}{n}\right) \quad \text{(A6.3)}$$

Here, the expected utility (*EU*) from the uncertain continuation payoff can belong to a risk-neutral, averse or seeking player. From Equations (A6.1-A6.3), we can derive the necessary conditions for the outcome (a sustained stock size of x) to be sustainable as an equilibrium outcome: In the very first round, the payoff for a player who follows the described strategy for the entire game (given the other players do so as well) must be equal to or bigger than the payoff the player would get by deviating, i.e. depleting the resource stock, in the very first round. To save space, let $EU(H_x/n)$ denote $EU\big((\Pr(T)H_x^T+(1-\Pr(T))\mathrm{H_x^{NT}})/n\big)$. In the very first round, no player deviates if Equation (A6.4) holds:

for all $i\in n$

$$\frac{50-x}{n}+\sum_{t=1}^{\infty}\delta_i^t\,EU\left(\frac{H_x}{n}\right)\geq\frac{50^2}{50+\frac{50-x}{n}(n-1)}\;\Leftrightarrow$$

$$\frac{1}{1-\delta_i}n\,EU\left(\frac{H_x}{n}\right)\geq\frac{50^2n}{50+\frac{50-x}{n}(n-1)}-\left(50-x-nEU\left(\frac{H_x}{n}\right)\right)\Leftrightarrow$$

$$\frac{((100-x)n-(50-x))n\,EU\left(\frac{H_x}{n}\right)}{50^2n^2-((100-x)n-(50-x))\left(50-x-n\,EU\left(\frac{H_x}{n}\right)\right)}\geq 1-\delta_i\Leftrightarrow$$

$$\delta_i\geq\hat{\delta}(x)=\frac{50^2n^2-((100-x)n-(50-x))(50-x)}{50^2n^2-((100-x)n-(50-x))\left(50-x-n\,EU\left(\frac{H_x}{n}\right)\right)} \quad \text{(A6.4)}$$

It is easy to verify that the critical discount factor $\hat{\delta}(x)$ of a risk averse player is for $x\in\{10,11,12,\dots 19\}$ higher than that of a risk neutral player because $EU_{averse}(H_x/n)<EU_{neutral}(H_x/n)$. Exactly how much higher will depend on the assumptions one makes on the level of risk aversion. (For a risk seeking player, the critical discount factor would be lower than that of a risk neutral player.)

In the subsequent rounds, because the players face the same game in each round, it is sufficient to check that the continuation payoff at time *t* is equal to or larger than the deviation payoff. Note that in subsequent rounds, there is no longer any uncertainty about the regeneration rate because the true scenario will be revealed after the first round. Thus, the following needs to hold:

for all $i\in n$

$$\sum_{\tau=t}^{\infty}\delta_i^{(\tau-t)}\left(\frac{H_x}{n}\right)\geq\frac{(x+H_x)^2}{x+H_x+\frac{H_x(n-1)}{n}}\;\Leftrightarrow$$

$$\frac{1}{1-\delta_i}\geq\frac{(x+H_x)^2n^2}{((x+H_x)n+H_x(n-1))H_x}\Leftrightarrow$$

$$\frac{((x+H_x)n+H_x(n-1))H_x}{(x+H_x)^2n^2}\geq 1-\delta_i\Leftrightarrow$$

$$\delta_i\geq\hat{\delta}(x)=\frac{(x+H_x)^2n^2-((x+2H_x)n-H_x)H_x}{(x+H_x)^2n^2} \quad \text{(A6.5)}$$

For all parameters in our model, we have verified that if Equation (A6.4) holds, then Equation (A6.5) also holds (these calculations are available upon request). In Table A6.1, we present the critical discount factor, from Equation (A6.4), for all resource stock sizes for all four treatments. The risk treatments discount factors are based on risk neutral players.

The first observation we can make is that if all players in a group, for all rounds of the game, believe that the game will last another round with a high enough probability ($\delta_i \geq \hat{\delta}(x)$), then each resource stock size of the game, $x \in \{5,6,7,\ldots,50\}$, can be sustained as an equilibrium outcome. This critical value ($\hat{\delta}(x)$) varies with the regeneration rate of the resource stock. To stay at a given stock size, the group can harvest an amount exactly corresponding to the regeneration rate at that stock size. So if the group is at a given resource stock size, and if the regeneration rate is relatively high, the incentive to deviate and deplete the resource stock is low because the expected value of the sum of future payoffs is also relatively high (the group will be able to harvest a high amount of resource units each round). This means that the critical value of the subjective discount factor can be lower. From Lindahl et al., we know that the critical value $\hat{\delta}(x)$ will be the same in all treatments for those resource stock sizes where the regeneration rate is the same. Thus, it will be the same for stock sizes of $x \in \{5,6,7,8,9\} \cup \{20,21,22,\ldots,50\}$.

For resource stock sizes where the regeneration rates potentially differ, i.e. for $x \in \{10,11,12,\ldots,19\}$, $\hat{\delta}(x)$ will be higher the more likely a threshold is (because the expected regeneration rate is lower). This is illustrated in Figure A6.1 (see also Table A6.1) where we have depicted these critical values for $x \in \{5,6,7,8,9\} \cup \{20,21,22,\ldots,50\}$ and for all four treatments (for a game with 4 players).

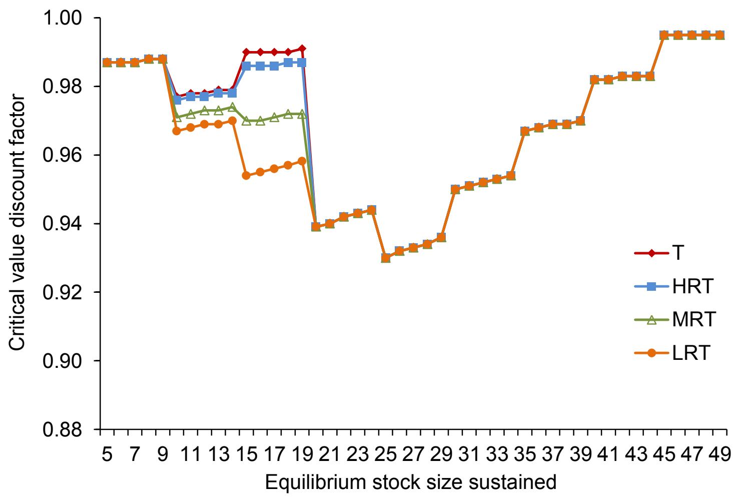

Fig. A6.1. Comparison of the critical values of the discount factor for the threshold (T), high-risk (HRT), medium-risk (MRT) and low-risk (LRT) treatment with four players.

Between stock sizes of 10 and 19, the incentive to deviate is higher and increasing with the probability of a threshold because the probability is high that the regeneration rate could become low. Thus, stock sizes between 10 and 19 (the range where the group would cross the threshold and where we find severe overexploitation according to the definition) are harder to sustain throughout the game the higher the probability of a threshold is.

To be able to formulate hypotheses based on Table A6.1, we need to make some assumptions about the distribution of the discount factors of the players in the game. We denote this distribution $F(\delta_i)$. We need to assume, for example, that the range of the critical values for the discount factors, which is in the range between 0.930 and 0.995, is a subset of the range of $F(\delta_i)$. Moreover, the distribution $F(\delta_i)$ is independent of treatment. Whereas the latter assumption is relatively straightforward, the former may need some elaboration. If the first assumption does not hold, i.e. if the discount factors of all players are below (above) the range of critical values, then no (all) equilibrium(s) can be sustained in the game and we would not see a distinction between the treatments.

Table A6.1. Critical discount factors for all resource stock sizes for all four treatments.

Stock size	T	HRT	MRT	LRT	Stock size	T	HRT	MRT	LRT
5	0.987	0.987	0.987	0.987	28	0.934	0.934	0.934	0.934
6	0.987	0.987	0.987	0.987	29	0.936	0.936	0.936	0.936
7	0.987	0.987	0.987	0.987	30	0.950	0.950	0.950	0.950
8	0.988	0.988	0.988	0.988	31	0.951	0.951	0.951	0.951
9	0.988	0.988	0.988	0.988	32	0.952	0.952	0.952	0.952
10	0.977	0.976	0.971	0.967	33	0.953	0.953	0.953	0.953
11	0.978	0.977	0.972	0.968	34	0.954	0.954	0.954	0.954
12	0.978	0.977	0.973	0.969	35	0.967	0.967	0.967	0.967
13	0.979	0.978	0.973	0.969	36	0.968	0.968	0.968	0.968
14	0.979	0.978	0.974	0.970	37	0.969	0.969	0.969	0.969
15	0.990	0.986	0.970	0.954	38	0.969	0.969	0.969	0.969
16	0.990	0.986	0.970	0.955	39	0.970	0.970	0.970	0.970
17	0.990	0.986	0.971	0.956	40	0.982	0.982	0.982	0.982
18	0.990	0.987	0.972	0.957	41	0.982	0.982	0.982	0.982
19	0.991	0.987	0.972	0.958	42	0.983	0.983	0.983	0.983
20	0.939	0.939	0.939	0.939	43	0.983	0.983	0.983	0.983
21	0.940	0.940	0.940	0.940	44	0.983	0.983	0.983	0.983
22	0.942	0.942	0.942	0.942	45	0.995	0.995	0.995	0.995
23	0.943	0.943	0.943	0.943	46	0.995	0.995	0.995	0.995
24	0.944	0.944	0.944	0.944	47	0.995	0.995	0.995	0.995
25	0.930	0.930	0.930	0.930	48	0.995	0.995	0.995	0.995
26	0.932	0.932	0.932	0.932	49	0.995	0.995	0.995	0.995
27	0.933	0.933	0.933	0.933					

Note: T denotes threshold, HRT high-risk, MRT medium-risk and LRT low-risk treatment. The discount factors of the latter three treatments (risk treatments) are based on risk neutral players.

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