Cooperation Studies of Catastrophe Avoidance: Implications for Climate Negotiations

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Highlights

- Despite more than 20 years of climate negotiations, the world still lacks a robust climate agreement
- We review recent laboratory cooperation studies of climate catastrophe avoidance
- We identify five key variables that influence the likelihood of averting disaster
- We consider how knowledge of these variables might improve the prospects of climate negotiations

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Abstract

Despite more than two decades of international negotiations, the world still lacks a credible approach for addressing the threat of dangerous climate change. It is becoming increasingly apparent that climate negotiators need to be equipped with better strategies if a tragedy of the climate commons is to be averted. We review the results arising from an emerging literature in which the problem of avoiding dangerous climate change has been simulated using cooperation experiments in which individuals play a game requiring collective action to avoid crossing a dangerous threshold. This literature has uncovered five key variables that influence the likelihood of averting disaster: (1) the risk of collective failure, (2) inequalities in responsibility, wealth, or risk, (3) uncertainty surrounding the threshold, (4) intergenerational discounting, and (5) the prospect of reward or punishment based on reputation. We consider how knowledge of the effects of these and other variables might be harnessed by climate negotiators to improve the prospects of reaching a solution to global climate change.

Keywords: Climate change · Cooperation · Climate negotiations · Global public good · Collective-risk social dilemma.

1. Introduction

Human greenhouse gas emissions from agricultural and economic activity are continuing to rise at unprecedented rates posing the risk that one day global average temperature will exceed a critical threshold or tipping point (Alley et al., 2003; Lenton et al., 2008; Schellnhuber et al., 2006). Catastrophe avoidance requires the collective action of many nations to reduce their emissions of greenhouse gases by 50% by the year 2050 so that atmospheric concentrations can be stabilised (Meinshausen et al., 2009; Peters et al., 2013; Roeckner et al., 2011). The protection of the global climate is a global public good that will benefit everyone, whether or not they help to deliver it. However, because climate protection requires economically costly emission abatement, each country has an incentive to act selfishly by refusing to cooperate in the hope that others will carry the burden of supplying the global public good—the so-called free rider problem. Climate protection is therefore an example of a more general and pervasive problem known as the "tragedy of the commons" (Hardin, 1968), wherein a group of individuals acting in their self interest ruthlessly overexploit a common resource to the detriment of their collective long-term best interests. The tragedy of the commons tell us that when individuals, groups, or countries are free to overexploit a resource, they typically do, leaving the public good at risk of collapsing due to the susceptibility of cooperation to exploitation by self-interested parties (Milinski, 2006).

2. Climate Negotiations

As the protection of the global climate commons depends upon the aggregate efforts of many countries, international climate negotiations are crucial so that emission reduction targets can be set, and countries can establish that they are not acting in isolation. However, ever since the United Nations Framework Convention on Climate Change (UNFCCC, 1992) was established at the Rio Earth Summit in 1992, progress on establishing an effective climate treaty has been painstakingly slow. This meeting produced an agreement compelling governments to take action to prevent "dangerous anthropogenic interference with the climate system" and triggered annual meetings—known as the conference of the parties—in which parties to the convention discuss progress on tackling climate change. To date, the agreement has been signed by more than 180 countries. However, other than advocating the desirability that anthropogenic emissions be reduced to earlier levels before the end of the decade, it did not specify any emission reduction targets for countries.

This led five years later at the conference of the parties in Kyoto (UNFCCC, 1998) to the establishment of the Kyoto Protocol in 1997, which sought to reduce greenhouse gas emissions by 5%, relative to 1990 levels. The Kyoto Protocol is an example of a top-down approach to climate policy (Hare et al., 2010) where a joint legally binding international agreement is reached, with a common global emission reduction objective to be attained through agreed targets and timetables. The treaty required that 55 countries accounting for at least 55% of global emissions ratify the agreement in order for it to come into full force, which did not happen until eight years later in February 2005 when Russia signed up to the agreement. However, one of the worlds largest emitters— viz. the United States—remains to this day a non-participant in the agreement. For this, and other reasons (see Barrett, 2007), the agreement has been unsuccessful in producing meaningful global emission reductions. The Kyoto Protocol expired in 2012 and much of the discussions during the negotiations leading-up to this date revolved around what a successor to it would look like.

The next milestone in climate negotiations occurred at the conference of the parties in Copenhagen in 2009 (UNFCCC, 2010), which saw a transition from a top-down to a bottom-up approach to climate policy. The meeting produced an agreement—known as the Copenhagen Accord—that average global temperature should not be allowed to exceed 2 °C relative to preindustrial levels in order to prevent dangerous anthropogenic interference with the climate system. To achieve this goal, a "pledge-and-review" mechanism (Rayner, 2010) was adopted, which requires each party to the accord to submit voluntary unilateral pledges regarding how much they are willing to reduce their emissions by 2020, before subjecting these to international review. The pledge phase of the accord is now complete and the final review phase will commence at the conference of the parties in Paris later this year. The advantage of this bottom-up approach is that it is more flexible, which has enabled it to attract more countries than the Kyoto Protocol—including all the world's largest emitters—helping to break deadlocks in the climate negotiations. However, the Copenhagen Accord is not a legally binding treaty and negotiators and stakeholders have expressed concerns that the Copenhagen pledges will fall short of the 2 °C target (Buhr et al., 2014).

Accordingly, after more than two decades of international bargaining, the world still lacks a robust climate agreement. Why has this process been so fraught? According to Barrett (2003, 2007) the architects of climate agreements have failed to craft a treaty that adequately restructures the incentives for cooperation. According to Barrett, an effective treaty requires the manipulation of incentives—using appropriate reward and sanctioning mechanisms—in order to make cooperation a more attractive strategy than defection. This, Barrett argues, is why the Kyoto protocol failed—it did not adequately restructure the incentives. However, even with an effective treaty on the table, the problem remains of trying to get countries to agree on it. For this to happen, countries must believe that climate change mitigation is a goal that warrants the sacrifices that must be made, and they must perceive the treaty to be equitable and fair. Climate negotiations are supposed to provide the justification for action and resolve issues of equity and fairness, but to date they have failed to overcome these and other barriers to cooperation. For example, the 2009 Copenhagen negotiations descended into chaos as conflicts between rich and poor, combined with doubts about whether climate change is an urgent and impending threat almost caused the meeting to collapse. It is clear therefore that climate negotiators need to be equipped with better strategies to make treaties easier to agree on. Accordingly, our focus here is not on how to design an effective climate treaty, but instead on how to cultivate the collective will amongst countries to take action to avoid dangerous climate change.

3. Overview of Article

We consider the lessons for climate negotiations that can be learned from laboratory cooperation experiments involving public goods games. In a typical public good game (Chaudhuri, 2011; Fehr & Gachter, 2000; Fischbacher & Gachter, 2010; Fischbacher et al., 2001; Ledyard, 1995; Parks et al., 2013), a group of players is given a sum of money and asked how much they are willing to invest in a group project. Any money invested in the group account is then increased in value (e.g., doubled) by the experimenter before being divided equally amongst all players. This game is a useful laboratory analogue of the process of providing public goods such as bridges, parks, and roads. However, protecting the global climate involves contributing to a public good to avoid incurring a *loss*—rather than to obtain a *gain*—and so these standard public goods games do not constitute an appropriate analogy of the climate change problem. Recently, however, a new class of public goods games—and an associated experimental literature—have emerged to simulate the inherent problems associated with avoiding dangerous climate change. In what follows, we provide an overview of the key insights arising from this new research field and their implications for climate negotiations.

The remainder of this article is structured as follows. We begin by describing a game known as the "collective-risk social dilemma" (Milinski et al., 2008) developed to simulate the problem of avoiding dangerous climate change. Next, we describe the key empirical results observed using this and kindred public good games of loss avoidance—with a focus on the factors that impede or enhance cooperation—and we consider how these insights might be used to improve the prospects of climate negotiations.

4. A Climate Catastrophe Avoidance Game

Simulating the problem of avoiding dangerous climate change requires an experimental paradigm that mimics the fundamental characteristics of the real climate game. This game has at least three key attributes: (1) To avert catastrophe, humankind must reduce greenhouse gas emissions in order to prevent global mean temperature from exceeding a dangerous threshold. The real climate game is therefore best understood as a threshold public good problem. A threshold public good is one in which a target level of contributions (viz. emission reductions) must be reached in order for that good (viz. climate protection) to be delivered. (2) Climate protection cannot be provided by the unilateral action of a single country, but instead depends upon the multilateral efforts of many nations to collectively reduce their emissions. (3) The provision of the global public good entails a social dilemma—countries can choose to reduce their emissions, which comes at a short-term economic cost, or they can choose not to do so, but run the risk of dangerous climate change further down the line, with more serious economic, environmental, and health costs.

Milinski and colleagues (Milinski et al., 2008) have devised a public goods game known as the collective-risk social dilemma that satisfies these constraints (Figure 1). The game involves groups of six players, where each player can be thought of as representing a country. At the start of the game, each player is given an operating fund of €40 and must decide whether to invest €0, €2, or €4 in each of 10 rounds to an account for climate protection. The identities of the players are kept anonymous, but at the end of each round their contributions are made public. If the combined investments in the climate account are equal to or greater than €120 by the end of the game then dangerous climate change is averted and the players get to keep any money not invested in climate protection. However, if the group fails to reach the threshold then dangerous climate change is simulated with a probability (e.g., 50%) that what remains of each player's operating fund will be lost. The €120 target can be construed as a temperature threshold—such as the 2 °C limit on warming identified in the Copenhagen Accord (UNFCCC, 2010)—whilst the player contributions are a metaphor for the level of investment of countries in emission reductions to avoid dangerous climate change.

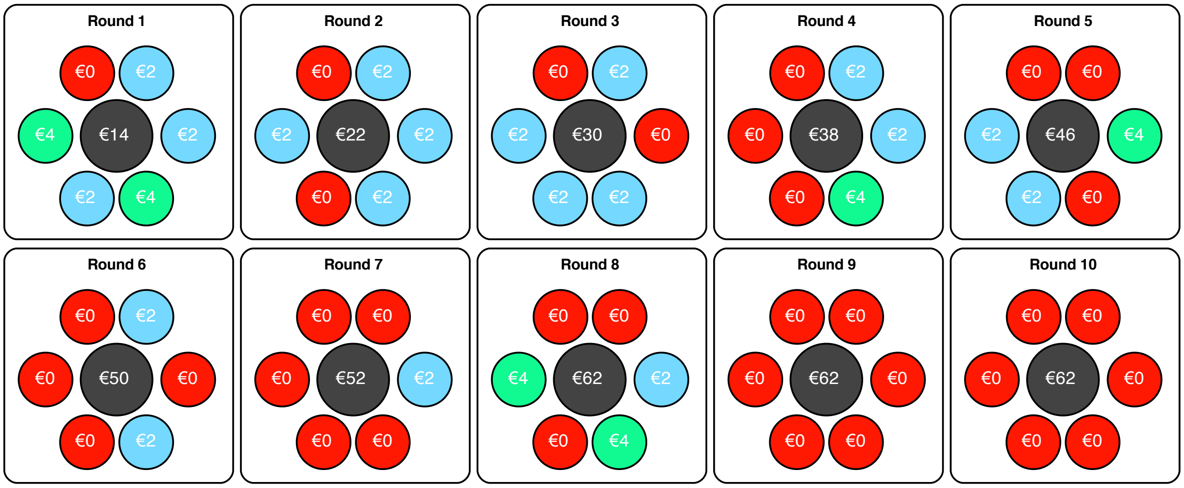

Figure 1: Schematic of the collective-risk social dilemma public goods game developed by Milinski et al. (2008). Each panel corresponds to a different round of the climate game. Within each panel, each coloured outer circle corresponds to a player and the associated value represents their degree of investment in climate protection on that round (€0, €2, or €4). The inner circle represents the cumulative sum of investments in the climate account. The objective of the group is to accumulate at least €120 of investments in the climate account by the end of round 10. In the example shown, the capacity to prevent dangerous climate change with certainty is lost by the end of round 8. See main text for further details.

5. Factors Affecting Cooperation

We now review five recent findings observed using the collective-risk game—and kindred climate public goods games—that cast light on the factors that spur and inhibit collective efforts to avoid dangerous climate change. Specifically, (1) we present evidence that the risk of collective failure is a major variable underpinning cooperation—the higher the perception of risk, the easier it becomes for groups to coordinate efforts to avert disaster. (2) We then show how inequality—either in terms of historic responsibility, wealth, or risk—acts as an impediment to cooperation, but this handicap can sometimes be ameliorated through communication or by setting intermediate climate targets. (3) Next, we show how uncertainty about the location of the threshold for dangerous climate change—but not the economic consequences of crossing it—breaks down cooperation, whereas certainty surrounding the threshold provides a powerful incentive for collective action. (4) Subsequently, we underscore how the well-known tendency for individuals to discount the effects of climate change on the self and future others extends to group cooperation settings and constitutes a formidable barrier to cooperation, but this barrier can be mitigated by building a sense of affinity between current actors and future generations. (5) Finally, we highlight the importance of reputation as a powerful tool for achieving stable group cooperation.

5.1. Perception of risk

To avoid crossing a dangerous threshold, countries must be convinced that they will be seriously adversely affected by climate change. This was demonstrated in the original experiment by Milinski et al. (2008) using the collective-risk game in which the risk of dangerous climate change occurring if the target level of investments in climate protection was not reached was manipulated. The experiment involved three conditions, each involving 10 groups of six players. In one condition, the probability of dangerous climate change occurring if group members failed to reach the target was 10% (low-risk); in a second condition it was 50% (moderate-risk); whilst in a third condition it was 90% (high-risk).

The results are shown in Figure 2 (left panel), which plots the number of groups that reached the threshold in the three conditions. It is apparent from inspection of this figure that a low or moderate perceived risk of severe climate damages renders a tragedy of the commons virtually assured—in the low-risk condition, all groups failed to reach the threshold, whilst in the moderate-risk condition only 1 group was successful. By contrast, in the high-risk condition 5 groups succeeded in reaching the threshold. This suggests that the perception that there is a high probability of being adversely affected by climate change is a necessary—but not sufficient—condition to avert catastrophe. These results mesh well with recent game theoretic analyses of the collective-risk game showing that coordination for a global good is best realised in small to medium sized groups where the perception of risk is high (Pacheco et al., 2014; Santos & Pacheco, 2011; Vasconcelos et al., 2014).

Further evidence for the pivotal link between perceived climate risks and cooperation comes from an earlier experiment by Milinski et al. (2006). The experiment employed a public good game analogous to the collective-risk game, except that groups did not have to reach a threshold by the end of the game to avoid catastrophe. Investments in the climate account were instead used to finance an advertisement in a large German newspaper encouraging people to reduce their fossil fuel usage to mitigate climate change. The authors were thus interested in whether groups of players would be willing to make altruistic investments in a climate change public good, in the absence of any personal financial risks to themselves.

In one condition, groups were given expert information about climate risks before the public good game in the form of a brief verbal passage (risk-informed), whereas in a second condition groups received no such information (risk-uninformed). The verbal passage in the risk-informed condition contained information about distant and intermediate climate risks. The distant risks included the increased risk of droughts, extreme precipitation, more frequent floods, rising sea levels, and increases in storm surges. The intermediate risks made reference to the possibility that climate change may cause the collapse of the deep circulation in the Atlantic Ocean switching off the heat conveyor in Europe, which could trigger a fall in temperature of $3-5\,^{\circ}\mathrm{C}$ in the next 10-20 years. The passage also acknowledged that climate change is already having adverse impacts by highlighting its contribution to the European heatwave of 2003, which killed 15,000 people.

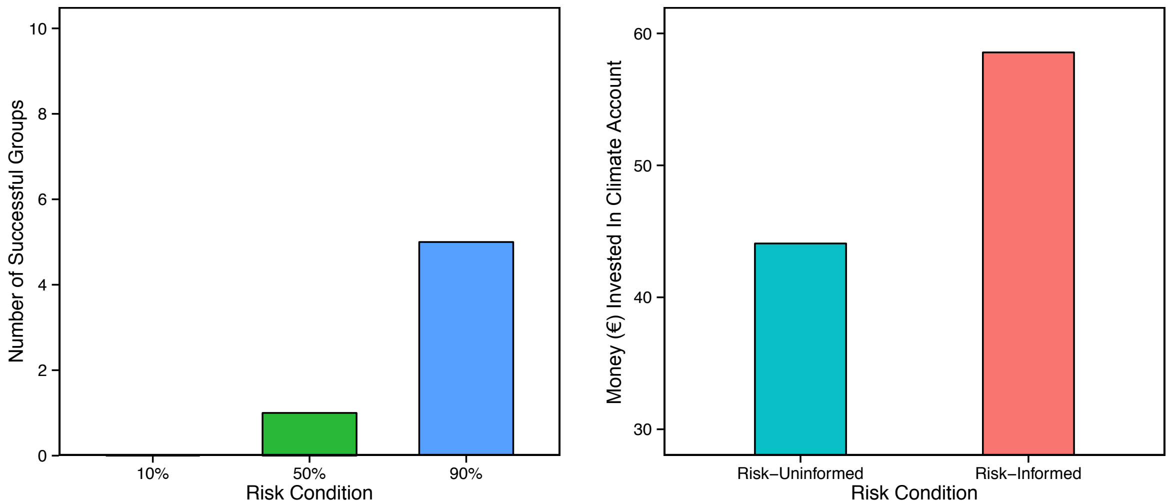

Figure 2: The impact of perceived risk of dangerous climate change on cooperation. Left panel: the number of groups (out of 10) reaching the threshold, as a function of the probability of dangerous climate change occurring in Milinski et al. (2008); Right panel: average investments in the climate account in the risk-uninformed and risk-informed conditions in Milinski et al. (2006).

The results are illustrated in Figure 2 (right panel) from which it can be seen that the mean level of investments in the public good—averaged over ten climate rounds—was higher in the risk-informed than the risk-uninformed condition. That players in either condition were prepared to contribute anything to the climate account is noteworthy, since they did not face any potential financial repercussions for failing to cooperate, unlike players in the experiment of Milinski et al. (2008). The results therefore demonstrate that people are willing to make altruistic investments to protect the climate, and this willingness is markedly enhanced when people are given expert information about climate risks.

The experiments just reviewed suggest the perceived risk of dangerous climate change is a major variable affecting the likelihood of avoiding catastrophe—the higher the perception of risk, the easier it is to coordinate efforts to escape a tragedy of the commons. Climate negotiators therefore need to be convinced of the high risks posed by dangerous climate change. If they have a misperception that the risk is low, then this will imperil efforts to coordinate for the global public good. Accordingly, it is important that the expert information that feeds into climate negotiations—notably the assessments of the Intergovernmental Panel on Climate Change (IPCC)—present an accurate overview of the severity of global climate disruption. However, several authors have expressed concerns that the IPCC assessments have been conservative in their projections of the impacts of climate change and that this may be attributable in part to an effort by climate scientists to "err on the side of least drama" in order to avoid the charge by skeptic groups of being "alarmist" (Brysse et al., 2013; Freudenburg

& Muselli, 2010; Lewandowsky et al., 2015). The experiment of Milinski et al. (2008) suggests it is important not to understate the severity of dangerous climate change, since a reduced perception of actual risk could severely hamper collective efforts to avert catastrophe. Finally, we note that in the laboratory even under high risk settings with a small group of six players, the risk of collective failure is high. This suggests the risk of collective failure will be much larger in the real climate game where—under the UN negotiating framework—almost 200 countries are vying to reach an agreement. Since the free rider problem is exacerbated as group size become larger (Pacheco et al., 2014; Santos & Pacheco, 2011; Vasconcelos et al., 2014), the highest levels of cooperation should be realised when the task of avoiding dangerous climate change is broken down into smaller negotiating groups of countries.

5.2. Player inequality

The experiments considered so far have assumed, for simplicity, that all players are equal. However, this is not an accurate reflection of the real climate game. In the real game, inequalities exist in terms of responsibility for mitigating climate change (wealthy countries have historically emitted more greenhouse gasses than poor countries), resource capacity (wealthy countries have more financial resources to combat climate change than poor countries), and risk (due to their geographical position, poor countries are more vulnerable to the effects of climate change than wealthy countries). Several studies have added greater ecological validity to the collective-risk game, by incorporating such inequalities in order to examine their impact on cooperation.

Tavoni and colleagues (Tavoni et al., 2011) examined the impact of inherited inequality using an augmented collective-risk game divided into "passive" and "active" phase components. In the passive phase, the computer determined the contributions made by each player to the climate account for the first three out of ten rounds. In one condition (equal condition), all six players in a group were forced to allocate €2 to the climate account, whereas in a second condition (unequal condition), half the players were forced to contribute €4, whereas the other half were forced to contribute €0. Given a starting operating fund of €40 for each player, this meant that by the end of the passive phase, all players in the equal condition had a remaining operating fund of €34 each, whereas in the unequal condition, the poor and rich players had a remaining operating fund of €28 and €40 each, respectively. In the active phase (rounds 4-10), players were able to decide for themselves whether to invest €0, €2, or €4 on each round.

In conjunction with the inequality manipulation, the authors incorporated a communication manipulation. In one condition, at the end of rounds 3 and 7, players were able to announce how much they intended to invest in the climate account over the next three rounds, via the submission of non-binding pledges (with-pledge condition). These pledges were then made public to the other players so that they could ascertain whether the threshold would be reached if players remained true to their commitments. This coordination mechanism was chosen based upon its similarity to the pledge-and-review instrument enshrined in the Copenhagen Accord. Contributions in this condition were

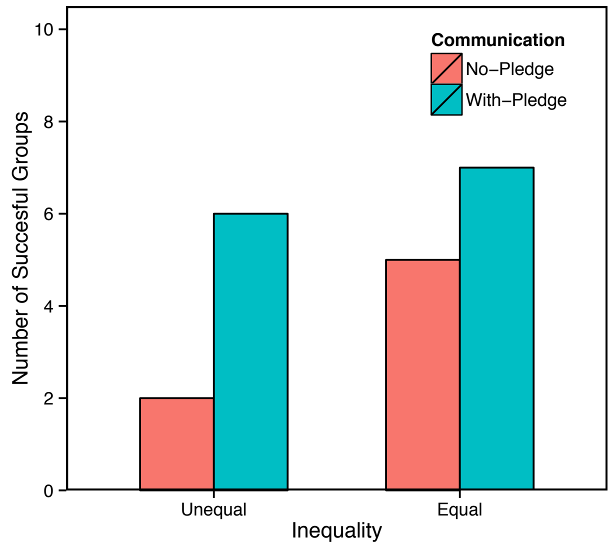

Figure 3: The number of groups (out of 10) reaching the threshold as a function of the equality and pledge manipulations in the study of Tavoni et al. (2011).

contrasted with those in a further condition where communication between players was prohibited (no-pledge condition).

The results of the study are shown in Figure 3 from which it can be seen that in the absence of pledges, inequality was an impediment to cooperation—5 (out of 10) groups reached the threshold in the equal condition, whereas only 2 groups reached the threshold in the unequal condition. However, allowing players to submit pledges enhanced cooperation in both conditions and almost neutralised the impediment of inequality—7 groups reached the threshold in the equal condition, compared with 6 groups in the unequal condition. Communication ameliorated the handicap of inequality because rich players were able to signal to the poor players early on their willingness to compensate for their lesser resource capacity to invest in climate protection, and the poor players, in turn, were willing to trust that the rich players would fulfil their pledges. These results show that if players are able to communicate their intentions so that they may coordinate their efforts then inequality need not be an impediment to cooperation.

The handicap of wealth inequality on cooperation can also be attenuated through the introduction of an intermediate climate target, as demonstrated in an experiment by Milinski et al. (2011). In their experiment, players were given an operating fund from which they could make investments in the climate account, but in departure from the original collective-risk game (Milinski et al., 2008), they also received an endowment. The endowment is meant to represent property such as real estate, whereas the operating fund represents money that people can spend for living. The experimenters created rich and poor players by varying the size of their operating funds and endowments—rich players received a €40 operating fund and a €60 endowment, whereas poor players received a €20 operating fund and a €30 endowment. The game was played using rich groups, poor groups, and mixed groups (3 rich players + 3 poor players).

All groups had to reach a threshold of €120 by round 10 to avoid dangerous climate change. However, unlike the standard collective-risk game, if they failed in this objective and dangerous climate change occurred then they got to keep what was left of their operating funds, but they lost their endowment (reflecting the loss of real estate inflicted by dangerous climate damage). In one condition, groups were informed that they also had to reach an intermediate threshold of €60 by the end of round 5. If they failed to reach the intermediate threshold then in rounds 6-10, there was a 20% probability in each round that an intermediate climate event would occur, the consequence of which was a 10% reduction of each player's operating fund and endowment. This condition was designed to emulate the two time horizons of climate negotiations—the long-term target of avoiding crossing the dangerous threshold of 2 °C of warming by 2050 (viz. the €120 threshold to-be-reached by round 10) and the short-term target of reducing emissions by 2020 embedded in the Copenhagen Accord (viz. the €60 threshold to-be-reached by round 5). Cooperation in this condition was contrasted with that in a further condition without an intermediate threshold.

The results are depicted in Figure 4, which shows contributions across the rounds as a function of group type and whether or not an intermediate threshold was provided.

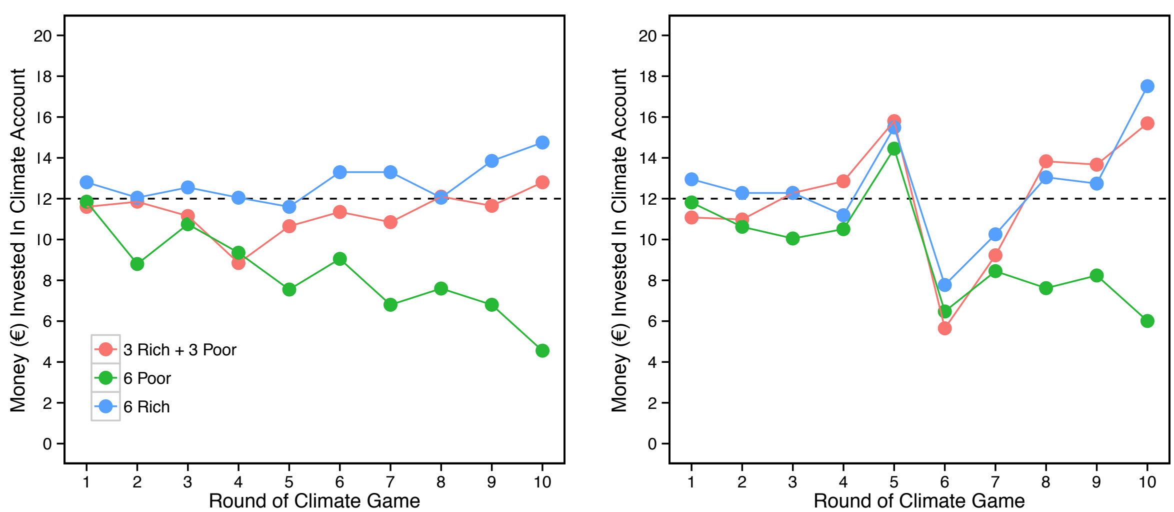

Figure 4: Average money invested in the climate account in each of 10 rounds of the climate game as a function of group composition in the experiment of Milinski et al. (2011). Left panel: investments without an intermediate threshold; Right panel: investments with an intermediate threshold. The broken horizontal line in each panel represents the average investment per round required to reach the €120 threshold.

In the absence of an intermediate threshold (left panel of Figure 4), investments in the climate account were highest amongst rich groups, followed by mixed groups, followed by poor groups. Whilst investments over the rounds were relatively stable in rich and mixed groups, they decreased roughly monotonically for poor groups. All of the rich groups; 60% of mixed groups; and none of the poor groups reached the final threshold. However, when an intermediate threshold was provided (right panel of Figure 4), the dynamics of investments over the rounds changed, with all group types exhibiting a punctuated peak in investments in round 5. Investments were once again highest amongst rich groups, lowest amongst poor groups, with mixed groups falling in between. Once again, the rich groups always averted catastrophe, but the key result was that 33% of the poor groups and 67% of mixed groups now reached the final threshold. The increase in cooperation in mixed groups in the presence of an intermediate threshold arose because the rich players compensated for the lower investments of the poor players, as in Tavoni et al. (2011).

In a more recent experiment, Burton-Chellew et al. (2013) examined the effect of heterogeneity not only in terms of wealth, but also in terms of risk from climate change, on cooperation. In their experiment, groups of players were assigned to one of four different conditions. In the egalitarian condition, all six players were given €40 in operating funds and faced the same risks if they failed to reach the threshold. In the unequal-wealth condition, players also faced the same risks from dangerous climate change, but differed in their resource capacity, with two rich players receiving operating funds of €80 each, and four poor players receiving operating funds of €20 each. In the rich-suffer and poor-suffer conditions, heterogeneity in the resource capacity of players was induced in the same way as in the unequal-wealth condition, but the risks for rich and poor players if climate change occurred were also varied. In the rich-suffer condition, the risk was higher for rich than for poor players (the probability that they would lose their operating fund was higher than for poor players), whereas the reverse was true in the poor-suffer condition.

As can be seen in Figure 5, cooperation was high in the egalitarian condition, with 7 (out of 8) groups reaching the threshold, whilst cooperation was only slightly—and non-significantly—reduced in the unequal-wealth and rich-suffer conditions, with 5 and 6 groups, respectively, reaching the threshold. That resource heterogeneity did not exert a greater impact on cooperation in these latter conditions occurred because when the rich players faced the same or greater risks from climate change as the poor players, they were willing to contribute more to the climate account than poor players in order to circumvent a catastrophe. The crucial question is whether this assistance would be provided when poor players were more at risk—viz. the scenario most representative of the real climate game. As can be seen in Figure 5, the answer is no; in the poor-suffer condition, cooperation collapsed, with only 1 group successfully managing to reach the threshold. Thus, when wealth and risk heterogeneity are combined, rich players are only willing to cooperate if it is in their self-interest to do so.

What implications can be drawn from these experiments on inequalities? The results of Tavoni et al. (2011) and Milinski et al. (2011) suggest that two fundamental pillars of the Copenhagen Accord—namely its bottom-up pledge-and-review mecha-

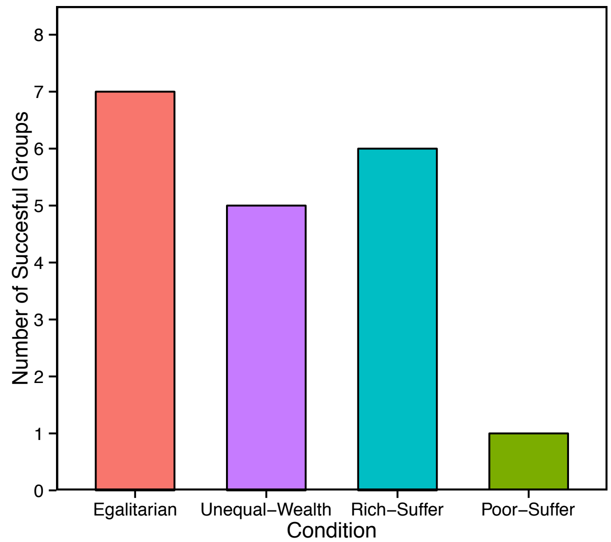

Figure 5: The number of groups (out of 8) reaching the threshold in the four conditions of the experiment by Burton-Chellew et al. (2013).

nism and its emphasis on short-term intermediate climate targets—may help to foster an equitable and fair distribution of commitments to reduce emissions amongst rich and poor countries. This is noteworthy, because conflicts between rich and poor dominated the negotiations in Copenhagen and the resulting agreement was not expected to alleviate these equity and fairness concerns. Ironically though, the results of the experiments suggest that these features of the Copenhagen Accord may actually help to encourage rich nations to take the lead in efforts to tackle climate change, thus reducing the financial burden on poorer countries. Nevertheless, the results of Burton-Chellew et al. (2013) suggest that asymmetries in climate risks between rich and poor countries may undermine such cooperative interactions. However, a significant shortcoming of their poor-suffer condition is its assumption that poor countries are more likely to suffer from dangerous climate change than rich countries. Whilst it is true that poor countries will be affected more by ongoing climatic changes than rich countries (IPCC, 2007), dangerous climate change will be so severe that in a globalised world all countries will be affected by it (Alley et al., 2003; Schellnhuber et al., 2006). Thus, a more ecologically valid scenario would be one in which the risks from dangerous climate change are the same for rich and poor, but the costs from those risks are larger for poor than for rich. We note that under such a scenario the imperative for rich countries to cooperate is much higher than under the conditions examined by Burton-Chellew and colleagues. This matter aside, what lessons can we learn from their experiment? The key implication of their results is that climate negotiations need to make transparent the fact that dangerous climate change will result in a tragedy of the commons that will bring ruin to all, not just a select few. If rich countries believe the effects of dangerous climate change will be localised to poor countries then this will reduce the likelihood of them taking the lead in tackling climate change.

5.3. Uncertainty surrounding the dangerous threshold

An important—but perhaps less obvious—difference between the real climate game and the experiments examined so far is that the latter assume that the location of the dangerous threshold; the effort that needs to be undertaken to avoid it; and the costs of crossing it are known with certainty. However, in reality, much uncertainty pervades these and other aspects of the climate change problem. Although the Copenhagen Accord identifies a dangerous temperature threshold of 2 °C, uncertainties nevertheless exist surrounding the specific concentration target that must be reached in order to avoid crossing it. Similarly, estimates of the expected damages resulting from catastrophic climate change differ widely. It therefore follows that any adequate laboratory analogue of the problem of avoiding dangerous climate change must incorporate such uncertainties. This has been done in a sequence of studies by Barrett and Dannenberg (2012, 2013, 2014) who have shown both experimentally (Barrett & Dannenberg, 2014) and theoretically (Barrett, 2013) that the existence of a threshold for dangerous climate change spurs cooperation, whereas uncertainty surrounding this threshold—but not the impact of crossing it—causes cooperation to collapse (Barrett & Dannenberg, 2012, 2013).

In the first of two important experiments, Barrett and Dannenberg (2012) examined the influence of uncertainty about the location of the threshold for avoiding catastrophe and the consequences of crossing it on cooperation. Their collective-risk game differs slightly from the standard game introduced by Milinski et al. (2008), so we will digress briefly to describe how. In their paradigm, groups consist of 10 players who are each allocated €31, which is divided into an operating fund of €11 and an endowment of €20. The operating fund can be used to invest in "weak" or "strong" emission abatement by purchasing chips (max = 10 of each type) at a cost of €0.10 or €1.00, respectively. As in the study of Milinski et al. (2011), the endowment represents property such as real estate that is vulnerable to damage from dangerous climate change. The game is played for 10 rounds and each round is divided into three stages: (1) a communication stage, where players can submit non-binding pledges; (2) a feedback stage, where these pledges are made public; and (3) a contribution stage, where players submit their actual contributions to climate protection. As in the collective-risk game, the goal is to reach a threshold level of investments T in order to avoid dangerous climate change. If this task is unsuccessful then a cost C is deducted from each player's endowment.

Barrett and Dannenberg's (2012) experiment involved four different conditions. In the certainty condition, T = €150 and C = 15. Thus, in this condition, the threshold for dangerous climate change and the impact of crossing it were both known with certainty. In the impact-uncertainty condition, T = €150 and C was uniformly distributed between €10 and €20. Thus, in this condition, the threshold was known with certainty, but the impact of crossing it was not. In the threshold-uncertainty condition, T was distributed uniformly between €100 and €200, and $C = 15$. Thus, in this condition, the impact of crossing the threshold for dangerous climate change was known with certainty, but the location of the threshold was not. Finally, in the impact + threshold uncertainty condition, T was distributed uniformly between €100 and €200, and C was distributed uniformly between €10 and €20. Thus, in this condition, both the threshold for dangerous climate change and the impact of crossing it were uncertain. In the uncertainty conditions, the actual values of T and C were determined at the end of the game by randomly sampling a value from a uniform distribution.

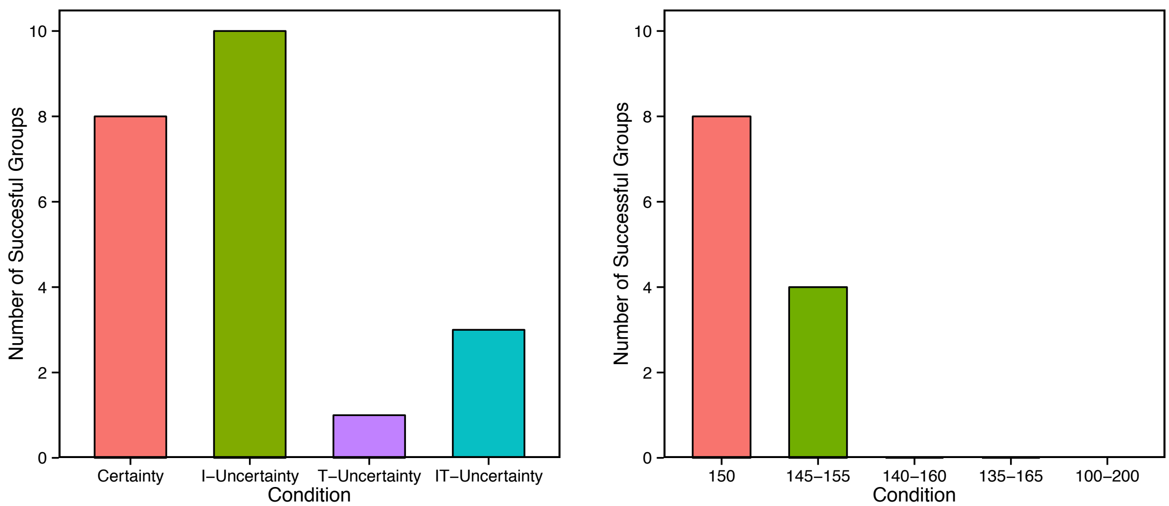

Figure 6: The impact of threshold uncertainty on the likelihood of avoiding catastrophe. Left panel: number of groups (out of 10) avoiding catastrophe as a function of uncertainty condition in the experiment of Barrett and Dannenberg (2012); Right panel: number of groups (out of 10) avoiding catastrophe as a function of uncertainty condition in the experiment of Barrett and Dannenberg (2013). *Note*—I-Uncertainty = impact uncertainty; T-Uncertainty = threshold uncertainty; IT-Uncertainty = impact + threshold uncertainty.

The results can be inspected in Figure 6 (left-panel), from which it can be seen that most groups (8 out of 10) in the certainty condition and all groups in the impact-uncertainty condition were successfully able to avert dangerous climate change. However, only 1 group in the threshold-uncertainty condition and 3 groups in the impact + threshold uncertainty condition, successfully averted catastrophe. These results clearly demonstrate that uncertainty surrounding the location of the threshold for dangerous climate change is a major handicap to cooperation that needs to be reduced if collective action is to be successful.

How much must uncertainty about the threshold be reduced? In a follow-up experiment, Barrett and Dannenberg (2013) parametrically varied the size of the window of uncertainty surrounding the threshold for dangerous climate change to determine its impact on cooperation. In the certainty condition, $T = 150$, whereas in four additional threshold-uncertainty conditions, the value of T was uniformly distributed between either: (1) 145 and 155, (2) 140 and 160, (3) 135 and 165, or (4) 100 and 200 ($C = 15$ in all conditions). When the threshold was known with certainty, 8 (out of 10) groups were successfully able to avert catastrophe, but even with a very narrow window of uncertainty surrounding the location of the threshold (viz. 145–155), the number of groups averting catastrophe was reduced to 4 (right panel in Figure 6). When the window of uncertainty was increased beyond this narrow range, no groups were successfully able to circumvent catastrophe. These results show that even a small degree of uncertainty about the location of the threshold is a major impediment to collective action. Thus, uncertainty about the location of the threshold must be eliminated completely to maximise the chances of a successful outcome.

With regards the prospects of escaping a real tragedy of the climate commons, the results of the experiments just reviewed suggest that uncertainty about the damage caused by dangerous climate change is relatively inconsequential, whereas uncertainty about the location of the threshold is crucial. Unless the location of this threshold is known with certainty, it is unlikely that countries will be able to take collective action to avert catastrophe. Although the Copenhagen Accord identifies a dangerous threshold of a 2 °C change in temperature, what it does not identify is the atmospheric concentration level required to avoid crossing it. Since it is the concentration level that must crucially be known with certainty to determine the degree of emission abatement required to avert dangerous climate change, this means that the real climate game is currently being played under a condition of threshold uncertainty, like in the experiments of Barrett and Dannenberg. Thus, a key priority for the climate negotiations is to identify a precise concentration level to ensure that countries avoid the temperature threshold.

5.4. Intergenerational discounting

The problem of avoiding dangerous climate change results not merely from a conflict between self and collective interest (tragedy of the commons), but also because the costs of failing to cooperate to avert it will be felt by future generations, leaving current actors with no direct incentive to fix the problem (tragedy of the horizon). Thus, a defining feature of climate change is its intergenerational nature, which involves trade-offs between the self and future others—the immediate self interest of the current generation must be balanced against the ethical and moral imperative to protect future generations from harm. It is well-known that temporal discounting—the tendency to prefer immediate over delayed rewards, and delayed over immediate costs—influences individual decision making (Frederick et al., 2002; Loewenstein et al., 2003). Temporal discounting over short-term time horizons is known as intragenerational discounting and encompasses time frames that exclude unborn generations, whereas temporal discounting over extremely long-term time horizons is known as intergenerational discounting and encompasses time frames that include future generations (Schelling, 1995, 2000; Sumaila & Walters, 2005). In individual decision making, both forms of discounting are known impediments to action on climate change (Lorenzoni & Pidgeon, 2006; Spence et al., 2012; Weber, 2006, 2010)—people discount the effects of climate change on their own future, as well as future others. Do intra- and intergenerational discounting also manifest in a group decision making setting resembling climate negotiations?

This question was addressed using the collective-risk game in an experiment by Jacquet et al. (2013). In their experiment, groups of players were given an operating fund of €40 and an endowment of €45. Players always received any money from their operating funds not invested in the climate account in cash immediately after the end of the game, whereas the endowment was only awarded if catastrophe was circumvented. The experiment involved three different conditions that differed in terms of the temporal delay between the end of the game and the endowment being awarded, and the number of beneficiaries of the endowment. In the short-delay condition, the endowment was paid to group members 1 day after the experiment; in the long-delay condition, it was paid to group members 7 weeks after the experiment; in the intergenerational condition, it was invested in a reforestation project to sequester CO_2, the beneficiaries of which would be future generations (a temporal delay of several decades, with a much wider range of beneficiaries). The difference in cooperation between the short- and long-delay conditions can be used as an index of intragenerational discounting, whereas the difference in cooperation between the short- or long-delay and intergenerational conditions can be used as an index of intergenerational discounting.

As can be seen from inspection of Figure 7 (left panel), intra- and intergenerational discounting caused a marked decrease in cooperation. In the short-delay condition, 70% of groups successfully reached the threshold, whereas only 36% of groups did so in the long-delay condition, and none of the groups reached the threshold in the intergenerational condition. Thus, the experiment provided evidence for the operation of both intra- and intergenerational discounting, but intergenerational discounting was the stronger impediment to cooperation of the two. The results suggest that the intergenerational aspect of climate change is likely to be a major obstacle to cooperation in climate negotiations.

How can this obstacle be surmounted? This question was addressed in a subsequent experiment by Hurlstone et al. (2015). Their experiment utilised the short-delay and intergenerational conditions of Jacquet et al. in conjunction with a third "affinity" condition. The affinity condition was the same as the intergenerational condition, except on rounds 1, 4, and 7, players were required to read a brief verbal passage before making their investment decisions. The passages were constructed to invoke a sense of affinity—a combination of empathy, perspective taking, and perceived connectedness—with future generations. One passage highlighted how past generations that the current generation feel a strong connection with made many sacrifices to make the world we inherited a better place. It highlighted how climate change is the "greatest problem of our time" and that we have a responsibility to reciprocate the kind acts performed by past generations for us by taking action to prevent dangerous climate change. A second passage highlighted the helpless nature of future generations by noting the power asymmetries between current and future generations—everything that we do will affect future generations, but nothing that they do will affect us. It underscored how we have an ethical and moral imperative to use our power responsibly by not imposing

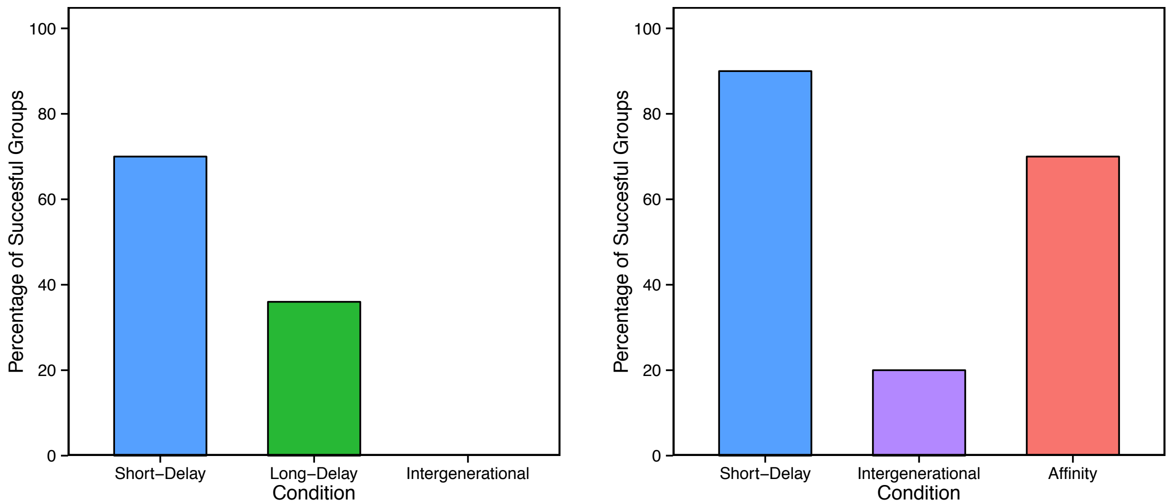

Figure 7: The impact of intra- and inter-generational discounting on cooperation. Left panel: the percentage of groups avoiding catastrophe in the short-delay, long-delay, and intergenerational conditions in the experiment of Jacquet et al. (2013); Right panel: the percentage of groups avoiding catastrophe in the short-delay, intergenerational, and affinity conditions in the experiment of Hurlstone et al. (2015).

the burden of dangerous climate change on our descendants. A third passage highlighted the finiteness of human life, but drew attention to how efforts to tackle climate change represent an opportunity to leave a positive lasting legacy that will live beyond one's existence on the planet. The passages were motivated by research showing that building affinity with future generations by increasing intergenerational identification; highlighting power asymmetries; and appealing to people's desire to leave positive legacies can reduce intergenerational discounting (Wade-Benzoni, 2008; Wade-Benzoni, Plunkett Tost, 2009; Wade-Benzoni et al., 2012).

The results are shown in Figure 7 (right panel). As in the experiment of Jacquet et al., intergenerational discounting had a negative impact on cooperation—only 20% of groups in the intergenerational condition successfully averted catastrophe, compared to 90% in the short-delay condition. However, the key result was that the verbal passages in the affinity condition mitigated the effect of intergenerational discounting—70% of groups in this condition managed to reach the threshold, a success rate which did not differ reliably from that in the short-delay condition.

The foregoing experiments suggest that intergenerational discounting is a major impediment to cooperation, but its effects can be lessened dramatically—and intergenerational beneficence enhanced—by crafting persuasive messages that build an affinity between current actors and future generations. The implication of these results for climate negotiations is that persuasive appeals for collective action to avoid dangerous climate change should be framed around intergenerational concerns, by highlighting power asymmetries, the opportunity for legacy creation, and our responsibility to "pay forward" the debts we owe to past generations.

5.5. Reputation

In the experiments considered so far, the reputation of players cannot be used as a tool for spurring cooperation—there are no incentives for players with a positive reputation to continue contributing to the public good, and no disincentives for players with a negative reputation to stop free-riding. However, if a positive reputation can be used as a currency by which to obtain rewards and avoid punishments, stable cooperation can be achieved. This was demonstrated in the experiment of Milinski et al. (2006; see also Fehr, 2004; Milinski, 2006; Milinski et al., 2002, 2004; Panchanathan & Boyd, 2004) described earlier, in which some groups were given expert information about climate risks, whereas others were not. However, this manipulation was ancillary to the primary objective of the experiment, which was to establish whether reputation could be used as a tool to sustain cooperation in the climate game.

In their experiment, rounds of the climate public good game were alternated with rounds of an indirect reciprocity game, where players could reward other players based on their reputation. In each round of the latter game, players adopted the role of potential "donor" or "receiver" once. When afforded the role of donor, a player had to decide whether or not to give a reward of €3 to another player at a cost of €1.50 to themselves; conversely, when given the role of receiver, a player could potentially receive a €3 reward from another player. Importantly, if a player acted as a potential donor to a second player, then the second player could not subsequently serve as the potential donor to the first. Thus, direct reciprocity—reciprocating the kind or unkind act of another ("you scratch my back, and I'll scratch yours")—was not possible; interactions were instead based on indirect reciprocity (cf. Nowak & Sigmund, 2005)—reciprocating the kind or unkind act of another to a third party ("you scratch my back and I'll scratch someone else's").

The key manipulation was that on "odd" rounds of the public good game, investments in the climate account were made public, whereas on "even" rounds the investments were made anonymous. Thus, on rounds in which investments were made public, there was an incentive for players to cooperate by investing in the public good because this affords a positive reputation, which should be rewarded in the indirect reciprocity game—viz. donors should offer support to players that cooperate in the public good game—whereas failure to cooperate affords a negative reputation, which may incur punishment—viz. donors should withhold support to players that do not cooperate in the public good game. By contrast, on the anonymous rounds, the incentive to cooperate and the disincentive to free-ride is removed because the reputation of other players is unknown and cannot be used as a basis for deciding to donate or not to another player in the indirect reciprocity game.

The results are shown in Figure 8, which plots the average group investments on each round of the public good game in the risk-informed and risk-uninformed conditions (see earlier). It is apparent from inspection of this figure that the data for both conditions exhibit a markedly scalloped appearance, with peaks on odd rounds

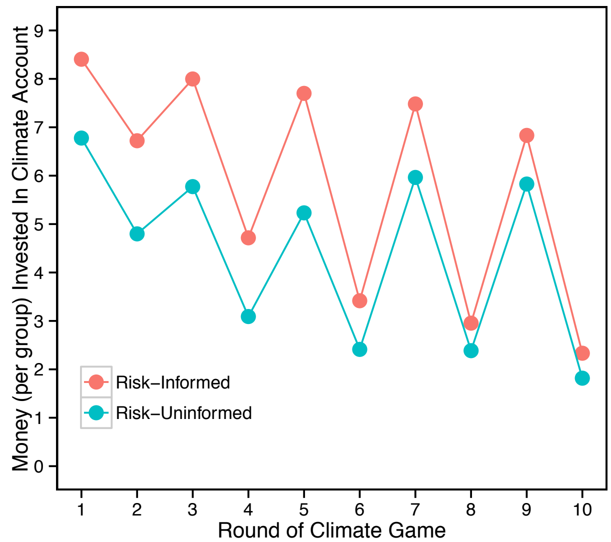

Figure 8: Money invested in the climate account on public (odd) and anonymous (even) rounds of the public good game for the risk-informed and risk-uninformed conditions in Milinski et al. (2006).

in which investments in the public good game were made public and troughs on even rounds where investments were anonymous. It can also be seen that public investments were not just markedly higher, they were also more stable, whereas anonymous investments decreased monotonically over rounds. Investments in the public good game were higher on public than anonymous rounds because cooperation was subsequently rewarded in the indirect reciprocity game and defection was punished—providing a powerful incentive to contribute to the public good.

These results show that if altruistic investments in climate protection can be socially reinforced and selfish investments socially punished—thus providing an incentive for free-riders to join collective efforts—then reputation is an unexpectedly powerful tool for achieving stable cooperation. This suggests that the reputations of countries should be made salient, whenever and wherever possible. How might this be accomplished? Countries could be ranked according to their emissions and investments in climate protection and this information could be used to create an "image score" that acts as a signal of their reputation (Dreber & Nowak, 2009; Pfeiffer & Nowak, 2006). To facilitate the communication of a countries social status, they could be further differentiated on the basis of these image scores into categories, such as "heavy lifters", "fair contributors", and "free-riders". The "heavy lifters" and "fair contributors" would be socially rewarded with praise, whereas the "free-riders" would be socially punished through shaming. Is this proposal far-fetched? We think not. Indeed, the executive secretary of the UN, Christiana Figueres, recently lamented Australia's lack of climate ambition stating that in terms of climate diplomacy, it has transitioned from "leadership to free-rider status". Faced with such social disapproval, some free-riding countries may choose to cooperate simply out of a desire to maintain a positive reputation. For other countries, shaming alone will not be sufficient. However, because those countries are engaged in multiple cooperative relationships, it will only be a matter of time before their poor reputations spill over into other situations requiring cooperation. The threat of other countries withholding their support during these situations should provide a powerful incentive for defecting countries to invest in their reputations by joining collective efforts to tackle climate change.

6. Summary

Avoiding dangerous climate change is perhaps the greatest collective action problem ever and is the "game we cannot afford to lose" (Dreber & Nowak, 2009). More than two decades of climate negotiations have failed to identify a cooperative solution to this problem. Laboratory cooperation experiments mimic the collective-risk social dilemma faced by countries playing the real climate game, and provide insights into the factors that might prevent a real tragedy of the climate commons. These experiments suggest that for cooperation to be achieved, (1) countries must be convinced of the very high risks of dangerous climate change, and (2) that failure to protect the global climate will bring ruin to all, not merely a select few. (3) They further suggest that knowledge of the temperature threshold for dangerous climate change will not prevent catastrophe, unless uncertainty surrounding the concentration level required to avoid crossing it can be reduced. (4) The intergenerational nature of climate change is a significant barrier to cooperation, but climate negotiators can attenuate its effects using affinity building messages that promote intergenerational identification, highlight power asymmetries between current and future actors, and appeal to people's preference to leave positive legacies. Finally, (5) people care about their reputations, which provide a signal of their trustworthiness to others. Accordingly, the reputations of countries should be made salient—and countries with poor reputations should be publicly shamed—so that the threat of social punishment in other cooperative interactions provides an incentive for them to invest in climate protection.

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